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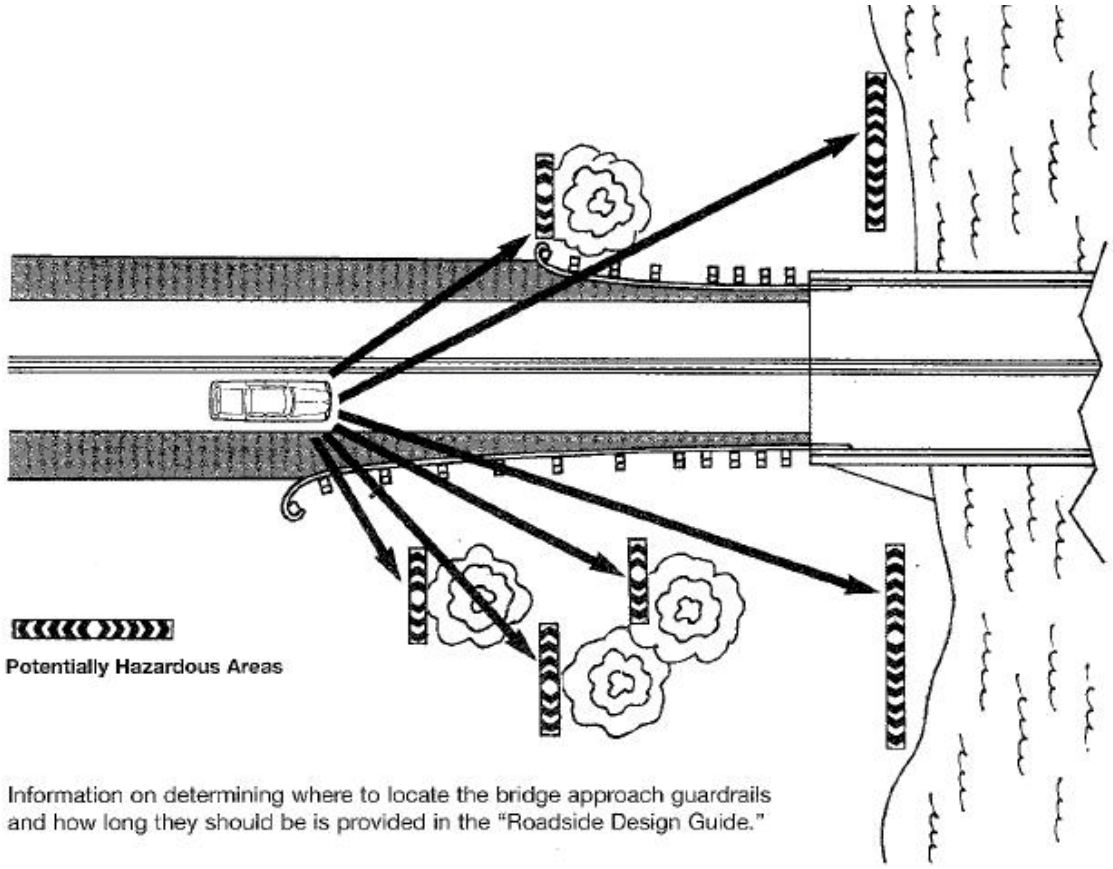
Engineer Research and
Development Center

Evaluation of Bridges Subjected to Military Loading and Dynamic Hydraulic Effects

Review of Design Regulations, Selection Criteria, and Inspection Procedures for Bridge Railing Systems

Alberto M. Figueroa, Elizabeth Negrón, Genock Portela,
Rodney N. González-Rivera, Henry Díaz-Álvarez,
and Gerardo I. Velázquez

August 2011



Information on determining where to locate the bridge approach guardrails and how long they should be is provided in the "Roadside Design Guide."

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Evaluation of Bridges Subjected to Military Loading and Dynamic Hydraulic Effects

Review of Design Regulations, Selection Criteria, and Inspection Procedures for Bridge Railing Systems

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Final report

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Abstract: This report presents the results of the initial phase of a research study with the objective of documenting the current state-of-the-practice, at the national level and for the 32 states and the Commonwealth of Puerto Rico having military installations, related to the requirements, selection criteria, and inspection process for bridge safety barriers. The focus of the study was directed at identifying policies and recommended practices related to low speed, low volume road environments.

This report includes basic policies and guidelines from pertinent Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO) documents that deal with aspects of roadway geometric design, roadside design, and safety barrier practices and their relation to bridge safety. Information is included about FHWA-approved crashworthy bridge railing systems used by some states.

State-specific tables that summarize the relevant information about the requirements and practices related to bridge safety barriers are included in this report. The tables were developed based on the review performed from the documents collected from each of the 33 jurisdictions and from FHWA and AASHTO sources.

An inspection procedure and field forms were developed for bridge inspectors to use in performing an evaluation of traffic safety features on bridges. The procedure and forms were developed from a comprehensive review of documents and current practices and include elements that are necessary for the consideration of traffic and user safety on public roads. Future research phases could include validation of the inspection process and use of the forms through implementation exercises and consideration of existing roadway conditions in military installations.

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Preface

This report describes design regulations, selection criteria, and inspection procedures for bridge railing systems used in the 32 states and in the Commonwealth of Puerto Rico having military installations based on Federal Highway Administration (FHWA) provisions. It is also intended to provide guidance for the traffic safety evaluation of bridges located within U.S. Army facilities that are open to public travel. The information reviewed for the development of this report was collected during fiscal year 2008. This project was arranged and supervised by Terry R. Stanton of the U.S. Army Engineer Research and Development Center (ERDC).

The work was performed by the University of Puerto Rico at Mayaguez (UPRM), under Contract No. W912HZ-07-C-0045, working jointly with ERDC personnel from the Structural Engineering Branch (StEB) of the Geotechnical and Structures Laboratory (GSL). This report was prepared by Alberto Figueroa, Elizabeth Negrón, and Genock Portela, UPRM; Rodney N. Gonzalez–Rivera, Henry Diaz-Alvarez, and Gerardo I. Velázquez, GSL. Technical review of the document was performed by Orlando Carrasquillo, and Sharon Garner, GSL.

The Army Bridge Inspection Program is sponsored by the Army Transportation Infrastructure Program (ATIP) of the Headquarters, Installation Management Command (IMCOM), San Antonio, TX. The IMCOM provided funding for this investigation. Questions should be directed to Ali A. Achmar, IMCOM ATIP Program Manager.

During this investigation, Terry R. Stanton was Chief, StEB; Bartley P. Durst was Chief, GSD; Dr. William P. Grogan was Deputy Director, GSL; and Dr. David W. Pittman, Director, GSL.

COL Kevin J. Wilson was Commander and Executive Director of ERDC. Dr. Jeffery P. Holland was Director.

Unit Conversion Factors

Multiply	By	To Obtain
degrees (angle)	0.01745329	Radians
feet	0.3048	Meters
inches	0.0254	Meters
miles (U.S. statute)	1,609.347	Meters
miles per hour	0.44704	meters per second
miles per hour	1.609344	Kilometers per hour
pounds (mass)	0.45359237	Kilograms
tons (2,000 pounds, mass)	907.1847	Kilograms
yards	0.9144	Meters

Glossary

ADT: Average Daily Traffic.

AADT: Average Annual Daily Traffic.

AASHTO: American Association of State Highway and Transportation Officials.

ADA: American with Disabilities Act.

APWA: American Public Works Association.

ASCE: American Society of Civil Engineers.

BDS: Bridge Design Specifications.

Bridge (Title 23 CFR 650.305; GPO, 2009): Structure including supports erected over a depression or an obstruction, such as water, highway, or railway, having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 ft between undercopings of abutments, or spring lines of arches, or extreme ends of openings for multiple boxes.

Bridge approach guardrail: Longitudinal barrier preceding the structure and attached to the bridge railing system that is intended to prevent a vehicle from impacting the end of the bridge railing or parapet. This barrier may include a transition rail.

Bridge owner: An authority or governmental department representing investors and/or taxpayers that is responsible for all the safety designs features and functions of a bridge.

Bridge railing: Longitudinal barrier intended to prevent a vehicle from running off the edge of a bridge or culvert.

BTS: Bureau of Transportation Statistics.

CALTRANS: California Department of Transportation.

CFR: Code of Federal Regulations.

Clear zone: Total roadside border area, starting at the edge of the traveled way, available for the safe use by errant vehicles. The clear zone may consist of a shoulder, a recoverable slope, a nonrecoverable slope, and/or a clear runout area.

Crash tests: Vehicular impact tests by which the structural and safety performance of roadside barriers and other highway appurtenances may be determined. The evaluation criteria consider: (1) structural adequacy, (2) impact severity, and (3) vehicular post-impact trajectory.

Crashworthy: System that has been successfully crash tested to a currently acceptable crash test matrix and test level; or, one that can be geometrically and structurally evaluated as equal to a crash tested system.

Combination railing: A bicycle or pedestrian railing system added to a crashworthy bridge vehicular railing or barrier system.

DOT: Department of Transportation.

End treatment: Designed modification of the end of a roadside or median barrier.

FHWA: Federal Highway Administration.

FLH: Federal Lands Highway.

Highway (Title 23 USC 101; FHWA 2009e): A road, street, and parkway; a right-of-way, bridge, railroad-highway crossing, tunnel, drainage structure, sign, guardrail, and protective structure, in connection with a highway; a portion of any interstate, or international bridge, or tunnel, and the approaches thereto, the cost of which is assumed by a State transportation department, including such facilities as may be required by the United States Customs and Immigration Services, in connection with the operation of an international bridge or tunnel.

Low volume road (FHWA 2009a): Facility lying outside of built-up areas of cities, towns, and communities; and it shall have a traffic volume of less than 400 vehicle/day.

Low speed road (AASHTO 2004): Facility with a posted speed limit not exceeding 45 mph (70 km/hr).

LRFD: Load Resistance Factor Design.

MASH: Manual for Assessing Safety Hardware.

MSD: Maneuver Sight Distance.

MUTCD (Manual on Uniform Traffic Control Devices) (Title 23 CFR Part 655 Subpart F): National standard for all traffic control devices installed on any street, highway, or bicycle trail open to public travel in accordance with Title 23 USC 109(d) and 402(a).

NACE: National Association of County Engineers.

National Bridge Inventory (NBI) (AASHTO 2003): The aggregation of structure inventory and appraisal data collected to fulfill the requirements of the National Bridge Inspection Standards.

National Bridge Inspection Standards (NBIS) (AASHTO, 2003): Federal regulations establishing requirements for inspection procedures, frequency of inspections, qualifications of personnel, inspection reports, and preparation and maintenance of bridge inventory records. Apply to all structures defined as bridges located on or over all public roads.

NCHRP: National Cooperative Highway Research Program.

NHS: National Highway System.

Professional Engineer (PE) (Title 23 CFR 650.305; GPO 2009): An individual, who has fulfilled education and experience requirements and passed rigorous exams that, under State licensure laws, is permitted to offer engineering services directly to the public.

Public Road (Title 23 USC 101; FHWA 2009e): Any road or street under the jurisdiction of and maintained by a public authority and open to public travel. Open to public travel means that the road section is available, except during scheduled periods, extreme weather, or emergency conditions, passable by four-wheel standard passenger cars, and open to the general public for use without restrictive gates, prohibitive signs, or regulation other than restrictions based on size, weight, or class of registration.

RDG: Roadside Design Guide.

Roadside: Area between the outside edge of the traveled way and the right-of-way limits.

Roadway: Portion of highway, including shoulders, for vehicular use.

ROW: All public roads are located within land, which is referred to as the road right-of-way.

Shoulder: Reserved area by the edge of a road; reserved for vehicle emergency or breakdown.

SSD: Stopping Sight Distance.

Traveled way: Portion of roadway for the movement of vehicles, excluding shoulders.

Transition rail: Section of longitudinal barrier needed where a semi-rigid approach barrier joins a rigid bridge railing. Produces a gradual stiffening of the overall approach protection system, so vehicular pocketing, snagging, or penetration can be reduced or avoided.

USC: United States Code.

VMT: Vehicle-miles traveled.

Warrant: The criteria by which the need for a safety treatment or improvement can be determined. Warrants are not absolute requirements, but convey concern over a potential traffic hazard.

1 Introduction

Bridges are vital elements of transportation systems. The design of bridges has a significant effect on the operation, service quality, and safety of road networks by restricting the traffic volume and vehicle weight that can be served. The bridge strength controls the loads of heavy trucks along specific routes; inadequate bridge strength will entail truck rerouting in the network resulting in delays and productivity losses. The bridge width controls the amount of traffic served in a particular route; a reduction in the number of lanes in the bridge, compared to its approaches, will restrict the traffic capacity and speed. The reduction in roadway width along a bridge can also have a significant effect on safety, depending how roadway users perceive and react to the more restrictive operating conditions on the bridge. The design of bridges must consider a balance between handling future traffic volumes and vehicle loads, and the cost of a heavier and wider bridge structure, without compromising the safety of road users (Barker and Puckett 1997).

Bridges and their approaches are generally recognized as high frequency sites for severe, single-vehicle crashes (FHWA 1998). Almost one-third of the road fatalities that occurred in the United States in the year 2005 happened as a consequence of an off-roadway crash, with nearly 20% of those fatal crashes related to bridges or culverts (NHTSA 2007). The safety inspection of bridges must take into consideration the effects of the roadway geometry, the type and volume of the vehicle traffic, the road operating characteristics, the road users, and the typical weather conditions, among other factors. All bridge construction, maintenance, and reconstruction projects must take into consideration the safety of all road users under different operating conditions and must assess the potential for vehicles leaving the traveled way and encroaching into the roadside area.

The selection, placement, and performance evaluation of roadside barriers, railings, and other devices is essential for bridge safety considerations. The inspection of bridges and culverts needs to methodically evaluate the selection and placement of safety barriers in order to prevent errant vehicles from falling off the bridge or culvert side, or from crashing into an unprotected end of a parapet wall or railing. The height of the drop, the structural characteristic and shape of the railings and wall ends, the vehicle size and

weight, and the vehicle speed at the moment of impact are major factors that determine the severity of an off-road crash. Traffic and pedestrian volumes are also important factors to consider in the selection and placement of adequate safety barriers on bridges.

Research objectives

Bridge safety barriers are evaluated in terms of their structural and functional adequacy. The evaluation of the bridge safety barriers located on low volume low speed roads certainly requires a particular analysis, depending on the state in which the facility is located and the type of railings preferred locally. In addition, the evaluation must consider the traffic volume, typical vehicle size and weight, the road design implications, and other conditions and features.

This research effort had the following objectives:

1. Perform a literature review of existing bridge safety barrier systems that have been tested and approved for operating conditions typical of low volume and low speed roads. The review focused on identifying typical design features and characteristics of the barriers and typical costs for the barrier materials.
2. Perform a literature review of existing federal and state regulations, selection criteria, and inspection procedures applicable to bridge safety barriers for low speed and low volume road conditions. The review was directed toward the 32 states and the Commonwealth of Puerto Rico, where military installations are located.
3. Provide bridge railing inspection guidance that can be implemented by military personnel in evaluating traffic safety features of existing bridge barriers on military installation roads. The guidance includes requirements related to structural and functional adequacy of barriers and information that can be used when there are no particular bridge barrier requirements or selection criteria in a particular state.

Scope of the research study

The scope of this study was to perform a review of the applicable and pertinent national regulations and policies and the current state of the practice at the state level for the selection and evaluation of bridge safety barriers. Based on this review, recommendations are provided related to the inspection of bridge safety barriers. Field validation and implementation

exercises of the inspection process and the field forms developed in this study will be performed in a future research phase. In addition, research is needed to incorporate additional elements in bridge safety inspections on military roads, such as the use of traffic control devices and development of potential crash severity indices based on operating speeds, traffic volume, roadway geometry, and other factors associated with local bridge conditions.

The consideration and evaluation of traffic safety measures includes four different aspects that are known generally as the Four E's of Safety: Engineering, Enforcement, Education, and Emergency Services. This study focused on the Engineering aspect of traffic safety as related to bridge design and safety barriers. Further research should be developed in order to establish a Safety Management System for roads open to public travel within military installations.

Justification and benefits

Much has been learned in the field of bridge inspection, and a national Bridge Inspection Training Program is now fully implemented. A thorough and complete bridge inspection is dependent upon the bridge inspector's ability to identify and understand the function of the major bridge components: the deck, the superstructure, the substructure, plus their respective elements (FHWA 2006). The bridge railings and other safety appurtenances are important elements associated with the bridge deck.

The current requirements for bridge design and inspection, together with the increasing unrestricted public use of roads on military installations, might raise tort liability concerns in the presence of adverse site conditions with high crash risk potential. Typical operating conditions on roads in military installations lean toward low speed and low volume environments comparable to rural local roads or small town street settings. The consideration of safety barriers based upon recommended guidelines or practices established for high-speed, high-volume truck traffic conditions might lead to cost-effectiveness issues on low speed roadway conditions. These issues are also dealt with at the national and local level in terms of the identification of trade-offs between mobility and accessibility of the road network, while considering context-sensitive and sustainable aspects in the road design and without sacrificing the safety for all road users.

The main benefits of this study are:

- Enhance safety of military roads open to public travel
- Reduce tort liability potential
- Provide uniformity in safety evaluation and inspection procedures
- Establish good community perception toward use of military roads.

Earlier design approaches where different road elements (alignment geometry, drainage features, bridges and other structures, pavements, traffic control devices, etc.) were analyzed and treated separately, with no apparent attempt at integration, throughout the design process are no longer effective. The treatment of the entire road system as a design entity calls for the development and application of uniform guidelines and inspection protocols. The application of such guidelines and protocols in the evaluation of the roadside condition for military roads will enhance the safety for all road users, while implementing measures that have proven to be successful at facilities with similar operating conditions and bridge structures.

2 Research Methodology

The research methodology for Part 3 of the Research Study included six tasks. Figure 1 shows the methodology followed to accomplish the study objectives. A general description of the tasks performed is presented in this chapter.

The first task included the comprehensive review of federal and national regulations and existing design practices, selection criteria, and inspection procedures for bridge safety barriers as established by FHWA, NCHRP, AASHTO, FLH, etc.

The second task consisted of a literature review related to proven safety barriers currently used in typical bridge applications. The review focused on bridge railing types. The purpose of this task was to collect information related to the design, structural adequacy, functional adequacy, and shape characteristics of the crashworthy barrier elements, their crash test level, and typical material costs, among other aspects.

The third task included data collection from the 32 states and the Commonwealth of Puerto Rico, identified as having military installations, about the state-of-the-practice regarding the selection criteria for safety features of bridge railing systems on local roads and their bridge inspection procedures. The objective of this task was to identify the characteristics of acceptable bridge safety barriers according to existing local bridge specifications. This task included making contact with officials from federal agencies and state DOT's to request and gather the information. A list of the State DOT's officials contacted in this study, along with their contact information, is provided in Appendix A.

The data collected from the 33 jurisdictions included the local state-of-the-practice about bridge safety barrier warrants and selection criteria, inspection procedures, preferred railing types and end treatments, standard drawings or standard plans, DOT official contact information, and local documents and references. Appendix A, *State Bridge Railing Policies*, contains information obtained from this task.

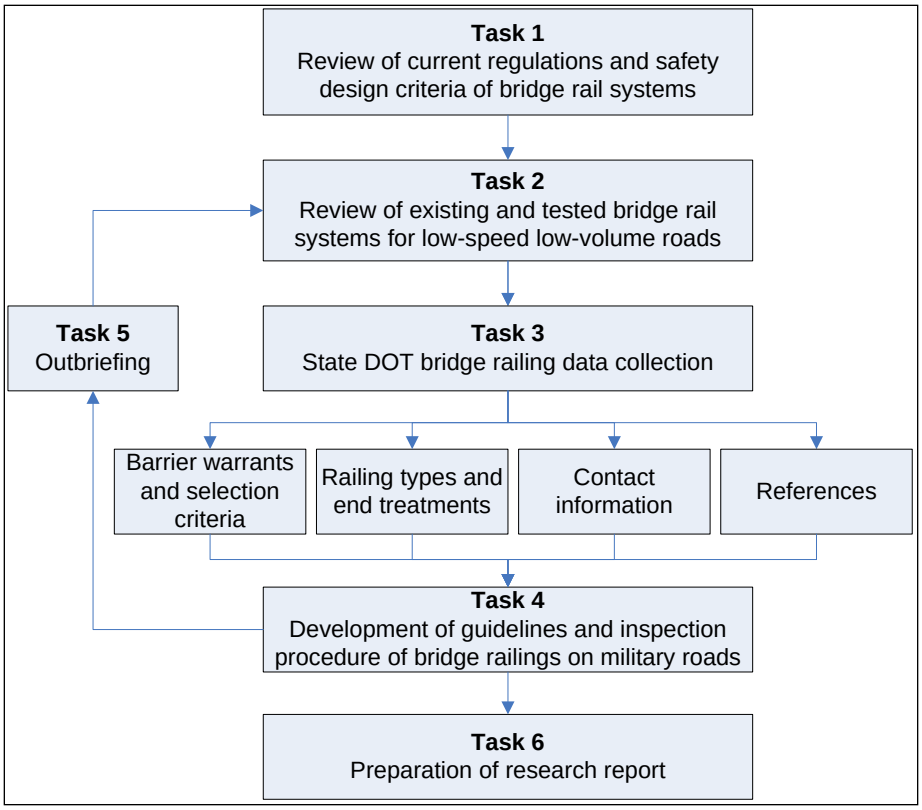


Figure 1. Research Methodology.

The fourth task consisted of analyzing the information obtained from the review process and the data collection to identify adequate barrier elements on bridges typical of traffic and road conditions on military installations. The analysis resulted in development of guidelines for design criteria and proper selection of safety barriers for bridges on military roads. The guidelines include an inspection process that can be implemented and a series of forms for use by the inspection team to assess the traffic safety level on bridges. The bridge inspection protocol is focused on visual inspection of safety devices at the roadside and the bridge deck. Appendix B, *Bridge Traffic Safety Features Inspection Forms*, contains the inspection forms suggested in this study for the assessment of bridge safety features.

The fifth task consisted of presentation of the preliminary research findings to U.S. Army Engineer Research and Development Center Officials for their review and comments. The presentation was made on March 11, 2008 at Dorado, Puerto Rico. Suggestions were provided about the format and type of information needed for the state-specific tables and the examples of crashworthy bridge railings. These suggestions were incorporated in this report.

The final task consisted in the presentation of the final research report to ERDC officials after all the information was reviewed and revised based on the comments and suggestions received from the ERDC Engineers at the Outbriefing.

3 Bridge Railings: General Policies and Guidelines

Title 23 CFR 625 designates the standards, policies, and standard specifications that are acceptable to FHWA for application in the geometric and structural design of highways. This chapter includes a general review of the most pertinent aspects of the documents pertaining to bridges and the design and inspection of roadway elements and safety appurtenances.

AASHTO is the principal source of information for national bridge design evaluation and inspection policies and guidelines. The four main AASHTO documents used in preparation of this report are the 2001 *Guidelines for Geometric Design of Very Low Volume Local Roads,* the 2004 *Policy on Geometric Design of Highways and Streets,* the 2006 *Roadside Design Guide,* and the 2007 *LRFD Bridge Design Specifications*. In addition, the 2009 *Manual for Assessing Safety Hardware* was published in the second part of 2009 during the review of this final report, and the main aspects of that document were incorporated in this report.

FHWA is the second main source of national information used in this study. Primarily, the three main FHWA documents used in this report are the 2005 *National Bridge Inspection Standards*, the 2005 *Bridge Rail Guide,* and the 2006 *Bridge Inspector's Reference Manual.*

Other relevant documents include the 1993 National Cooperative Highway Research Program Report 350 - Recommended Procedures for the Safety Performance Evaluation of Highway Features and the 2005 Federal Lands Highways Barrier Guide for Low Volume and Low Speed Roads.

AASHTO Policy on Geometric Design of Highways and Streets, 2004

The *AASHTO Policy on Geometric Design of Highways and Streets* (generally referred as the “Green Book”) is designated by the FHWA as a reference for the design of roadway and appurtenances. The policy contains the latest design practices in universal use as the standard for highway geometric design and provides guidance to designers by referencing recommended range of values for critical dimensions. The policy is intended as a

comprehensive reference manual for assistance in administrative, planning, and educational efforts pertaining to design formulation.

The emphasis of the policy has been placed on cost-effective design, while expanding the traditional design procedure to reflect the needs of non-users and the environment. These guidelines are intended to provide operational efficiency, comfort, safety, and convenience to the motorists.

Design values for different highway functional classifications are provided, such as the design speed, the horizontal and vertical alignment, the number of lanes, the traveled way width, the roadway width, the right-of-way width, the structural capacity of new and in-place bridges, and the horizontal clearance to obstructions. The policy presents ranges of values for a number of situations and allows sufficient flexibility to encourage independent designs tailored to particular situations.

AASHTO Guidelines for Geometric Design of Very Low Volume Local Roads (ADT≤400), 2001

AASHTO, in conjunction with the FHWA and with the help of the National Association of County Engineers (NACE), the American Society of Civil Engineers (ASCE), the U.S. Forest Service, the American Public Works Association (APWA), and the National League of Cities, developed this document to address the unique needs and the appropriate geometric design of very low volume roads.

These guidelines address the unique design needs of very low volume local roads and the cost-effectiveness issues, which distinguish geometric design for these roads from the policies normally applied to higher volume roads. A recommended approach to geometric design is provided, for both new construction and existing roads, that is based on research concerning safety and cost-effectiveness of safety features incorporated into geometric elements and on review of site specific safety conditions.

National Bridge Inspection Standards (NBIS), 2005

The *NBIS* is a set of regulations developed by the FHWA, which establishes national standards for the proper safety inspection and evaluation of all highway bridges in accordance with the Title 23 USC 151 (2005a). These standards apply to all structures longer than 20 ft defined as highway bridges on public roads. The primary purpose of the *NBIS* is to identify and

evaluate existing bridge deficiencies to ensure the safety of the traveling public.

Bridge inspection organization

The *NBIS* requires that a State DOT, or Federal Agency, owner of a highway bridge shall include a bridge inspection organization. The manager of the bridge inspection organization shall be a registered professional engineer (PE) with at least ten years experience in bridge inspections and shall have successfully completed a FHWA-approved bridge inspection training course.

The bridge inspection organization is responsible for (1) formulation of bridge inspection policies and procedures, (2) quality assurance and quality control, (3) preparation and maintenance of a bridge inventory, 4) bridge inspections, and (5) inspection reports and load ratings. Bridge inspections shall be performed in accordance with the inspection procedures presented in the *AASHTO 1994 Manual for Condition Evaluation*, as amended by the 1995, 1996, 1998, 2000, 2001, and 2003 interim revisions.

A bridge shall be inspected at regular intervals that shall not exceed 24 months. Some bridges will require inspection at less than 24 months intervals, and others might be inspected at intervals greater than 24 months, without exceeding 48 months with prior written approval from the FHWA. The latter might be possible when past inspection findings and analysis justifies the increased inspection interval. State DOTs and Federal Agencies are responsible for establishing the criteria for the frequency of inspections considering factors such as the age of the bridge, traffic characteristics, and known deficiencies.

AASHTO LRFD Bridge Design Specifications (BDS), 2007

The *AASHTO LRFD BDS* contains improved bridge design and analysis specifications, which had been implemented by all 50 states, Washington DC, and the Commonwealth of Puerto Rico, as of October 2007. The *LRFD BDS* is mandated by the FHWA for use on all State projects using federal funding; and in 2010, the use of this code became compulsory on all State bridges, regardless of funding, and on all local bridges using federal funding.

The *LRFD BDS* is the most current specification regarding performance requirements for railings on new and rehabilitated bridges. According to the *LRFD BDS*, railings shall be provided along the edges of structures for the protection of traffic and pedestrians. Other applications may be warranted for bridge-length culverts; the guidance applicable for such structures may be found in the *AASHTO Roadside Design Guide* (2006).

The establishment of criteria for the placement, selection, and evaluation of bridge railings shall be the responsibility of the bridge owner. The bridge owner is responsible for making sure that the railing chosen satisfies the criteria as completely as possible and practical, and the owner needs to develop their own guidelines for the preservation, or upgrading, of their in-place railings. The factors to consider when selecting a bridge railing are: (1) protection of the occupants of a vehicle in a collision with the railing, (2) protection of other vehicles near the collision, (3) protection of persons and property on roadways and other areas underneath the structure, (4) railing cost effectiveness, and (5) appearance and freedom of view from passing vehicles.

Railings on new bridge structures shall satisfy the *NCHRP Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features* (Ross et al. 1993) crash testing requirements. In the case of existing bridge railings that have been designed to meet *AASHTO Standard Specifications for Highway Bridges* (2002) criteria, and that may have been crash tested under previous guidelines in the *NCHRP Report 230: Recommended Procedures for the Safety Evaluation of Highway Safety Appurtenances* (Michie 1981), their use may be accepted based on the evaluation of their in-service performance.

AASHTO Roadside Design Guide (RDG), 2006

The *AASHTO RDG* presents a summary of information and recommended practices about roadside design safety and serves as a guide to assist highways agencies in the development of their standards and policies. The purpose of the *AASHTO RDG* is to present the concepts of roadside safety in such a way that the most practical, appropriate, and beneficial roadside design can be accomplished for each project.

A roadside environment free of fixed objects, with stable, flattened slopes enhances the opportunity for reducing the severity of off-road crashes. When such a roadside environment cannot be provided, treatments should

be considered to provide an extra margin of safety for drivers who inadvertently leave the roadway.

The *AASHTO RDG* provides guidelines about the design and maintenance of roadside areas, guidelines for selecting and designing appropriate barrier systems, and performance requirements and warrants for safety treatments that can be provided to reduce the severity of off-roadway crashes, such as roadside and median longitudinal barriers, bridge railings, transition sections, sign breakaway supports, end treatments, and crash cushions.

The installation of roadside barriers is a major aspect of the roadside design. These roadside features protect errant vehicles from potential hazards by containing and redirecting them away from the hazards. All roadside safety devices approved for installation in a public road must have been subjected, to and met the requirements of, *NCHRP Report 350* standard crash tests.

NCHRP Report 350: Recommended Procedures for the Safety Performance Evaluation of Highway Features, 1993

The *NCHRP Report 350* presents standard procedures for crash testing of both permanent and temporary highway safety features and evaluation criteria for assessing tests results. The standard test procedures for traffic safety devices feature six test levels, from TL-1 to TL-6, to evaluate the occupant risk, the structural integrity of the barrier, and the post-impact behavior of the test vehicle. Each test level is defined by the impact conditions, such as the speed and the angle of impact, and the type of test vehicle. Table 1 presents a summary of the standard parameters of the *NCHRP Report 350* test levels.

NCHRP Report 350 utilizes six production model vehicles to test the performance of safety devices. Vehicles 700C and 820C are compact passenger cars, vehicle 2,000P is a pickup truck, vehicle 8,000S is a single unit truck, vehicle 36,000V is a tractor/van-type trailer unit, and 36,000T is a tractor/tank trailer unit. The numeric portion of the test vehicle designation is the vehicle's mass in kilograms. Tests for the 700C vehicle are optional.

The three primary factors considered in the crash performance evaluation of safety devices are: (1) structural adequacy, (2) occupant risk, and (3) post impact trajectory. The structural adequacy factor refers to the device's capability to contain, redirect, permit controlled penetration of the impacting vehicle, or permit a controlled stop in a predictable manner.

Table 1. NCHRP 350 test matrix of safety devices.

Test Level	Test Vehicle	Nominal Impact Speed, mph (km/hr)	Nominal Impact Angle (deg)
TL-1	700C 820C 2,000P	31 (50) 31 (50) 31 (50)	20 20 25
TL-2	700C 820C 2,000P	43 (70) 43 (70) 43 (70)	20 20 25
TL-3	700C 820C 2,000P	62 (100) 62 (100) 62 (100)	20 20 25
TL-4*	8,000S	50 (80)	15
TL-5*	36,000V	50 (80)	15
TL-6*	36,000T	50 (80)	15
* TL-3 crash criteria are also applied.			

The occupant risk factor relates to the degree of hazard to which occupants in the impacting vehicle would be subjected. The risk is measured in terms of the velocity at which a hypothetical unrestrained occupant strikes some part of the vehicle interior and the subsequent occupant ride-down accelerations. The third factor relates to the path that the vehicle would take after impact, and the possibility of the involvement of other vehicles in the crash due to the impacting vehicle trajectory. It is also used to determine if undesirable post impact vehicle behaviors after collision such as snagging and pocketing will occur.

Manual for Assessing Safety Hardware (MASH), 2009

The *NCHRP Report 350* was revised to update the test vehicles, the number and impact conditions of the test matrices, and the evaluation criteria, and to add new features to the test guidelines. *MASH 2009* supersedes *NCHRP Report 350* for the purpose of evaluating new permanent and temporary safety hardware devices; it does not supersede the design guidelines of safety hardware devices contained in the *2006 AASHTO Roadside Design Guide*.

Table 2 presents a summary of the updated standard parameters of the *MASH* test levels. Longitudinal barriers, including bridge railings, are the only safety devices for which the six test levels are defined. All other safety devices are designed for TL-1 through TL-3 only.

Table 2. MASH 2009 test matrix of safety devices.

Test Level	Test Vehicle	Nominal Impact Speed, mph (km/hr)	Nominal Impact Angle (deg)
TL-1	1100C** 2,270P**	31 (50) 31 (50)	25** 25
TL-2	1100C** 2,270P**	44 (70) 44 (70)	25** 25
TL-3	1100C** 2,270P**	62 (100) 62 (100)	25** 25
TL-4*	10,000S**	56 (90)**	15
TL-5*	36,000V	50 (80)	15
TL-6*	36,000T	50 (80)	15

Notes:
* TL-3 crash criteria are also applied.
** Modifications are from the NCHRP Report 350.

FHWA will not consider new applications for crashworthy approval of safety devices under *NCHRP Report 350* after January 1, 2011, although all highway safety hardware accepted under *NCHRP Report 350* criteria may remain in place and may continue to be manufactured and installed. Highway safety hardware installed on new construction and reconstruction projects shall be those accepted under *NCHRP Report 350* or *MASH*.

FHWA Bridge Rail Guide, 2005

The *FHWA Bridge Rail Guide* (2005b) was prepared by CALTRANS for the purpose of providing general information about current crashworthy bridge railing systems developed to meet *NCHRP Report 350* test standards. The guide includes information about the railing type, the test level, and typical costs for 94 railings, as well as indicating the location where the railing is typically used with pictures and drawings, if available. Chapter 5 of this report includes a series of tables that contain relevant information and pictures of the crashworthy bridge railings by material type that are published in the Bridge Rail Guide. This information is presented in this report, as requested, to make it easily available to bridge inspectors and allow them to familiarize themselves with typical crashworthy bridge railings used in the states.

Federal Lands Highways Barrier Guide for Low Volume and Low Speed Roads, 2005

The *Federal Lands Highways Barrier Guide* was prepared for the purpose of providing assistance in the warranting, selection, and design of roadside barriers for Federal Lands Highways projects on low volume low speed facilities. Similar to the *AASHTO 2006 RDG*, this report is not a standard, but it presents practical and useful guidance for common roadside conditions and situations encountered in the design of roadside barriers.

The typical character of FLH projects includes roadside safety concerns because of the presence of mountainous terrain, forests, boulders, and water hazards. It is also common for environmental, wildlife, and aesthetics concerns to be in conflict with roadside safety concerns.

Roadside design and barrier placement criteria in this report expand on the *AASHTO 2006 RDG* design process, making it more applicable to low volume low speed rural conditions. An alternate design process is included for locations with restricted conditions or severe cost constraints. The process identifies the most severe hazards close to the roadway that are appropriate for shielding by barriers, taking into considerations the costs, the expected crashes into the barriers, and local conditions, policies and resources. Hazards are classified into low, moderate, and high severity hazards. Possible corrective actions for hazards classified into each of these groups are presented to provide guidance to design engineers.

4 Geometric Design Aspects Related to Bridges

This chapter presents a review of relevant geometric design aspects of low volume roads included in the *AASHTO's Green Book* and the *Guidelines for Geometric Design of Very Low Volume Roads*. The intent is to present bridge inspectors with design guidelines of major roadway elements associated with bridges and not to provide a comprehensive review of all the design concepts provided in those two documents. For the complete set of policies and guidelines regarding roadway geometric design elements, readers are referred to the above mentioned documents.

Classification of highways

Classification schemes for road networks include the administrative classes in the National Highway System (NHS), the classification by jurisdiction (Interstates, U.S. highways, State roads, County roads, and City streets) and the AASHTO's functional classification.

AASHTO's *Policy on Geometric Design of Highways and Streets* (2004) defines functional classification as the process by which streets and highways are grouped into classes, or systems, according to the character of service they are intended to provide. This classification has become the predominant method for classifying highways. The functional classification is based on a five-stage movement hierarchy, which establishes that trips on a road network have an order of functionality based on the total amount of traffic volume: (1) main movement, (2) distribution, (3) collection, (4) terminal access, and (5) transition. Highways are functionally classified into three groups, namely: arterials, collectors, and local roads.

Arterial roads are divided into principal arterials and minor arterials. Principal arterials are facilities where the main movements take place, while minor arterials function primarily as distributors. These facilities provide high mobility, while operating under high volume and high speed conditions, offering service to major points of interest in rural and urban areas, and requiring the highest and most demanding design specifications.

Collector roads are facilities that move traffic between arterial and local roads, typically serving moderate traffic volumes. Collectors provide a balance between the mobility and accessibility aspects of arterials and local roads, respectively, representing a design compromise between these two classes.

Local roads include all facilities that provide terminal access to farms, residences, businesses, and other properties. These roads typically operate under low volume and low speed conditions. Local roads constitute approximately 70% of the total roadway mileage in the United States, while carrying 13% of the total VMT (BTS 2008).

The extent of the local road system is one of the principal reasons for the need to develop safe and cost efficient geometric design guidelines for such roads. The traffic conditions and geographical locations of these roads result in challenges to engineers in the application of existing AASHTO policies and guidelines.

Geometric design criteria

The road functional classification, the traffic volume, and the design speed are important factors that influence geometric design aspects, like the roadway alignment, longitudinal grades, cross-section width, and safety specifications. Chapter 5 of the *AASHTO's Green Book* (2004) contains design policies and recommended practices for local roads. Recommended design values for local roads are provided for traffic volume (AADT) categories ranging from less than 400 vehicle/day to more than 2,000 vehicle/day. AASHTO's geometric design criteria for arterial and collector roads are given for the same categories of traffic volume.

AASHTO's Guidelines for Geometric Design of Very Low Volume Roads defines very low volume roads as facilities with less than 400 vehicle/day. The document provides geometric guidelines for roads that serve low traffic volumes based on research concerning the cost-effectiveness of safety features and on reviews of site specific safety conditions. The application of these guidelines allows designers to use their engineering judgment to reduce the design criteria, as long as safety is not compromised. These design guidelines may be applied in lieu of *AASHTO's 2004 Policy on Geometric Design of Highways and Streets*, and the *2006 Roadside Design Guide*.

The *Manual on Uniform Traffic Control Devices (MUTCD)* (FHWA 2009a) defines low volume roads as facilities lying outside of built-up areas of cities, towns, and communities, and with traffic volumes of less than 400 vehicle/day. It further specifies that a low volume road shall not be a freeway, an expressway, an interchange ramp, a freeway service road, a road on a designated State highway system, or a residential street in a neighborhood.

For the purpose of this report, the AASHTO definition of a low volume road is preferred over the one in the MUTCD. In order to determine the applicable design guidelines for low volume roads, the operating characteristics, the geometry constraints, and configuration of the area where the road is located need to be analyzed. The AASHTO guidelines apply for both rural and urban roads; however, the guidelines for each area type are different. The main guidelines for the geometric design of bridges on low volume and low speed roads are included in the following sections.

Minimum bridge roadway width

Key cross-section elements include the traveled way and shoulder widths. For low volume roads, the design criterion addresses the total roadway width (i.e., traveled way + shoulders). Low volume roads might not include pavement markings, and in some cases, the material used for the shoulder construction does not contrast with the traveled way, not providing a clear demarcation between the traveled way and the shoulder.

For new bridges, the minimum clear bridge roadway width should comply with the values provided in Table 3 and included in the following:

- Bridges on local roads with traffic volumes less than 400 vehicle/day should have a minimum width equal to the width of the traveled way plus 0.6 m (2 ft) on each side.
- In cases where the approach roadway width is paved, the minimum width of the bridge should be equal to the total roadway width of the approach roadway.
- When the bridge has a length of over 30 m (100 ft) and traffic volumes over 2,000 vehicle/day, the minimum width of the traveled way plus 1 m (3 ft) on each side is acceptable for the minimum bridge width.
- For roads with traffic volumes less than 100 vehicle/day, one-lane bridges can be provided as long as this type of structure can operate effectively.

- Where one-lane bridges are to be designed, their minimum width should be 4.5 m (15 ft), and their maximum width, recommended by AASHTO, should be 4.9 m (16 ft), in order to avoid drivers using them as two-lane structures. These structures should provide visible pull-offs at each end for drivers to wait for the bridge to clear, in case of the simultaneous arrival of two or more vehicles.

Table 3. Minimum clear roadway widths and design loadings for new and reconstructed bridges (Exhibit 5-6, AASHTO 2004].

Metric			US Customary		
Design volume (veh/day)	Minimum clear roadway width for bridges[a]	Design loading structural capacity	Design volume (veh/day)	Minimum clear roadway width for bridges[a]	Design loading structural capacity
400 and under	Traveled way + 0.6 m (each side)	MS 18	400 and under	Traveled way + 2 ft (each side)	HS 20
400 to 2000	Traveled way + 1.0 m (each side)	MS 18	400 to 2000	Traveled way + 3 ft (each side)	HS 20
over 2000	Approach roadway width[b]	MS 18	over 2000	Approach roadway width[b]	HS 20

[a] Where the approach roadway width (traveled way plus shoulders) is surfaced, that surface width should be carried across the structures.

[b] For bridges in excess of 30 m [100 ft] in length, the minimum width of traveled way plus 1 m [3 ft] on each side is acceptable.

For existing bridges, the width of the adjacent roadway and the safety performance of the existing bridge need to be considered when evaluating the bridge design and the appropriate bridge width. In cases where a safety problem related to the width of an existing bridge is identified, acceptable minimum roadway widths are presented in Table 4.

The need for widening an existing bridge structure will have to be proven by providing evidence from a site-specific study that reveals a safety problem. The study shall involve analyzing the crash records of the location and performing a field visit to identify skid marks in the pavement, damage to the guardrails, or other evidence of a safety problem. The study should also include the expressed concerns of local residents and the police.

Table 4. Minimum Clear Roadway Widths and Design Loadings for Existing Bridges (Exhibit 5-7, AASHTO 2004)

Metric			US Customary		
Design volume (veh/day)	Design loading structural capacity	Minimum clear roadway width (m)[a,b,c]	Design volume (veh/day)	Design loading structural capacity	Minimum clear roadway width (ft)[a,b,c]
0 to 50	M 9	6.0[d]	0 to 50	H 10	20[d]
50 to 250	M 13.5	6.0	50 to 250	H 15	20
250 to 1500	M 13.5	6.6	250 to 1500	H 15	22
1500 to 2000	M 13.5	7.2	1500 to 2000	H 15	24
over 2000	M 13.5	8.5	over 2000	H 15	28

[a] Clear width between curbs or rails, whichever is the lesser.

[b] Minimum clear widths that are 0.6 m [2 ft] narrower may be used on roads with few trucks. In no case shall the minimum clear width be less than the approach traveled way width.

[c] Does not apply to structures with total length greater than 30 m [100 ft].

[d] For single-lane bridges, use 5.4 m [18 ft].

Roadway alignment

The horizontal alignment of the approach roadway to a bridge is an important aspect to consider in the design of the structure. Road alignment aspects should provide for the safe and continuous operation of road users. Consideration to the relationship between design speed, curve radius and super-elevation, and side friction is essential for the design of horizontal curves. Newman (AASHTO 2001) indicated that since horizontal curve design criteria, such as the maximum side friction factor (f_{max}) and the minimum radius (R_{min}), are based on driver comfort levels, the values given in *AASHTO's Green Book* can be lowered for low volume roads with no negative implication on safety.

AASHTO (2001) provides suggested horizontal curve design values for high-volume low speed roads. Super-elevation rates higher than 6% are not recommended for these roads due to the safety implication of higher super-elevation rates on low speed operating conditions.

For new low volume roadways without substantial recreational vehicle and truck volumes, acceptable design radii of horizontal curves may be obtained by applying a reduction of 5 to 10 mph in the design speed to the values presented in the *AASHTO's Green Book*.

For new low volume roadways with substantial recreational vehicle and truck volumes, acceptable design radii based on no reduction in the design speed should be used for very low design speeds (15 mph) in order to prevent truck rollover at low speeds. For higher speeds, acceptable design radii values could be based in a reduction in design speed of no more than 5 mph.

For additional guidelines on horizontal curve design criteria for different categories of very low volume local roads, refer to Chapter 5 of *AASHTO's Green Book* and Chapter 4 of *AASHTO's Guidelines for Geometric Design of Very Low Volume Roads*.

Sight distance

Sight distance is the length of the roadway ahead that is visible to the driver. Typically, roadway design practice provides Stopping Sight Distance (SSD) as a minimum value. The SSD provides a sufficiently long distance to allow a road user that is traveling at the design speed to perceive and avoid colliding with a 2-ft tall object on its path. The SSD is composed of the brake reaction distance and the braking distance. Figure 2 presents the SSD model used for level roads. Values of 2.5 sec for the brake reaction time and 11.2 ft/sec^2 (3.4 m/sec^2) for the deceleration rate are suggested by AASHTO to represent estimates for the 95th percentile and 10th percentile, respectively, of the road user population. A modified SSD model that incorporates the effect of the roadway longitudinal grade is presented in *AASHTO's Green Book*.

Metric	US Customary
$d = 0.278Vt + 0.039\frac{V^2}{a}$	$d = 1.47Vt + 1.075\frac{V^2}{a}$
where: t = brake reaction time, 2.5 s; V = design speed, km/h; a = deceleration rate, m/s^2	where: t = brake reaction time, 2.5 s; V = design speed, mph; a = deceleration rate, ft/s^2

Figure 2. Stopping sight distance model (AASHTO 2004).

On local roads with very low volumes and where the expectation of stopped vehicles is rare, the sight distance provided may be sufficient for a vehicle to maneuver around a small object, instead of coming to a full stop. The *AASHTO Guidelines for the Geometric Design of Very Low Volume*

Roads indicate that new low volume roads may provide lower sight distances than *AASHTO's Green Book* based on a lower expectation of stopped vehicles on these roadways. Acceptable sight distance criteria for new and existing roads are provided based on traffic volumes and the potential risk of locations, such as intersections, narrow bridges, sharp curves, steep grades, etc.

An alternative is the Maneuver Sight Distance (MSD) model developed in the *NCHRP Report 400* (Fambro et al. 1997). The MSD model can be applied to roads with traffic volumes less than 100 vehicle/day, and to roads with traffic volumes between 100 and 250 vehicle/day located at low-risk locations (e.g., away from intersections, narrow bridges, highway-railroad grade crossings, sharp curves, and steep downgrades).

The second approach suggests the application of different brake reaction time and driver deceleration rate values in the AASHTO SSD model. For low volume roads with traffic volumes between 100 and 250 vehicle/day located at high risk locations, and for roads with traffic volumes between 250 and 400 vehicle/day, the suggested parameter values are 2 sec and 13.4 ft/sec^2, respectively. Table 5 presents the design sight distance values for low volume roads based on the modified SSD parameter values.

Table 5. Design sight distance guidelines for new construction of very low volume roads (Exhibit 8, AASHTO 2001).

Metric				
	Minimum sight distance (m) for specified design traffic volumes and location types			
	0–100 veh/day	100–250 veh/day		250-400 veh/day
Design speed (km/h)	All locations	"Lower risk" locations[1]	"Higher risk" locations[2]	All locations
20	15	15	15	15
30	25	25	30	30
40	35	35	40	40
50	45	45	55	55
60	60	60	70	70
70	75	75	90	90
80	95	95	110	110
90	120	120	130	130
100	140	140	155	155
US Customary				
	Minimum sight distance (ft) for specified design traffic volumes and location types			
	0–100 veh/day	100–250 veh/day		250-400 veh/day
Design speed (mph)	All locations	"Lower risk" locations[1]	"Higher risk" locations[2]	All locations
15	65	65	65	65
20	90	90	95	95
25	115	115	125	125
30	135	135	165	165
35	170	170	205	205
40	215	215	250	250
45	260	260	300	300
50	310	310	350	350
55	365	365	405	405
60	435	435	470	470

[1] away from intersections, narrow bridges, railroad-highway grade crossings, sharp curves, and steep downgrades
[2] near intersections, narrow bridges, or railroad-highway grade crossings, or in advance of sharp curves or steep downgrades

Sight distance on curves

Providing adequate sight distance on curves is another important safety consideration in the design of horizontal and vertical alignments. Sight distance on horizontal curves is determined by having a minimum inside lateral distance clear of sight obstructions to allow drivers to see an obstacle ahead in the curve. Table 6 provides design guidelines for sight distance on horizontal curves for very low volume local roads.

Table 6. Design guidelines for sight distance on horizontal curves for new construction of very low volume local roads (Exhibit 10, AASHTO 2001).

Metric

All locations for 0–100 vpd and "lower risk" locations for 100–250 vpd[1]											"Higher risk" locations for 100–250 vpd and all locations for 250–450 vpd[2]										
Design speed (km/h)	Stopping sight distance (m)	Width on inside of curve clear of sight obstructions[3] (m) Radius of curvature (m) 10	50	100	200	500	1000	2000	4000	6000	Design speed (km/h)	Stopping sight distance (m)	Width on inside of curve clear of sight obstructions[3] (m) Radius of curvature (m) 10	50	100	200	500	1000	2000	4000	6000
20	15	2.7	0.6	0.3	0.1	0.1	0.0	0.0	0.0	0.0	20	15	2.7	0.6	0.3	0.1	0.1	0.0	0.0	0.0	0.0
30	25	–	1.6	0.8	0.4	0.2	0.1	0.0	0.0	0.0	30	30	–	2.2	1.1	0.6	0.2	0.1	0.1	0.0	0.0
40	35	–	3.0	1.5	0.8	0.3	0.2	0.1	0.0	0.0	40	40	–	3.9	2.0	1.0	0.4	0.2	0.1	0.1	0.0
50	45	–	–	2.5	1.3	0.5	0.3	0.1	0.1	0.0	50	55	–	–	3.8	1.9	0.8	0.4	0.2	0.1	0.1
60	60	–	–	–	2.2	0.9	0.5	0.2	0.1	0.1	60	70	–	–	–	3.1	1.2	0.6	0.3	0.2	0.1
70	75	–	–	–	3.5	1.4	0.7	0.4	0.2	0.1	70	90	–	–	–	5.0	2.0	1.0	0.5	0.3	0.2
80	95	–	–	–	5.6	2.3	1.1	0.6	0.3	0.2	80	110	–	–	–	7.5	3.0	1.5	0.8	0.4	0.3
90	120	–	–	–	–	3.6	1.8	0.9	0.5	0.3	90	130	–	–	–	–	4.2	2.1	1.1	0.5	0.4
100	140	–	–	–	–	4.9	2.4	1.2	0.6	0.4	100	155	–	–	–	–	6.0	3.0	1.5	0.8	0.5

US Customary

All locations for 0-100 vpd and "lower risk" locations for 100–250 vpd[1]											"Higher risk" locations for 100–250 vpd and all locations for 250–450 vpd[2]										
Design speed (mph)	Stopping sight distance (ft)	Width on inside of curve clear of sight obstructions[3] (ft) Radius of curvature (ft) 50	100	200	500	1000	2000	5000	10000	20000	Design speed (mph)	Stopping sight distance (ft)	Width on inside of curve clear of sight obstructions[3] (m) Radius of curvature (ft) 50	100	200	500	1000	2000	5000	10000	20000
15	65	10.2	5.2	2.6	1.1	0.5	0.3	0.1	0.1	0.0	15	65	10.2	5.2	2.6	1.1	0.5	0.3	0.1	0.1	0.0
20	90	–	10.0	5.0	2.0	1.0	0.5	0.2	0.1	0.1	20	95	–	11.1	5.6	2.3	1.1	0.6	0.2	0.1	0.1
25	115	–	–	8.2	3.3	1.7	0.8	0.3	0.2	0.1	25	125	–	–	9.7	3.9	2.0	1.0	0.4	0.2	0.1
30	135	–	–	11.3	4.5	2.3	1.1	0.5	0.2	0.1	30	165	–	–	16.8	6.8	3.4	1.7	0.7	0.3	0.2
35	170	–	–	–	7.2	3.6	1.8	0.7	0.4	0.2	35	205	–	–	–	10.5	5.2	2.6	1.1	0.5	0.3
40	215	–	–	–	11.5	5.8	2.9	1.2	0.6	0.3	40	250	–	–	–	15.5	7.8	3.9	1.6	0.8	0.4
45	260	–	–	–	16.8	8.4	4.2	1.7	0.8	0.4	45	300	–	–	–	22.3	11.2	5.6	2.3	1.1	0.6
50	310	–	–	–	–	12.0	6.0	2.4	1.2	0.6	50	350	–	–	–	–	15.3	7.7	3.1	1.5	0.8
55	365	–	–	–	–	16.6	8.3	3.3	1.7	0.8	55	405	–	–	–	–	20.4	10.2	4.1	2.1	1.0
60	435	–	–	–	–	23.6	11.8	4.7	2.4	1.2	60	470	–	–	–	–	27.5	13.8	5.5	2.8	1.4

[1] "lower risk" locations are locations away from intersections, narrow bridges, railroad-highway grade crossings, sharp curves, and steep grades
[2] "higher risk" locations are locations near intersections, narrow bridges, or railroad-highway grade crossings, or in advance of sharp curves or steep downgrades
[3] width on inside of curve clear of sight obstructions is measured from the centerline of the inside lane

The major concern when designing vertical curves (sag and crest curves) is to provide a smooth and gradual change between roadway grades that result in a safe and comfortable operation for drivers, while at the same time providing an efficient design in appearance and drainage. Table 7 presents the suggested values of the rate of vertical curvature K to calculate the appropriate length of crest vertical curves. The K values are multiplied by the algebraic difference in grades to obtain the corresponding curve length.

For existing low volume roads, the cost associated to increment sight distance in adverse horizontal and vertical alignments might not be cost effective in most situations. If a safety problem is identified related to sight distance restrictions, alternative safety treatments, such as the use of traffic control devices and traffic calming, should be evaluated.

Table 7. Guidelines for minimum rate of vertical curvature to provide design stopping sight distance on crest vertical curves for new construction of very low volume local roads (Exhibit 12, AASHTO 2001).

Metric

Design speed (km/h)	All locations for 0–100 vpd and "lower risk" locations for 100-250 vpd[1]: Stopping sight distance (m)	Rate of vertical curvature, K[3]: Calculated	Rate of vertical curvature, K[3]: Design	"Higher risk" locations for 100–250 vpd and all locations for 250–400 vpd[2]: Stopping sight distance (m)	Rate of vertical curvature, K[3]: Calculated	Rate of vertical curvature, K[3]: Design
20	15	0.3	0.5	15	0.3	0.5
30	25	0.9	1	30	1.4	2
40	35	1.9	2	40	2.4	4
50	45	3.1	4	55	4.6	5
60	60	5.5	6	70	7.4	8
70	75	8.5	9	90	12.3	13
80	95	13.7	14	110	18.4	19
90	120	21.9	22	130	25.7	26
100	140	29.8	30	155	36.5	37

US Customary

Design speed (mph)	All locations for 0–100 vpd and "lower risk" locations for 100–250 vpd[1]: Stopping sight distance (ft)	Rate of vertical curvature, K[3]: Calculated	Rate of vertical curvature, K[3]: Design	"Higher risk" locations for 100–250 vpd and all locations for 250–400 vpd[2]: Stopping sight distance (ft)	Rate of vertical curvature, K[3]: Calculated	Rate of vertical curvature, K[3]: Design
15	65	2.0	2	65	2.0	2
20	90	3.8	4	95	4.2	5
25	115	6.1	7	125	7.2	8
30	135	8.4	9	165	12.6	13
35	170	13.4	14	205	19.5	20
40	215	21.4	22	250	29.0	29
45	260	31.3	32	300	41.7	42
50	310	44.5	45	350	56.8	57
55	365	61.7	62	405	76.0	76
60	435	87.7	88	470	102.4	103

[1] "lower risk" locations are locations away from intersections, narrow bridges, railroad-highway grade crossings, sharp curves, and steep grades

[2] "higher risk" locations are locations near intersections, narrow bridges, or railroad-highway grade crossings, or in advance of sharp curves or steep downgrades

[3] the rate of vertical curvature, K, is the length of curve (L) per percent algebraic difference in intersecting grades (A); i.e., K = L/A.

5 Roadside Design Guidelines

This chapter presents a review of the main roadside design aspects and their relation to bridge safety included in the *AASHTO Roadside Design Guide* (2006) and the *FLH Barrier Guide* (2005). The intent of the chapter is to provide bridge inspectors with relevant information for bridge safety evaluations and not to provide a comprehensive review of all the roadside design concepts provided in the two mentioned documents.

The roadside is the area between the outside shoulder edge and the right of way limits. The main objective of roadside design is to provide a safe area for drivers who leave the road and encroach on the roadside. The *AASHTO 2006 RDG* presents six strategies for reducing roadside obstacles that represent the proper approach to be taken when encountering obstacles within the established clear zone of a roadway: (1) remove the obstacle; (2) redesign the obstacle, so it can be safely traversed; (3) relocate the obstacle to a place where it would be less likely to be struck; (4) use an appropriate breakaway design to reduce impact severity; (5) shield the obstacle with a traffic barrier; and (6) delineate the obstacle.

Two key aspects of roadside design are the determination of the clear zone width and establishing the need for the installation of safety barriers when the roadside clear zone cannot be provided.

Clear zone distance

The clear zone is the lateral distance, starting from the edge of the traveled way, available for the safe use of errant vehicles. The desired clear zone width depends on the traffic volume, the roadway design speed, and the side slopes. Table 8 presents the *AASHTO 2006 RDG's* recommended clear zone values.

Side slopes are classified in three categories: recoverable slopes, non recoverable slopes, and critical slopes. A recoverable slope allows a vehicle to slow down or stop, and return to the road in a safe manner; it is defined as a slope 1V:4H or flatter. A non-recoverable slope, defined between 1V:3H and 1V:4H, will not allow the vehicle to slow down or stop as easily, probably resulting in the vehicle reaching the end of the slope before trying to return to the roadway. Critical slopes, defined as 1V:3H or steeper, increase

the likelihood of a vehicle overturning, prompting the installation of a safety barrier, whenever the clear zone distance is not provided.

Table 8. Recommended clear zone values (AASHTO 2006].

[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 crash history, the designer may provide clear-zone distances greater than the clear-zone shown in Table 3.1. Clear zones may be limited to 30 ft for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates 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 toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of slope. Determination of the width of the recovery area at the toe of slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of slope. While the application may be limited by several factors, the foreslope parameters which may enter into determining a maximum desirable recovery area are illustrated in Figure 3.2.

The *AASHTO 2006 RDG's* recommended clear zone values in Table 8 provide limited information for low speed road conditions. *Federal Lands Highways* (2005) developed guidance associated to the determination of clear zone distances and the selection of safety barriers for low speed low volume roads. Table 9 presents recommended clear zone values for roads with speeds below 40 mph as an extension of *AASHTO RDG* values in Table 8.

Correction factors for the recommended clear zone values on the high side of horizontal curves are provided in both *AASHTO's RDG* and *FLH Guide.* The correction factors are applied whenever engineering judgment finds it essential, normally in locations with high crash records, or where site specific safety evaluation has deemed it necessary.

Table 9. Clear zone values for low speed facilities (FLH 2005).

(Continued) (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
20 mph	Under 750	2 - 6	3 – 7	**	2 - 6	2 - 6	3 - 7
	750 - 1500	3 - 7	5 - 8		2 - 6	2 - 6	3 - 7
	1500 - 6000	5 - 8	6 - 10		3 - 7	3 - 7	5 - 8
	over 6000	7 - 10	7 - 10		5 - 8	5 - 8	7 - 10
25 - 30 mph	Under 750	3 - 7	5 – 8	**	2 - 6	2 - 6	3 - 7
	750 - 1500	5 - 8	6 - 10		3 - 7	3 - 7	5 - 8
	1500 - 6000	7 - 10	7 - 10		5 - 8	5 - 8	7 - 10
	over 6000	7 - 10	10 - 12		7 - 10	7 - 10	7 - 10
35 mph	Under 750	5 - 8	6 – 10	**	3 - 7	3 - 7	5 - 8
	750 - 1500	7 - 10	7 - 12		5 - 8	5 - 8	7 - 10
	1500 - 6000	10 - 12	12 - 14		7 - 10	7 - 10	10 - 12
	over 6000	12 - 14	14 - 16		10 - 12	10 - 12	12 - 14

* See the AASHTO *Roadside Design Guide* for design speeds 40 mph and higher.

** Foreslopes between 1V: 4H and 1V: 3H are traversable but non-recoverable. Since vehicles will not reduce speed or change direction on these slopes the needed clear zone is determined by the slopes above and below the non-recoverable slope and extended by the width of the non-recoverable slope. See Chapter 3 of the *RDG* for more information on this procedure. Foreslopes steeper than 1V: 3H are considered hazards.

For low volume roads, the clear zone decision shall be based on the results of a site-specific safety evaluation. AASHTO (2001) provides the following additional guidelines in exercising engineering judgment to decide the appropriate or necessary clear zone:

- A clear recovery area of 6 ft should be considered at locations that present low cost and minimal social and environmental impacts.
- A clear recovery area less than 6 ft may be provided at locations with cost, terrain, and right of way constraints, and with potential social and environmental impacts.

The roadside design can be modified to site-specific conditions, considering trade-offs between cost effectiveness and safety. When analyzing the need for appropriate clear zones, the location crash history, the expected growth of traffic, and the presence of heavy vehicles need to be considered.

Safety barrier warrants

The decision to install a safety barrier is based on warrants that provide guidance to the designer in evaluating the potential safety and operational benefits of traffic control devices or features (AASHTO 2007). Warrants are not absolute requirements; they are means of conveying concern over a potential traffic hazard.

Barrier warrants recommend the installation of a barrier only if it reduces the severity of potential crashes, as their installation could lead to increasing crash frequencies, due to their proximity to the traveled way. When designing low volume roads, the use of barriers is not generally cost effective due to the low frequency of collisions, except at locations where the potential consequences of leaving the roadway are likely to be severe, such as bridges.

FLH (2005) indicates the following process for warranting barriers: (1) determine the needed clear zone, (2) identify potential hazards, (3) analyze roadside safety strategies, and (4) evaluate the installation of roadside barriers. The analysis of the current roadway and traffic conditions and crash history is needed in existing roads in order to have a comprehensive view of the site roadside safety needs. A crash history that includes at least three to five years is recommended to identify crash patterns in many locations; longer analysis periods are recommended for low volume roads.

Barriers can also be warranted by means of a benefit/cost analysis, where factors such as design speed, traffic volumes, and roadway geometry are considered. NCHRP Report 492 (Mak and Sicking 2003) developed the Roadside Safety Analysis Program (RSAP) and included an improved cost-effective analysis procedure for assessing roadside safety improvements.

The identification of fixed objects or roadside features and its potential crash severity is a critical step of the barrier warranting process. FLH (2005) provides severity classifications of low (Group 1), moderate (Group 2), and high (Group 3) for several potential roadside hazards. The severity classification varies with the hazard type, size, and quantity. The severity is a measure of the consequences of a crash once the hazard is struck and is as a function of the vehicle speed and the relative seriousness of a crash.

Tables 10-13 present the severity classification of four groups of potential roadside hazards to be used as a guide in the warranting process of safety barriers.

The hazard severity classifications are associated to a severity index that considers the mix of likely crash types, i.e., fatal, injury, and property-damage-only. The severity index is measured using a zero to ten scale. All the severity indices are estimated for a 100 km/hr (62mph) crash, but

Table 10. Severity classification for fixed objects (FLH 2005).

Potential Hazard	Group 1 (Low Severity)	Group 2 (Moderate Severity)	Group 3 (High Severity)
Bridge piers, abutments and railing ends			X
Boulders, less than 0.3 m (1 ft) in diameter		X	
Boulders, 0.3 m (1 ft) in diameter or larger			X
Non-breakaway sign and luminaire supports		X	
Individual trees, greater than 100 mm (4 in) and less than 200 mm (8 in) diameter	X		
Individual trees, greater than 200 mm (8 in) diameter		X	
Groups of trees, individually greater than 100 mm (4 in) diameter*			X
Utility poles		X	

* Because of driver expectancy, a group of trees at a consistent offset for lengthy distances may experience lower encroachment rates, even though the offset may be within the clear zone. In such instances, it may be appropriate to consider the trees a Group 2 hazard.

Table 11. Severity classification for drainage features (FLH 2005).

Potential Hazard	Group 1 (Low Severity)	Group 2 (Moderate Severity)	Group 3 (High Severity)
Cross Drain Culvert Ends:			
Exposed culvert ends with no headwalls, 1 m (36 in) in diameter or less		X	
Exposed culvert ends with no headwalls, greater than 1 m (36 in) in diameter			X
Sloped culvert ends, less than 1.2 m (4 ft) in diameter	X		
Sloped culvert ends, greater than 1.2 m (4 ft) and less than 2.4 m (8 ft) in diameter		X	
Sloped culvert ends, 2.4 m (8 ft) or greater in diameter			X
Vertical headwalls, less than 1.0 m (3 ft) in height		X	
Vertical headwalls, 1 m (3 ft) or higher			X
Headwalls with parallel sloped wingwalls, 0.6 m (2 ft) or less height		X	
Headwalls with parallel sloped wingwalls, greater than 0.6 m (2 ft) height			X
Headwalls with flared and sloped wing walls, 1.0 m (3 ft) or less height		X	
Headwalls with flared and sloped wing walls, greater than 1.0 m (3 ft) height			X
Culvert end sections with crashworthy grates	X		
Parallel Drain Culvert Ends:			
Exposed culvert ends with no headwalls, less than 0.6 m (2 ft) in diameter	X		
Exposed culvert ends with no headwalls, 0.6 m (2 ft) and less than 1.2 m (4 ft) in diameter		X	
Exposed culvert ends, 1.2 m (4 ft) or greater in diameter			X
Mitered culvert ends, less than 1 m (3 ft) in diameter	X		
Mitered culvert ends, 1 m (3 ft) or greater in diameter		X	
Vertical headwalls, less than 1 m (3 ft) above ditch section		X	
Vertical headwalls, 1 m (3 ft) or higher above ditch section			X

Table 12. Severity classification for grading features (FLH 2005).

Potential Hazard	Group 1 (Low Severity)	Group 2 (Moderate Severity)	Group 3 (High Severity)
Parallel Ditches:			
Ditches outside the preferred cross section on Figures 3.6 and 3.7 of the *RDG* and with foreslope flatter than 1V: 3H	X		
Ditches with foreslopes 1V: 3H or steeper (Deep ditches should also meet the foreslope criteria below)		X	
Slopes			
1V: 3H foreslope less than 2 m (7 ft) high*	X		
1V: 3H foreslope 2 m (7 ft) and higher*		X	
1V: 2H to 1V: 1.5H foreslope less than 4 m (13 ft) high*		X	
1V: 2H to 1V: 1.5H foreslope 4 m (13 ft) high and higher			X
Vertical foreslope or fill wall less than 2 m (7 ft) high		X	
Vertical foreslope or fill wall 2 m (7 ft) and higher			X
Backslopes that are uneven, or with deep erosion ruts, large rocks, and trees		X	
Vertical backslope with horizontal projections of 200 mm (4 in) or smaller	X		
Vertical backslope with horizontal projections larger than 200 mm (4 in)		X	
Downward intersecting slope (transverse to travel way, such as a river bank) 1V: 4H or steeper, between than 0.5 (2 ft) high to 2 m (6 ft) high		X	
Downward intersecting slope (transverse to travel way, such as a river bank) 1V: 4H or steeper, 2 m (6 ft) or higher			X
Upward intersecting slope (transverse to travel way, such as an overpass fill) 1V: 4H to flatter than 1V: 1.5H, greater than 0.3 m (1 ft) high		X	
Upward intersecting slope (transverse to travel way, such as an overpass fill) 1V: 1.5 H or steeper, greater than 0.3 m (1 ft) high			X

* Slopes are assumed to be relatively smooth and free of obstacles. If slopes are uneven, have deep erosion ruts, large rocks and trees or other vegetation that may cause a vehicle to be unstable, then the classification should be increased one category. Conditions at the bottom of these slopes must also be evaluated.

Table 13. Severity classification for other features (FLH 2005).

Potential Hazard	Group 1 (Low Severity)	Group 2 (Moderate Severity)	Group 3 (High Severity)
Parallel smooth retaining wall or cut slope	X		
Retaining wall parallel or flared away from approaching traffic at flatter than 1:8	X		
Retaining wall flared away from approaching traffic at 1:8 or steeper		X	
Water at a depth of 0.3 m (1 ft) to 1 m (3 ft)		X	
Water at a depth of 1 m (3 ft) or deeper			X

generally will have the same relative meaning at lower speeds (FLH 2005). Appendix A of the *AASHTO 2006 RDG* defines the scale using proportions of crash types.

FLH (2005) provides the following guidance about possible corrective measures for each of the three severity classes, namely Groups 1, 2, and 3:

- Group 1 hazards are estimated to have a severity index of below 3 (i.e., fatalities are unlikely). The low crash severity implication of these hazards suggests that accepting the risk and leaving the hazard could be appropriate in some locations. If possible, avoid having these conditions in the clear zone, or take low cost corrective actions.
- Group 2 hazards are estimated to have a severity index of 3 to 4.9 (i.e., some possibility of serious injury and fatality, but probably less severe than barriers). Current acceptable roadside barriers are estimated to have a severity index of 4.9 (FLH 2005); therefore, this group of hazards generally does not warrant shielding with a roadside barrier.
    - Consider cost effective strategies to reduce the probability of a crash by eliminating the hazard, by relocating the hazard outside of the clear zone, or by reducing the severity of the hazard.
    - Group 2 hazards should be considered for the same corrective actions as Group 3 hazards, if there is evidence of crash history, or the hazards are located so that a vehicle could strike more than one hazard in the same run-off-the-road event.
- Group 3 hazards have a severity index of 5 and higher (i.e., may be more severe than to crash into a barrier). Evaluate the need for possible use of roadside barriers if it is too expensive or impractical to eliminate either the hazard or make it crashworthy. If a barrier is found not to be warranted, or if an alternate treatment is less than expensive than a barrier, treat as a Group 2 hazard.

Bridge piers, abutments, and railing ends are classified in the high severity group as the consequences of drivers' going over the edge of the structure, or hitting the abutment or railing end, if unshielded, are severe; and for this reason, railings are generally warranted (AASHTO 2006). Culverts are classified in different categories depending on their dimensions and other characteristics. The governmental authority or department responsible for all safety design features and functions of a bridge shall develop the

appropriate warrants for the bridge sites. The bridge railing installed should comply with the warrants established, and be as safe as practical.

Bridge safety barrier system components

After deciding that a barrier is warranted, the selection of the appropriate barrier system is based on the required level protection. A bridge railing system can be composed of up to four components: (1) the bridge rail, (2) the transition rails, (3) the standard section or approach guardrails, and (4) the end terminals, as shown in Figure 3.

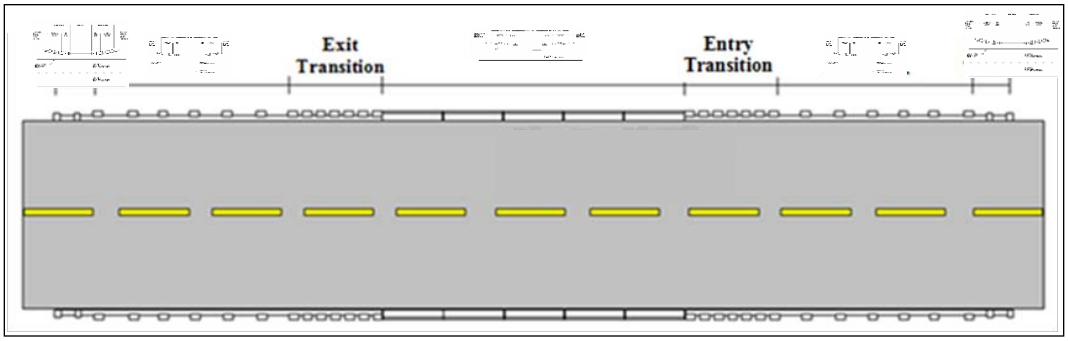


Figure 3. Typical components of bridge safety barriers.

The barriers on bridges and their approaches need to provide vehicular containment and prevent motorist penetration into the hazard being over-passed, such as a stream, or under-passing roadway, or railroad. The design of the bridge railings and the approach guardrails also needs to prevent rollover, minimize snagging and the possibility of vehicle spinout, and to provide smooth vehicular redirection parallel with the barrier system, while providing tolerable deceleration limits for seat belted occupants (FHWA 2006).

The bridge rail is an integral part of the bridge deck structure, intended to prevent a vehicle from running off the edge of it. Bridge railings are typically designed to have no deflection when struck by a vehicle. A bridge railing shall have the proper strength and design to contain and redirect a vehicle without snagging, vaulting, stopping abruptly, or penetrating the vehicle's passenger compartment.

The transition section is the element used when the type and materials, and deflection capabilities of the bridge rail and the approach guardrail differ (a rigid bridge rail vs. a semi-rigid approach guardrail). The transition

provides a gradual stiffening of the approach guardrail in order to prevent vehicles from snagging, pocketing, or penetrating it.

The approach guardrail is a longitudinal barrier, preceding the structure and attached to the bridge rail, to prevent a vehicle from hitting a hazard in front or at the side of the structure, or impacting the end of the bridge railing or parapet.

The end treatment is a designed modification of the end of a roadside barrier or bridge end to prevent it from penetrating the vehicle compartment and causing harm to the vehicle's occupants.

Barrier selection guidelines

There are seven factors to consider in the selection of a barrier. These are the barrier performance capability, the barrier deflection capability, and its compatibility with existing systems, costs, maintenance, aesthetics, and field performance.

The test level (TL-1 to TL-6) identifies the barrier performance capability based on the vehicle weight, and the impact speed and angle. The following test level applications are suggested in *AASHTO RDG* (2006):

- TL-1: work zones with low posted speed and low volume local streets
- TL-2: work zones, and most local and collector roads with low posted speeds and with a low number of heavy vehicles expected
- TL-3: high speed arterials with low mixtures of heavy vehicles and with favorable site conditions
- TL-4: high speed highways, freeways, expressways, and interstate highways with a mixture of trucks and heavy vehicles
- TL-5: same locations as TL-4, but with a significant percent of the ADT made of large trucks, or with unfavorable site conditions
- TL-6: same locations as TL-4, but with a significant percent of the ADT made of tanker trucks and unfavorable site conditions.

AASHTO LRFD BDS (2007) establishes that all bridge railings must be crash tested and approved by the NCHRP Report 350 criteria in Table 1.

The available deflection distance dictates the type of barrier to be used. In locations where the distance between the barrier and the potential hazard is large, the use of a flexible barrier system that deflects upon impact and

imposes lower impact forces on the vehicle and its occupants is allowed. Where the hazard is immediately adjacent to the barrier (e.g., as on a bridge), a semi rigid or rigid barrier is the appropriate choice.

The cost of bridge railings is subdivided in three categories: initial, long-term maintenance, and crash costs. The initial cost of a bridge rail is directly proportional to its strength; as the strength and rigidity of the rail increase, so does the initial cost. Maintenance costs are inversely proportional to the railing strength; as the strength increases, the costs of maintenance decrease. Crash costs include damages to the impacting vehicle and its occupants. It is also important to use railing designs, which minimize deck damage, since this type of damage significantly increases the crash cost.

Documenting the in-service performance of bridge railings will help in determining if the railing is working properly and in determining its long-term maintenance and the life-cycle costs. A bridge railing's documented past performance can be the determining factor for its selection in a particular project.

Warrants for bridge railing systems

Bridge owners shall develop warrants for the bridge site. A bridge railing should be chosen to satisfy the concerns of the warrants as completely and practically as possible (AASHTO 2007).

Bridge railing warrants should contain the test level that a railing shall comply. The test level chosen shall be the responsibility of the authority in charge of the design of the bridge, and it shall be selected in accordance with the site conditions. The design speed and design vehicle for a road facility can be controlling factors in the development of warrants for a bridge site.

TL-3 is the most common test level requirement used by state DOTs for bridge railings and roadside barriers. Bridges with low traffic volumes at reduced speeds do not require the installation of high performance bridge railings. Low volume secondary road facilities with posted speed limits not exceeding 45 mph and without large truck traffic could use railings approved for TL-2. *AASHTO* (2006) does not recommend TL-1 bridge railings, since operating speeds could exceed the 31 mph TL-1 criteria.

The height of the railing helps prevent vehicles from rolling over it; especially heavy vehicles with a higher center of gravity. Bridge railings shall be at least (AASHTO 2007):

- 27 in. (685 mm) for TL-3
- 32 in. (810 mm) for TL-4
- 42 in. (1,070 mm) for TL-5, and
- 90 in. (2,290 mm) for TL-6.

The shape of the face of a railing has a significant effect in its performance. A vertical face concrete rail is the preferred shape when there is high volume of heavy truck traffic, since other safety shapes can cause the vehicle to rollover.

The use of curbs higher than 8 in. in front of bridge rails should be avoided, and the installation of raised sidewalks is reserved to low speed roads. A combination barrier should be placed at the outer edge of the sidewalk in these situations, as shown in Figure 4.

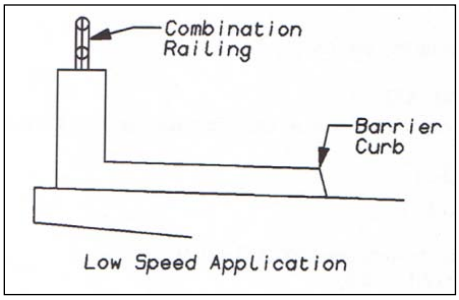


Figure 4. Combination railing application for low speed highways (AASHTO 2007).

On high speed facilities, the pedestrian walkway should be separated from the roadway by the installation of a traffic railing, which gives maximum protection to pedestrians, as shown in Figure 5. The minimum height of a pedestrian railing shall be 42 in. (1,070 mm) measured from the top of the walkway.

When the railing is composed of both vertical and horizontal elements, the spacing for the lower 27 in. (685 mm) of the rail should not allow a 5.9-in. (150 mm) diameter sphere to pass, while spacing for the upper section should not allow a 7.8-in. (200 mm) diameter sphere to pass through.

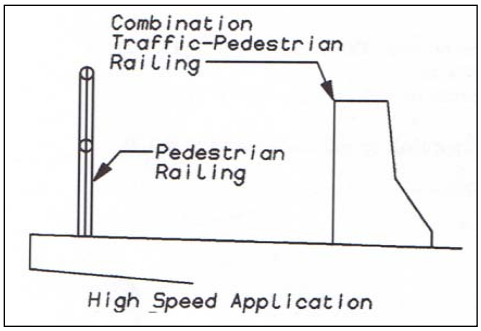


Figure 5. Pedestrian railing application for high speed highways (AASHTO 2007).

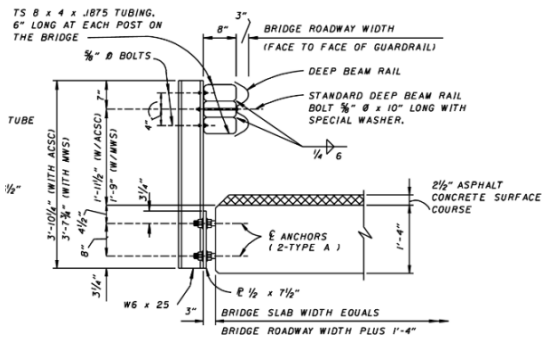
Crashworthy bridge railing systems

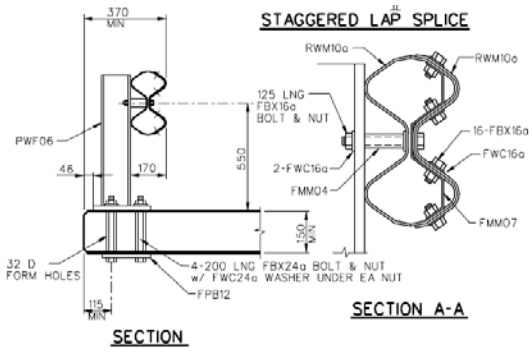
AASHTO LRFD BDS requires that a bridge railing be crash tested to *NCHRP 350* test criteria before its use. In the case of existing structures with railings that were designed in accordance with *AASHTO Standard Specifications for Highway Bridges* criteria or structures with railings that may have been crash tested under the previous *NCHRP 230: Recommended Procedures for the Safety Performance Evaluation of Highway Safety Appurtenances*, their continued use may be acceptable based on an evaluation of their in-service performance.

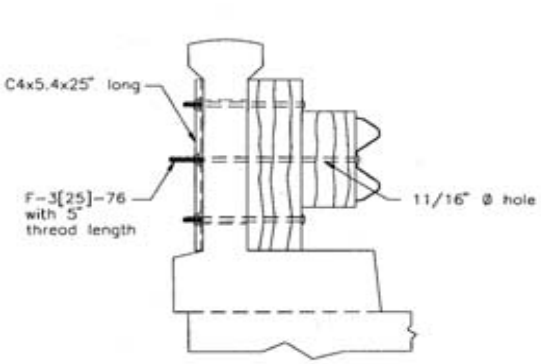
FHWA maintains a website that includes information about crashworthy bridge railings and longitudinal roadside barrier systems, transitions, and end treatments, under the various crash test requirements of NCHRP Reports 350 and 230. Acceptance letters, as well as links to manufacturers' websites for information on proprietary systems are included on the FHWA website. The website is found at the following address: http://safety.fhwa.dot.gov/-roadway_dept/policy_guide/road_hardware/.

The *FHWA Bridge Rail Guide* (2005b) provides the test level, general information, and typical costs for bridge railings that meet the NCHRP Report 350 criteria. This guide has six sections with different railing types: W-beam bridge rails, Thrie-beam bridge rails, metal tube bridge rail, vertical concrete parapets, F-shape concrete barriers, and timber bridge rails. Tables 14-20 provide information on crashworthy bridge railings. The intent of the tables is to allow bridge inspectors access to general information about crashworthy bridge railings. All tables are organized by test level accepted and rail height.

Table 14. Crash tested w-beam railings.

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Box Beam Rail	TL-2	27 in.	Ohio	$41/ft
Barrier Profile			Barrier Picture	
				
Comments: Its minimum height after maintenance overlays is 27 in.				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Type T6 Tubular W-Beam	TL-2	27 in.	Texas	$38/ft
Barrier Profile			Barrier Picture	
				
Comments: Its minimum height after maintenance overlays is 27 in.				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
W-Beam Retrofit	TL-2	28.5 in.	West Virginia	N/A
Barrier Profile			**Barrier Picture**	
				
Comments: Its minimum height after maintenance overlays is 28.5 in.				

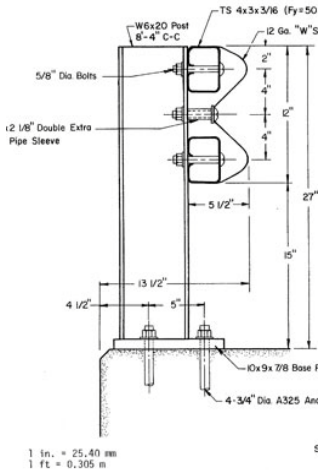
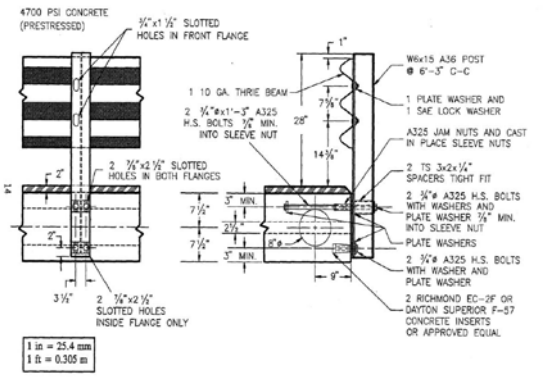
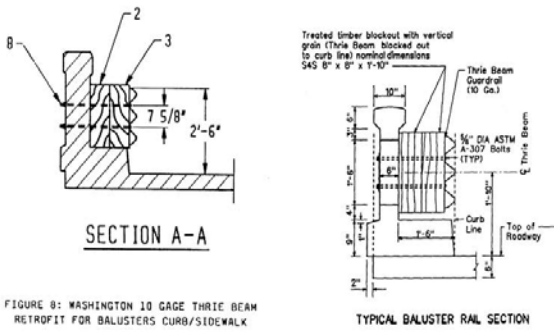
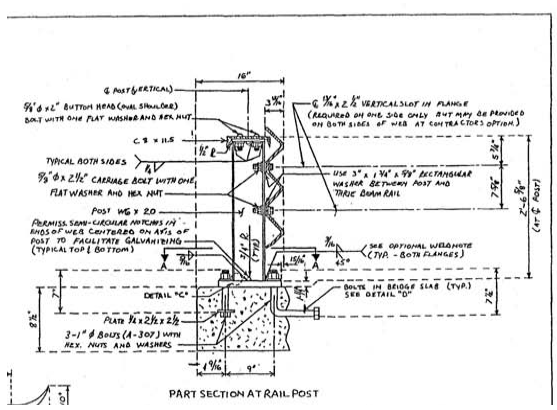
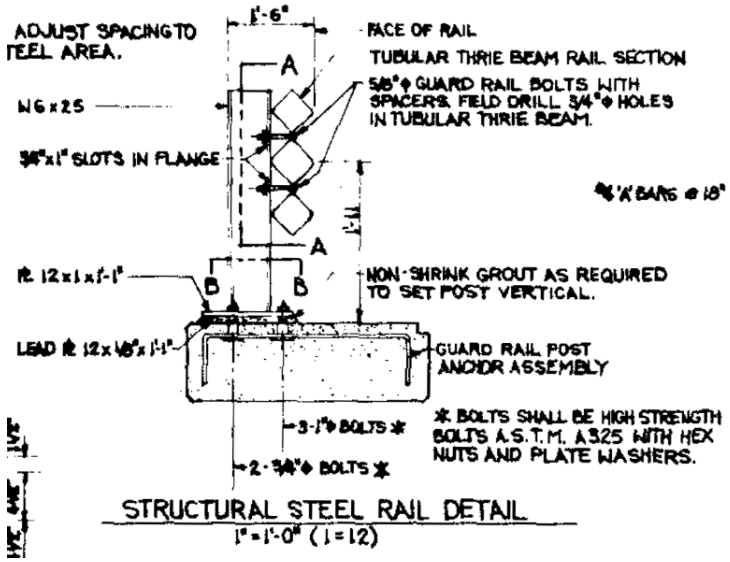
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Texas T101	TL-2	32 in.	Federal Lands	$90/ft
Barrier Profile			**Barrier Picture**	
				
Comments: This railing is 27 in. high with two rectangular tubes and W beam, and with W6×20 posts spaced a maximum of 8.33 ft apart. Its minimum height after maintenance overlays is 27 in.				

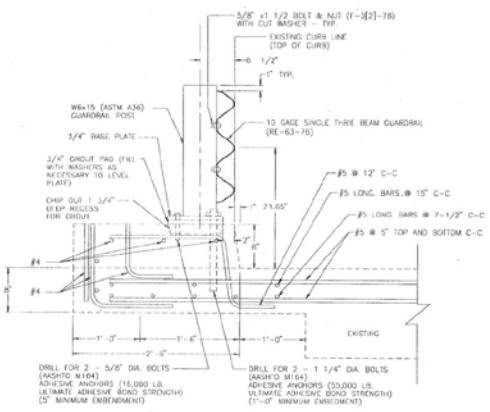
Table 15. Crash tested Thrie-beam railings.

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Oregon Thrie Beam Side Mount	TL-2	29 in.	Oregon	$69.60/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Washington 10-Gauge Thrie Beam Retrofit	TL-2	30 in.	Washington	$40/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Missouri Thrie Beam Rail and Channel	TL-3	30.5 in.	Missouri	$100/ft - $125/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Nebraska Tubular Thrie Beam Rail	TL-3	32 in.	Nebraska	Not Available
Barrier Profile				
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
DL Thrie Beam Retrofit	TL-4	32 in.	Delaware	Not Available
Barrier Profile			Barrier Picture	
				
Comments: Its minimum height after maintenance overlays is 28.5 in.				

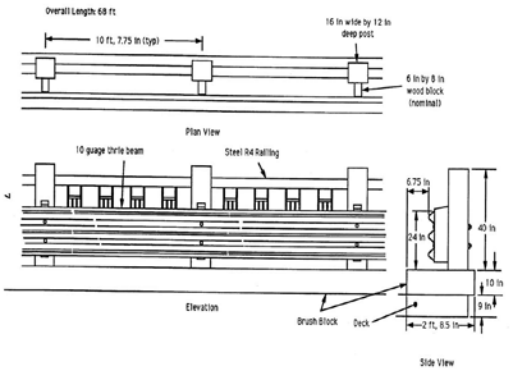
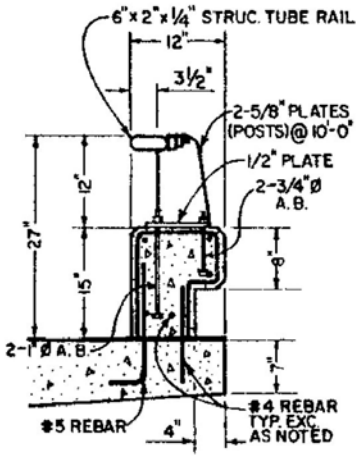
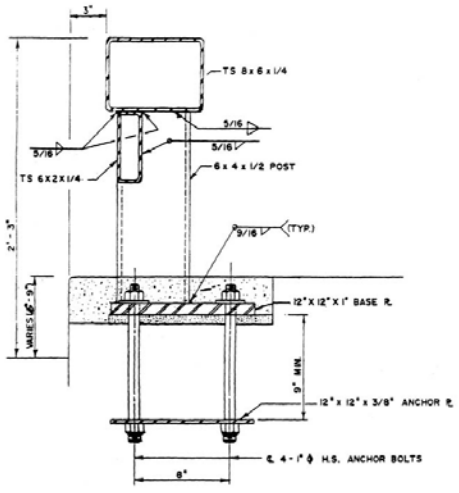
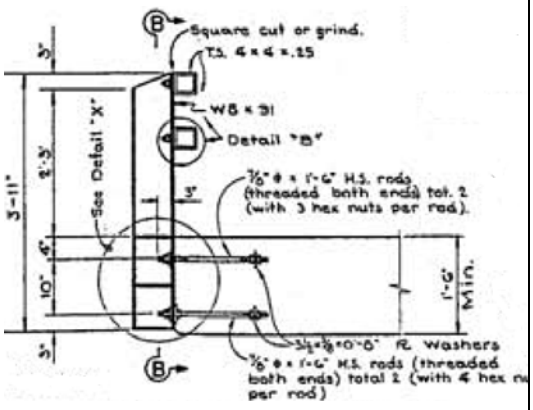
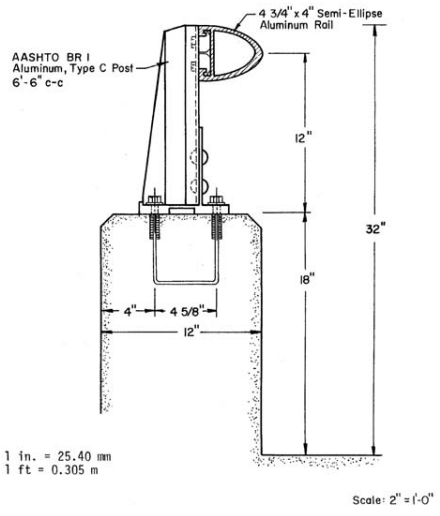
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
R-4 Thrie Beam Retrofit	TL-4	34 in.	Michigan	$25/ft
Barrier Profile			Barrier Picture	
				

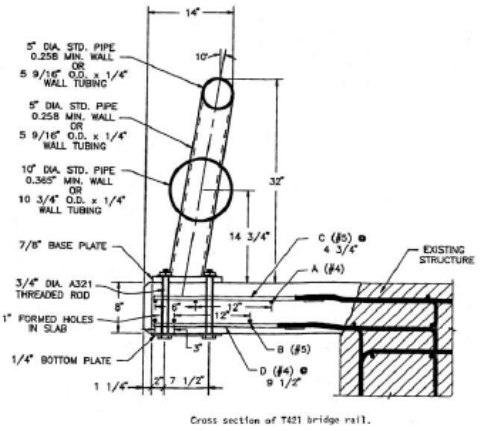
Table 16. Crash tested metal tube bridge railings.

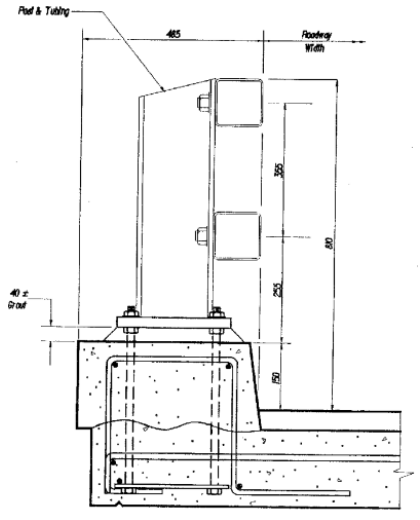
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
California Type 9 (AASHTO BR-2)	TL-2	27 in.	California	Not Available
Barrier Profile			Barrier Picture	
				

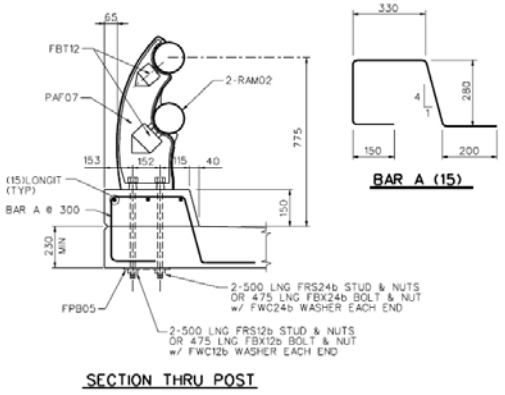
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Washington DC, Historic Bridge Rail Retrofit (Curb Mount)	TL-2	27 in.	Washington, DC	Not Available
Barrier Profile			Barrier Picture	
				

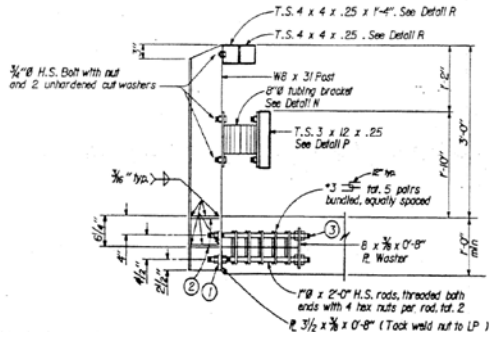
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
California Side Mount Type 115 Rail	TL-2	30 in.	California	Not available
Barrier Profile			Barrier Picture	
				

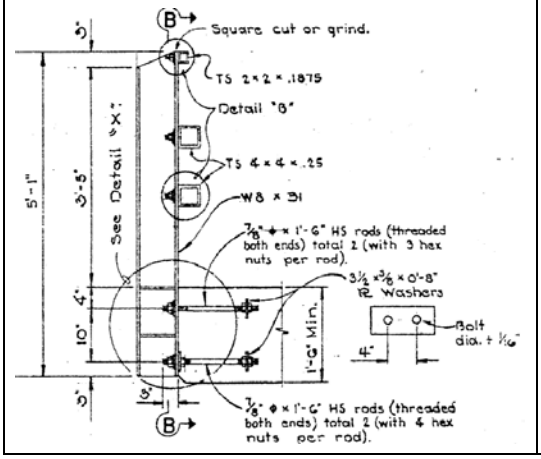
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Standard 1 Bar Metal Rail	TL-2	32 in.	North Carolina	$110/ft
Barrier Profile			Barrier Picture	
				

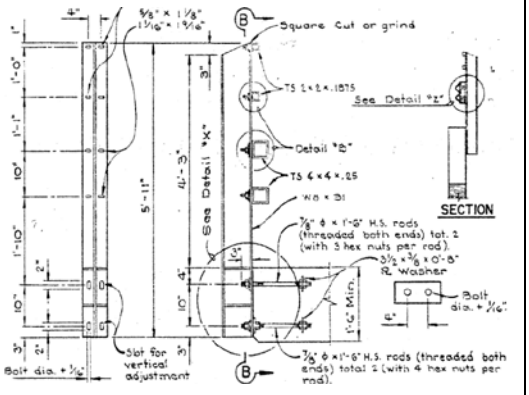
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Texas Type 421 Aesthetic Rail	TL-2	32 in.	Texas	Not Available
Barrier Profile			Barrier Picture	
 Cross section of T421 bridge rail.				

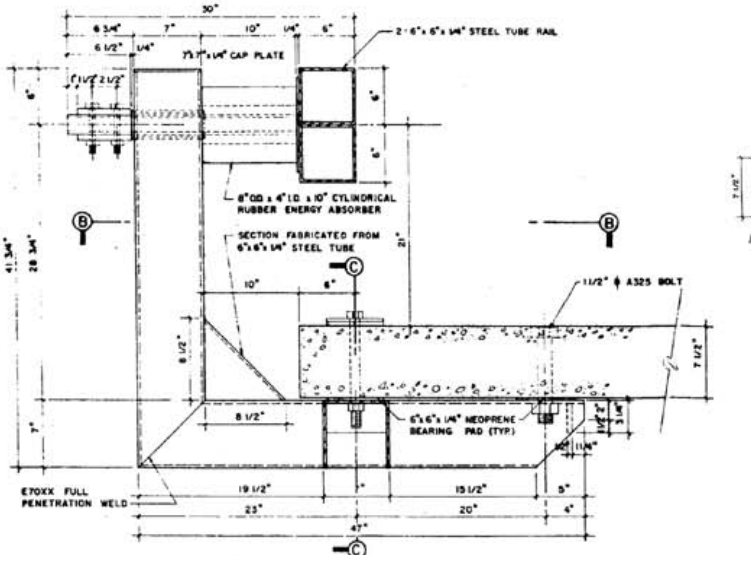
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Oregon 2 Tube Curb Mount	TL-2	32 in.	Oregon	$90/ft
Barrier Profile			Barrier Picture	
 All Dimensions Shown Are mm unless Otherwise Noted.				

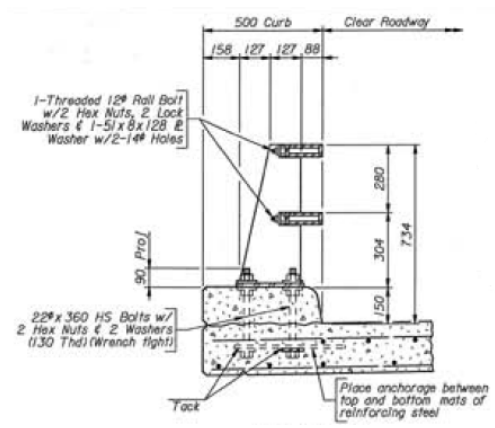
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Foothills Parkway Aluminum Bridge Rail	TL-2	33 in.	Federal Lands	$75/ft
Barrier Profile			Barrier Picture	
				

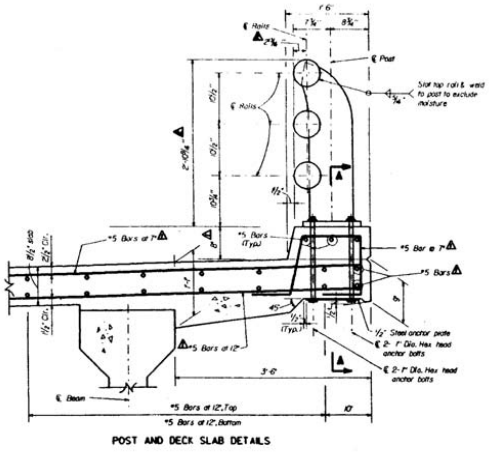
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
California Type 18	TL-2	36 in.	California	Not Available
Barrier Profile			Barrier Picture	
				

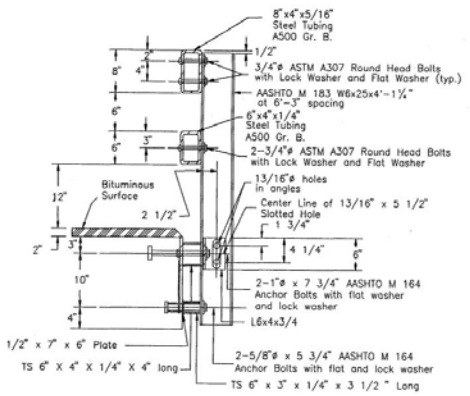
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
California Type 116 Rail	TL-2	42 in.	California	Not Available
Barrier Profile			Barrier Picture	
				

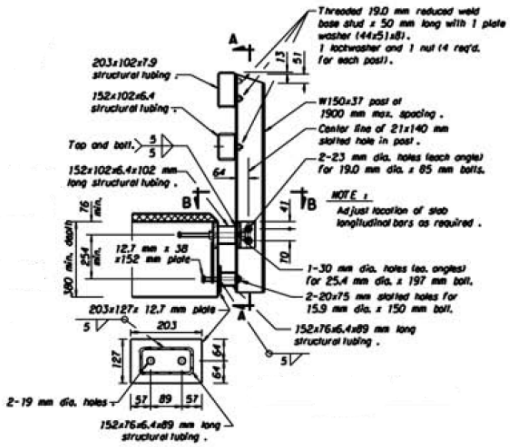
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
California Type 117 Rail	TL-2	54 in.	California	Not available
Barrier Profile			Barrier Picture	
				

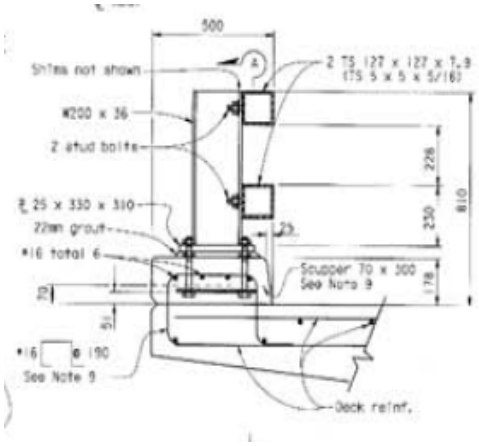
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Texas Energy Absorbing Bridge Rail	TL-3	27 in.	Texas	Not available
Barrier Profile				
				

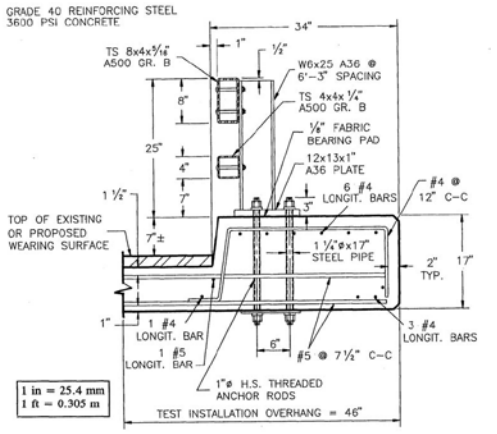
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Wyoming 2 Tube Curb Mounted	TL-3	29 in.	Wyoming	$53/ft
Barrier Profile			Barrier Picture	
				

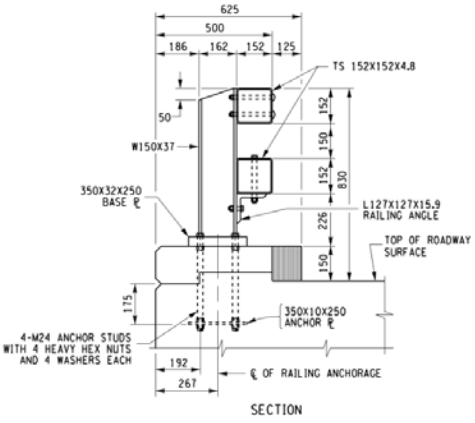
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
George Washington Parkway Steel Bridge Rail	TL-3	42 in.	Virginia	$200/ft
Barrier Profile			Barrier Picture	
 POST AND DECK SLAB DETAILS				

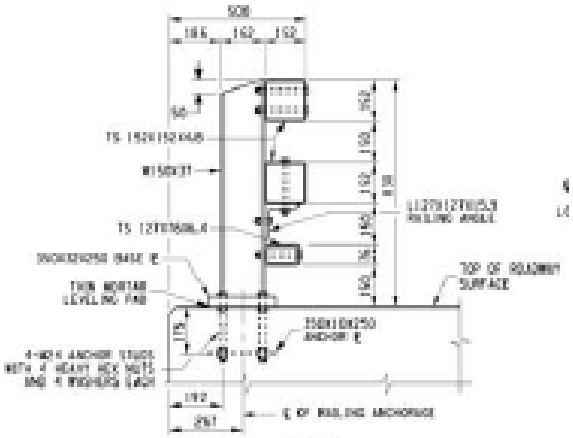
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Illinois 2399 Side Mount	TL-4	32 in.	Illinois	$75/ft
Barrier Profile			Barrier Picture	
				

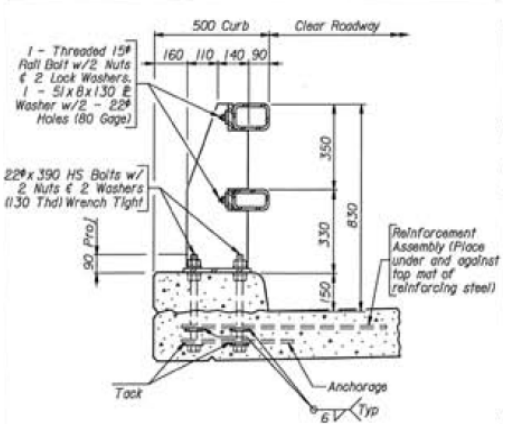
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Oregon 2 Tube Side Mount	TL-4	32 in.	Oregon	$77/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Alaska Rail (Curb Mount)	TL-4	32 in.	Alaska	$90/ft
Barrier Profile			Barrier Picture	
				

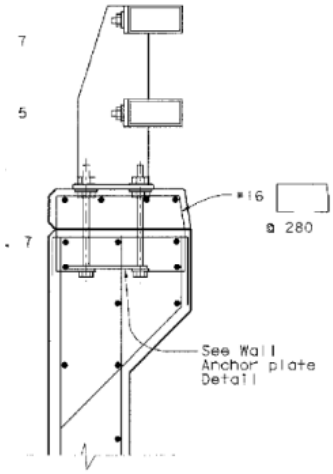
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Illinois 2399 Curb Mount	TL-4	32 in.	Illinois	$75/ft
Barrier Profile			Barrier Picture	
				

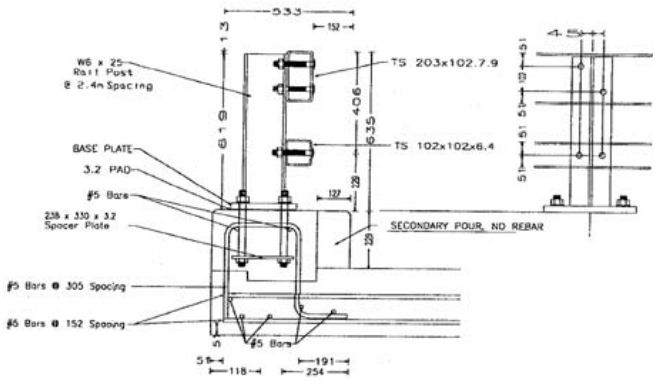
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Two Rail Barrier	TL-4	32 in.	New York	$243/ft
Barrier Profile			Barrier Picture	
				

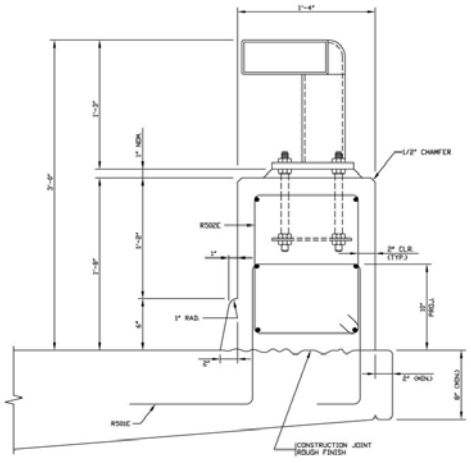
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Three Rail Barrier Top Deck Flush Mount	TL-4	32 in.	New York	$515/ft
Barrier Profile				
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Wyoming 2 Tube Steel Railing	TL-4	32 in.	Wyoming	$55/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
2 Tube Bridge Rail	TL-4	32.5 in.	Michigan	$100/ft
Barrier Picture				
				

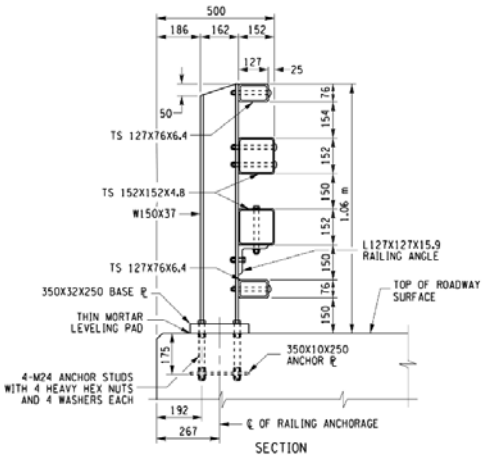
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
California ST 10 Rail	TL-4	33 in.	California	$120/ft
Barrier Profile			Barrier Picture	
 **SECTION E-E** No scale Reinf. same as for Section D-D except as noted.				

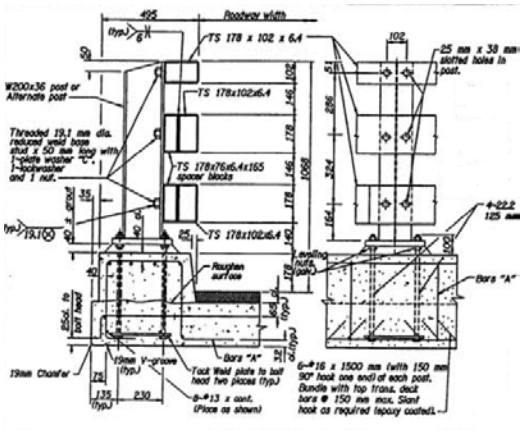
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
NETC-2 Rail Curb Mounted Railing	TL-4	34 in.	Nebraska	Not Available
Barrier Profile				
				

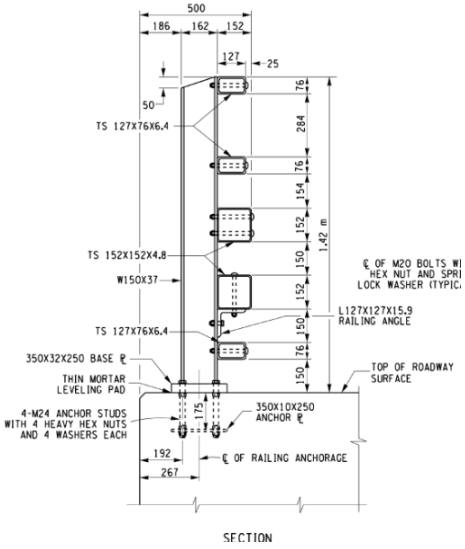
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Minnesota Combination Bridge Rail, Design #3	TL-4	36 in.	Minnesota	$75/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Aesthetic Parapet Type BR27D	TL-4	42 in.	Michigan	$120/ft
Barrier Picture				
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Michigan Multi Tube Bridge Rail	TL-4	42 in.	Michigan	$150/ft
Barrier Picture				
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Four Rail Barrier	TL-4	42 in.	New York	$515/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Oregon 3 Tube Curb Mount	TL-4	42 in.	Oregon	$80/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Five Rail Barrier	TL-4	56 in.	New York	$382/ft
Barrier Profile			Barrier Picture	
				

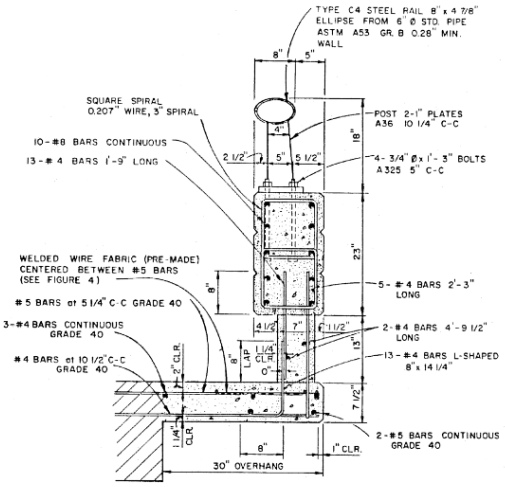
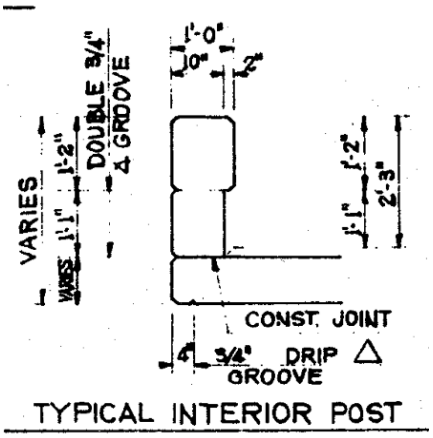
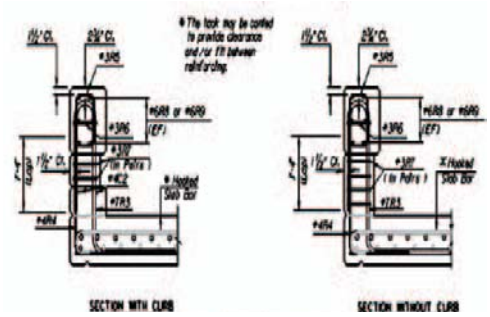
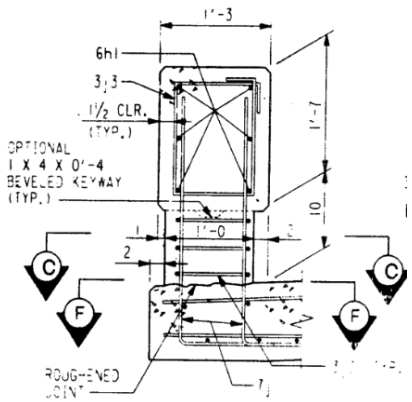
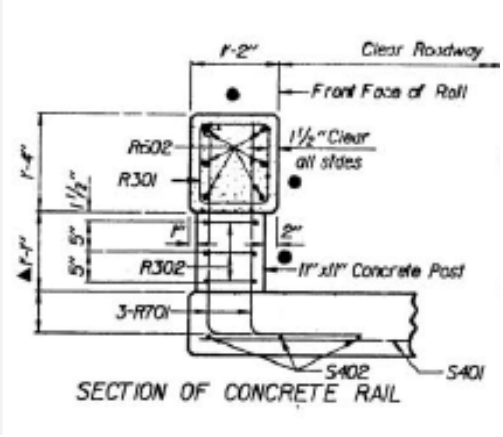
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
TX Type C202	TL-5	54 in.	Texas	$75/ft
Barrier Profile				
				

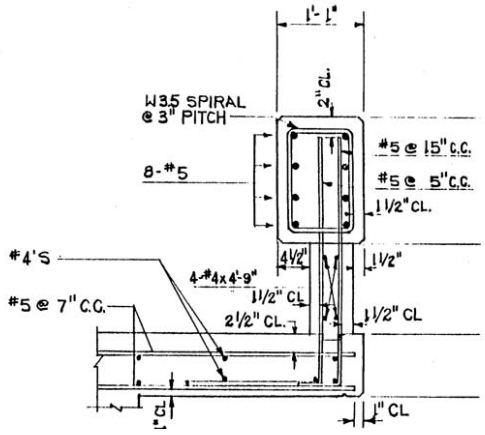
Table 17. Crash tested concrete parapet.

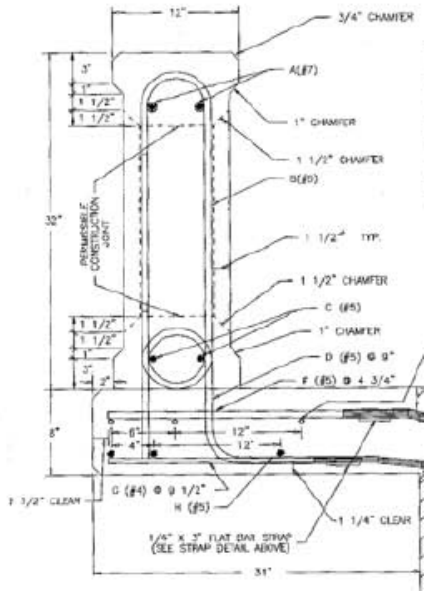
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Modified Kansas Corral Bridge Rail	TL-2	27 in.	Federal Lands	$90/ft
Barrier Profile			Barrier Picture	
				

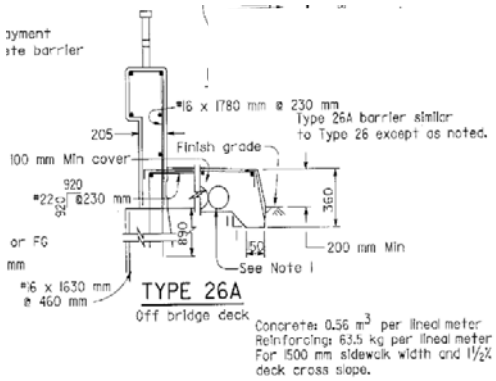
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Modified Kansas Corral Rail	TL-2	27 in.	Kansas	$35/ft (w/out curb) $41 (with curb)
Barrier Profile			Barrier Picture	
				

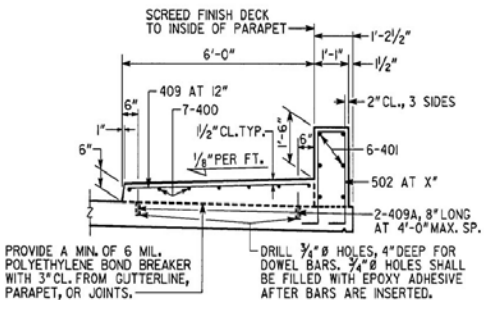
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Iowa Concrete Open Railing	TL-2	29 in.	Iowa	$36/ft
Barrier Profile			Barrier Picture	
				

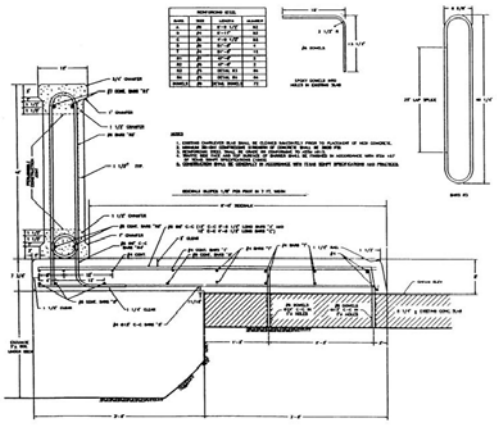
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Concrete Beam and Post	TL-2	29 in.	Nebraska	Not Available
Barrier Profile			Barrier Picture	
				

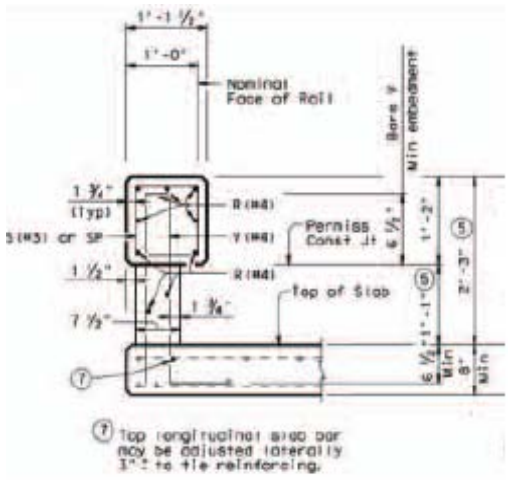
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
TR1 Modified Bridge Rail	TL-2	29 in.	Oklahoma	$35/ft
Barrier Profile			Barrier Picture	
				

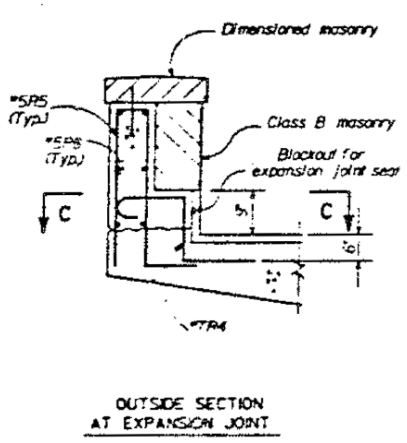
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Texas Type T411 Aesthetic Rail	TL-2	32 in.	Texas	$75/ft
Barrier Profile			Barrier Picture	
				

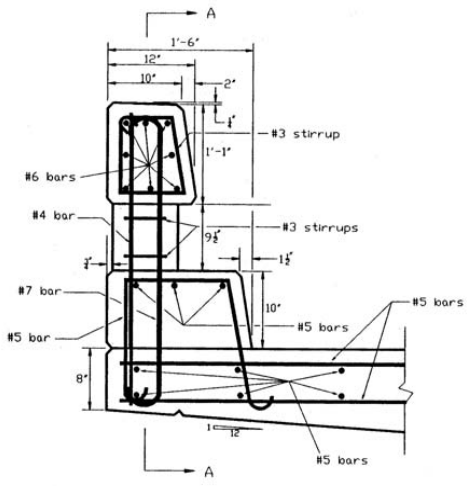
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Type 26 Concrete Barrier with sidewalk	TL-2	36 in.	California	$90/ft
Barrier Profile			Barrier Picture	
				

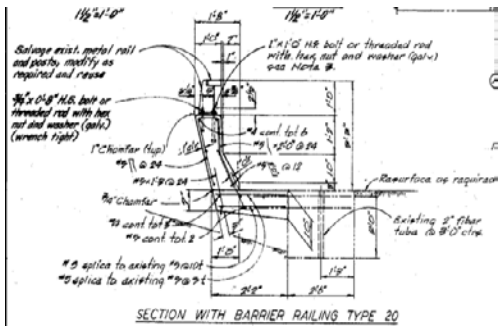
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Vertical Parapet with two pipe aluminum handrail	TL-2	42 in.	Georgia	$90/ft
Barrier Profile			Barrier Picture	
				

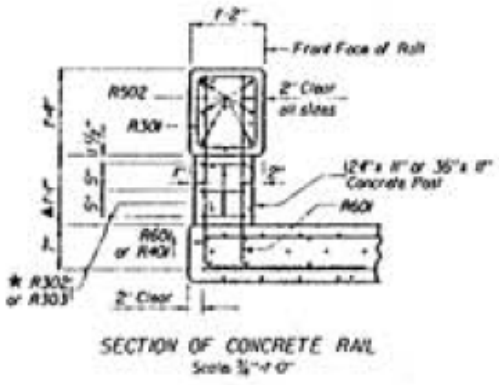
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Type C411	TL-2	42 in.	Texas	$75/ft
Barrier Profile			Barrier Picture	
				

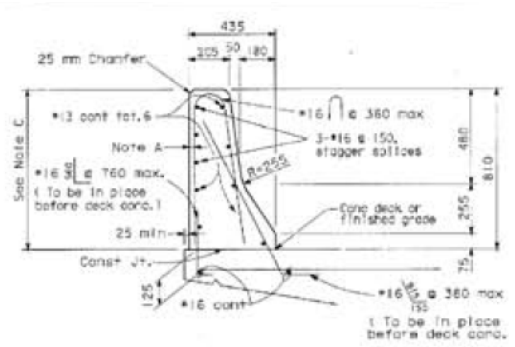
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Type T203	TL-3	27 in.	Texas	$38/ft
Barrier Profile			Barrier Picture	
				

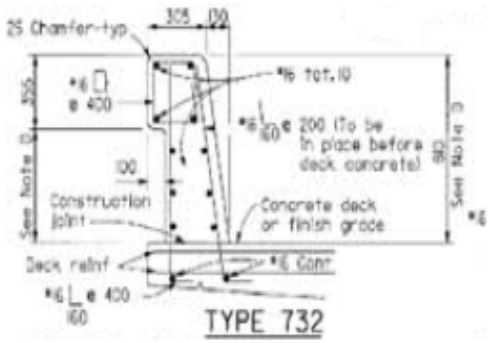
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Baltimore Washington Parkway Stone Rail	TL-3	32 in.	Maryland	$300/ft
Barrier Profile			Barrier Picture	
				

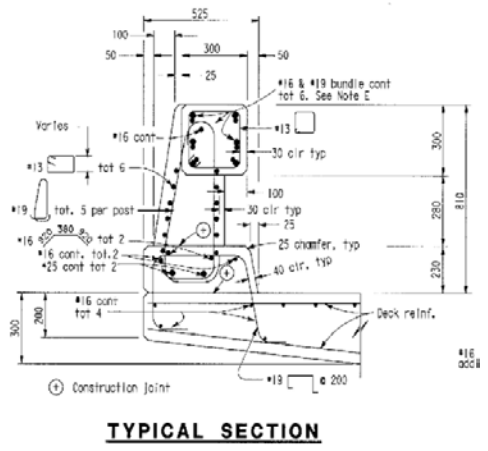
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Natchez Concrete Bridge Rail	TL-3	32.5 in.	Federal Lands	$90/ft
Barrier Profile			Barrier Picture	
				

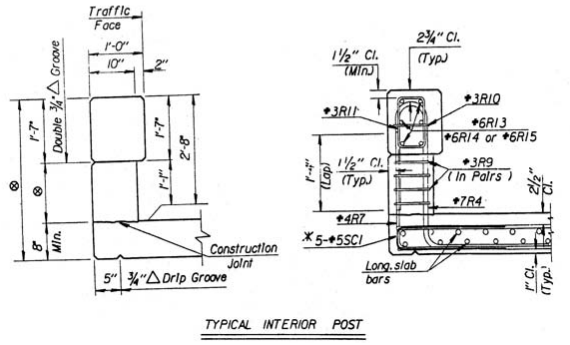
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
California Type 20	TL-3	39 in.	California	Not Available
Barrier Profile			Barrier Picture	
			Not Available	

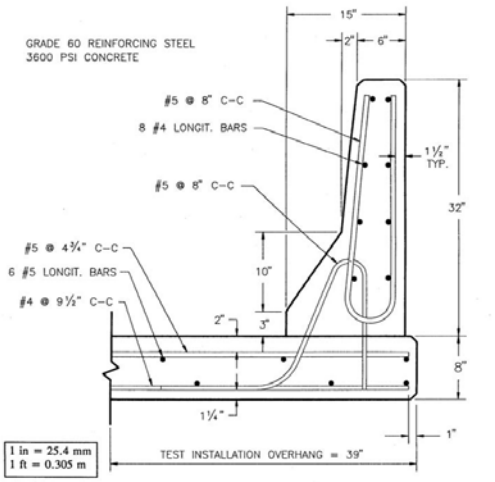
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Nebraska Open Concrete Bridge Rail	TL-4	29 in.	Nebraska	Not Available
Barrier Profile			Barrier Picture	
				

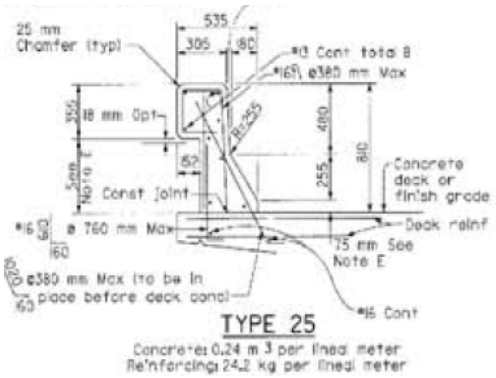
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
32-in. New Jersey Concrete Barrier	TL-4	32 in.	California	$47/ft
Barrier Profile			Barrier Picture	
				

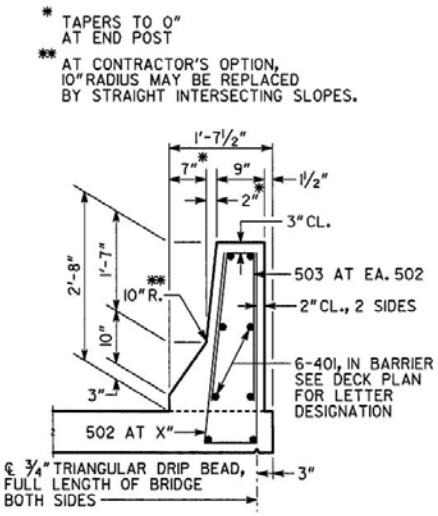
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Type 732 Concrete Barrier	TL-4	32 in.	California	$70/ft
Barrier Profile			Barrier Picture	
				

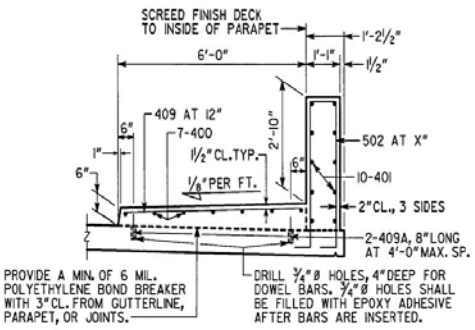
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Type 80 & 80SW Concrete Barrier	TL-4	32 in.	California	$150/ft
Barrier Profile			Barrier Picture	
 TYPICAL SECTION				

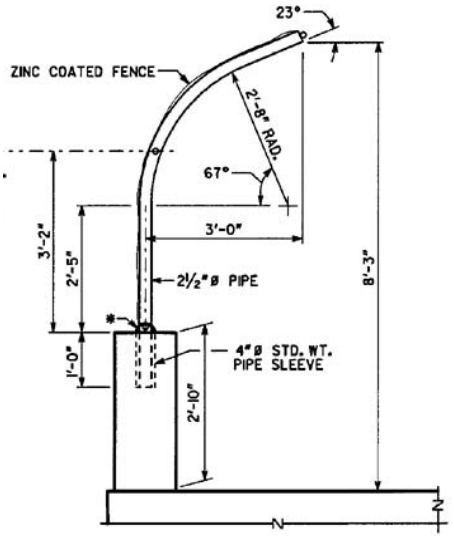
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Kansas 32-in. Corral Rail	TL-4	32 in.	Kansas	$42/ft (w/out curb) $48 (with curb)
Barrier Profile			Barrier Picture	
				

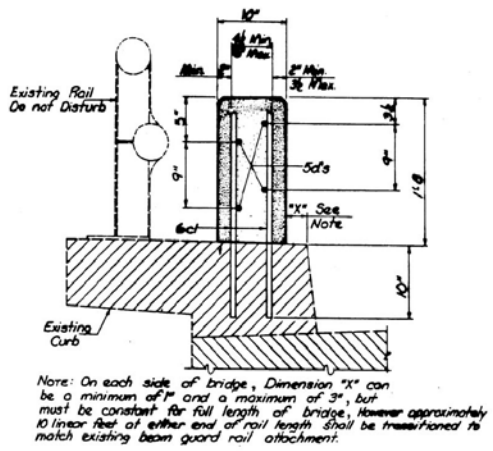
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
New Jersey Barrier	TL-4	32 in.	Missouri	$50/ft - $55/ft
Barrier Profile			Barrier Picture	
				

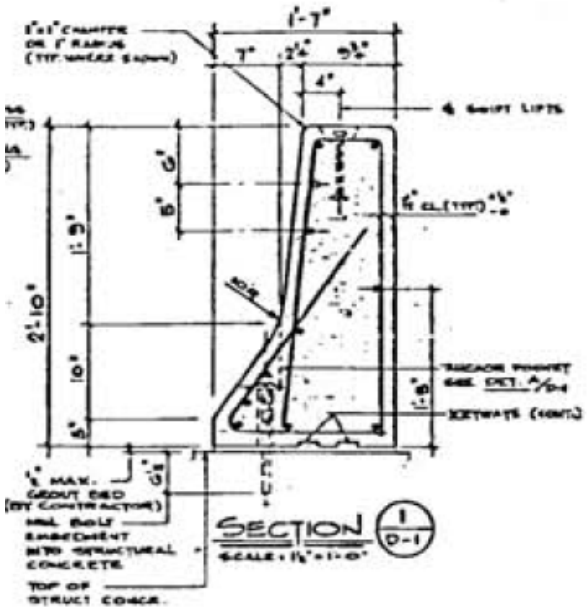
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
New Jersey Concrete Barrier	TL-4	32 in.	California	$50/ft
Barrier Profile			Barrier Picture	
				

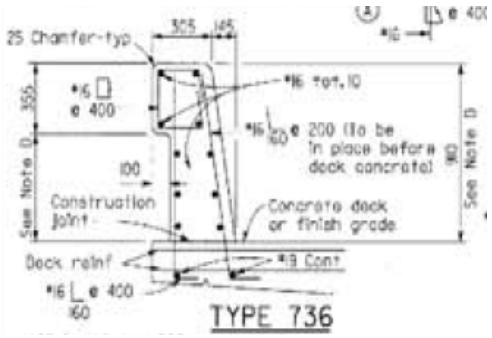
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
New Jersey Barrier	TL-4	32 in.	Georgia	$34/ft
Barrier Profile			Barrier Picture	
 New Jersey Concrete Barrier				

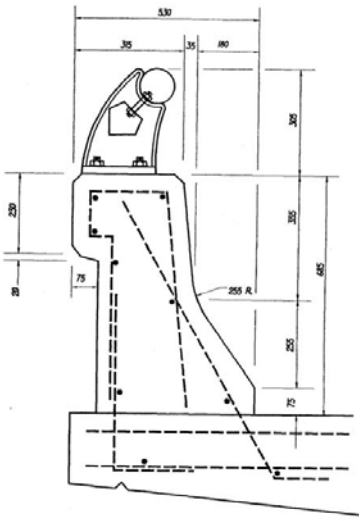
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Vertical Parapet with security fence	TL-4	34 in.	Georgia	$55/ft
Barrier Profile			Barrier Picture	
				

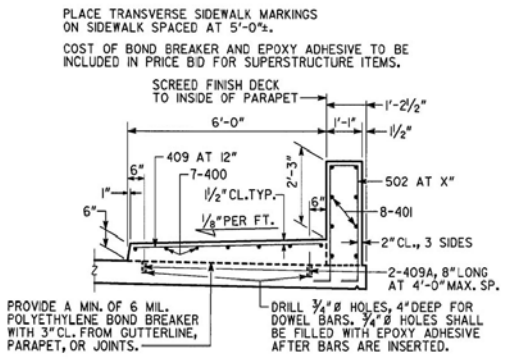
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Vertical Parapet with security fence	TL-4	34 in.	Georgia	$55/ft
Barrier Profile			Barrier Picture	
				

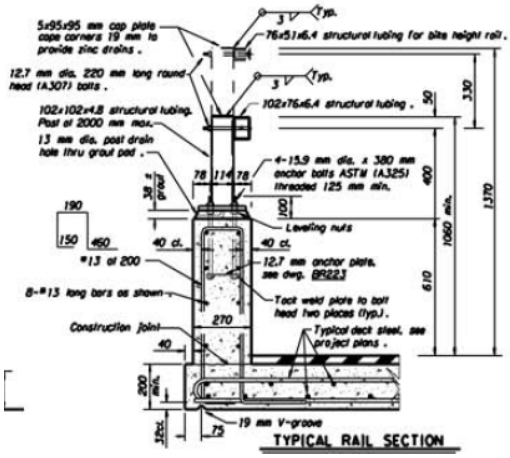
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Iowa Concrete Block Railing Retrofit	TL-4	34 in.	Iowa	$40/ft
Barrier Profile			Barrier Picture	
				

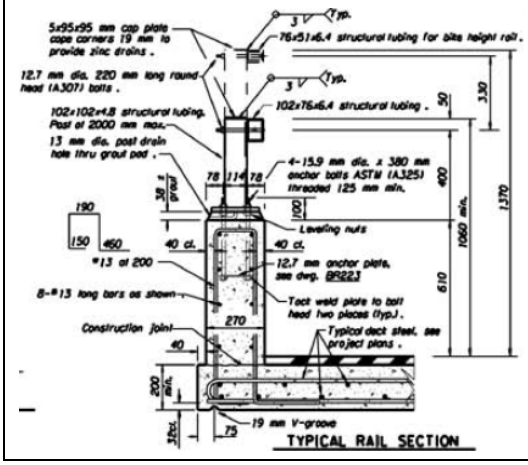
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
LB Foster Precast New Jersey Shape, Bolted Down	TL-4	34 in.	New Jersey	Not Available
Barrier Profile				
				

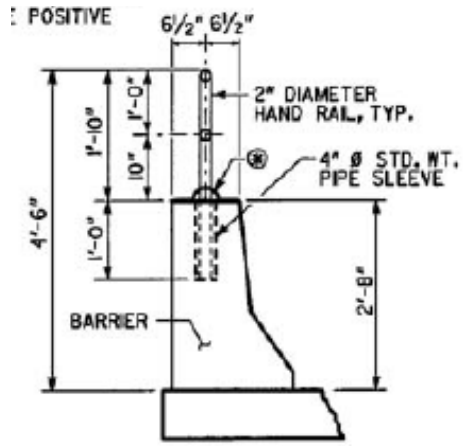
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Type 736 Concrete Barrier	TL-4	36 in.	California	$70/ft
Barrier Profile			Barrier Picture	
				

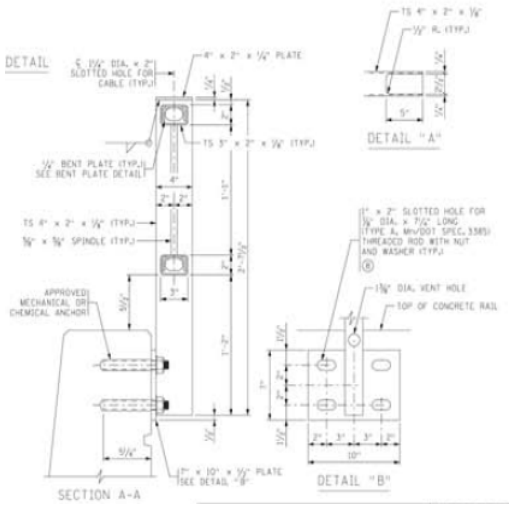
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
New Jersey Safety Shape Parapet	TL-4	39 in.	Nevada	Not Available
Barrier Profile			Barrier Picture	
				

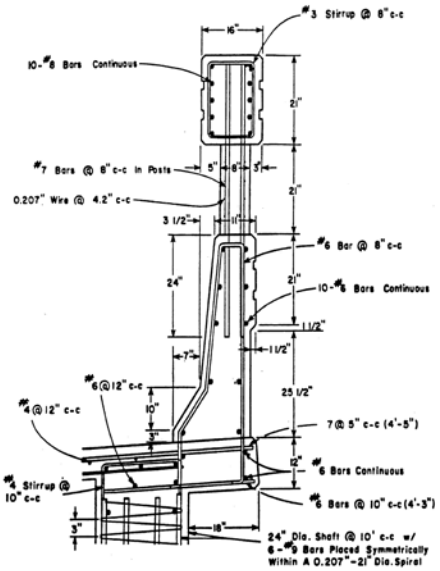
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Vertical Parapet with single pipe aluminum handrail	TL-4	42 in.	Georgia	$80/ft
Barrier Profile			Barrier Picture	
 2'-3" Vertical Parapet and Sidewalk (Used With 1'-3" Single Pipe Aluminum Hand Rail)				

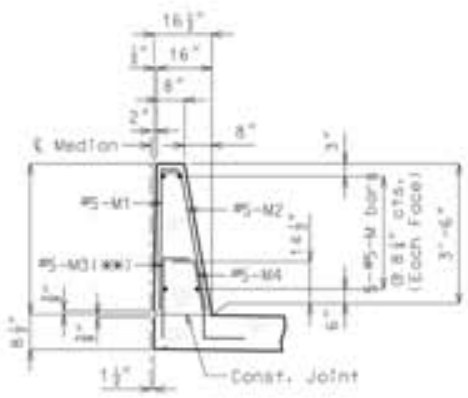
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Parapet Flush Mount	TL-4	54 in.	Oregon	$92/ft
Barrier Profile			Barrier Picture	
				

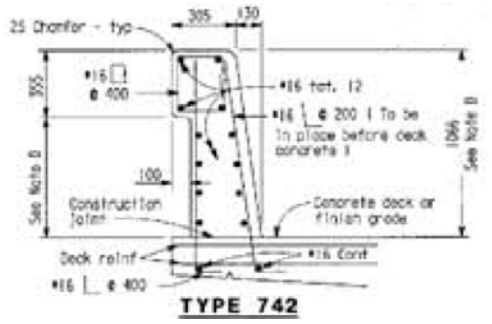
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Parapet Sidewalk Mount	TL-4	54 in.	Oregon	$92/ft
Barrier Profile			Barrier Picture	
				

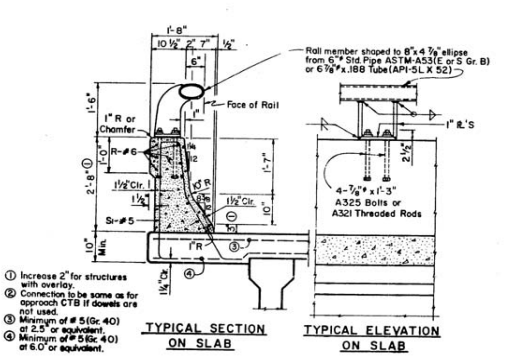
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
New Jersey Barrier with 22-in. steel bicycle rail	TL-4	54 in.	Georgia	$68/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Bicycle Rail Attachment to Safety Shape Concrete Barrier	TL-4	54.5 in.	Minnesota	$75/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Type T501SW	TL-4	72 in.	Texas	$107/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
42-in. Single Slope Concrete Barrier	TL-5	42 in.	Missouri	$70/ft - $75/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Type 742 Concrete Barrier	TL-5	42 in.	California	$85/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Type HT	TL-5	50 in.	Texas	$95/ft
Barrier Profile			Barrier Picture	
				

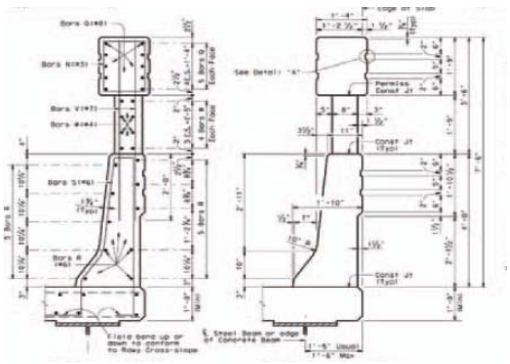
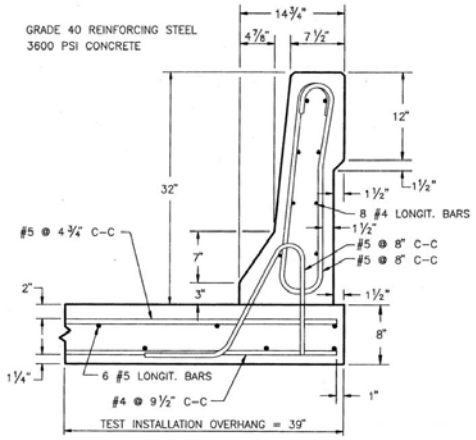
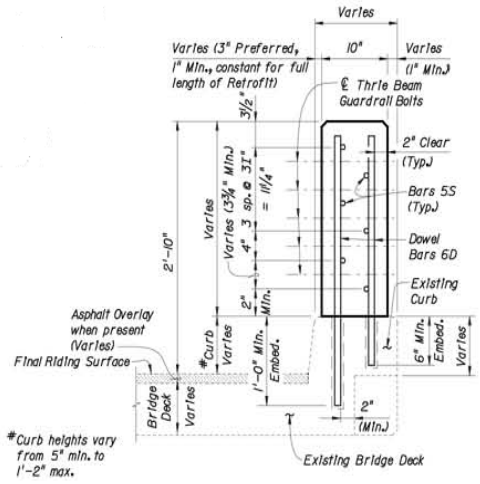
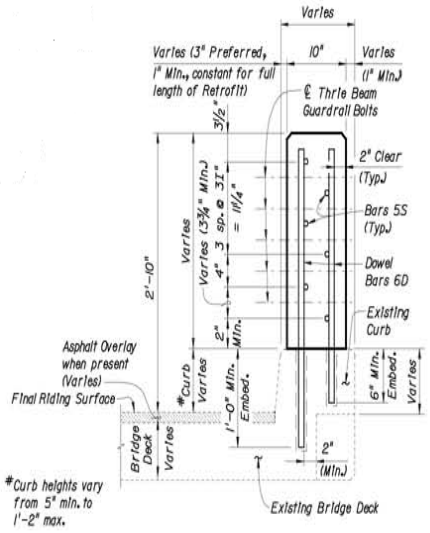
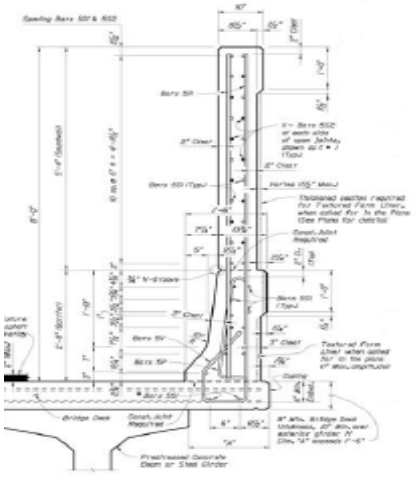
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Texas TT Rail	TL-6	90 in.	Texas	$250/ft
Barrier Profile			Barrier Picture	
				

Table 18. Crash Tested F Shape Concrete Barrier.

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
32-in. F-Shape	TL-4	32 in.	Florida	$35/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Vertical Face Guide, 34 in. Retrofit	TL-4	34 in.	Florida	$40/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Vertical Face Guide, 42 in. Retrofit	TL-4	42 in.	Florida	$55/ft
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Soundwall/F-Shape	TL-4	8 ft	Florida	$200/ft
Barrier Profile			Barrier Picture	
				

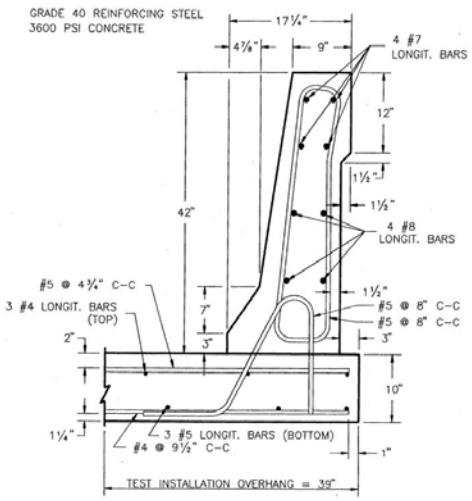
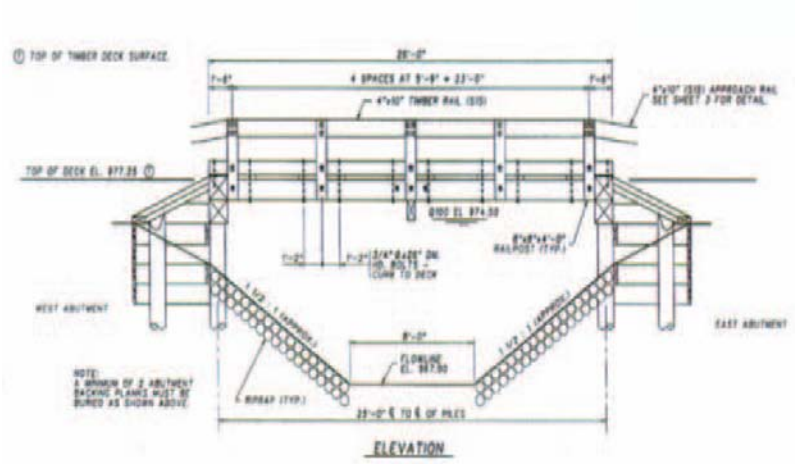
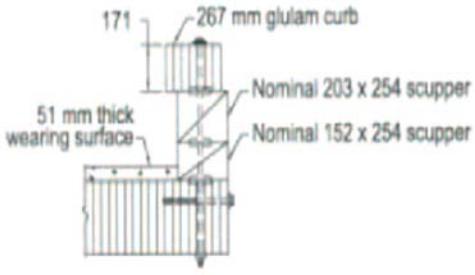
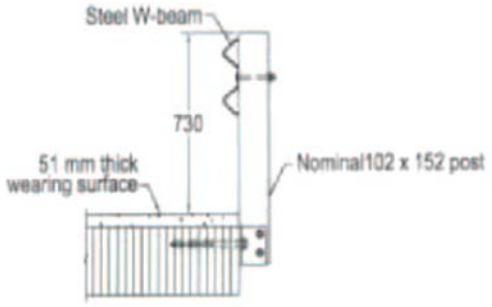
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
42-in. F-Shape	TL-5	42 in.	Florida	$45/ft
Barrier Profile			Barrier Picture	
				

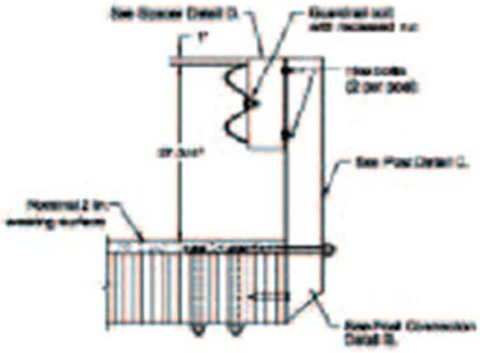
Table 19. Crash tested timber bridge rail.

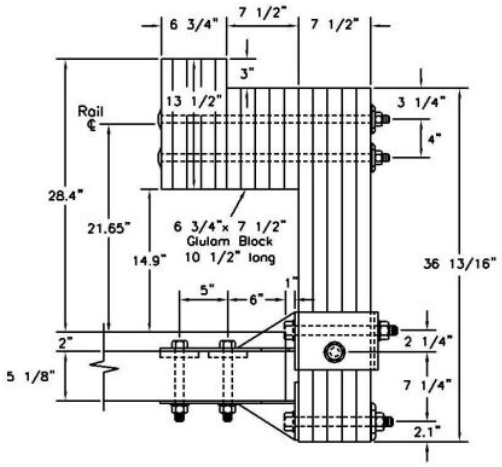
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Panel-Lam Timber Vehicle Bridge Rail	Not Available	48 in.	Not Available	Not Available
Barrier Profile				
				

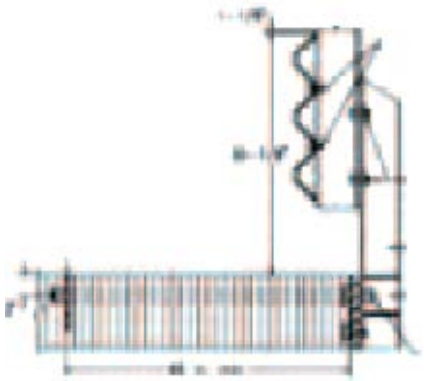
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Timber Curbs for Longitudinal Timber Decks	Below TL-1	12 in.	Not Available	Not Available
Barrier Profile			Barrier Picture	
				

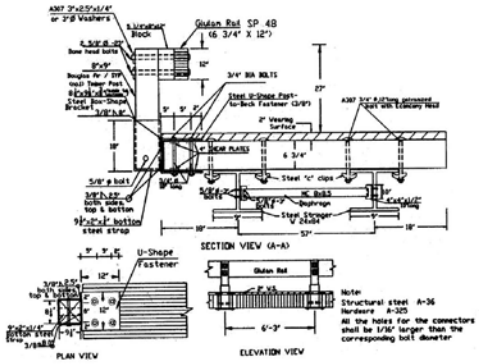
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Curb Type Glulam Rail for Longitudinal Timber Decks	TL-1	21 in.	Not Available	Not Available
Barrier Profile			Barrier Picture	
				

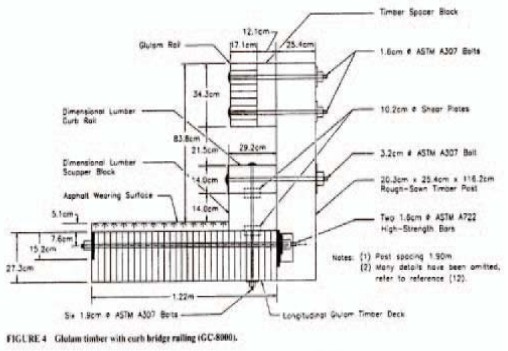
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
W-Beam Breakaway Timber Post Railing	TL-1	29 in.	Not Available	Not Available
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
W-Beam Breakaway Steel Post Railing	TL-1	41 in.	Not Available	Not Available
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Glulam Rail with Steel Box Attachment, side mount	TL-2	32 in.	Not Available	Not Available
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Steel Thrie Beam Rail, side mount	TL-2	32 in.	Not Available	Not Available
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Timber Rail 3 Bridge Rail	TL-3	27 in.	Not Available	Not Available
Barrier Profile			Barrier Picture	
				

Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Glulam Timber Rail with Curb, GC 8000 design	TL-4	33 in.	Not Available	Not Available
Barrier Profile			Barrier Picture	
				

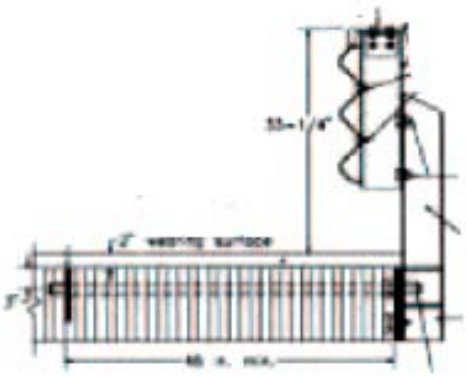
Barrier Name	Test Level	Height	Location Used	Unit Cost ($/ft)
Steel Thrie Beam Rail with upper channel TCB8000 design	TL-4	33 in.	Not Available	Not Available
Barrier Profile			Barrier Picture	
				

Table 20. Recommended shy line offsets (AASHTO 2006).

Design Speed		Shy Line Offset, L_S	
km/h	[mph]	m	[ft]
130	[80]	3.7	[12.1]
120	[75]	3.2	[10.5]
110	[70]	2.8	[9.2]
100	[60]	2.4	[7.9]
90	[55]	2.2	[7.2]
80	[50]	2.0	[6.6]
70	[45]	1.7	[5.6]
60	[40]	1.4	[4.6]
50	[30]	1.1	[3.6]

The information was collected from the FHWA Bridge Rail Guide and was complemented with the following references:

- FHWA Safety Program Website (FHWA 2009c): http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/bridgerailings/index.cfm
- TXDOT Bridge Railing Manual (TXDOT 2006): http://onlinemanuals.txdot.gov/txdotmanuals/rlg/index.htm

- Online Guide to Bridge Railings (Worcester Polytechnic Institute 2007): http://civil-ws2.wpi.edu/Documents/Roadsafe/Guides/bridgeRailGuide/-index.php?action=home.

Table 14 provides general information on four TL-2 W-Beam railings.

Table 15 provides general information on six Thrie-Beam railings, meeting varying criteria from TL-2 to TL-4.

Table 16 provides general information on 30 metal tube railings. The metal tube railings included are either aluminum or steel and have been crash tested to meet criteria from TL-2 to TL-5.

The guide has 37 concrete parapet railings, varying from TL-2 to TL-6. Table 17 provides general information on New Jersey shaped concrete railings, New Jersey shaped concrete parapets with rails, and vertical concrete parapets with aluminum tubes.

Table 18 provides general information on five F-shaped concrete barriers, four complying with TL-4 criteria and one with TL-5.

The timber bridge rail section contains ten rails that are mostly utilized in parks or other areas where the vehicle volume and the operating speeds are low. The railings included are mostly TL-1 or above, except the timber curbs for longitudinal timber decks that are considered below TL-1. Table 19 provides general information on timber railings.

Approach guardrails

Approach guardrails are roadside barriers intended to screen motorists from hazardous features beneath the bridge as they are approaching the bridge. Approach guardrails are attached to the bridge railing end by a transition section. Often, an approach guardrail is a very important safety feature at a bridge, or large culvert location.

Approach guardrails shall be structurally and functionally adequate. To be structurally adequate, they shall be properly connected to the bridge rail; they must not separate from the bridge in the event of a crash. Also, they shall have the adequate support in the transition area; this can be done by reducing the post spacing, or by increasing the post size.

A functionally adequate approach guardrail should have sufficient length to prevent a vehicle from going around it and impacting the object of concern, or entering the hazardous area, as shown in Figure 6. It should also redirect an impacting vehicle in a stable manner, without causing it to rollover, to come to an abrupt stop, or directing it into opposing traffic, in the case of two-way, two-lane roads (FHWA 1998).

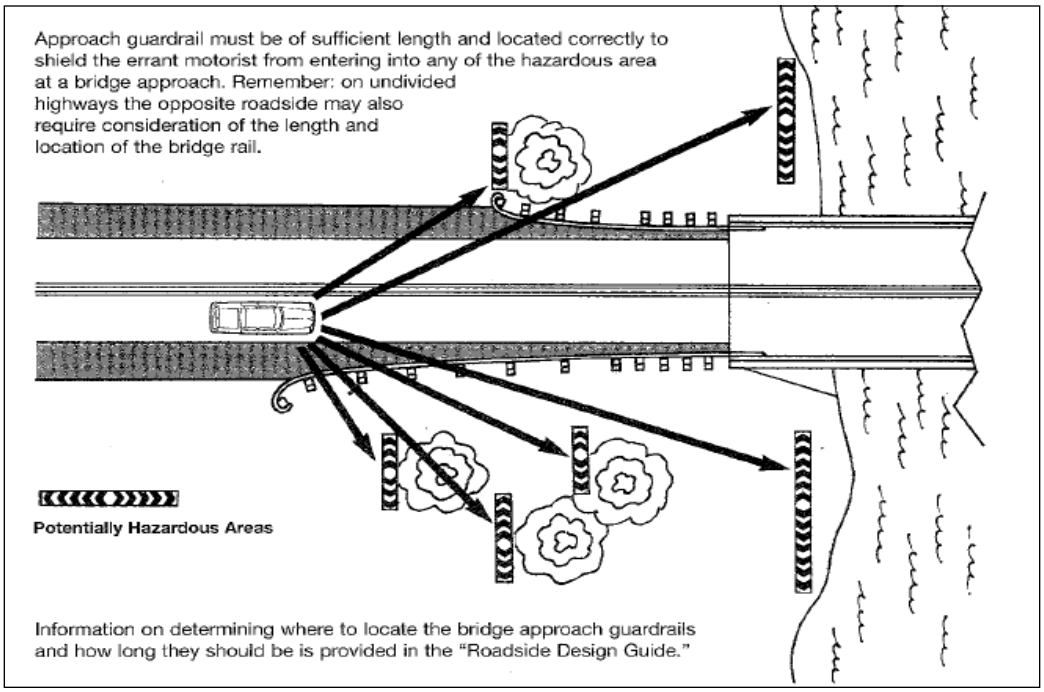


Figure 6. Approach guardrail length of need (FHWA 1998).

Adequately anchored approach guardrails can develop sufficient tension in a crash to safely redirect a car without separating from the bridge rail. When they are installed parallel to the road, or flared at a rate of 1V:15H or flatter, with an appropriate stiffened transition section, they should not pocket or deflect sufficiently to abruptly stop a vehicle. An approach guardrail that curves, or that is not sufficiently stiffened in the transition section, can form a pocket that traps the car and brings it to an abrupt stop (FHWA 1998). Figure 7 presents examples of proper and improper approach guardrail alignment.

Approach guardrails are an integral part of the bridge railing system, but they are not always considered warranted. In the case of bridge length culverts, or in urban areas with sidewalks and a high number of intersections, or on restricted low speed roads, the installation of approach guardrails may not be cost effective, or it may not be possible.

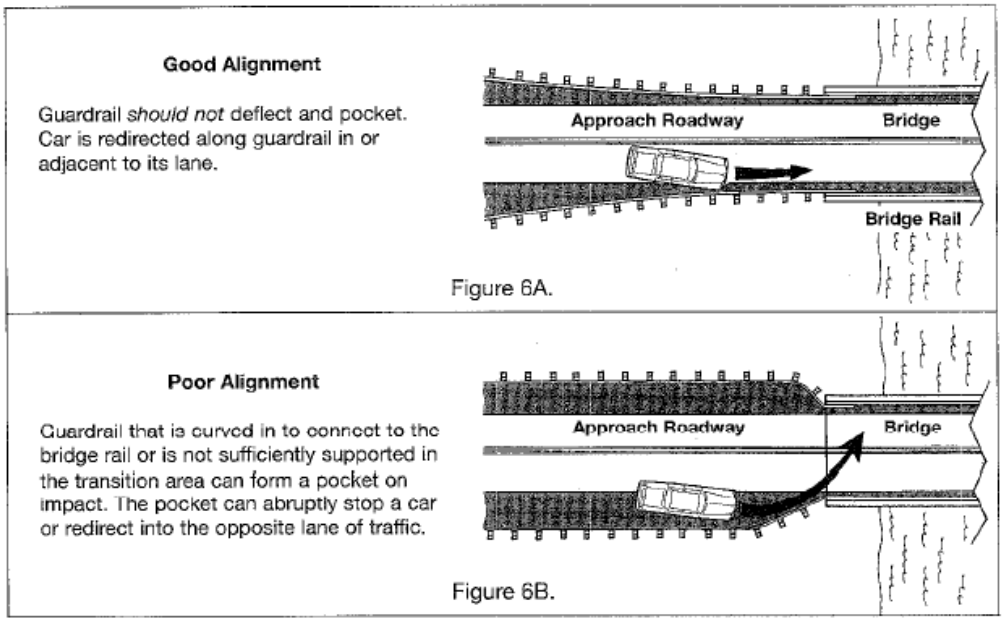


Figure 7. Approach guardrail alignment (FHWA 1998).

When circumstances require it, the use of alternate safety treatments should be considered. *AASHTO LRFD BDS* (2007) presents the following alternatives for urban areas where city streets and/or sidewalks prevent installation of approach guardrails: (1) extending the bridge rail or guardrail in a manner that prevents encroachment of a vehicle onto any highway system below the bridge, (2) providing a barrier curb, (3) restricting speed, (4) adding signing of intersections, and (5) providing recovery area.

In high speed rural areas, an approach guardrail should be provided with a crashworthy end terminal at its nosing.

Placement procedure

After establishing that an approach guardrail is warranted and selecting the type of barrier to be used, it is the responsibility of the designer to specify the required layout of the barrier system.

The most important factors to consider are the lateral offset from the edge of the traveled way, the terrain effects, the flare rate, and the length of barrier needed. The *AASHTO RDG* (2006) explains the proper barrier placement procedure and the calculation of the placement variables.

Lateral offset

AASHTO RDG (2006) recommends that a roadside barrier be installed as far from the traveled way as possible. This allows drivers the possibility of regaining control of the vehicle without crashing into the barrier. It is also important that the distance between the traveled way and the roadside barriers be uniform throughout the road alignment. This creates a level of expectation in drivers that enhances roadway safety. It is important to remember that roadside barriers are also roadside obstacles; and they should only be warranted when the consequences of a vehicle striking the barrier are less severe than the consequences of a vehicle striking the obstacle to be shielded.

Barrier deflection distance

When using flexible or semi-rigid barriers, the barrier deflection plays an important role in its placement with respect to the object. It is not prudent to install a barrier at a distance less than its maximum deflection in front of the obstacle. The barrier to obstruction distance for rigid objects should not be less than its dynamic deflection for impact by a 2,000 kg (4,400 lbs) pickup truck at an impact of approximately 25 deg and a speed of 60 mph (AASHTO 2006). If there's not sufficient space to provide the adequate barrier to object distance, the barrier should be stiffened in advance and alongside the object, by any or various of the following approaches: (1) reducing the post spacing, (2) increasing post size, (3) use of soil plates, (4) intermediate anchorages, or (5) stiffened rail elements.

Shy line distance

The distance from the edge of the traveled way, beyond which a roadside object will not be perceived as an obstacle and result in motorists reducing their speed or changing the vehicle position on the traveled way is the shy line offset (AASHTO 2006). Table 20 presents the appropriate shy line distances by roadway design speed. A roadside barrier should be placed beyond the shy line offset, especially in isolated installations. When barriers are installed in long continuous segments of highway, the shy line offset is not as critical, and the installation of the barrier starting beyond the shy line and gradually transitioned nearer to the traveled way is allowed.

A safe roadway design practice is to maintain a continuous shoulder through the bridge roadway width in order to keep the same uniform

clearance between the safety feature and the traveled way of the approach roadway. For existing bridges that are narrower than their approach roadways, the *AASHTO RDG* (2006) recommends that where the bridge rail is within the suggested shy line offset, the approach guardrail should be flared, in order to gradually introduce drivers to the barrier system.

Terrain effects

Terrain conditions between the traveled way and the barrier can have an effect on a barrier's impact performance. Particular attention should be placed on curbs and side slopes. Both of these conditions may cause a vehicle to be airborne at the moment of impact with the barrier, thus preventing the barrier from performing correctly and keeping the vehicle from going over it.

On high speed highways, the potential consequences of a vehicle impacting a curb and causing a vaulting effect can be severe; therefore, the use of any guardrail/curb combination is discouraged. Where there are no other choices, the curb's height shall not exceed 4 in., and other considerations such as the stiffening of the guardrail and the installation of a rubrail should be considered.

On lower speed facilities, the potential risk of vaulting still exists, but the consequences are lessened, and for this reason, a change in design might not be required, since it will not be cost-effective.

The consequences of a vehicle impacting a barrier on terrain steeper than a 1V:10H slope can be severe. The vehicle can impact the barrier too high and go over it, or in some cases, it can impact the barrier to low and become snagged in one of the barrier's parts.

AASHTO RDG (2006) recommends that the slope of the area adjacent to the barrier be 1V:1oH, as shown in Figure 8; otherwise, a flexible or semi-rigid barrier should be used. Barriers should never be placed on slopes steeper than 1V:6H.

Flare rate

A flared barrier is one that is not parallel to the edge of the traveled way. Flared placement of the roadside barrier is generally used with the purpose of locating the barrier's end terminal farther away from the traveled way,

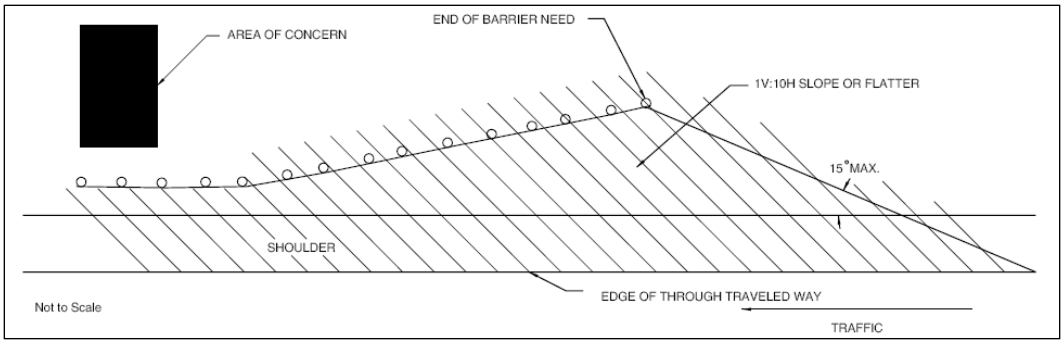


Figure 8. Recommended roadside slopes for barrier placement (AASHTO 2006).

minimizing drivers' reaction by gradually introducing a barrier installation, gradually transitioning the roadside barrier to an obstacle that is closer to the roadway (e.g., bridge parapets), and to reduce the total length of barrier needed.

On the negative side, flaring a barrier can lead to higher vehicle impact angles, which in turn leads to an increase in the severity of the crash. Also, it can increase the likelihood of vehicles being redirected back to the roadway, which can prove to be particularly harmful in two-way roadways, where the vehicle can be redirected into opposing traffic.

Barrier flare rates are a function of the roadway design speed and the barrier type, as shown on Table 21. The *AASHTO RDG* (2006) recommends the use of flatter flare rates in facilities that have steep embankments, where the placement of the barrier will require extensive grading.

Table 21. Recommended flare rates for roadside barriers (AASHTO 2006).

Design Speed		Flare Rate for Barrier inside Shy Line	Flare Rate for Barrier beyond Shy Line	
km/h	[mph]		*	**
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

*Suggested maximum flare rate for rigid barrier system

**Suggested maximum flare rate for semi-rigid barrier system

Length of need

The length of need is the length of barrier required to shield an obstacle within the established clear zone. Several variables affect the barrier's length of need: (1) the lateral extent of the area of concern (L_A), (2) the lateral extent of runout length (L_R), (3) the tangent length of barrier upstream from the area of concern (L_1), (4) the lateral distance from the edge of the traveled way (L_2), and (5) the flare rate, as shown in Figure 9.

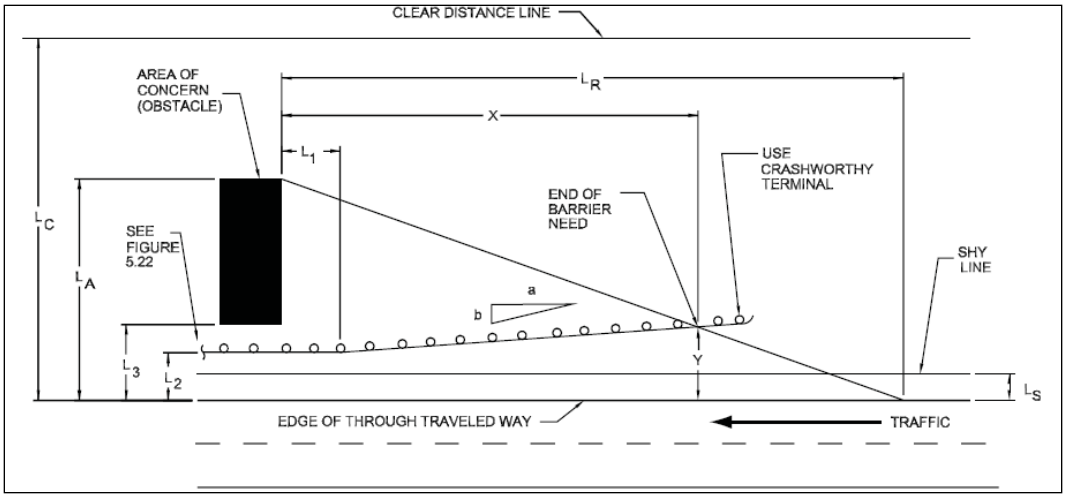


Figure 9. Barrier length of need variables (AASHTO 2006).

The lateral extent of the area of concern is the distance from the traveled way to the far side of the fixed object, or to the outside edge of the clear zone L_C.

The lateral extent of the runout length (L_R) is the theoretical distance needed for a vehicle that has left the roadway to come to a stop, measured along the roadway from the upstream corner of the obstruction to the point where the vehicle is assumed to leave the road. Values for L_R are presented in Table 22.

The tangent length of barrier upstream from the area of concern, L_1, is selected by the designer. In bridges where there is a difference between the railing and the approach barrier, a transition needs to be provided. Under these circumstances, L_1 should be at least as long as the transition section. When the barrier is installed without a flare rate, L_1 becomes zero.

Table 22. Recommended values for runout lengths (AASHTO 2006).

Design Speed		Traffic Volume (ADT)							
		Over 6000 vpd		2000 – 6000 vpd		800 – 2000 vpd		Under 800 vpd	
		Runout Length L_R		Runout Length L_R		Runout Length L_R		Runout Length L_R	
km/h	[mph]	m	[ft]	m	[ft]	m	[ft]	m	[ft]
110	[70]	145	[475]	135	[445]	120	[395]	110	[360]
100	[60]	130	[425]	120	[400]	105	[345]	100	[330]
90	[55]	110	[360]	105	[345]	95	[315]	85	[280]
80	[50]	100	[330]	90	[300]	80	[260]	75	[245]
70	[45]	80	[260]	75	[245]	65	[215]	60	[200]
60	[40]	70	[230]	60	[200]	55	[180]	50	[165]
50	[30]	50	[165]	50	[165]	45	[150]	40	[130]

A barrier should be installed as far as practical from the traveled way, providing drivers the maximum recovery area possible for them to maneuver and come to a stop in the case where they lose control of the vehicle and encroach on the roadside. The lateral distance from the traveled way, L_2, shall be determined by the designer, taking into considerations the shy line offset. The *AASHTO RDG* (2006) recommends that the minimum value of L_2 should be equal to the value of the shy line offset that corresponds to the design speed of the road being evaluated.

The total barrier length of need (X), and its lateral offset from the edge of the traveled way to the beginning of the length of need (Y) are calculated using Equations 1 and 2 (distances in feet), respectively.

$$X = \frac{L_A + \left(b/a\right)\left(L_A\right) - L_2}{\left(b/a\right) + L_A / L_R} \quad (1)$$

$$Y = L_A - \frac{L_A}{L_R}\left(X\right) \quad (2)$$

where:

X = Length of need
Y = Lateral offset
L_A = Lateral extent of the area of concern
L_R = Lateral extent of the runout length
L_1 = Tangent length of barrier upstream from the area of concern

L_2 = Lateral distance from the edge of the traveled way
(a:b) = Flare rate.

When calculating the length of need of an approach barrier for opposing traffic in a two-way, two-lane road, the calculation is similar, with the only difference that L_A will be measured from the center line of the two-way road, or from the left edge of the traveled way of the opposing traffic.

The resulting length of need value calculated from Equation 1 must be adjusted upward to account for the manufacturer's length of barrier sections. If gating end terminals are used, the length of the terminal is not considered as part of the barrier length of need.

Transitions

A transition section is the section of barrier that connects the approach barrier with a bridge railing of different type and material. This section should produce a gradual stiffening of the approach guardrail to avoid vehicular pocketing, snagging, or penetration at the connection.

Transitions might not be required in urban or suburban roadways with speeds of 45 mph or less (AASHTO 2006), and also where compatible bridge railing and approach guardrail designs are provided.

AASHTO RDG (2006) indicates that for a proper installation and performance of the transition section, the following conditions are needed:

1. The approach rail/bridge rail splice or connection must be as strong as the approach rail itself.
2. Strong post systems or combination normal post and strong beam systems can be used on transitions to rigid bridge railings or other rigid objects. A rubrail may be desirable in some designs using W-beam or box beam transition members, to prevent potential snagging.
3. Tapering of the rigid bridge railing end behind the transition members at their connection point may also be desirable, especially when the approach transition is recessed into the concrete end of the bridge railing or other rigid object.
4. The transition section should be at least 10 to 12 times the difference in the lateral deflection of the two systems in question.
5. The stiffness of the transition should increase smoothly and continuously from the less rigid to the more rigid system, usually accomplished by

decreasing the post spacing, increasing post size, or doing both, and by strengthening the rail element.

6. Drainage features, such as curbs, raised inlets, curb inlets, ditches, or drainage swales, when constructed in front of barriers, especially in the transition area, may initiate vehicle instability. Exceptions are made for transition designs, which incorporate a curb to reduce the probability of a vehicle snagging on the end of a rigid bridge railing.

FHWA (2009d) has information on currently approved crashworthy transition designs. The information includes a description, the name of the manufacturer, the *NCHRP 350* test level, and the standard plans with the transition details. The information can be found at the following address: http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/listing.cfm.

End treatments and crash cushions

An end treatment is the designed modification of the end of a roadside or median barrier. Crash cushions are safety devices that prevent errant vehicles from impacting fixed objects by slowly decelerating vehicles to a safe stop. These devices are generally used to prevent barrier elements from penetrating the vehicle's compartment and harming its occupants, and to avoid vehicle's instability as a result of an abrupt deceleration.

Table 23 shows the test level criteria for end treatments and crash cushions from the *NCHRP Report 350* criteria.

Table 23. End terminals and crash cushions NCHRP 350 crash test criteria.

Test Level	Test Vehicle	Nominal Impact Speed, mph (km/hr)	Nominal Impact Angle (deg)
TL-1	820C 2,000P	31 (50)	0 15 20
TL-2	820C 2,000P	43 (70)	0 15 20
TL-3	820C 2,000P	62 (100)	0 15 20

MASH (AASHTO 2009) replaced the test vehicles (shown in Table 1) and expanded the number of test parameters for terminals and crash cushions, including an impact angle of 25 deg and adding another passenger car 1500A.

The use of a crashworthy end treatment is essential when the barrier terminates within the clear zone. A crashworthy end treatment should not spear, vault, or roll a vehicle for head-on or side impacts; and it should have the same redirectional capabilities within its length of need as the standard roadside barrier; proper anchorage must be provided.

There are two types of end treatments: gating and non-gating. A gating end treatment permits a vehicle that impacts it at the nose or at an angle near the nose to pass through it. A gating terminal should have a traversable area free of fixed objects behind it. This area should be approximately 75 ft (23 m) parallel to the rail and 20 ft (6 m) perpendicular to the rail.

A non-gating end treatment redirects impacting vehicles without allowing them to pass through it, whether the impact is at the nose or at any point throughout the entire length of the device.

Crash cushions, or impact attenuators, are ideal for locations where fixed objects cannot be removed, relocated, or made breakaway, and cannot be adequately shielded by a longitudinal barrier. The most common locations for their installation are: (1) exit ramp gores, (2) bridge railing ends requiring shielding, (3) steep downgrades on routes having high truck traffic, and (4) in construction and maintenance zones.

6 States' Bridge Railing Policies

The *AASHTO LRFD BDS* and the *NBIS* require that the States create their own policies or regulations regarding the warrants, selection criteria, and evaluation process of their new and existing bridge railing systems. Every bridge owner is thus responsible for creating their own bridge railing warrants, selection criteria, and the procedures for the evaluation of their in-place railings based on a safe and cost-efficient approach.

This chapter presents the procedure followed to collect the information about the current design policies, selection criteria, and inspection procedures for bridge railing systems in the 32 states and in the Commonwealth of Puerto Rico with military installations. The information was collected by performing an internet search of the particular DOT websites and by contacting the respective agency officials by phone and e-mail to request the relevant documents, or to confirm that the ones gathered from the websites are the current policies in that jurisdiction.

This report includes summary tables with the information collected for each jurisdiction. The table information was obtained from resources such as Bridge Design Manuals, Bridge Inspection Manuals, Standard Specifications, or Standard Plans. A compact disc was recorded with the documentation collected from the thirty-three jurisdictions. The documents collected from each jurisdiction are organized in separate folders on the disc. An additional folder containing the national policies and guidelines, available in digital format, was also included.

The information about the practices, regulations, and procedures of the jurisdictions with regards to the warrants, selection criteria, railing types, inspection procedures, and the standard plans for their bridge railings, transitions and end treatments, if available, are included in Appendix A.

The jurisdictions that have not developed their particular policies and guidelines follow the ones included in the AASHTO LRFD Bridge Design Specifications, National Bridge Inspection Standards, AASHTO Manual for Condition Evaluation, FHWA Recording and Coding Guide, AASHTO Roadside Design Guide, and the FHWA list of approved crashworthy bridge railings, transitions, and end treatments.

Data collection methodology

The intent of this study was to obtain information necessary for the U.S. Army Corps of Engineers to develop criteria for the warrants, selection, and inspection of new and in-place bridge railings on facilities for which they are the owner.

The first task performed was a review of the existing national policies, regulations, guidelines, and inspection procedures for bridge railings. An extensive analysis of the following documents was performed: *U.S. Code of Federal Regulations, AASHTO LRFD Bridge Design Specifications, AASHTO Manual for Condition Evaluation and LRFD of Highway Bridges, AASHTO Policy on Geometric Design of Highways and Streets, AASHTO Guidelines for Geometric Design of Very Low Volume Local Roads, AASHTO Roadside Design Guide, FHWA Barrier Guide for Low Volume Low Speed Roads,* and *FHWA Bridge Rail Guide*. This review helped to establish the current state of the practice regarding the requirement, selection, and evaluation of bridge railings and also to provide information about currently approved crashworthy bridge railings.

After collecting the information on the national standards, policies, and guidelines, the search focused on collecting information from the 32 states and Puerto Rico having military installations. A search of the State DOT's internet sites was made to gather the information available, such as: Bridge Design Manuals, Bridge Inspection Manuals, and Bridge Railing Standard Plans. The second phase included making contact by phone or e-mail to each of the 32 states' DOT, informing them about our study and asking for information regarding bridge railing warrants, selection criteria, types of railings used on low volume low speed roads, the typical costs of railing systems, their inspection procedures, and evaluation ratings.

The third phase included reviewing all the documents collected for each of the 33 jurisdictions to identify the relevant information. This review was aimed at discovering what the different jurisdictions had in their standards, policies, and regulations about warrants, selection criteria, and inspection of their bridge railings. The information gathered was inserted into tables summarizing the bridge railing policies of the various jurisdictions reviewed.

Not all the jurisdictions had their design documents available on the internet, and some of the documents that were available were not current;

in an effort to acquire the relevant documents, phone calls were made to officials from each State DOT. Officials from the divisions of bridge design, maintenance and operations, and safety were contacted to request the documents and other information required for the purpose of this study. The phone calls were helpful in obtaining the design documents that were not available through the internet and in obtaining additional information regarding the practices of each DOT with regard to bridge railings. It is important to point out that not all of the jurisdictions had developed the documents requested; some were in the process of developing them, and others informed us that they directly followed AASHTO and FHWA standards.

After completing the tables, the final task consisted of e-mailing the State or Commonwealth DOT officials that were contacted originally, asking that they verify that the information in the table was accurate. Twenty-one of the thirty-three jurisdictions (64%) responded to our request. The replies contained corrections to the tables and also included additional information and references.

7 Bridge Inspection

Bridge inspections are required to periodically evaluate the bridge performance, to initiate maintenance actions, and to establish priorities for repair and evaluation programs. *AASHTO* (2003) establishes five types of inspections corresponding to different periods in the useful life of a bridge:

1. Initial Inspection: the first inspection of a bridge as it becomes part of the bridge file or inventory. This is a fully documented investigation performed by professionals meeting the required qualifications. This inspection has two main purposes: to provide all Structure Inventory and Appraisal data required by Federal and State regulations, and to determine the baseline structural conditions, including the description and location of existing or potential problems.
2. Routine Inspection: a regularly scheduled inspection consisting of observations and measurements needed to determine the physical and functional condition of the bridge, to identify any changes from initial conditions, and to ensure that the structure continues to satisfy present service requirements. These inspections should satisfy the maximum inspection frequency established in the *NBIS*. The results of routine inspections should be fully documented with appropriate photographs and a written report, which should include recommendations for maintenance and the schedule of in-depth inspections, when necessary.
3. Damage Inspection: an unscheduled inspection to assess structural damage resulting from environmental factors or human actions. The inspection should be sufficient to determine the need for emergency load restrictions, or closure of the bridge to traffic.
4. In-Depth Inspections: close-up inspection of one or more bridge members, above and below water level, to identify any deficiencies not detectable in routine inspections. This type of inspection may be scheduled independently of a routine inspection, generally at a longer interval, or it may be scheduled as a follow up to a damage inspection, or an initial inspection.
5. Special Inspections: recurring inspections to monitor a particular known or suspected deficiency. The individual performing the inspection should be a qualified professional familiar with the bridge. The inspector should be fully informed about the nature of the deficiency and provided with appropriate guidelines and procedures for conducting the inspection. The

frequency of these inspections depends on the severity of the known deficiency.

Frequency of inspections

AASHTO (2003) states that the intervals at which inspections are performed should not exceed two years. In cases where the Bridge Owner wants to inspect the bridge at intervals greater than two years, a detailed plan, which includes the reason supporting this decision, must be presented to the appropriate federal and state agencies for approval. Among the factors to consider are age, traffic volume, size, susceptibility to collision, extent of deterioration, performance history of the bridge type, load rating, location, national defense designation, detour length, and social and economic impacts due to the bridge being out of service.

Bridge railing inspection procedures

The inspection of the bridge railings should focus on their condition, the adequacy of the geometry, and their structural capacity. The railing system should be inspected for:

- evidence of impact damage or rotation,
- condition of connection of the railing (parapet) to the bridge deck, and
- deterioration of the various railing system elements.

The areas of the bridge, where the railing has been impacted, shall be recorded as evidence to determine if the location poses a potential hazard for drivers. Inspectors should verify the railing's anchor bolts for exposure, and the base of the railing for separation from the deck. All of the railing system elements should be carefully inspected (posts, beams, transitions, and treatments).

The *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* was created by FHWA for use by the state, federal, and other agencies in recording and coding the data elements that will comprise the *National Bridge Inventory (NBI)* data base. The *NBI* is a collection of information covering about 600,000 of the Nation's bridges located on public roads, including Interstate Highways, U.S. highways, state and county roads, as well as publicly-accessible bridges on federal lands. It presents a state by state summary analysis of the number, location, and general condition of highway bridges within each state.

The coded items in the *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* are an integral part of the data base that is used to meet federal reporting requirements as presented in Title 23 of the Code of Federal Regulations. The items of relevance for the safety evaluation of bridges are: Item 36 Traffic Safety Measures, Item 68 Deck Geometry, and Item 72 Approach Roadway Alignment.

Deck geometry

Item 68 Deck Geometry of the Coding Guide evaluates the curb-to-curb bridge roadway width and the minimum vertical clearance over the bridge roadway. This item is coded by determining two appraisal ratings, one for bridge roadway width and one for the minimum vertical clearance. The lower of these two is the appraisal rating. The Coding Guide includes the following scenarios to choose from for the bridge roadway width appraisal:

- Bridges with two lanes carrying two-way traffic
- Bridges with one lane carrying two-way traffic
- All other two-way traffic situations
- Bridges with one-way traffic.

The bridge roadway width evaluation criterion should evaluate the bridges, according to the guidance provided in the Section **Minimum Bridge Roadway Width** in Chapter 4 of this report.

Approach roadway alignment

Item 72 Approach Roadway Alignment of the Coding Guide evaluates the bridge potential for the reduction in vehicle operating speeds by comparing the alignment of the bridge approaches to the general highway alignment of the roadway section (FHWA 2006). The rating guidelines are correctly applied by determining if the vertical or horizontal curvature of the bridge approaches differs from the section of highway the bridge is on, resulting in a reduction of vehicle operating speed to cross the bridge. The guidelines are the following:

- If no reduction in the operating speed of a vehicle is required compared to the highway, code Item 72 as an "8."
- If only a very minor reduction in the operating speed of a vehicle is required (≤ 9 mph) compared to the highway, code Item 72 as a "6."

- If a substantial reduction in the operating speed of a vehicle (≥ 10 mph) is required compared to the highway, code Item 72 as a "3."

The Coding Guide suggests that the presence of a narrow bridge does not affect the Approach Roadway Alignment Appraisal, as the narrow bridge rating would be accounted for in Item 68 Deck Geometry. The inspector must use engineering judgment to determine the appropriate rating for this item, as a narrow bridge will certainly have an effect on most road users due to the more restrictive roadway conditions at the bridge.

Traffic safety features

Item 36 Traffic Safety Features of the Coding Guide is directed to the comparison of the traffic safety features in place at the bridge site to current national standards set by regulation, so that an evaluation of their adequacy can be made. The rating for the traffic safety features is a four digit code composed of four segments, one for each of the bridge railing system elements: bridge railing, transition, approach guardrail, and approach guardrail ends, as shown in Table 24.

Table 24. NBI code for the evaluation of traffic safety features.

SEGMENT	DESCRIPTION	LENGTH
36A	Bridge Railings	1 Digit
36B	Transitions	1 Digit
36C	Approach Guardrail	1 Digit
36D	Approach Guardrail Ends	1 Digit

The evaluation of each element consists in determining its adequacy, both structurally and functionally. When evaluating the elements of a bridge railing system, consideration shall be given to the following:

1. Bridge Railings

    a. Verify the height, material, strength, and geometric features, since these factors affect the proper functioning of the bridge railing.

    b. Railings must be in compliance with *MASH* or *NCHRP Report 350* criteria. In the case of older existing bridges with railings designed in accordance to the *AASHTO Standard Specifications*

for Highway Bridges or crash tested under the previous standards in *NCHRP Report 230*, the railings may be acceptable after an evaluation of their in-service performance.

c. The different components of a bridge railing by type, as shown in Figure 10, are:

c_b = maximum clear opening below the bottom rail
S = post setback distance
c = maximum opening between rails
A = railing contact width
H = railing height.

The rail contact widths for typical bridge railings may be taken, as shown in Figure 11 (AASHTO 2007).

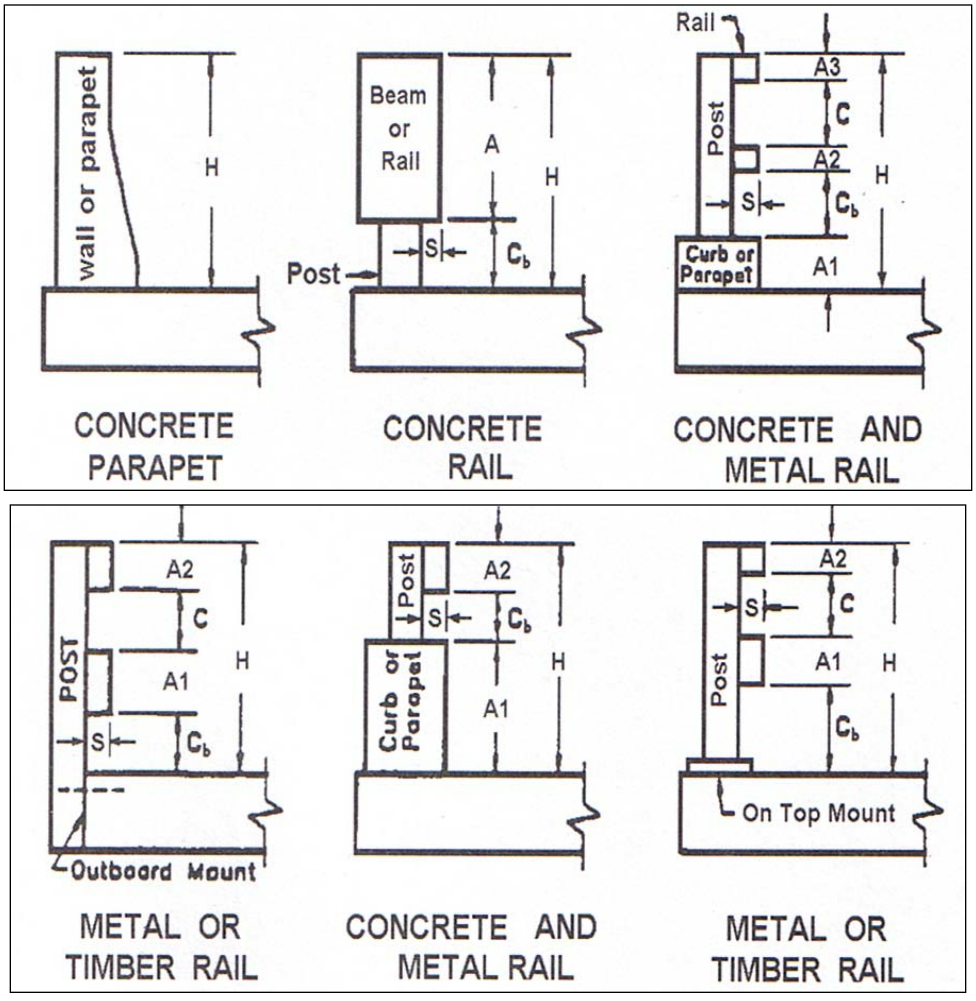


Figure 10. Bridge railing components (AASHTO 2007).

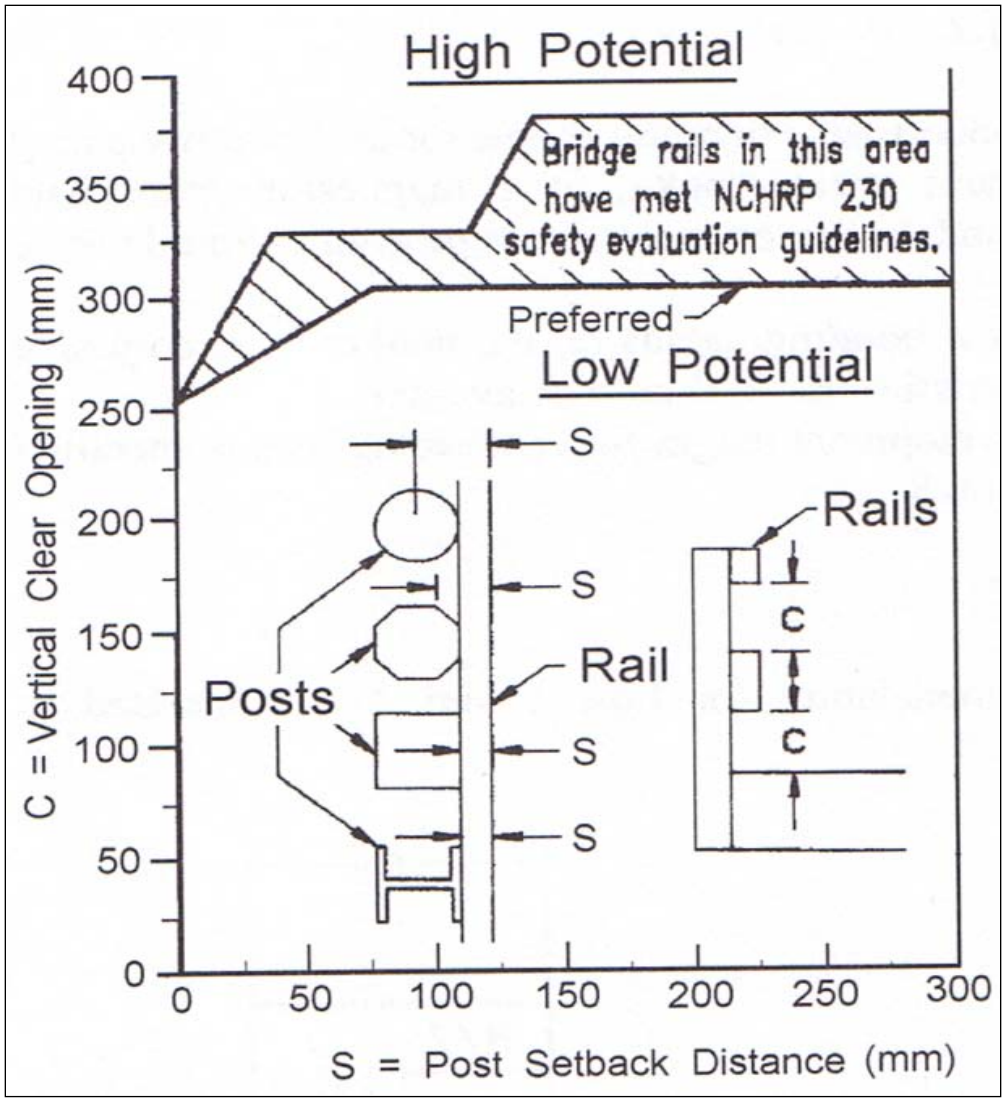


Figure 11. Potential for wheel, bumper, or hood impact with post (AASHTO 2007).

2. Transitions

    a. Transition should be firmly attached to the bridge railing.

    b. Verify the gradual stiffening of the approach guardrail as it comes closer to the bridge railing. Guardrail posts should be installed closer together as the transition gets closer to the bridge railing, following standard plans. In some cases, it might be useful to install larger posts.

3. Approach Guardrails

    a. Verify structural adequacy. Approach guardrails should have the adequate length of need, height, and materials to prevent a

vehicle from going around or over it, and to contain a vehicle in case of an impact.

b. Compatibility of approach guardrail with transition design.

4. End Treatments

a. Ends of approach guardrails should be flared, buried, made breakaway, or shielded with an approved crashworthy end treatment or crash cushion.

The evaluation of traffic safety features presented in the Coding Guide is based on a zero ("0"), one ("1"), or "N" rating, as shown in Table 25. Collision damage and deterioration of the elements are not considered when coding this item.

Table 25. Rating codes for traffic safety features.

CODE	DESCRIPTION
0	Feature does not meet currently acceptable standards, or a safety feature is required and none is provided.
1	Inspected feature meets currently acceptable standards.
N	Not applicable, or a safety feature is not required.

A functionally adequate bridge railing has the capability of containing and smoothly redirecting a vehicle safely. A functionally inadequate bridge rail can result in a vehicle vaulting over it, snagging on one of its features causing it to come to an abrupt stop, and becoming unstable and possibly even redirecting it into the other direction of traffic. Follow guidance in Chapter 5 of this report to rate the adequacy of the traffic safety features.

The *AASHTO LRFD BDS* has developed two diagrams that allow designers and inspectors to determine the snagging potential of bridge post railings. Figure 12 determines the snagging potential of a vehicle's wheel, bumper, or hood by using the clear opening between rails and the post setback distance as parameters. The post setback for the various shape posts recognizes the snagging potential. The diagram is divided into three sections, low snagging potential, compliance with *NCHRP Report 230,* and high snagging potential. For post railings, the vertical clear opening and the post setback shall be within or below the shaded area in Figure 11.

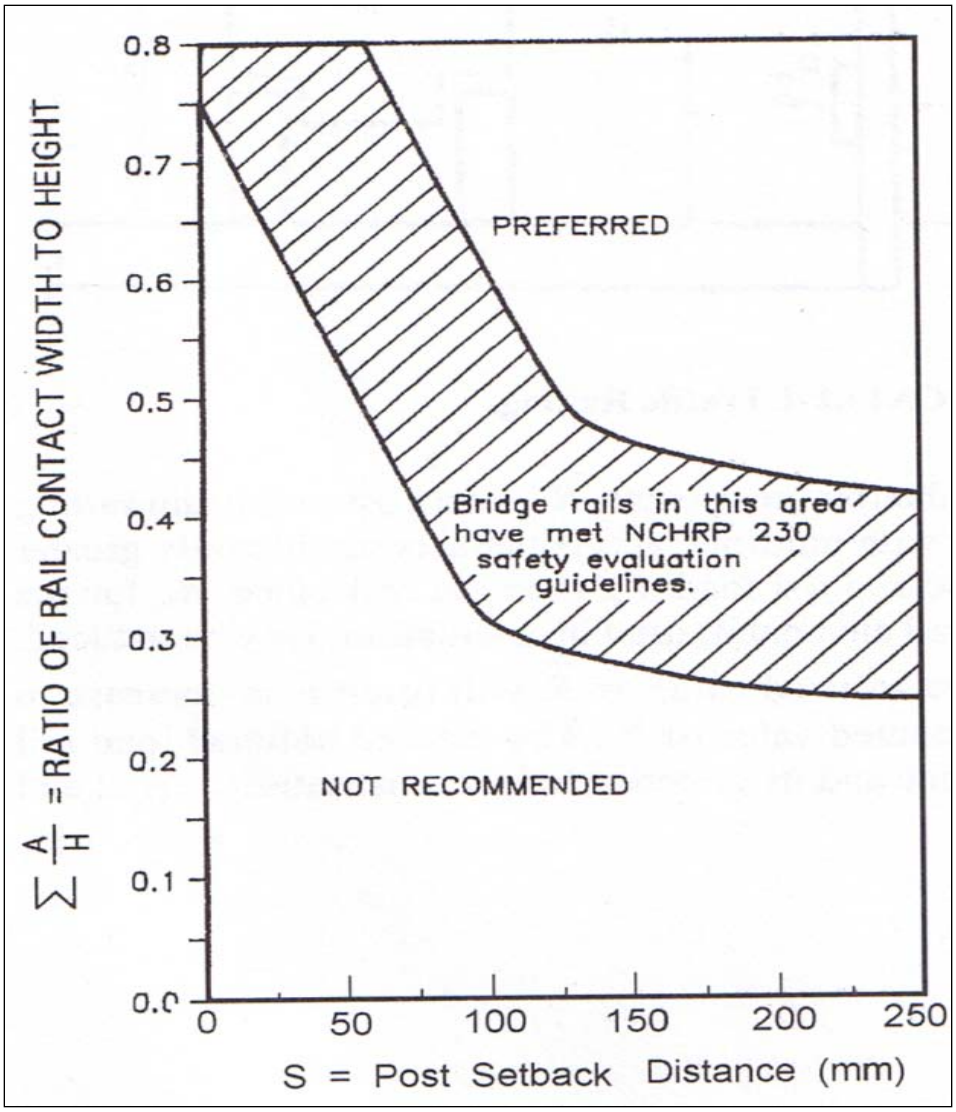


Figure 12. Post setback criteria (AASHTO 2007).

Figure 12 evaluates the preferred post setback criteria, using the ratio of the rail contact width to the height and the existing post setback distance. This relationship will allow inspectors to determine if the bridge railing design is preferred, if it complies with *NCHRP Report 230* criteria, or if the post railing is not recommended. As the setback distance increases, the snagging potential of the post railing decreases.

Bridge inspection protocol

An inspection protocol is necessary for performing the assessment of traffic safety features on bridges in a consistent manner. Figure 13 shows the recommended protocol that consists of five steps.

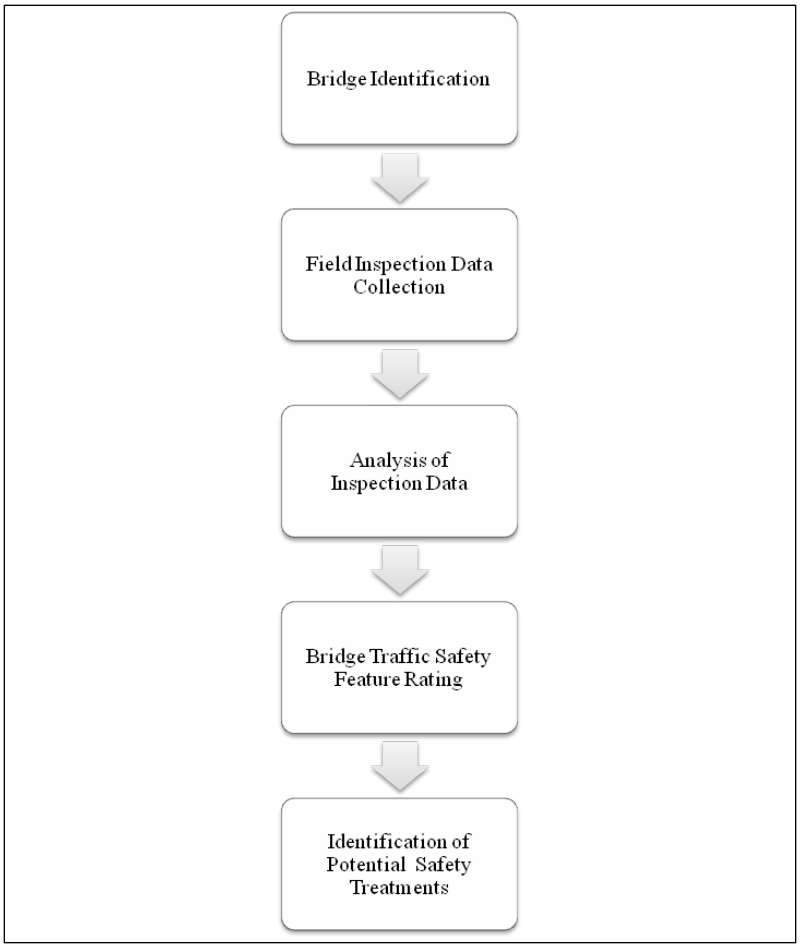


Figure 13. Process for bridge safety features assessment.

Bridge identification

Bridges are selected for inspection when a scheduled inspection is due, or when there is a specific deficiency or problem on the bridge, and there is the need to prioritize and perform an unscheduled inspection. Previous inspection reports should be reviewed by inspectors to identify previous findings that might require a more detailed inspection in the field. When performing an initial inspection, design plans will provide inspectors the required information for the inspection.

The assessment of traffic safety features on bridges should be performed by a professional with the required qualifications. Some State DOTs have created a subdivision inside their Bridge Design Office that is responsible for the design and inspection of traffic safety features on bridges.

Field inspection data collection

The information collected in the field by the inspectors will be documented in the inspection forms. The next section offers a detailed description of the data collection process, the type of information required, and the manner in which the inspection should be performed in the field.

Analysis of inspection data

After the information has been collected from the roadway site, the bridge, the approach roadway, and the traffic safety features, the inspector is responsible for comprehensively analyzing the information to determine whether or not the safety features comply with the original bridge design plans, the agency standard plans, or the recommended values given in standards and guides such as the *AASHTO Green Book, AASHTO Bridge Design Specifications, AASHTO Roadside Design Guide,* and *FHWA Bridge Rail Guide,* among other references.

Bridge traffic safety feature rating

Each traffic safety feature on the bridge must be assigned a safety rating based on the Coding Guide. Further research is necessary to develop detailed scientific procedure to establish the safety hazard rating on a bridge. The current procedure uses a series of judgments taking into consideration the traffic safety features' compliance with each of the items considered in its evaluation with the established design guidelines.

Identification of potential treatments

After a potential safety hazard or non-compliant safety feature has been identified from the bridge inspection, it is the responsibility of the engineer to identify possible solutions or treatments. The safety treatments to be recommended will depend on the site condition and the particular deficiency identified in the field.

Bridge inspection form

The utilization of checklists or inspection forms has proven to be a great asset in the field of traffic safety, particularly for road safety audits. Inspection forms should be a reflection of the inspection process, and as such, they should facilitate the process and reduce the time it takes to perform the inspection. An inspection form was developed in this study to

aid inspectors in the second step of the process of rating traffic safety features on a bridge. The inspection form is included in Appendix B of this report.

The data collection method consists of two parts. The suggested data collection protocol is shown in Figure 14.

The first part corresponds to the collection of general information about the roadway site and the bridge. This part is completed once for a bridge through its service life, unless changes are made to the roadway design or configuration, or the bridge itself.

The second part corresponds to specific information related to the approach roadway, the entry and exit influence zones, and each component of the bridge railing system (entry end treatment, entry approach guardrail, entry transition, bridge rail, exit transition, exit approach guardrail, and exit end treatment).

The collection of data should be performed for each direction, or in the case of bridges with one way traffic, twice in the same direction, but taking into consideration the bridge railing systems on both sides of the bridge structure. As previously stated, the major data collection effort is performed only once for each bridge, unless changes are made to the roadway design or configuration, or the bridge itself. The following sections explain some of the data collection elements on the form sections.

General site and bridge information

Section One: Site identification

This section's information pertains to the road in which the bridge is located, such as State, route number, county and/or township, year built, year reconstructed, road functional classification, AADT and date of AADT, number of lanes, posted speed limit, design speed, roadway type, starting and ending mileposts, direction of traffic, and inspector information. This information includes the following:

- Road Functional Classification: classify the function and service provided by the road within the highway and street network as:
- RURAL - R
- 01 Principal Arterial- Interstate
- 02 Principal Arterial – Other

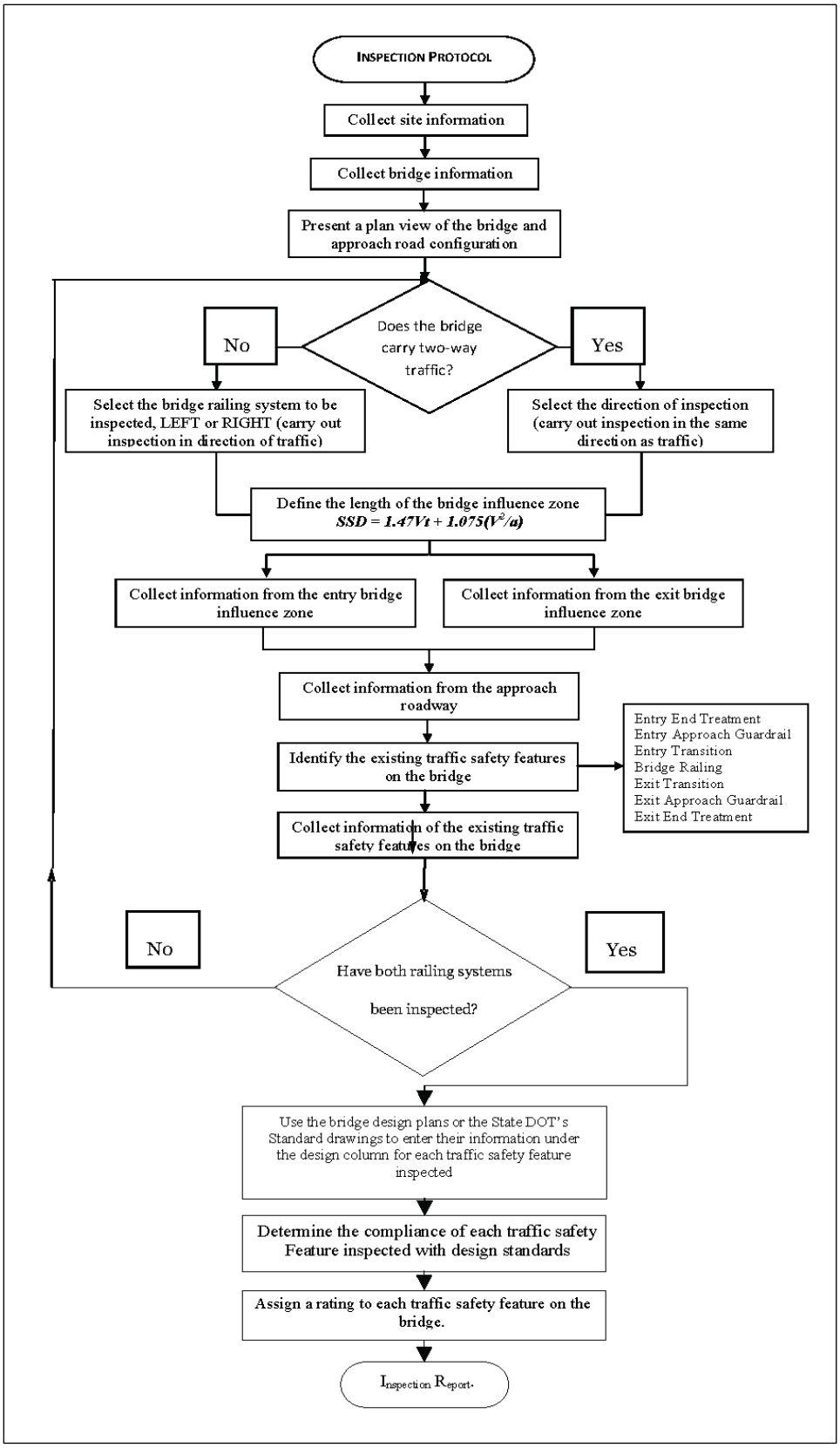


Figure 14. Inspection data collection protocol.

- 03 Minor Arterial
- 04 Major Collector
- 05 Minor Collector
- 06 Local
- URBAN - U
- 11 Principal Arterial – Interstate
- 12 Principal Arterial – Freeway-Expressway
- 14 Other Principal Arterial
- 16 Minor Arterial
- 17 Collector
- 19 Local
- AADT / Date of AADT: record the annual average daily traffic for the site and the date of the estimate of measurement.
- Number of lanes: record the number of traffic lanes on the road.
- Direction of traffic: indicate if the traffic direction along the bridge is one-way, two-way, two-way traffic on the road but one single lane operation on the bridge, and road not open to public travel.

Section Two: Bridge information

This section's information should be consistent with the bridge identification in the National Bridge Inventory. The information required is: the NBI structure number, bridge material, type of service, bridge length, number of spans, pavement type, bridge roadway width, number of lanes, pavement markings, and shoulder and sidewalk width. This information is described as follows:

- NBI Structure Number: identification number assigned to a bridge structure by its owner. This number should not change throughout the service life of the bridge.
- Bridge Material: material used for the construction of the bridge, according to FHWA (1995):

    - Concrete
    - Concrete continuous
    - Steel
    - Steel continuous
    - Prestressed concrete
    - Prestressed concrete continuous
    - Wood or Timber
    - Masonry

- Aluminum, Wrought Iron, or Cast Iron
- Other

- Type of Service: type of service provided by the bridge structure:

  - Highway
  - Railroad
  - Pedestrian – bicycle
  - Highway – railroad
  - Highway – pedestrian
  - Overpass structure at an interchange or second level of a multilevel interchange
  - Third level (Interchange)
  - Four level (Interchange)
  - Building or plaza
  - Other

- Pavement type: record the type of pavement surface on the bridge deck.
- Pavement makings: record the presence, or absence, of lines at the center and on the left and right borders of the roadway on the bridge.
- Shoulder width: record the width, in feet, of the left and right shoulders on the bridge, if present.
- Sidewalk width: record the width, in feet, of the left and right sidewalks on the bridge, if present.
- Plan View of Bridge and Approach Roadway Configuration: provide aerial photograph, design drawing, or sketch showing the configuration of the roadway horizontal alignment of the bridge and the approach roadway.

Approach road and traffic safety features information

This section includes the following information on approach road and safety features:

- Direction of Inspection: record the direction in which the inspection is being performed. Identification of the direction in which the inspection is being performed is important to help inspectors to identify particular elements of the bridge railing system after leaving the site. Inspections of one-way traffic bridges should be done only in one direction, but taking into consideration the two railing systems in the bridge (Left Side,

Right Side). This section of the inspection form was designed to be filled once per direction or bridge side (in the case of one-way bridges).

Sections Three and Four: Bridge entry and bridge exit influence zones

These sections include the following information on bridge entry and bridge exit influence zones:

- Length of Influence Zone: record the roadway distance, in feet, measured from each end of the bridge structure that allows drivers to be aware of the presence of the bridge structure and its conditions, and adjust their behavior, if deemed necessary.

  The length of the bridge influence zone should be calculated using the stopping sight distance (SSD) model in AASHTO (2004), as shown on Figure 2. For a level road with a speed of 45 mph, the SSD corresponds to 360 ft. This value can be assigned to the length of the bridge influence zone when inspecting low speed roads (posted speed equal or less than 45 mph). For roads with longitudinal grades higher than 3%, it is recommended that the SSD value be modified for their effect on vehicle speeds. When shorter bridge influence zones are justified, alternative SSD values can be calculated by using the actual operating speed, the posted speed limit, or by using the alternate methods explained in Chapter 4.

  Both entry and exit influence zones need to be defined, if the speed conditions vary for individual directions on two-way traffic sites. When inspecting bridges that carry one-way traffic, there is only one length for the influence zone, which means that sections three and four will be completed only once throughout the inspection.

- Record the presence of intersections, horizontal curves, vertical curves, or a combination of any of these elements within the entry and exit influence zone.
- Visibility of Bridge: indicate if the visibility of the bridge from the end of the entry and exit bridge approaches is at least equal to the SSD value assigned as the length of the influence zone.
- If the bridge is not visible from the end of the entry influence zone (section 3), record the distance, in feet, at which the bridge becomes visible within the influence zone. Section four corresponds to the bridge exit influence zone. Inspectors should indicate the presence of

any obstruction to the drivers' sight, which limits their visibility toward the end of the exit influence zone. This information will help inspectors to apply their engineering judgment about the bridge safety risk.

Section Five: Approach roadway information

This section includes information that characterizes the cross-section conditions of the approach roadway and consists of the following:

- Traveled way width: measure the width, in feet, of the portion of the road intended for the movement of vehicles.
- Shoulder width: measure the width, in feet, of the left and right shoulders on the roadway, if present.
- Sidewalk width: measure the width, in feet, of the left and right sidewalks on the bridge, if present.
- Roadway grade: measure the longitudinal roadway grade and record as a percent.
- Pavement type: record the type of pavement surface on the roadway as "high type" (e.g., concrete, asphalt) or "low type (e.g., gravel, earth).
- Pavement makings: record the presence, or absence, of pavement lines at the center and on the left and right borders on the roadway.
- Side slopes: Measure the grade of the road side slopes, if applicable for both sides of the approach road.
- Drainage channels must be considered, if present within the clear zone. The evaluation of vee, rounded, and trapezoidal channels is found in the AASHTO RDG (2006). When a drainage channel is present, record both foreslope and backslope values in the box for the side in which the channel is present. If there are drainage channels on both sides of the road, then all L and R spaces will be filled out on both boxes.
- Clear Zone: record the clear zone distance available on site and determine the suggested clear zone distance by AASHTO RDG (2006). The clear zone should be measured within the bridge influence zone from the edge of the traveled way to the face of the safety barrier, if present, or to the roadside obstacle.
- Existing Traffic Safety Features on the Bridge: provide a checkmark on the boxes provided in the drawing to identify the presence of the particular elements of the bridge barrier system. Complete the following sections on the form, as applicable.

Sections 6 to 12 require information corresponding to each of the existing traffic safety features on the bridge. The form is divided in four columns.

The first column identifies the data element. The second column, "EXISTING," deals with the existing conditions on the bridge. The third column, "DESIGN," deals with the conditions established on the design plans, if available. The forth column, "COMPLIANCE," allows the inspector to provide his/her judgment about the compliance of the particular safety feature with the design plans for the bridge site. If design plans are not available, local or national standard practices or guidance might be used for making the decision.

Section Six: Entry end treatment

This section includes the following information on the existing entry end treatment:

- Type: record the type of existing end treatment. FHWA provides documentation, photos, and/or standard details of crash tested end treatments for identification purposes.
- Test Level: record the test level of the end treatment, if known. If design plans are not available, verify that the test level of the end treatment is consistent with the one required for the existing road operating conditions. When the existing end treatment does not correspond to any existing crash tested design, or does not meet the design plans or standard requirements, the inspector should write "not applicable" in the design column for all items of the section.
- Anchorage: For impacts within the approach guardrail's length of need, the end treatment should have the same redirectional characteristics as the standard guardrail, meaning that it should be properly anchored (AASHTO 2006). Verify that the anchorage system has been properly installed, according to its design, that it has not been impacted or bent, and that there are no missing bolts or cables. The suggested evaluation criteria are the following:

    - Functional: anchor properly installed, with no missing elements, and showing minor, or no, impacts preventing it from working properly.
    - Damaged: end treatment has been impacted, or design elements are either missing or not installed, according to specifications. Anchor is loose or unattached to rail.
    - Not present: end treatment type requires the installation of an anchorage system, or none is provided. Without an anchorage

system, the existing end treatment is not considered functionally adequate.
    - Not Applicable: a review of the bridge design plans or the standard plans determine that the existing end treatment does not require the installation of an anchorage system.

- Grading: determine the existing grade of the terrain at the front and sides of the terminal. AASHTO guidelines suggest a grade not steeper than 1V:10H.

Section Seven: Entry approach guardrail

This section includes the following information on the entry approach guardrail:

- Type: record the type of approach guardrail or standard section (e.g., w-beam, thrie beam, F-shape, or New Jersey shape). FHWA provides documentation, photos, and/or standard details of crash tested standard sections for identification purposes.
- Test Level: record the test level of the standard section, if known. If design plans are not available, verify that the test level of the guardrail is consistent with the one required for the existing road operating conditions. When the existing approach guardrail does not correspond to any existing crash tested design, or does not meet the design plans or standard requirements, the inspector should write “not applicable” in the design column for all items of the section.
- Height: measure the height of the rail for the existing approach guardrail and determine if the installation height is in compliance with the design plans or standard plans for that barrier type.
- Post Spacing: measure and record the spacing between posts of flexible or semi-rigid barrier systems. The spacing is measured from center to center of adjacent posts.
- Grading: determine and record the existing terrain grade at the sides of the standard section. AASHTO guidelines suggest a grade not steeper than 1V:10H.
- Flare Rate: record the flare rate of the standard section, if present. *AASHTO RDG* (2006) includes suggested maximum flare rate values.
- Lateral Offset: measure and record the distance from the edge of the traveled way to the face of the barrier. The shy line distance identifies the distance at which an object or barrier is perceived by drivers as a

potential hazard. *AASHTO RDG* (2006) provides suggested values for this distance.

- Length of Need: measure and record the length of the approach guardrail from the end of the bridge railing end or transition section to the back of the end treatment, if present. The suggested length of need is calculated using Equation 1.

Section Eight: Entry transition

A transition section should be installed when standard railing sections and bridge railings have different deflection characteristics. This section includes the following information:

- Type: record the type of transition section (e.g., w-beam, or thrie beam). FHWA provides documentation, photos, and/or standard details of crash tested transition sections for identification purposes.
- Test Level: record the test level of the transition section, if known. If design plans are not available, verify that the test level of the transition is consistent with the one required for the existing road operating conditions. When the existing transition does not correspond to any existing crash tested design, or does not meet the design plans or standard requirements, record “not applicable” in the design column for all items of the section.
- Length: measure and record the length of the transition section. Generally, the transition length should be 10 to 12 times the difference in the lateral deflection of the two systems in question (AASHTO 2006).
- Height: measure and record the height of the rail of the existing transition and determine if the installation height is in compliance with the design plans or standard plans for that barrier type.
- Post Spacing: measure and record the spacing between posts of flexible or semi-rigid barrier systems. The spacing is measured from center to center of adjacent posts. The stiffness of the transition should increase smoothly and continuously from the less rigid to the more rigid system.
- Connection: observe and record, if the connection between the bridge rail and the approach guardrail has been properly installed, according to its design, and that it has not been impacted, is not missing hardware, or the connection has not become loose or separated. The connection to the bridge rail is a crucial element of the transition, since it prevents the guardrail from pulling out and leaving the bridge end unprotected. The suggested evaluation criteria are the following:

- Functional: connection is properly installed, hardware elements are in place, there is no evidence of damage that would prevent it from working properly, and it is properly attached to the railing.
- Damaged: connection has been impacted, hardware elements are missing or have not been installed, or the connection has become loose or it is not attached to the railing.
- Not installed: transition is not connected to the bridge rail.

Section Nine: Bridge railing

This section relates to the bridge railing. Railings are always warranted; under no circumstances should a bridge be left unshielded. The information in this section includes:

- Type: record the type of railing (e.g., w-beam, thrie beam, or F-shape, New Jersey shape). FHWA provides documentation, photos, and/or standard details of crash tested bridge railings for identification purposes.
- Test Level: record the test level of the railing, if known. If design plans are not available, verify that the test level of the railing is consistent with the one required for the existing road operating conditions. When the existing railing does not correspond to any existing crash tested design, or does not meet the design plans or standard requirements, record "not applicable" in the design column for all items of the section.

  If no information is available about the crashworthiness of the existing bridge railing in accordance with NCHRP Report 350 or MASH criteria, the checks on Section Thirteen should be performed. The checks will help inspectors to assess if the existing bridge railing complies with NCHRP Report 230 criteria.

  When the bridge rail does not correspond to any crashworthy design and the checks in Section 13 demonstrate the railing has a high snagging potential or has inadequate post setback criteria, record NO in the compliance column.

- Height: measure and record the height of the existing railing and determine if the installation height is in compliance with the design plans or standard plans for that railing type.

- Post Spacing: measure and record the spacing between posts of flexible or semi-rigid barrier systems. The spacing is measured from center to center of adjacent posts.
- Lateral Offset: measure and record the distance from the edge of the traveled way and the face of the barrier.
- Length: measure and record the existing length of the railing. A bridge railing should extend for the entire length of the bridge, including the abutments.
- Sketch of Bridge Railing: if necessary, provide a sketch of the bridge railing with its dimensions. A picture from the side of the bridge railing can be also provided.

The description of the inspection data for sections 10, 11, and 12 is similar to the description provided for Sections 8, 7, and 6, respectively.

Section Thirteen: Checks for bridge railing compliance with NCHRP 230

Existing bridge railings designed to meet criteria contained in the AASHTO Standard Specifications for Highway Bridges, and/or crash tested under NCHRP 230 criteria, may be acceptable for use on new or reconstruction projects based upon evaluation of their in-service performance (AASHTO 2006). Railings not found in the FHWA Bridge Rail Guide, or without information about their crashworthiness (FHWA letter of approval), should be evaluated to verify their compliance with NCHRP Report 230 crash testing guidelines.

To perform the check, collect the following information: maximum opening between rails (C), clear opening below the bottom rail (C_b), post setback distance (S), rail contact width (A), and height of the rail (H), as shown on Figure 10.

Figure 11 is used to perform the snagging potential check for the bridge railing. The check is needed to verify that the vertical clear opening (C) and the post setback criteria (S) are within or below the shaded area on the figure, indicating that the railing meets NCHRP 230 criteria, or that the potential for vehicles snagging on the railing post is low.

Figure 12 is used to perform the check for railing post setback. The check is needed to verify that the combination of $\Sigma A/H$ and the post setback (S) are within, or above, the shaded area, indicating that the design post setback

distance of the railing meets NCHRP Report 230 criteria, or that the design is preferred.

The last page of the inspection form is a summary table to present the results of the evaluation for each direction of the traffic safety features on the bridge site inspected.

8 Conclusions and Recommendations

Conclusions

Current bridge design specifications require the use of bridge railings on all bridges open to public travel in order to protect road users from running off the edge of the bridge. The *AASHTO Roadside Design Guide* (2006) establishes that a bridge railing system can be composed of up to four elements: bridge railings, transition sections, approach guardrails, and end treatments. Although the installation of a bridge railing system with all the elements is the safest design option, the complete system might not be always the most cost-effective alternative for low speed low volume road facilities. The existing operating and geometric conditions on the bridge and approach roadways need to be evaluated for the purpose of reaching a balance between safety and costs.

The minimum setting for low volume and low speed road facilities, under favorable bridge site and approach roadway conditions, could include only the bridge railing and the end treatment to protect road users from the consequences of impacting an unshielded railing end. Favorable site conditions include, but are not limited to, flat horizontal and vertical alignment, continuous roadway width along the bridge, recoverable roadside lateral slopes, adequate sight distance provided, low operating speeds, and low truck traffic volumes. In addition, the historic record of crashes on the site must be considered, along with the evaluation during nighttime conditions and during extreme weather conditions.

According to the data collected for this report, the 32 states and the Commonwealth of Puerto Rico that have military installations follow the bridge railing requirement for all their bridges. The jurisdictions mostly differ in the selection criteria and the types of railings commonly used in each jurisdiction. Most jurisdictions establish the type of railing to be used by specifying the *NCHRP 350* Test Level with which they must comply.

A total of 58% of the jurisdictions require the use of bridge railings that meet particular *NCHRP 350* test levels, while the other 42% have no written guidance specifying the bridge railing test level. Of the 58% of jurisdictions that have a test level requirement, 30% require the use of bridge railings that meet TL-4 criteria; these jurisdictions allow the use of bridge railings

meeting other test levels with prior coordination and approval of the corresponding authority. The other 28% of the jurisdictions give designers the freedom to select the test level from a series of test levels specified in their design guidelines; each test level is accompanied by a description of the particular situations for which they can be used. A total of 24% of the jurisdictions allow the use of TL-2 bridge railings on low speed roads.

Out of the 33 jurisdictions researched, 32 prefer the use of concrete railings for their bridges; Alaska being the only state that has established the Two-Tube Metal Railing as its standard bridge railing. Out of the other 32 jurisdictions, 24 use both concrete and metal railings, and the other 8 use only concrete railings on their bridges. States that use only concrete railings on their bridges are: Arkansas, Georgia, Iowa, Kansas, Maryland, Mississippi, Nevada, North Carolina, South Carolina, and Utah. Only two states, New York and Wisconsin, have timber railing details in their standard drawings.

Alaska, North Carolina, Oklahoma, Puerto Rico, and Virginia are the five jurisdictions that had not developed their own guidelines for the selection and inspection of bridge railings as of October 2008. These jurisdictions directly follow the design requirements established in *AASHTO LRFD Bridge Design Specifications* (2007) and the *FHWA National Bridge Inspection Standards*. The jurisdictions that do not have standard drawings and details of the approved and crash tested railings refer to FHWA Standards for Bridge Railings and other safety appurtenances, which are available through the internet at:
http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/.

The inspection protocol proposed in this study can be implemented for the inspection of existing bridges when there is no inspection procedure developed by a particular jurisdiction. The inspection procedure uses a field form to guide evaluators throughout the process of inspecting the traffic safety features. The inspection form consists of thirteen sections that require collection and recording of data about the site, the bridge influence area, the bridge, the approach roadway, the existing bridge railing, the transition, the approach guardrail, and the end treatment. The purpose of the inspection form is to help the inspector identify deficiencies and inadequacies of the traffic safety devices on the bridge by comparing the data collected with the requirements, standards, design plans, and policies for each jurisdiction.

Recommendations

Recommended future studies include implementing the inspection procedure and utilizing the proposed forms at existing bridges to identify modifications needed, or improvements that could be made, to the inspection protocol and form. Also, the study could include the consideration of traffic control devices in the bridge influence area that might help establish operation guidelines on military roads. Use of such traffic controls could provide cost effective safety treatments where improvements or modifications to a bridge structure and railing system cannot be made in a timely manner, or are not feasible. The identification of low cost safety treatments based on traffic control devices or operating regulations could be implemented to improve the safety of road users until the bridge could be scheduled for reconstruction.

Additional research could be developed to assist inspectors in better estimating and judging the railing safety rating based on the potential speed reduction caused by the bridge approach width and the approach roadways on low speed roads. This research study could be based on the evaluation of existing operating conditions (traffic speeds, volume, etc.), geometry, and weather conditions, on bridge sites with adverse site conditions. Evaluation of the crash history on those sites to correlate bridge and approach information, crash information, and vehicle operating information could be incorporated into the study.

References

AASHTO. 2009. *Manual for Assessing Safety Hardware*. Washington, DC.

AASHTO. 2007. *Load Resistance Factor Design Bridge Design Specifications*. Washington, DC.

AASHTO. 2006. *Roadside Design Guide*. Washington, DC.

AASHTO. 2004. *A Policy on Geometric Design of Highways and Streets*. Washington, DC.

AASHTO. 2003. *Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges*. Washington. DC.

AASHTO. 2002. *Standard Specifications for Highway Bridges, 17th Edition*. Washington, DC.

AASHTO. 2001. *Guidelines for Geometric Design of Very Low Volume Local Roads (ADT ≤ 400 vpd)*. Washington, DC.

Barker, R. and Puckett, J. 1997. *Design of Highway Bridges Based on AASHTO LRFD Bridge Design Specifications*. New York, USA: John Wiley and Sons, Inc.

Bureau of Transportation Statistics. 2008. *National Transportation Statistics 2007*. Washington, DC: U.S. Department of Transportation.

Fambro, D.B., Fitzpatrick, J., and Koppa, R. 1997. *Determination of Stopping Sight Distances*. NCHRP Report 400. Washington, DC: Transportation Research Board.

Federal Lands Highway Central Division. 2005. *Barrier Guide for Low Volume and Low Speed Roads*. Report FHWA-CFL/TD-05-009. Washington, DC: U.S. Department of Transportation.

FHWA. 2009a. Manual on Uniform Traffic Control Devices for Streets and Highways. 2009 Edition [Internet]. Washington, DC: U.S. Department of Transportation. Available at: http://mutcd.fhwa.dot.gov/ [Accessed December 23, 2009].

FHWA. 2009b. Roadside Hardware Policy and Guidance [Internet]. Washington, DC: FHWA Safety Program, U.S. Department of Transportation. Available at: http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/ [Accessed December 23, 2009].

FHWA. 2009c. Bridge Railings [Internet]. Washington, DC: FHWA Safety Program, U.S. Department of Transportation. Available at: http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/bridgerailings/index.cfm [Accessed December 23, 2009].

FHWA. 2009d. Longitudinal Barriers [Internet]. Washington, DC: FHWA Safety Program, U.S. Department of Transportation. Available at: http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/listing.cfm [Accessed December 23, 2009].

FHWA. 2009e. Legislation, Regulations, and Guidance [Internet]. Washington, DC: U.S. Department of Transportation. Available at: http://www.fhwa.dot.gov/legsregs/legislat.html [Accessed December 23, 2009].

FHWA. 2006. *Bridge Inspector's Reference Manual*. Report FHWA NHI 03-001. Washington, DC: U.S. Department of Transportation.

FHWA. 2005a. *Code of Federal Regulations, Title 23*. Washington, DC: U.S. Department of Transportation.

FHWA. 2005b. Bridge Rail Guide [Internet]. Washington, DC: U.S. Department of Transportation. Available at: http://www.fhwa.dot.gov/bridge/bridgerail/index.cfm [Accessed December 23, 2009].

FHWA. 1998. *Improving Highway Safety at Bridges on Local Roads and Streets*. Washington, DC: U.S. Department of Transportation.

FHWA. 1995. *Recording and Coding Guide for the Structures Inventory and Appraisal of the Nation's Bridges*. Report FHWA-PD-96-001. Washington, DC: U.S. Department of Transportation.

Government Printing Office. 2009. Electronic Code of Federal Regulations [Internet]. Washington, DC: National Archives and Records Administration. Available at: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?&c=ecfr&tpl=/ecfrbrowse/Title23/23tab_02.tpl [Accessed December 23, 2009].

Mak, K.K. and D.L. Sicking. 2003. *Roadside Safety Analysis Program*. NCHRP Report 492. Washington, DC: Transportation Research Board.

Michie, J.D. 1981. *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*. NCHRP Report 230. Washington, DC: Transportation Research Board.

National Highway Traffic Safety Administration. 2007. *Traffic Safety Facts 2006: A Compilation of Motor Vehicle Crash Data from the Fatality Analysis Reporting System and the General Estimates System*. Washington, DC: U.S. Department of Transportation.

Ross, H.E., D. L. Sicking, and R.A. Zimmer. 1993. *Recommended Procedures for the Safety Performance of Highway Features*. NCHRP Report 350. Washington, DC: Transportation Research Board.

TXDOT. 2006. Bridge Railing Manual [Internet]. Texas: Texas Department of Transportation. Available at: http://onlinemanuals.txdot.gov/txdotmanuals/rlg/index.htm [Accessed December 23, 2009].

Worcester Polytechnic Institute. 2007. Online Guide to Bridge Railings [Internet]. Worcester, Massachusetts. Available at: http://civil-ws2.wpi.edu/Documents/Roadsafe/Guides/bridgeRailGuide/index.php?action=home. [Accessed December 23, 2009].

The references used for the collection of the state-specific railing data are included in each of the state tables provided in Appendix A.

Appendix A: State Bridge Railing Policies

The following tables include the information collected about the current practice, requirements, and guidelines for the 32 states and the Commonwealth of Puerto Rico having military installations. The information in the tables include warrants for railing installation, selection criteria, inspection procedures, types of railings approved for use in that particular state, the standard drawings or plans, and end treatments. The tables also include contact information for the officials from each state that provided the data, as well as the documents and links used.

ALABAMA	
Warrants	Railing Installation: Use bridge railing as detailed on Standard Drawing I-131, and approach railing per roadway standard drawings. Use of other crash tested rail systems shall require prior approval from the State Bridge Engineer. Railing Transition: No information was found. Pedestrian Railings: No was information found.
Selection Criteria	Materials: Concrete Height: Varies according to railing type. See Standard Drawings. Shape of face: Varies according to railing type. See Standard Drawings. Compliance with NCHRP 350:
Inspection Procedures	No Bridge Inspection Manual was found on the internet.
Railings	Concrete Railings ✓New Jersey ✓Vertical Slope
Standard Drawings / Standard Plans	**Plan Title** — **Plan No.** - Culvert Barrier Rail — CBR-1, CBR -2 - Barrier Rail for Non Skewed Bridges and Bridges Skewed less than 15 degrees — I-131-3 - Barrier Rail Extension for Bridges Skewed 15 degrees and greater — I-131-4 and -5 - Standard for Standard Details — I-131-6
End Treatments	No information was found.
Contact Log	Name/Position: William F. Conway / Bridge Engineer Phone: (334) 242-6500 E-mail: conwayf@dot.state.al.us
References Used [Accessed Dec. 2009]	ALDOT Structures Design and Detail Manual (January 2008) http://www.dot.state.al.us/Docs/Bureaus/Bridge/Bridge+Index.htm ALDOT Standard Drawings (2008) http://www.dot.state.al.us/Docs/Bureaus/Bridge/Standard+Drawings.htm

ALASKA	
Warrants	The Alaska DOT is currently working on the development of a Bridge Design Manual. The Alaska DOT Bridge Design Manual will be available approximately by the end of 2011, according to Elmer E. Marx, P.E.; Bridge Design Engineer. Railing Installation: Alaska Multistate Two-Tube Railing is the most common bridge railing used by Alaska DOT; another type of bridge railing used is the "F" type concrete barrier, but this railing is mostly used on bridges located on railroad overpasses. Railing Transition: **Plan Title** — **Plan No.** Bridge Rail W-Beam Transition — G-30.00 Bridge Rail Thrie Beam Transition — G-31.00 Pedestrian Railings: Oregon 3-tube railing for combination traffic and pedestrian use.
Selection Criteria	Materials: Concrete and metal Height: Varies according to railing type. See Standard Drawings. Shape of face: Varies according to railing type. See Standard Drawings. Compliance with NCHRP 350: All railings approved for use by Alaska DOT are in compliance with NCHRP 350 TL-4.
Inspection Procedures	The Alaska DOT does not have a Bridge Inspection Manual. The Alaska DOT follows the NBIS and AASHTO CoRe Element Manual.
Railings	Concrete Railings ✓F-Shape Metal Railings ✓Two Tube Rail (This is the most commonly used railing. It is even used on highways, according to the contact, Elmer Marx.)
Standard Drawings / Standard Plans	**Plan Title** — **Plan No.** Precast Concrete F-Shape Barrier — G-46.10 Std Drawing for Two Tube Rail was not available.
End Treatments	**Plan Title** — **Plan No.** W-Beam Guardrail Downstream End Anchor — G-13.00 Beam Guardrail Buried in Backslope Terminal — G-15.10 Beam Guardrail Buried in Backslope Terminal Concrete Anchor and Miscellaneous — G-15.10 Beam Guardrail Buried in Backslope Terminal Rub-rail and Post Anchors — G-15.10 Widening for Guardrail End Terminals — G-20.10 Wood Post Controlled Release Terminal (CRT) — G-25.20W
Contact Log	Name/Position: Elmer Marx, P.E./Bridge Design Engineer Phone: (907) 465-6941 E-mail: elmer.marx@alaska.gov
References Used [Accessed Dec 2009]	Standard Drawings, 2003 (Section G: Guardrail, Median Barriers and Crash Cushions) http://www.dot.state.ak.us/stwddes/dcsprecon/stddwgspages/guardrail_eng.shtml

<table>
<tr><th colspan="3">ARIZONA</th></tr>
<tr><td>Warrants</td><td colspan="2">Railing Installation: All new bridge railings installed on the State Highway System should have a minimum rating of TL-4. The preferred TL-4 bridge railing is the 32-in. F-shape concrete barrier; and the preferred TL-5 bridge railing is the 42-in. F-shape concrete barrier. Other acceptable TL-4 and TL-5 bridge railings are available from Bridge Group.

Railing Transition: No information was found.

Pedestrian Railings:</td></tr>
<tr><td></td><td>Plan Title</td><td>Plan No.</td></tr>
<tr><td></td><td>Combination Pedestrian-Traffic Bridge Railing
Pedestrian Fence for Bridge Railing SD 1.04</td><td>SD 1.04
SD 1.05</td></tr>
<tr><td>Selection Criteria</td><td colspan="2">Materials: Concrete and metal

Height: 32 in. (TL- 4); 42 in. (TL- 5). See Standard Drawings.

Shape of face: Varies according to railing type. See Standard Drawings.

Compliance with NCHRP 350:
✓According to FHWA requirements, all proposed new bridge railings for use on the National Highway System should meet the crash testing requirements of NCHRP Report 350, “Recommended Procedures for the Safety Performance Evaluation of Highway Features,” after October 1, 1998.

✓Bridge railings currently in use that have been found acceptable under the crash testing and acceptance criteria specified in NCHRP Report 230, or AASHTO Guide Specifications for Bridge Railings will be considered as meeting the requirements of NCHRP Report 350 without the need of further testing, as indicated in the following table:

<table><tr><th>Testing Criteria</th><th colspan="3">Acceptance Equivalencies</th></tr><tr><td>NCHRP Report 350</td><td>TL-2</td><td>TL-4</td><td>TL-5</td></tr><tr><td>AASHTO Guide Specifications</td><td>PL-1</td><td>PL-2</td><td>PL-3</td></tr></table></td></tr>
<tr><td>Inspection Procedures</td><td colspan="2">No Bridge Inspection Manual was found.</td></tr>
<tr><td>Railings</td><td colspan="2">Concrete Railings:
✓32-in. F-Shape
✓42-in. F-Shape
✓Combination Pedestrian- Traffic Bridge Railing

Metal Railings
✓Thrie Beam
✓Two Tube Bridge Rail</td></tr>
<tr><td>Standard Drawings / Standard Plans</td><td>Plan Title
32-in. F-Shape Bridge Concrete Barrier and Transition
42-in. F-Shape Bridge Concrete Barrier and Transition
Thrie Beam Guard Rail Transition System
Combination Pedestrian - Traffic Bridge Railing
Pedestrian Fence For Bridge Railing SD 1.04
Two Tube Bridge Rail (1 of 4)</td><td>Plan No.
SD 1.01
SD 1.02
SD 1.03
SD 1.04
SD 1.05
SD 1.06a</td></tr>
</table>

	Two Tube Bridge Rail (2 of 4) Two Tube Bridge Rail (3 of 4) Two Tube Bridge Rail (4 of 4) Barrier Junction Box	SD 1.06b SD 1.06c SD 1.06d SD 1.11
End Treatments	No information was found.	
Contact Log	Name: Peshem Yang Phone: (602) 712-8606	
References Used [Accessed Dec. 2009]	Railing Standard Drawings http://www.dot.state.az.us/Highways/bridge/DetailDwg/Railing.asp Bridge Design Guidelines http://www.dot.state.az.us/Highways/bridge/Guidelines/DesignGuidelines/index.asp	

ARKANSAS	
Warrants	Railing Installation: Traffic Railings for all new and rehabilitated bridges are concrete. Metal traffic railings have not been specified on Federal, or State funded projects in the last 30 years, or so. On existing bridges within the limits of a construction project, if the bridge otherwise is not receiving any rehabilitation work, the existing bridge railing may remain regardless of whether it is NCHRP 350 compliant. However, a guard rail transition from the approach railing to the bridge railing that meets NCHRP 350 is provided. Railing Transition: Guardrail transitions shall be NCHRP 350 compliant. Pedestrian Railings: No information was found.
Selection Criteria	Materials: Concrete Height: 2 ft-9 in. and 3 ft-6 in. Shape of face: F-Shape and Single Slope Compliance with NCHRP 350: Bridge Railings for new and rehabilitated bridges on and off system built with Federal or State funds comply with NCHRP 350.
Inspection Procedures [Accessed Dec. 2009]	Refer to the FHWA Recording and Coding Guide, http://www.fhwa.dot.gov/BRIDGE/mtguide.pdf, and the following FHWA website at: http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/bridgerailings/index.cfm.
Railings	Concrete Railings ✓F-Shape ✓Single Slope
Standard Drawings / Standard Plans [Accessed Dec. 2009]	The Arkansas DOT uses only two types of concrete bridge railings for their new and rehabilitated bridges; these are the 2 ft-9 in. F-Shape and the 3 ft-6 in. Single Slope. They don't have Standard Drawings that cover either. The Arkansas DOT refers to the FHWA web page for the use of traffic safety features. http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/bridgerailings/index.cfm
End Treatments [Accessed Dec. 2009]	The Arkansas DOT refers to the FHWA web page for the use of traffic safety features. See Standard Drawings for barrier terminals and crash cushions approved by the FHWA at: http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/term_cush.cfm
Contact Log	Name/Position: Glen Cheatham / Heavy Bridge Maintenance Engineer Phone: (501) 569-2466 E-mail: Glenn.Cheatham@arkansashighways.com
References Used [Accessed Dec. 2009]	Arkansas DOT Bridge Inspection Manual, 2008 Ed. FHWA Bridge Railing Website http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/bridgerailings/ Information is provided by Phil Brand from the Arkansas DOT's Bridge Division at Phil.Brand@arkansashighways.com.

<table>
<tr><th colspan="2">CALIFORNIA</th></tr>
<tr><td>Warrants</td><td>Railing Installation: Metal beam guardrail is the standard for embankment and fixed object protection. Concrete guardrails can only be used when the following criteria are met:
1. The proposed location is a metropolitan area (Population greater than 200,000).
2. The distance from the edge of the traveled way to the face of the guardrail is less than 4.3 m.
3. There is less than a 6-hr working window for maintenance work during a five-day work week (based on traffic volume projections of growth for the next five years).
4. The proposed location has been struck three or more times in the last year.
*Exceptions must be approved in writing by the Headquarters Traffic Operations Liaison.

Railing Transition: Transitions are required for guardrails approaching structures; they are also necessary where the face of the guardrail is less than 1.2 m in front of the rigid object.

Plan Title — Plan No.
Metal Beam Guardrail –Connections to Bridge Railings without sidewalks-details No.1 — A77J1
Metal Beam Guardrail –Connections to Bridge Railings without sidewalks-details No.2 — A77J2
Metal Beam Guardrail-Connections to Abutments and walls — A77J3
Metal Beam Guard Railing-Transition Railing (Type WB) — A77J4
Metal Beam Guard Railing-Connections to Bridge Railingswith Sidewalks- Details No.1 — A77K1
Metal Beam Guard Railing Connections to Bridge Railings with sidewalks- Details No.2 — A77K2
Double Thrie Beam Barrier-Connection to Bridge Railings Without Sidewalks — A78F1
Single Thrie Beam Barrier-Connection to Bridge Railings Without Sidewalks — A78F2
Thrie Beam Barrier-Typical Layout Connection to Bridge Railing — A78H
Double Thrie Beam Barrier-Connection to Concrete Barrier — A78I
Single Thrie Beam Barrier-Transition Railing (type STB) — A78J
Double Thrie Beam Barrier-Transition Railing (Type DTB) — A78K

Pedestrian Railings: No information was found.</td></tr>
<tr><td>Selection Criteria</td><td>Materials: Concrete and metal

Height: Varies according to barrier type.

Shape of face: Varies according to barrier type.

Compliance with NCHRP-350: No Information was found.</td></tr>
<tr><td>Inspection Procedures</td><td>Use CALTRANS Element Level Inspection Manual.</td></tr>
<tr><td>Railings</td><td>Chain Link Railing
Cable Railing
Metal Beam Railing
Metal Railing
Steel Bridge Railing</td></tr>
</table>

	Concrete Railing
Standard Drawings/ Standard Plans	Metal Railings **Plan Title** — **Plan No.** California ST-30 — B11-65 California ST-40 — B11-66,67 California ST-10 — B11-68,69,70 Concrete Railings **Plan Title** — **Plan No.** Type 25 — B11-53 Type 26 — B11-54 Type 732 — B11-55 Type 736 — B11-56 Type 742 — B11-57 Type 80 — B11-60, 61 Type 80SW — B11-62,63,64
End Treatments	• The approach end of a concrete barrier must be shielded from traffic. Recommended methods of shielding are: o Bury the end of a concrete barrier in a cut slope o Extend the end of a concrete barrier at a 1:20, or flatter flare to a point outside the clear recovery zone o Install an approved crash cushion at the approach end of the concrete barrier. • When lateral clearances are limited, a proprietary end terminal system will be specified. When the plans and special provisions require end terminal systems, ensure the systems are installed according to the manufacturers' instructions. Standard Plans: **Plan Title** — **Plan No.** Type SRT — A77L1 Type SKT — A77L2 Type ET — A77L3 Type CAT — A77L4 Type FLEAT — A77L5 Type SFT — A77H1 Metal Railing-Rail Tensioning Assembly — A77H2 Metal Railing- Anchor Cable and Anchor Plate Details — A77H3 Metal Railing-End Anchor Assembly (Type CA) — A7711 Metal Beam Guard Railing-Buried Post End Anchor — A7712 Single Thrie Bram Barrier-End Anchor Assembly — A78E1 Double Thrie Beam Barrier-End anchor assembly details — A78E2 Double Thrie Beam Barrier-Crash Cushion end Treatment — A78E3
Contact Log	Name: John Jewell Phone: (916) 227-5824 E-mail: John.Jewell@dot.ca.gov (Railings)
References	2006 Standard Specifications 2006 Standard Plans Traffic Manual (Ch7) Caltrans Element Level Inspection Manual (2000), Revised 2007

COLORADO			
Warrants	Railing Installation: No was information found. Railing Transition: No was information found. Pedestrian Railings: Pedestrian railings shall be designed in accordance with AASHTO Specifications. Handrails shall be provided for all stairs and for ramps with grades greater than 5%. The rail height shall be 34 to 38 in. (per ADA guidelines), as measured from the tread at the face of the riser for stairs and from the ramp surface for ramps.		
Selection Criteria	Materials: Concrete and metal Height: Varies according to railing type. (See Standard Plans.) Shape of face: Varies according to railing type. (See Standard Plans.) Compliance with NCHRP 350: Any new and/or rehabilitated bridges financed with Federal-aid funds are expected to be provided with crash tested bridge rails. An exception to this policy can only be made for bridges to be rehabilitated by formally requesting a variance for the site based on an analysis of the following criteria: - Existing rail type - Condition of structure (deterioration) - Accident history - Traffic information (ADT, speed) - Alignment (straight, curved) - Replacement scheduled within the Five Year Plan. Bridge rails on any existing bridges located with the limits of any Federal-aid projects are expected to be evaluated considering, at a minimum, the factors identified above. Bridge rails that meet, or can be modified to meet, current AASHTO specifications, but which have not been crash tested, may remain in place.		
Inspection Procedures	No CDOT Bridge Inspection Manual. CDOT uses the NBIS and the Pontis Coding Guide for the Inspection of their bridge rails.		
Railings	Concrete Railings ✓F-Shape ✓New Jersey Metal Railings ✓W-Beam		
Standard Drawings/ Standard Plans	**Plan Title** Guardrail Type 3 W-Beam Guardrail Type 7 F-Shape barrier Precast Type 7 Concrete Barrier	**Plan No.** M-606-1 M-606-13 M-606-14	**Sheet No.** 1-16 1-4 1-3
End Treatments	No information was found.		
Contact Log	Name/Position: Jeff Anderson /CDOT Bridge Section Phone: (303)757-9188 E-mail: jeff.anderson@dot.state.co.us		
References	Bridge Design Manual 2006 Standard Drawings		

GEORGIA	
Warrants	Railing Installation: Bridge barrier shall be concrete bridge barrier, or concrete parapet, with one or two pipe handrail in accordance with this section. Aesthetic barriers, where applicable, may be used with the prior approval of the State Bridge Engineer. ✓**Bridges without sidewalks on non-bicycle routes** Provide a 32-in. high concrete bridge barrier with a 9-in. top. Generally this is a New Jersey shape, but if the roadway uses a different shape, the bridge should match the roadway. ✓**Bridges without sidewalks on bicycle routes** Provide a 32-in. high concrete bridge barrier with a 13-in. top and one pipe galvanized steel handrail with the posts embedded in the top of the barrier similar to fence posts for a total railing height of 3 ft-6 in. Maximum post spacing is 8 ft. ✓**Bridges with sidewalks** Provide a 2 ft-3 in. parapet and the Georgia Standard 3626 one rail aluminum handrails, for a total railing height of 3 ft-6 in. measured from the top of the sidewalk, in accordance with the AASHTO Specifications. This detail is also used when a bicycle route is present, whether the bicycle traffic is on the road or on the sidewalk. See fence requirements below. ✓**Bridges over Interstate, Limited Access Highways and Railroads** If a sidewalk is present, the bridge is in an urban area, and the bridge is over an interstate or other limited access highway or over a railroad, use a 2 ft-10 in. high parapet and a chain link fence. If a sidewalk is not present, but the bridge is over an interstate highway in Atlanta, a fence will probably be required on top of a barrier with a 13-in. wide top. Get guidance from Bridge Design if this situation arises. ✓**Architectural rails** Sometimes in historic areas, an architectural rail is required. The Texas rail can be used where there is a sidewalk, but has only been crash tested for speeds less than 45 mph. The Kansas corral rail can be used up to 55 mph. Because of the expense of these rails, use them only with permission from the Bridge Office. Railing Transition: **Plan Title** — **Plan No.** Guardrail Connection at Bridge End or at Concrete Barrier End — gse4012c Pedestrian Railings: No information was found.
Selection Criteria	Materials: Concrete Height: Varies according to rail type. See Standard Drawings. Shape of face: Varies according to railing type. See Standard Drawings. Compliance with NCHRP-350: No information was found.
Inspection Procedures	No Bridge Inspection Manual was found on the internet.
Railings	Concrete Railings: ✓New Jersey Shape Metal Railings ✓W-Beam ✓Thrie Beam
Standard Drawings / Standard Plans	**Plan Title** — **Plan No.** One Pipe Aluminum Handrailing for Bridges — gse3626

	Two Pipe Aluminum Handrailing for Bridges	gse3632
	W-Beam Guardrail	gse4010
	Post and Offset Blocks for "W" and "T" Beam Guardrail (Replaces Standards 4011 & 4271) - Added Comp. Block	gse4011a
	Location of Guardrail in Medians - Location of Guardrail at Turnouts	gse4022a
	Guardrail Location Details for Multi-Lane Divided Highways	gse4051
	Guardrail Location Details for Undivided Highways and Roads	gse4052
	Guardrail Location at Fixed Objects in the Median	gse4055
	"T" Beam Guardrail	gse4270
	Guardrail Location On Roads with Curb and Gutter or Curbs	gse4280
	Concrete Median Barrier - Permanent (Types 20,21 And 7-M and Conc. Glare Screens)	gse4940
	Concrete Side Barrier Types 7-C, 7-R,7-T and 7-W (Replaces Standard 4948)	gse4948a
	Concrete Side Barrier Types 2, 2-A, 2-B, and 2-C (Replaces Standard 4948)	gse4948b
	Concrete Side Barrier Types 6, 6-A, 6-B, and 6-C (Replaces Standard 4948)	gse4948c
	Details of Precast Temporary Barrier	gse4961
End Treatments	**Plan Title**	**Plan No.**
	End Post and End Post Guardrail Attachment Detail	gse3054
	Guardrail Anchorage Type 1	gse4012d
	Guardrail Anchorage Type 5 and 6 - Guardrail Attachment to Columns, Piers, Walls	gse4013
	Guardrail Anchorage Type 12	gse4040
	Concrete Barrier - Temporary (End Treatment Options)	gse4960
	Temporary Traffic Impact Attenuator - Sand Loaded Modules	gse4962
Contact Log	Name: Paul Liles E-mail: pliles@dot.ga.gov	
References Used [Accessed Dec. 2009]	GDOT Bridge and Structures Design Policy Manual, 2005 (Rev2007) http://www.dot.state.ga.us/doingbusiness/PoliciesManuals/roads/BridgeandStructure/GDOT_Bridge_and_Structures_Policy_Manual.pdf GDOT English Construction Standards http://tomcat2.dot.state.ga.us/stds_dtls/index.jsp	

HAWAII	
Warrants	Railing Installation: For New and Rehabilitated Bridge Projects ✓TL-4 will be specified for freeways and high speed roads. ✓Higher test level criteria (TL-5, TL-6) may be specified for unusual conditions (i.e., high truck volume roadways). ✓For low speed and low truck volume roadways, a lower test level (i.e., TL-2) may be specified if coordinated with HWY-DB. Railing Transition: Where approach guardrail is warranted, a transition section utilizing the slotted double nested thrie beam with reduced post spacing is required to adequately connect the semi-rigid metal guardrail to the rigid concrete parapet, or bridge end post. ✓In 2003, FHWA found that HDOT transitions type C, D, and E meet NCHRP 350 criteria for TL-4 and are approved for use on the National Highway System. Details for these transitions appear on the "NCHRP 350 Bridge Rail Transition Compliance" document. Pedestrian Railings: Hawaii DOT does not have standard pedestrian or bike railings. They typically use pedestrian/bike railings with 3 ft-6 in. height and follow AASHTO LRFD Bridge Design Specifications.
Selection Criteria	Materials: Concrete and metal (Timber rails could be considered if justified.) Height: Varies according to railing type. Shape of face: Varies according to railing type. Compliance with NCHRP-350: Bridge Railings on all roadway systems shall have been successfully crash tested in accordance with NCHRP Report 350 criteria.
Inspection Procedures	The Hawaii DOT has a "Bridge Inspection Program" document that serves as a guide for bridge inspectors and program managers. The Hawaii DOT uses the NBIS, PONTIS, and FHWA Bridge Inspector's Reference Manual for the inspection of their bridges. Hawaii DOT follows the NBI criteria for the inspection of bridge railings: 0 : Does not meet currently available standards 1: Meets currently available standards N: Not applicable HDOT also performs a condition inspection of the bridge railings.
Railings	Concrete Railings ✓Vertical Concrete Parapet ✓New Jersey Barrier ✓Tall Wall ✓F Shape Barrier ✓Single Slope Semi Rigid Metal Guardrail System ✓Strong Post W-Beam Guardrail ✓Strong Post Rubrail (W-Beam) Guardrail ✓Strong Post Modified Thrie Beam Guardrail Timber Bridge Rail: To date, HDOT has not used timber rails because of maintenance concerns but they could be considered if justified.
Standard Drawings / Standard Plans	Hawaii DOT refers to the FHWA web page, where they can find approved (crash tested) bridge railings.

End Treatments	All guardrail end terminals, buried guardrail end terminals, and crash cushions must receive approval from the FHWA and State Highways Traffic Branch and be placed on the approved list before being installed on State roadways. ✓For both Low and High speed roadways, TL-3 is adopted as the standard test level criteria for guardrail end terminals/crash cushions. Lower test levels may be utilized on low speed roadways but must meet manufacturer's recommendation. ✓The proprietary FLEAT® -350 is the preferred guardrail end terminal because it is similar to the ET-2000 and the SKT-350, but it is shorter in length (37 ft-6 in. versus 50 ft). The FLEAT should be installed with a 2 ft-6 in. straight flare offset to maximize the energy absorbing features. ✓If the FLEAT 350 cannot be installed, either the SKT 350, or the ET 2000 should be installed. The SKT 350 and the ET 2000 shall be installed with a 50:1 straight flare, but it can be installed tangential to the roadway, if the 50:1 straight flare cannot be obtained. ✓Existing SRT 350 end terminal and the "GREAT"® crash cushion system, currently installed and in good operational condition, shall remain in place, but no new SRT350 and "GREAT" ® systems shall be installed. o If more than 50% of a SRT 350, or "GREAT" ® system terminal is damaged, the District should replace the damaged system with a new NCHRP 350 approved end terminal / crash cushion. o If less than 50% of an existing SRT 350, or "GREAT" ® system needs repair, one may either repair the system, or replace the system with a new NCHRP 350 approved terminal / crash cushion. Hawaii DOT refers to the FHWA web page for the selection of approved end terminals.
Contact Log	Name/Position: Paul Santo / Bridge Design Engineer Phone: (808) 692-7611 E-mail: paul.santo@hawaii.gov
References Used [Accessed Dec 2009]	Design Criteria for Bridges and Structures, 2008 Bridge Inspection Program, 2008 Statewide Policy for Permanent Highway Safety Hardware, 1999 FHWA website http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/bridgerailings/

INDIANA	
Warrants	Railing Installation: ✓The basic parameter for bridge-railing selection is the Test Level required at the site. This is a function of: 1. highway design speed; 2. average annual daily traffic and percent trucks; 3. bridge railing offset; 4. highway geometry (grades and horizontal curvature); 5. height of deck; and 6. type of land use below deck. ✓To limit the number of necessary bridge railings, three of these Test Levels have been selected to be used in Indiana's bridges. ✓Warrants for the selection of the Test Level (TL-2, TL-4, and TL 5) of the bridge railing are presented in Section 61-6.01 of Ch 61 of the Design Manual. Once the Test Level has been determined, a bridge railing type should be selected to match the required Test Level and other considerations (e.g., aesthetics, owner preference). Railing Transition: The preferred transition for each bridge railing type is shown in Figure 61-6B of INDOT Bridge Design Manual. Most systems include both a guardrail transition and a bridge railing transition. The details are shown in the INDOT Standard Drawings identified in Figure 61-6B Design Manual. Pedestrian Railings: ✓If a sidewalk is to be placed on a bridge, and the design speed is 80 km/hr or higher, a bridge railing should be used to separate vehicular traffic from pedestrians, and a pedestrian railing should be placed on the outside edge of the sidewalk. ✓If the design speed is 70 km/hr or lower, the need for protection of pedestrians by means of a combination vehicular bridge railing/pedestrian railing will be considered on a site-by-site basis.
Selection Criteria	Materials: Concrete and metal Height: Varies according to railing type. (See Figure 61-6B of INDOT Bridge Design Manual.) Shape of face: Varies according to railing type. Compliance with NCHRP-350: Indiana Design Manual requires crash tested bridge railings on all projects. The appropriate Test Level is selected based on design speed, ADT, offset, % trucks, etc. The test level is selected based on the following: 1. TL-2 bridge railing is appropriate on a bridge, which meets the following: a. the bridge is located on a route, not on the State highway system, and the adjusted AADT in the construction year appears within the TL-2 range, shown in Figure 49-9D(50), 49-9D(60), 49-9D(70), 49-9D(80), or 49-9D(90), Median Barrier and Bridge Railing Test Level Selection, for the appropriate design speed; or b. the bridge is located on a State-highway-system route with a design speed of 70 km/hr or lower, and the adjusted AADT in the construction year appears within the TL-2 range, shown in Figure 49-9D(50), 49-9D(60), or 49-9D(70), for the appropriate design speed. 2. A TL-4 bridge railing is appropriate on every bridge, which meets the following: a. the criteria for TL-2 are not met; and b. the adjusted AADT in the construction year appears within the TL-4-range,

	shown in Figure 49-9D(50), 49-9D(60), 49-9D(70), 49-9D(80), 49-9D(90), 49 9D(100), or 49-9D(110), for the appropriate design speed. 3. A TL-5 bridge railing is appropriate on a bridge, where the adjusted AADT in the construction year appears within the TL-5 range shown in Figures 49-9D(50) through 49-9D(110), whichever applies. 4. The decision to use a TL-6 bridge railing is a policy decision based on a site-by-site evaluation; a TL-6 bridge railing may be selected on a highway with an extremely high volume of large trucks (or tanker trucks), where rollover or penetration beyond the barrier would result in severe consequences.
Inspection Procedures	No Bridge Inspection Manual was found on the internet.
Railings	**TL-2** TS-1 (Used only on a local-public agency collector or local road). PF-2 PS-2 TX (Used on aesthetically sensitive area). **TL-4** 33-in. F-Shape TR CF-1 PS-1 PF-1 **TL-5** 45-in. F-Shape TF-2 ** See details of the transition for each of these rails on Figure 61-6B of INDOT's Bridge Design Manual.
Standard Drawings	**Plan Title** / **Plan No.** TS-1 — None PF-2 — 706-BRPP-02, 05, 06 PS-2 — 706-BRPP-04 through 06 TX — 706-BRTX-01 through 04 33-in. F-Shape — 706-BCBR-01 through 04 TR — 706 TBRC-01, 02, 03; 706-TBRE-01; 706-TBRF-01,02 CF-1 — 706-BRTM-01, and 02 PS-1 — 706-BRPP-03, 05, and 06 PF-1 — 706-BRPP-01,05, and 06 45-in. F-Shape — 706-BCBR-02, 03, and 04 TF-2 — 706-BCTF-01 through 10
End Treatments	No information was found.
Contact Log	Name: Bill Dittrich Phone: (317) 232-5474 E-mail: bdittrich@indot.in.gov
References Used [Accessed Dec. 2009]	INDOT Design Manual (Last update 2005) http://www.in.gov/dot/div/contracts/standards/dm/index.html

<table>
<tr><th colspan="2">IOWA</th></tr>
<tr><td>Warrants</td><td>
Railing Installation: Most new Iowa highway bridges are designed only for vehicular traffic and make use of the F-shape barrier rail detailed on standard sheets developed by the office. The standard barrier rail meets NCHRP Report 350 Test Level 4 (TL-4) if 34 in. (865 mm) tall, or Test Level 5 (TL-5) if 44 in. (1.120 m) tall. Although in the past TL-4 has been considered adequate for most Iowa highways, the Highway Division Management Team recently adopted a more conservative policy that requires TL-5 rails for all mainline interstate bridges and for primary highway bridges with certain conditions. The designer will need to check all primary highway bridges with respect to the new policy.

The standard F-shape barrier rail is tall enough that it restricts sight distance for motorists in some vehicles; and in some highway situations, an open railing may be advisable.

If a railroad is below the bridge, however, taller barrier rails and/or splashboards may be required. The Union Pacific Railroad requires a barrier rail with a minimum height of 42 in. (1070 mm), and the designer may need to increase the height an additional 2 in. (50 mm) for future deck overlay.

For bridges given special aesthetic treatment, railings usually will be redesigned to meet the aesthetic theme. Because traffic railings typically will need to meet Test Level 4 (TL-4) or 5 (TL-5), but crash testing is not economically feasible, the designer will need to consider existing crash tested railings. The designer should consult the Federal Highway Administration (FHWA) NCHRP Report 350 Hardware web site that contains a listing of crash tested railings and select a design that meets the test level criterion.

Railing Transition: See Standard Plan Details.

Plan Title — Plan No.
Details of Thrie Beam Guardrail Bridge Connection — RE-27B
34-in. to 44-in. Concrete Barrier Transition Section — RE-44G
Steel Beam Guardrail Standard Transition Section (STS) — RE-68
Guardrail Installation Connection to Bridge Endpost or Concrete Bar — RE-69A
Guardrail Installation Connection to Retrofit Bridge Endpost — RE-69B
Guardrail Installation Connection to Existing Endposts — RE-69C

Pedestrian Railings: Where a sidewalk is provided on a bridge, the outer edge of the sidewalk shall be protected with a pedestrian railing. The minimum height of the railing shall be 42 in. (1.070 m) above the sidewalk surface [AASHTO-LRFD 13.8.1]. Horizontal or vertical parts of the railing shall be spaced closely enough, so that a 6-in. (150 mm) sphere will not pass through the lower 27-in. (685-mm) portion and an 8-in. (200-mm) sphere will not pass through the horizontal band 27 in. to 42 in. (685 to 1070 mm) above the sidewalk.

Plan Title — Sheet No.
F-Shape Pedestrian Rail – Steel – Integral Abutment — 1029A
F-Shape Pedestrian Rail – Steel – Stub Abutment — 1029B
F-Shape Pedestrian Rail – Steel – Integral Abutment — 1029C
F-Shape Pedestrian Rail – Steel – Stub Abutment — 1029D
</td></tr>
<tr><td>Selection Criteria</td><td>
Materials: Concrete

Height: 34 in. (F-Shape TL-4); 44 in. (F-Shape TL-5)

Shape of face: Varies according to railing type.

Compliance with NCHRP-350: Typical railings used in Iowa’s highways should comply with NCHRP-350 TL-4; if a project requires a traffic rail tested above TL-4, the Methods Section in the Design Office will provide the designer with additional information.
</td></tr>
<tr><td>Inspection</td><td>Iowa DOT does not have a Bridge Inspection Manual.</td></tr>
</table>

Procedures	Iowa's DOT follows the National Bridge Inspection Standards; and they also use a PONTIS Manual for the elements level inspection but this manual is currently being updated.
Railings	Concrete railings ✓F-Shape ✓Open Railing (Used on special cases, where there is limited sight distance. Its use shall be approved by the supervising Section Leader).
Standard Drawings / Standard Plans	**Plan Title** — **Sheet No.** Barrier Rail End Section Details with 7-ft Wing — 1017 Barrier Rail-Skewed Stub Abutments with wing extensions — 1018, 1018A 3 ft-8 in. Barrier Rail-(R.A) Skewed Stub Abutments with wing extensions — 1018C 3 ft-8 in. Barrier Rail-(L.A) Skewed Stub Abutments with wing extensions — 1018D Barrier Rail-Integral Abutment-Urban Approach Slab with curb — 1019A Barrie Rail-Stub Abutment-Wing Ext. 0° Skew-Urban Approach Slab with curb — 1019B Barrier Rail-Integral Abutment Bridges — 1020A Barrier Rail-0° Skew Stub Abutments with wing extensions — 1020B Barrier Rail-Integral Abutments with wing extensions — 1020C 3 ft-8 in. Barrier Rail-Integral Abutments — 1020D 3 ft-8 in. Barrier Rail-0° Skew Stub Abutments with wing extensions — 1020E 3 ft-8 in. Barrier Rail-Integral Abutments with wing extensions — 1020F F-Shape Barrier Rail-Sidewalk — 1028A Continuous Concrete Slab Bridge Standards **Plan Title** — **Sheet No.** Barrier Rail Details — J-40-45-06 / J-40-47-06 Open Rail Details (TL-4) — J-40-48-06 Open Rail Details (TL-4) — J-40-49-06
End Treatments	**Plan Title** — **Plan No.** Formed Steel 'W' Beam Railing Terminal Sections — RE-2A Formed Steel Beam Railing Transition and Terminal Sections (Thrie Beam) — RE-2B Cable Guardrail End Anchorage — RE-29A Beam Guardrail End Anchorage (W Beam) — RE-33A Beam Guardrail End Anchorage (Thrie Beam) — RE-33B Concrete Barrier End Section — RE-44H Guardrail Terminal (FLEAT-350) — RE-76
Contact Log	Name/Position: Scott Neubauer/Bridge Rating Engineer Dean Bierwagon/Methods Engineer Phone: (515) 239-1290 / (515) 239-1585 E-mail: Scott.Neubauer@dot.iowa.gov; Dean.Bierwagen@dot.iowa.gov
References Used [Accessed Dec 2009]	Iowa DOT LRFD Bridge Design Manual http://www.dot.state.ia.us/bridge/manualasd.htm Iowa DOT LRFD Bridge Design Manual - Railing Section Revised Jan2008 http://www.iowadot.gov/bridge/manuallrfd.htm Iowa DOT Traffic Barriers Standard Drawings http://www.dot.state.ia.us/design/stdplne_re.htm Iowa DOT Bridge Railings Standard Drawings ftp://165.206.203.34/dotmain/bridges/standards/english/EnglishDeckRailBridges.pdf

<table>
<tr><th colspan="2">KANSAS</th></tr>
<tr><td>Warrants</td><td>
Railing Installation: Kansas will use a minimum TL-4 bridge rail on state routes.
The KDOT uses two types of railings, the Corral Rail and the Barrier Curb Type F4. The height of the Kansas Corral Rail is 27 in. or 32 in.. The height of the Barrier Rail is 32, 42, or 51 in. The preferred railing is the 32-in. Kansas Corral Rail, or the 32-in. “F4” Barrier Rail.
✓Bridges on curves with a radius of 500 ft or less should have a rail height of 42 in. on the extrados as an additional safety precaution.
✓The 51-in. Barrier Rail is used in the median as a glare barrier.
✓Over a railroad, the barrier height is a function of the shoulder width.
o Use a 32-in. barrier with 6 ft-0 in. shoulders and use a 42 in. with 4 ft-0 in. shoulders.
o Provide the 42-in. barrier for the 4 ft-0 in. shoulders for a distance of 25 ft-0 in. from centerline of track or access road.
✓The Barrier Curb (Type “F4” preferred) should be used as follows:
o All open span bridges on “A” and “B” Routes require a 32-in. high rail as a minimum. Interchange structures over Interstate highways should consider same.
o All open span bridges on or over limited access road in Urban areas and with an AADT greater than 5,000** on the structure.
o Multi-level interchange structures should consider a 51-in. high Barrier Curb.
o If other than “A” or “B” routes, refer to Section 13 for the AASHTO LRFD Bridge Design Specifications to determine Testing Level required. If the Test Level Selection Criteria indicates a TL-4 level is required, use a 32-in. high rail. If a TL-5 level is required, use a 42-in. high Barrier Curb regardless of Route classification.
o Other structures shall be determined at the time of field check.
✓The Corral Rail should be used as follows:
o All open span bridges on “A” and “B” Route require a 32-in. high rail as a minimum. Over-the-side drainage is preferred when possible.
o If other than “A” or “B” routes, refer to Section 13 for the AASHTO LRFD Bridge Design Specifications to determine Testing Level required. If the Test Level Selection Criteria indicates a TL-3 level is required, use a 27-in. high rail. If a TL-4 level is required, use a 32-in. high rail. (If a TL-5 railing is required, use a 42-in. Barrier.)
o All Structures were a type “F4” railing is not required.
Railing Transition: For cases in which a guard fence is required, it shall be rigidly attached to the bridge following recommended details. A guard fence will be used at most locations; however, the final determination should be made during the field check.
The standard guard fence transition details are shown on Figure 3.2.10-30 of KDOT Bridge Design Manual, Details of Thrie Beam Guard Fence Transition (Std. RD613).
Many existing guard fence to bridge rail transitions are substandard as compared to the current treatments. An acceptable modification to existing designs incorporates the use of a rubrail along with reduced post spacing near the bridge. See Figure 3.2.10-32 of KDOT Bridge Design Manual, W-Beam with Rubrail Bridge Approach Transition (Std. RD615) for rubrail retrofit details.
<table>
<tr><th>Plan Title</th><th>Plan No.</th></tr>
<tr><td>Guardrail Transition Details of Thrie Beam Retrofit</td><td>RD608</td></tr>
<tr><td>Thrie Beam Guard Fence Transition</td><td>RD613</td></tr>
<tr><td>W-Beam with rubrail Bridge Approach Transition</td><td>RD615</td></tr>
<tr><td>W-Beam with Rubrail- Bridge Approach Transition</td><td>RD616</td></tr>
</table>
Pedestrian Railings: If the design of the structure includes a sidewalk, a concrete barrier
</td></tr>
</table>

	rail will be used between the traveled way and the sidewalk. ✓For design speeds less than or equal to 40 mph, the minimum height of the separator railing above the sidewalk shall be 24 in., and the railing surface shall be smooth to avoid snag points for pedestrians or cyclists. ✓For design speeds over 40 mph, or if a high volume of bicycle traffic is expected and the risk involved if a cyclist would fall over the separator is great, use a minimum railing height of 42 in. A height of 42 in. would enable a falling cyclist to grasp the railing. The height of the railing on the outside edge of the sidewalk shall be a minimum of 42 in. for pedestrians and a minimum of 54 in. for bicycles.
Selection Criteria	Materials: Concrete Height: 27 in., 32 in., 42 in., and 51 in. Shape of face: Varies according to railing type. See Standard Drawings. Compliance with NCHRP-350: Bridge railings on bridges on Federal-aid projects must be (or have been) crash tested and meet the acceptance criteria in NCHRP Report 350 "Recommended Procedures for the Safety Performance Evaluation of Highway Features."
Inspection Procedures	No Bridge Inspection Manual was found on the internet.
Railings	✓Corral Rail: The corral-type rail may be either an open section or a closed section, depending upon whether or not bridge drainage at the curb line is a requirement. Most rural bridges using the corral railing will be of the open type, which allows bridge drainage over the side. ✓Barrier Curb Type F4
Standard Drawings	**Plan Title** / **Plan No.** / **No.Sheet** 27-in. Kansas Corral Rail (with rubrail) / BR183(A-GG) / 7 F4 Barrier Curb (Bridges) / BR184 (A-B) / 2 F4 Barrier Curb (Railroad Overpass) / BR185 (A-B) / 2 Bill of Rein. Steel and Bending Diagram for F4 Barrier / BR185C / 1
End Treatments	**Plan Title** / **Plan No.** Guardrail End Terminal (ET Plus) / RD606 Guardrail End Terminal (FLEAT) / RD606B Guardrail End Terminal (SKT) / RD606C Guardrail Protection on Low Fill Culverts (Parallel) / RD617 Guardrail Protection on Low Fill Culverts (Flared) / RD617A Guardrail End Terminal Type II / RD618 Inertial Barrier General Configurations / RD620 Guardrail End Terminal (SRT-Flared) / RD621A Impact Attenuator (Quadguard® System) / RD626 Impact Attenuator (SCI-TL2) / RD627 Impact Attenuator (SCI-TL3) / RD627A
Contact Log	Name: John Jones Phone: (785) 368-7175 E-mail: jjones@ksdot.org
References Used [Accessed Dec. 2009]	KDOT Design Manual-Volume III Bridge Section 01/08 Revision http://kart.ksdot.org/ Bridge Standard Drawings & Road Standard Drawings http://kart.ksdot.org/

KENTUCKY	
Warrants	Railing Installation: Use railings appropriate to the road class: ✓Use Railing System Type I (Exhibit 614) on culverts only. ✓Use Railing System Type II (Standard Drawing BDP-005) with "Railing System Type II Guardrail Treatment" (Standard Drawing BHS-007) on side-by-side box beam bridges and on short structures. ✓Use Railing System Type III (Exhibit 601) on all other bridges. Railing Transition: **Plan Title** — **Plan No.** *Bridge Series* Barrier Transition — BGX-010-04 Curved Barrier Transition — BGX-013-02 *Roadway Barrier Series* Guardrail Connector to Bridge End Type A and A-1 — RBC-001-09 Guardrail Connector to Bridge End Type A and A-1 Components — RBC-001-09 Guardrail Connector to Bridge End Type A and A-1 Components — RBC-003-07 Guardrail Connector to Bridge End Type "D" — RBC-004-05 Guardrail Connector to Concrete Median Barrier End — RBC-100-03 Connection Details of Crash Cushion Type VI to Double Face Guardrail — RBC-110-09 Pedestrian Railings: No information was found.
Selection Criteria	Materials: Concrete and metal Height: Varies according to railing type. See Standard Drawings. Shape of face: Varies according to railing type. See Standard Drawings. Compliance with NCHRP-350:
Inspection Procedures	No Bridge Inspection Manual was found on the internet.
Railings	Concrete Railing ✓New Jersey Barrier Metal Railing ✓W-Beam
Standard Drawings / Standard Plans	**Plan Title** — **Plan No.** *Roadway Barrier Series* Railing System Type I (W-Beam Guardrail) — RBR-001-11 *Bridge Series* Railing System Type II Guardrail Treatment — BHS-007-05 Railing System Type II — BDP-005-03 Railing System Type III — BHS-008

End Treatments	Plan Title	Plan No.
	Crash Cushion Type VII Class B and C (One & Two Direction)	RBE-040-09
	Crash Cushion Type VI (One & Two Direction)	RBE-060-13
	Concrete Median Barrier End	RBE-060-13
	Concrete Median Barrier End for Crash Cushion Type IX	RBE-070-04
	Crash Cushion Type VI-BT & CT	RBE-100-09
	Crash Cushion Type IX	RBE-200-04
	Crash Cushion Type IX	RBE-205-04
Contact Log	Name: Mark Hite Phone: (502) 564 - 4560 E-mail: mark.hite@ky.gov	
References Used [Accessed Dec 2009]	Standard Plans, Bridge Series http://www.kytc.state.ky.us/design/standard/pdf2008/Std%20Table%20of%20Contents.htm#general2 Standard Plans, Roadway Series http://www.kytc.state.ky.us/design/standard/pdf2008/Std%20Table%20of%20Contents.htm#barriers	

LOUISIANA	
Warrants	Railing Installation: No information was found. Railing Transition: In cases where new construction ties to existing construction there must be adequate transition between sections of F-shape barrier and Brush Curb Rail used on earlier bridges. Pedestrian Railings: For bridges with curbed roadway approaches and sidewalks or bikeways a vertical face parapet with pipe rail is generally used on the outside of the sidewalk, and must meet the requirements for "Combination Rail" mentioned in the AASHTO Bridge Specifications. For higher design speeds, a barrier rail shall be required to separate the sidewalk from the travel lane, and a pedestrian or bicycle rail shall be used on the outside of the sidewalk.
Selection Criteria	Materials: Concrete and metal Height: Varies according to railing type. Shape of face: Varies according to railing type. Compliance with NCHRP-350: Crash tested and approved effective barrier systems, end treatments, and crash cushions, shall be used to achieve the highest levels of highway safety. Any highway safety appurtenances, which do not meet the appropriate crash test requirements, or are not considered as operational by FHWA and LA DOTD, shall not be specified in any plans.
Inspection Procedures	No Bridge Inspection Manual was found on the internet. Refer to FHWA Recording and Coding Guide, 1995.
Railings	Concrete Railings ✓F-Shape ✓Vertical Wall ✓Single Slope Metal Railings ✓W-Beam Strong Post ✓Thrie Beam Strong Post
Standard Drawings/ Standard Plans [Accessed Dec. 2009]	Standard Plans for railings to be purchased http://www.dotd.louisiana.gov/doclist.asp?ID=22
End Treatments	The blunt ends of temporary barriers shall be made crashworthy by means of either an end treatment device, or by flaring away from traffic and carrying beyond the clear zone distance. Virtually all impact attenuators used in Louisiana are proprietary items. ✓The "Hex-Foam® Sandwich" is among the most commonly used attenuators in the state. The designer using the manufacturer's design information shall determine its length and width. The construction and the installation of such devices shall always be in accordance with the manufacturer's recommended procedures. ✓The "GREAT"® is another form of attenuator, which is compatible with "Hex-Foam" both in performance and cost. However, the use of this attenuator is generally reserved for very narrow locations as opposed to the "Hex-Foam," which is available in varying widths.
Contact Log	Name/Position: Paul Fossier - LADOTD Office of Engineering / Bridge Design Squad

	Bill Shrewsberry / Highway/ Rail Safety Engineer Phone: (225)379-1323/ (225)379-1543 E-mail: PaulFossier@dotd.la.gov; BillShrewsberry@dotd.la.gov
References Used [Accessed Dec. 2009]	LADOT Bridge Design Manual http://www.dotd.louisiana.gov/doclist.asp?ID=49

MARYLAND	
Warrants	Railing Installation: ✓On Controlled Access Highway (No Pedestrian or Cyclists Allowed.) o Use Jersey Barrier with no railing. o For bridges on sections of highway, which experience heavy volumes of truck traffic, use a 42-in. tall Jersey barrier. ✓Non-Controlled Access Highway – No Sidewalks required on Structure. o Except on those structures where a decision to accommodate cyclists has been made, use Jersey barrier with single strand railing with a shoulder 4 ft wide or less, or within 1 mile of school, park or playground, or within ½ mile of a developed area (residential or commercial). o Use Jersey barrier with no railing on all structures with a shoulder wider than 4 ft that are either more than 1 mile away from a school, park, or playground, or more than ½ mile away from a developed area (residential or commercial). A developed area would consist of several homes grouped together along a section of highways, whereas a nondeveloped area could consist of woods or fields alongside of the road with only a few scattered homes set back from the edge of the road. ✓Non-Controlled Access Highway – Sidewalk Required on the Structure. o Use Vertical Parapet with railing having a combined height of 3 ft-6 in. above the sidewalk level. ✓Others o For structures with one lane in each direction, or with a hydraulic need to accommodate over the road flow, the use of 5-in. tubular rail is acceptable with an end treatment to fit the site. o On all structures carrying two-way traffic, where the distance between the normal termination point of thrie beam on the approach and trail end is 40 ft or less, carry thrie beam attached to a 2 ft-10 in. high vertical face concrete barrier across the entire structure. Transition to W-beam off both ends of barrier (Similar to MD 661.01). o On structures where the parapet is being rehabilitated, designers must consider other alternatives that fit the unique characteristics of the site. All new alternatives must strive to include a crash tested barrier that is safely transitioned to an acceptable highway barrier. Railing Transition: ✓Controlled Access Highway (No pedestrian or cyclist allowed.) o Use Thrie Beam Attachment on all approach ends (MD 661.01). o Use W Beam Attachment on all trail ends (MD 660.41). ✓Non-Controlled Access Highways (No sidewalk required on structure.) o Where there is a W-Beam traffic barrier on the adjacent highway, use Thrie Beam attachment on approach ends (MD 661.01). Use W-Beam Attachment on trail ends (MD 660.41). For bridges carrying one lane of traffic in each direction not separated by a traffic barrier or raised median curb, all four corners shall be treated as approach ends. o Where there is no traffic barrier on the adjacent highway, taper the parapet away from road until the additional offset equals 10 ft minimum on the approach ends. No end treatment is required on trail ends. ✓Non-Controlled Access Highway – Sidewalk Required on the Structure. o Where there is a W-beam traffic barrier on the adjacent highway, use W-beam attachment on trail end approach ends. On approach end, maintain 5-ft sidewalk width with no offset between the sidewalk and curb for 25 ft minimum beyond

	end of endpost. o Where there is no traffic barrier on the adjacent highway, taper the parapet away from the road (25 ft minimum taper length) until the additional offset equals 10 ft minimum on approach ends. No end treatment is required on trail ends. Pedestrian Railings: On bridges located on non-controlled access highways, where a sidewalk is required, the use of a Vertical Parapet with railing of a combined height of 3 ft-6 in. above the sidewalk level is required.
Selection Criteria	Materials: Concrete and metal Height: Varies according to railing type. (See Bridge Railing Standard Drawings.) Shape of face: Jersey face, Vertical face Compliance with NCHRP-350: All structures in Maryland must have a crash tested railing, according to Maryland's DOT Policy & Procedure Memorandum.
Inspection Procedures	National Bridge Inspection Standards Pontis Element Level Rating
Railings	Concrete Railings: ✓F-Shape (TL-4)- (Most common bridge barrier used in Maryland, same on low and high volume roads) Metal Railings: ✓Strong post W-Beam (TL-3) (Most common roadside barrier used in Maryland) ✓One Strand Aluminum Railing ✓Two Strand Aluminum Railing ✓Three Strand Aluminum Railing ✓Two Strand Structural Tube Rail
Standard Drawings / Standard Plans	**Plan Title** — **Plan No.** One Strand Aluminum Railing — BR-SS (5.01) Two Strand Aluminum Railing — BR-SS (5.01) Three Strand Aluminum Railing — BR-SS (5.01) Two Strand Structural Tube Rail — BR-SS (5.07)
End Treatments [Accessed Dec. 2009]	It is the policy of the Administration to install traffic barrier end treatments that meet current Federal Highway Administration (FHWA) requirements on the ends of existing and proposed W-beam, or concrete traffic barriers for all highway projects (see TABLE 7 of Maryland's DOT Guidelines for Traffic Barrier Placement and End Treatment Design for exceptions). End Treatments used by the Maryland DOT: ✓Roadside W-beam End Treatments o Type A o Type B o Type C o Type G ✓Two Side End Treatments o Type D o Type E o Type F o Type H o Type J ✓Downstream Anchor o Type K

	✓Traffic Barrier Anchor o Type L ✓Bullnose End Treatment ✓Reference for Standards and Approved Substitutes http://www.sha.state.md.us/BusinessWithSHA/bizStdsSpecs/desManualStdPub/publicationsonline/ohd/bookstd/index.asp
Contact Log	Name: Joe Miller – Paul Matys Phone: (410) 545-8311 – (410) 545-8513
References Used [Accessed Dec. 2009]	Guidelines for Traffic Barrier Placement and End Treatment Design (2006) http://www.sha.state.md.us/businessWithSHA/bizStdsSpecs/desManualStdPub/publicationsonline/ohd/caddstd/pdf/Guidelines_for_Traffic_Barrier.pdf Standard Drawings 2007 http://www.sha.state.md.us/businesswithsha/bizStdsSpecs/obd/BridgeStandards/index.asp

<table>
<tr><th colspan="2">MASSACHUSETTS</th></tr>
<tr><td>Warrants</td><td>Railing Installation: Designers shall select the appropriate bridge railing/barrier for a project based on the application matrix presented in Table A1 obtained from MassHighway's Bridge Design Manual. According to this matrix, the railing CT-TL-2 is used on Non NHS highways with design speeds less than 45 mph.

Table A1. Bridge Railing Application Matrix.
<table><tr><th>Railing/Barrier</th><th>Test Level</th><th>To Be Used</th><th>Application Notes</th></tr><tr><td>CT-TL2</td><td>TL-2 - less than 45 MPH</td><td>Non-NHS highways only with design speeds not exceeding 45 MPH</td><td>Off system municipally owned bridges w/ or w/out pedestrians; no protective screen</td></tr><tr><td>S3-TL4</td><td>TL-4</td><td>NHS and Non-NHS highways, except limited access highways and their ramps</td><td>W/ or w/out pedestrians</td></tr><tr><td>CP-PL2</td><td>TL-4</td><td>NHS and Non-NHS highways, except limited access highways and their ramps</td><td>W/ or w/out pedestrians, mainly urban & RR bridges and all structures over electrified AMTRAK rail lines; must be used with either Type II screen or hand rail</td></tr><tr><td>CF-PL2</td><td>TL-4</td><td>NHS and Non-NHS highways, except limited access highways and their ramps</td><td>Bridges where pedestrians are prohibited by law; often on undivided state highway bridges</td></tr><tr><td>CF-PL3</td><td>TL-5</td><td>NHS and Non-NHS limited access highways and their ramps</td><td>All Interstate and limited access state highway bridges</td></tr></table>
Railing Transition: No information was found.

Pedestrian Railings: No information was found.</td></tr>
<tr><td>Selection Criteria</td><td>Materials: Concrete and metal

Height:
✓CF-PL3 Median Barrier: 3 ft-6 in.
✓CF-PL3 Barrier: 3 ft-6 in.
✓CF-PL2 Barrier: 2 ft-8 in.
✓CP-PL2 Barrier: 2 ft-0 in.
✓CT-TL2 Barrier: 3 ft-6 in.
Shape of face: Varies according to railing type. (See Part II of MassHighway Bridge Design Manual.)

Compliance with NCHRP-350: Railings/barriers that have not been crash tested will not be used on any MassHighway bridge project.
✓Non-NHS highways: Crash tested to meet the requirements of NCHRP 230 or 350; however, every attempt should be made to use a railing crash tested to NCHRP 350.
✓NHS highways: Federal Highway regulations require that only railings/barriers crash tested to meet the requirements of NCHRP 350 be used on these highways.</td></tr>
<tr><td>Inspection Procedures</td><td>National Bridge Inspection Standards (NBIS)
Massachusetts DOT Bridge Inspection Manual is currently being updated.</td></tr>
</table>

<table>
<tr><td>Railings</td><td>Concrete Railings:
✓CF-PL3 Median Barrier
✓CF-PL3 Barrier
✓CF-PL2 Barrier
✓CP-PL2 Barrier
✓CT-TL2 Barrier

Metal Railings
✓S3-TL4</td></tr>
<tr><td>Standard Drawings / Standard Plans</td><td>The railings used by MassHighway are detailed in Chapter 9 of Part II of the Bridge Design Manual.

Plan Title — Sheet No.
CT-TL2 Barrier — 9.2
S3-TL4 — 9.3
CP-PL2 Barrier — 9.4
CF-PL2 Barrier — 9.5
CF-PL3 Barrier — 9.6
CF-PL3 Median Barrier — 9.7</td></tr>
<tr><td>End Treatments</td><td>No information was found.</td></tr>
<tr><td>Contact Log</td><td>Name/Position: Alexander Bardow / Director of Bridges and Structures
Daniel Crovo
Phone: (617) 973-7580
E-mail: Alexander.bardow@mhd.state.ma.us</td></tr>
<tr><td>References Used [Accessed Dec. 2009]</td><td>Part I Bridge Design Manual-2005
http://www.mhd.state.ma.us/default.asp?pgid=content/bridgeman_new02&sid=about
Part II Bridge Design Manual-2005
http://www.mhd.state.ma.us/default.asp?pgid=content/bridgeman_new&sid=about#9</td></tr>
</table>

MICHIGAN	
Warrants	Railing Installation: ✓Bridge Barrier Railing, Type 4, is used on all new structures and major rehabilitation bridge projects without sidewalks (see Standard Plan B-17-Series). ✓On structures where sight distance is a problem, Type 5 may be substituted (see Standard Plan B-20-Series). ✓At stream crossings or scenic areas, Bridge Railing, 2 Tube, Aesthetic Parapet Tube or 4 Tube may be used (see Standard Plan B-21-Series, B-25-series or B-26-Series). Railing Transition: No information was found in the Bridge Design Manual Ch 7, or in the Bridge & Road Standard Drawings. Pedestrian Railings: On bridges where pedestrian or bicycle traffic is separated from vehicular traffic by a standard barrier, it is not necessary to provide a vehicular railing at the fascias. In such cases, pedestrian fencing is desirable. For structures without sidewalks, but where some pedestrian traffic is likely, a Bridge Railing, 4 Tube, or Aesthetic Parapet Tube is to be used.
Selection Criteria	Materials: Concrete and metal Height: Varies according to railing type. See Standard Drawings. Shape of face: Varies according to railing type. See Standard Drawings. Compliance with NCHRP-350: Railings used by Michigan DOT shall be of a type that has passed full scale impact (crash) tests.
Inspection Procedures	The MDOT uses 2007 Pontis Bridge Inspection Manual for the condition inspection of their bridges. Elements #330, #334, #331, #332, and #333 correspond to bridge railings: ✓Element #330: Uncoated Metal Bridge Railing o This element defines all types and shapes of uncoated/unpainted metal bridge railing. Steel, aluminum, metal beam, rolled shapes, etc., will all be considered part of this element. The element is neither coated nor painted. ✓Element #334: Coated Metal Bridge Railing o This element defines all types and shapes of coated / painted / galvanized metal bridge railing. ✓Element #331: Reinforced Concrete Bridge Railing o This element defines all types and shapes of reinforced concrete bridge railing. All elements of the railing must be concrete. Concrete barriers with decorative metal rails are included here. Example in use: Open concrete parapet with metal rail, Solid concrete parapet rail. ✓Element #332: Timber Bridge Railing o This element defines all types and shapes of timber bridge railing. All elements of the railing must be timber. ✓Element #333: Miscellaneous Bridge Railing o This element defines all types and shapes of bridge railing, except those defined as metal, concrete, or timber. This element may include combinations of materials, such as thrie beam retrofit, concrete post, and metal panel rail.
Railings	Concrete Railings ✓Type 4 Barrier ✓Type 5 Barrier

	Metal Railings ✓2-Tube Railing ✓4-Tube Railing ✓Aesthetic Parapet Tube Railing	
Standard Drawings / Standard Plans	**Plan Title**	**Plan No.**
	2-Tube Bridge R	IU6.29.06 & 6.29.06A
	Aesthetic Tube Railing	IU6.29.10 & 6.29.10 (A-D)
	Barrier Railing Type 4	IU6.29.09 & 6.29.09 (A-E)
	Barrier Railing Type 5	6.29.08
	4-Tube Bicycle Railing Option	IU6.29.17 & 6.29.17 (A-H)
End Treatments	**Plan Title**	**Plan No.**
	Guardrail Approach Terminal 1B & 1T	R-61-G
	Guardrail Approach Terminal 2B & 2T (ET & SKT)	R-62-F
	Guardrail Approach Terminal 3B & 3T	R-63-B
	Guardrail departing Terminals Type B & T	R-66-D
	Guardrail Anchorage, Bridge Details	R-67-F
Contact Log	Name: Steven Beck Phone: (517) 373-0097 E-mail: BECKS2@michigan.gov	
References Used [Accessed Dec. 2009]	Michigan Design Manual, Bridge Design http://mdotwas1.mdot.state.mi.us/public/design/englishbridgemanual/ Bridge Standard Plans http://mdotwas1.mdot.state.mi.us/public/design/englishbridgeguides/ Road Standard Plans http://mdotwas1.mdot.state.mi.us/public/design/englishstandardplans/index.htm	

<table>
<tr><th colspan="2">MISSISSIPPI</th></tr>
<tr><td>Warrants</td><td>The Mississippi DOT does not have a Bridge Design Manual. The information summarized below was obtained from Mississippi DOT Roadway Design Manual.

Railing Installation: Barrier protection is normally warranted on all approach ends to bridge rails or parapets. No roadside barrier is needed on the trailing end of a one-way bridge, unless a barrier is warranted for other reasons (e.g., fill slope steeper than 3:l).

Railing Transition: The Mississippi Standard Roadway Design Drawings presents those guardrail-to-bridge-rail transitions, which are acceptable for use on Department projects.

Plan Title — Plan No.
Bridge End Section Type A & C — GR-2
Bridge End Section Type E, F &G — GR-2A
Bridge End Section Type D — GR-2B
Bridge End Section Type H (Wood Posts) — GR-2C
Bridge End Section Type H (Steel Posts) — GR-2D
Bridge End Section Type G Modified — GR-2E

Pedestrian Railings: If a sidewalk is placed on a bridge, it may be warranted to provide a bridge rail to separate the vehicular traffic from pedestrians, and then use a pedestrian rail on the outside edge of the sidewalk. The following will apply:
1. V > 50 mph: As discussed in Section 9-6.02, it is not acceptable to place a bridge rail at the back of a sidewalk, where the design speed is greater than or equal to 50 mph. Therefore, a separate pedestrian rail is required on all bridges with sidewalks on these facilities.
2. V < 45 mph: On facilities with sidewalks on bridges and where V < 45 mph, the need for special protection of pedestrians by use of a combination vehicular bridge rail / pedestrian rail will be considered on a case-by-case basis.</td></tr>
<tr><td>Selection Criteria</td><td>Materials: Concrete

Height: Mississippi DOT generally uses 32-in. Jersey parapets; certain circumstances might require the use of a 42-in. jersey parapet.

Shape of face: New Jersey shape

Compliance with NCHRP-350: As of August 1998, FHWA has mandated that all roadside safety hardware used on the National Highway System must meet the performance crash testing criteria in NCHRP 350 Recommended Procedures for the Safety Performance Evaluation of Highway Features. This applies to roadside barriers, impact attenuators, end treatments, bridge rails, and guardrail-to-bridge-rail transitions.</td></tr>
<tr><td>Inspection Procedures</td><td>No Bridge Inspection Manual was found on the internet.</td></tr>
<tr><td>Railings</td><td>Concrete Railings
✓New Jersey</td></tr>
<tr><td>Standard Drawings / Standard Plans</td><td>No Bridge Standard Drawings were available.</td></tr>
<tr><td>End Treatments</td><td>The terminal treatment for the approaching end of roadside barriers must meet the current acceptable crash-test performance criteria. The Department has not designated specific terminal types for use. The project contract package will provide appropriate pay items for flared terminals and for unflared terminals, and the project plans will identify where each type is used. In general, Department policy is to use a flared terminal, unless site conditions render this impractical; i.e., there is insufficient space for the flare. The</td></tr>
</table>

	contract package will also provide the current list of approved flared and unflared terminals for contractor selection. The following applies to the terminal treatment for the trailing end of a roadside barrier: 1. Two-way Roadways. If the trailing end is within the clear zone for the opposing direction of travel, the trailing end terminal must meet the same crashworthy requirements as the approaching end. If outside of the clear zone, it is not necessary to provide a crashworthy terminal on the trailing end. The Type I Anchorage system, as presented in the Standard Drawings, may be used at these locations. 2. One-Way Roadways. It is not necessary to provide a crashworthy terminal on the trailing end. The Type I Anchorage system, as presented in the Standard Drawings, may be used at these locations. **Plan Title** — **Plan No.** Type 1 Cable Anchorage (Foundation Tube) — GR-3 Type 1 Cable Anchorage (Concrete Footing) — GR-3A Typical Installation at Bridge End During Construction Phases — TGR-2 Modified Eccentric Loader Terminal ("Melt") Anchorage Assembly Details — GR-HW
Contact Log	Name: Richard Withers - Nick Altobelli Phone: (601) 359-7167 – (601) 359-7168 E-mail: nalto@mdot.state.ms.us
References Used [Accessed Dec. 2009]	GoMDOT Roadside Design Manual, 2001 http://www.gomdot.com/Divisions/Highways/Resources.aspx?Div=RoadwayDesign Roadway Design Standard Drawings http://gomdot.com/Divisions/Highways/Resources/RoadwayDesign/Drawings/Home.aspx

MISSOURI	
Warrants	Railing Installation: ✓TL-4 shall be used for concrete safety barrier curbs. TL-4 is defined by AASHTO as being "generally acceptable for the majority of applications on high-speed highways, freeways, expressways, and interstate highways with a mixture of trucks and heavy vehicles." When a concrete barrier is used as follows: o Type C (and Type D, as required) is the preferred configuration for new construction. o Type A (and Type B, as required) is only to be used for new construction projects in a retrofit condition, or to "tie in" to existing Type A concrete barrier, which exists on adjoining sections of roadway. ✓TL-3 is the most common NCHRP-350 test level of guardrails used by MoDOT, since it accounts for small cars and pickup trucks at 60 mph, which represents 90% of all vehicle traffic in Missouri. Railing Transition: No information was found. **Plan Title** — **Plan No.** Bridge Anchor Section (Safety Barrier Curb on Bridge) — 606.22S Bridge Anchor Section (Thrie Beam Rail on Bridge) — 606.23H Pedestrian Railings: No information was found.
Selection Criteria	Materials: Concrete and metal Height: ✓Concrete: 32 in. (TL-4), 42 in. (TL-5) ✓Metal: 28 in. Shape of face: New Jersey Shape (Concrete), W-Beam and Thrie Beam (Metal) Compliance with NCHRP-350: The MoDOT recommends the use of railings and end treatments that are in compliance with the NCHRP-350.
Inspection Procedures	MoDOT follows FHWA Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges for NBIS Bridge Inspections.
Railings	Concrete Railings ✓Type A: Double face New Jersey Barrier ✓Type B: Single face New Jersey Barrier ✓Type C: Double face Vertical Concrete Parapet ✓Type D: Single face Vertical Concrete Parapet Metal Railings ✓Type A – Single W-Beam Rail with 6 ft-3 in. post spacing ✓Type B – Double W-Beam Rail (single beam on each side of post) with 6 ft-3 in. in post spacing, generally for use in median. ✓Type D – Single w Beam Rail with 12 ft-6 in. post spacing, for use at end of road or street. ✓Type E – Single Thrie Beam Rail with 3 ft-1½ in. post spacing.
Standard Drawings / Standard Plans	**Plan Title** — **Plan No.** Permanent Concrete Traffic Barrier — 617.10E CIP Barrier Curb Elevation With Rustication and Waterstop — BAN 1

	CIP Barrier Curb Elevation Without Rustication	BAN 2
	CIP Barrier Curb End Post For Integral End Bent	BAN 4
	CIP Barrier Curb End Post For Integral End Bent	BAN 4a
	CIP Barrier Curb End Post For Non-Integral End Bent	BAN 5
	CIP Barrier Curb End Post For Semi-Deep Abutments	BAN 6
	CIP Barrier Curb Elevation for Double Tee Girder With Rustication and Waterstop	BAN 7
	CIP Barrier Curb End Post For Continuous Concrete Slab Bridge	BAN 11
	Type D Barrier Curb as Retaining Wall	BAN 15D
	CIP Type D Barrier Curb End Post For Non-Integral End Bent	BAN 16
	Type C & D Bridge Anchor Attachment Connection Plate	-
	Standard sheet for Type D Barrier Curb	MBC 01
	Standard sheet for Type D Barrier Curb	MBC 02
	Standard sheet for Type C Barrier Curb	MBC 03
	Standard sheet for Type C Barrier Curb	MBC 04
	Curb Blockout at End Bents	CBO 01 CBO 02 CBO 03
	Guardrails	606.00AT
	Thrie Beam rails for new structures slab depth 8.5 in. and over	THB-1a
	Thrie Beam rails for new structures slab depth 8.5 in. and over-details	THB-1b
	Thrie Beam for new dbl tee structures slab depth 8.5 in. and over	THB-1c
	Thrie Beam rail for rehab structures slab depth 22 in. and over	
	Thrie Beam rail for rehab structures slab depth 22 in. and over-details THB-2b Thrie beam rail for rehab or widening slab depth 8.5 in. to 19 in.	THB-2a THB-3a
	Thrie beam rail for rehab or widening slab depth 8.5 in. to 19 in.-details	THB-3b
	Thrie beam rail for rehab box girder or deck girder	
	Thrie beam for rehab box girder details	THB-4a
	Thrie beam for rehab box girder using latex, Low slump or Silica Fume Overlay	THB-4b THB-4c
	Thrie beam rail for rehab box girder with Large Cantilever	
	Rehab Thrie Beam	THB-4d
	New Bridge Thrie Beam	THBOS-1
	New Bridge Thrie Beam double tee	THBOS-2
	Rehab thrie beam	THBOS-3 THBOS-4
End Treatments	The end terminals have been classified into three groups: Type A, B, and C. The type of classification does not reflect any national standards, only MoDOT classification for specification purposes. Additional information on crashworthy end terminals and internet links to terminals approved by MoDOT are available at MoDOT's end terminal website. ✓**Type A Crashworthy End Terminal**. A Type A terminal is an end treatment used for one-sided barriers such as roadside guardrail, or roadside concrete barrier. Type A devices can also be used on one-sided barriers in the median, provided sufficient clear space is available behind the system to allow opposite direction traffic to recover from an errant path. ✓**Type B Crashworthy End Terminal**. A Type B terminal is an end treatment used for double-sided barrier, most often in the median. Such a device can safely be	

impacted from several angles including, in most cases, the entirely opposite direction. Type B terminals cannot, however, be installed in paved surface locations, unless the installation is temporary and the paved area is to be resurfaced after the system's removal.

- ✓**Type C Crashworthy End Terminal**. A Type C terminal is an end treatment used for double-sided barrier, in gore areas and in the median. Like the Type B, this device can be safely impacted from several angles usually ranging from head-on to the entirely opposite direction. Type C terminals, however, may be installed in both paved and unpaved surface locations, but must be installed on an asphalt or concrete pad in non-paved areas.

  For temporary installations, typically acceptable Type C crash cushions are the Quadguard-CZ and the ADIEM II.

The MoDOT webpage refers to the FHWA for a list of crashworthy end terminals and crash cushions meeting NCHRP-350 criteria and FHWA approval.

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

Existing bridge end treatments that do not conform to current standards are to be considered for replacement or modification. In order to determine the appropriate solution for the specific non-standard bridge end connection, the Bridge Division Liaison Engineer is to be consulted. Where guardrail at the downstream end of a one-way bridge is necessary because of a high fill or other condition, the guardrail is connected to the bridge anchor section.

End Treatments in Low Volume-Low Speed Roads

On certain low volume highways throughout the state, bridge ends may be delineated in lieu of shielding. This option is viable where the operating speed is less than 60 mph and the AADT is 400 or fewer vehicles per day. The delineation-only option is primarily governed by the parameters of speed and volume. The use of this alternative treatment is not allowed on any of the following:

- ✓Use of delineation-only is prohibited on Major Highways (Principal Arterials and above), as well as the National Highway System (NHS).
- ✓Use of the delineation-only option is not recommended on bridge ends in areas of poor geometry (horizontal alignment, vertical alignment, sight distance, etc.).
- ✓Use of delineation-only it is not recommended in areas with an accident history (as calculated between two points at least 0.25 miles from either approach) in excess of the statewide average for similar road. If further analysis of either of these situations proves the delineation option to be viable, then a design exception should be obtained for its use.
- ✓Additionally, the delineation-only option should be limited to those bridge replacements or rehabilitations, where the existing structure was unshielded and the existing roadway template cannot reasonably accommodate the installation of guardrail without some modification.

Turned down ends offer a solution to terminating guardrail at some bridge ends, or other roadside obstacles, on certain, low volume highways throughout the state. While the use of these terminals has generally been discontinued for new construction, they may represent appropriate design for roads with low traffic volumes, traveled by motorists who are generally familiar with the roadway and its geometrics.

Use of turned down ends is primarily governed by the parameters of speed and volume. Irrespective of any values for these parameters; however, the use of turned down ends are prohibited on the following:

- ✓Major highways
- ✓The National Highway System (NHS)

	✓Areas of poor geometry ✓Areas with an accident history in excess of the statewide average for similar road ✓Areas with a posted speed 60 mph or greater.
Contact Log	Name: Mike Harms Phone: (573) 751-0265 E-mail: Michael.Harms@modot.mo.gov
References Used [Accessed Dec. 2009]	MoDOT Engineering Policy Guide (Sections 606, 617 & 751) http://epg.modot.mo.gov/index.php?title=Main_Page MoDOT Standards for Construction http://www.modot.mo.gov/business/standards_and_specs/currentsec600.htm MoDOT Bridge Standard Drawings http://www.modot.mo.gov/business/consultant_resources/bridgestandards.htm

<table>
<tr><th colspan="2">NEVADA</th></tr>
<tr><td>Warrants</td><td>Railing Installation: There is no application in Nevada for railings that comply with NCHRP 350 TL-1 and TL-2.
✓TL-3: The minimum acceptable performance level for all bridges in Nevada, except on NHS facilities. Acceptable for a wide range of high speed arterial highways with very low mixtures of heavy vehicles and with favorable site conditions.
✓TL-4: Minimum Performance level for Bridges on the NHS. Generally acceptable for the majority of applications on high speed highways, freeways, and expressways and Interstate highways with a mixture of trucks and other heavy vehicles.
✓TL-5: Special case where large trucks make up a significant portion of the vehicular mix. A TL-5 rail can only be used when approved by the Chief Structures Engineer.
✓TL-6: Special case where the alignment geometry may require the use of an extra height rail. A TL-6 rail can only be used when approved by the Chief Structures Engineer.

Railing Transition: Standard Plans Details are used for most applications of guardrail-to-bridge-rail transitions. Special designs, if required for unusual circumstances, are developed by the bridge designer with input from the Roadway Design Division.

Plan Title — Plan No.
Guardrail-Bridge Rail Connection, Triple Corrugation — R-80
Guardrail-Barrier Rail Connection, Triple Corrugation — R-81
Guardrail- Bridge Rail Connections, W-Beam — R-83
Guardrail- Barrier Rail Connections, W-Beam — R-84

Pedestrian Railings:

Plan Title — Plan No.
Pedestrian Rail Type “M” — B-12
Pedestrian Rail Type “R” — B-13</td></tr>
<tr><td>Selection Criteria</td><td>Materials: Concrete and metal (The use of metal railings is discouraged by the NDOT, and its use may only be considered where aesthetics or other special conditions require it.)

Height: Varies according to railing type. See Standard Drawings.

Shape of face: Varies according to railing type. See Standard Drawings.

Compliance with NCHRP-350: Bridge Rails used in Nevada are in compliance with the NCHRP 350 TL-3 through TL-6.</td></tr>
<tr><td>Inspection Procedures</td><td>No Bridge Inspection Manual was found on the internet.
Nevada DOT follows the National Bridge Inspection Standards.</td></tr>
<tr><td>Railings</td><td>Concrete Railings
✓<u>32-in. Concrete F-Shape</u>: NDOT typically uses this bridge rail on all bridge rails for which the 42-in. F-Shape and 42-in. Vertical wall are not applicable. The 32-in. F-Shape meets TL-4 criteria. The advantages of this type of rail when compared to a metal beam rail include its superior performance when impacted by large vehicles, its relatively low maintenance costs and its better compatibility with the bridge deck system. The disadvantages include its higher dead weight.
✓<u>42-in. Concrete F-Shape</u>: Meets TL-5 criteria. NDOT typically uses this type of rail if:
- Roadway approach barrier is 42 in. high
- Across railroads
- Across multiple use facilities
- Curved structures with high degree of curvature.
✓<u>42-in. Vertical Concrete Wall</u>: NDOT typically uses this rail where sidewalks are present on the bridge and where the bridge rail is located between the sidewalk and roadway. Its height conforms to the LRFD requirements for pedestrian rails;</td></tr>
</table>

	therefore, its use where sidewalks are present avoid the need to extend the height of a 32-in. concrete bridge rail to meet the height requirements of a pedestrian rail or bicycle rail. ✓TL-6 Rail: This special rail may be considered where extra protection for semi trucks is warranted because: - The road is a high speed facility. - There are a significant number of trucks using the facility. - The alignment has a sharp degree of curvature. - The potential consequences of rail penetration would be catastrophic. The advantage of this system is the extra protection it provides to higher profile vehicles. The disadvantages include the poor aesthetics due to its design and the design of the bridge deck; and the superstructure must include the extra weight of the rail and the impact load. Metal Railings ✓Metal Beam Bridge Rail: NDOT strongly discourages the use of metal beam bridge rail systems. Its use may only be considered where aesthetics or other special conditions are important. The Chief Structure Engineer must approve the use of any metal beam bridge rail. When compared to a concrete bridge rail, metal beam rail advantages include lower dead weight and providing an open view of the surrounding scenery. The disadvantages include a lesser ability to contain heavier vehicles, higher maintenance costs, and a more complex structural connection to the bridge deck system.
Standard Drawings	**Plan Title** — **Page No.** Typical Guardrail Installation — R-69 Typical Guardrail Installation — R-70 Special Guardrail Installation CRT Post — R-74 Guardrail Installation Deflections and Back Spacing — R-76 Guardrail Installation Modified Post — R-77 Galvanized Guardrail Triple Corrugation Wood Post — R-78 Galvanized Guardrail Triple Corrugation Steel Post — R-79 Galvanized Guardrail, W-Beam, W-Beam — R-82 Concrete Barrier Rail — R-85 Concrete Barrier Rail — R-86 Concrete Barrier Rail Type A to Type FA — R-87 Concrete Barrier Rail Type A to Type F-Shape Type A — R-88 Vertical Taper Concrete Barrier Rail — R-89 Portable Precast Concrete Barrier Rail — R-90
End Treatments	**Plan Title** — **Plan No.** Guardrail Terminals Grading Plan — R-71 Trailing End Anchor — R-72 Buried End Anchor-W-Beam & Thrie Beam — R-73 Anchor Terminal — R-75
Contact Log	Name: Todd Stefonowicz Phone: (775) 888 - 7540 E-mail: - tstefonowicz@dot.state.nv.us
References Used [Accessed Dec. 2009]	Standard Plans for Road and Bridge Construction, 2007 Edition http://www.nevadadot.com/business/contractor/Standards/ NDOT Bridge Design Manual, Railing Section, 2008

NEW JERSEY	
Warrants	Railing Installation: The railing systems used on all New Jersey bridge structures meet NCHRP Report 350 TL-4 criteria. The railings used are mentioned below and can be found on Section 23 of the NJDOT Bridge Design Manual. Railing Transition: **Plan Title** — **Plan No.** Beam Guide Rail Attachment — CD-612-13, 14, 15, 16 Pedestrian Railings: In considering the height of the parapet/railing configurations, an 1100 mm high railing should be provided for bicycle traffic and an 870 mm high railing should be provided for pedestrian traffic, as warranted. Min. height, 54 in., is measured from top of surface on which bicycle rides, to the rail. If a concrete barrier is used, smooth rub rails shall be attached to the barriers at a handlebar height of 42 in. Chain link fence may be used in lieu of bicycle railing. However, smooth rub rails shall be attached to the fence posts at the prescribed 42 in. height.
Selection Criteria	Materials: Concrete and metal Height: Varies according to railing type. (See Details on Standard Drawings.) Shape of face: Varies according to railing type. Compliance with NCHRP-350: All railings used by the NJDOT are in compliance with the NCHRP Report 350 TL-4 criteria.
Inspection Procedures [Accessed Dec. 2009]	Recording and Coding Guide for Structure Inventory and Appraisal of New Jersey Bridges http://www.state.nj.us/transportation/eng/structeval/pdf/RecordingandCodingGuide.pdf
Railings	✓Type 1. The 4-bar tubular open steel bridge railing system, for traffic and pedestrian use, provides better driver visibility because of its see through feature. Refer to Standard Drawings 2.2-1 and 2.2-2 for detailing of this system. ✓Type 2. Concrete parapets, 2 m high and integrated with a sidewalk, are used for spans over electrified railroad tracks. ✓Type 3A. The 815-mm concrete parapet surmounted by a 1.9-m high chain link fence is used on local roads or land service roads, which require pedestrian sidewalks. This system is used only where Type 3B cannot be used. ✓Type 3B. Same as Type 3A, except it has a curved top. This system cannot be used on narrow sidewalks, unless a 760-mm minimum horizontal clearance between curb and tip end of curved chain link fence post is provided. ✓Type 4. An 815-mm high parapet surmounted with an ornamental one-rail railing. Ornamental one-rail railing is considered on an individual bridge basis, depending on overall aesthetic considerations. This system is used on low level, short span bridges over a shallow stream, or drainage area. ✓Type 5. Concrete parapets, 865 mm minimum height, with NJ barrier curb configuration, are generally used on bridges, which do not have sidewalks. Ornamental one-rail railing may be considered on an individual bridge basis. ✓Type 6. Concrete parapets, 2.0 m high, integrated with NJ barrier configuration, are used on spans over electrified railroad tracks, where sidewalks are not required. See Guide Sheet Plate 3.7-1. ✓Type 7. A curved-top, totally enclosed chain link fence system, is used on pedestrian bridges. Enclosed fence shall be used for the full span length, including shoulders. The extent of its use on ramps shall be determined on a project-by-project basis.

<table>
<tr><td>Standard Drawings / Standard Plans</td><td>
<table>
<tr><th>Plan Title</th><th>Plan No.</th></tr>
<tr><td>1 Rail Railing</td><td>SP2.1-1</td></tr>
<tr><td>2 Rail Railing</td><td>SP2.1-2</td></tr>
<tr><td>4 Bar Open Steel Bridge Railing (Typical Section and Elev.)</td><td>SP2.2-1</td></tr>
<tr><td>4 Bar Open Steel Bridge Railing (Details)</td><td>SP2.2-2</td></tr>
<tr><td>4 ft-2 in. Heavy Truck Parapet</td><td>SP2.2-3</td></tr>
<tr><td>3 ft-6 in. F-Shape Parapet</td><td>SP2.2-4</td></tr>
</table>
</td></tr>
<tr><td>End Treatments</td><td>
The standards for “leading” traffic end terminations within the “clear zone” are:

Flared Guide Rail Terminal like Slotted Rail Terminals (SRT350), or Flared Energy-Absorbing Terminal (FLEAT): Standard end terminal, where room exists for a parabolic flare. For details, see the Manufacturer’s recommendation and the Department Qualified Products list.
Tangent Guide Rail Terminal like Extruder Terminals (ET-2000) or Sequential Kinking Terminal (SKT-350): End terminal used, where insufficient room exists for parabolic flare. For details, see the Manufacturer’s recommendation and the Department Qualified Products list.
Controlled Release Terminals (CRT): End terminal used, where insufficient space exists at driveways or intersecting streets. For details, see Sheet 63 of Roadway Construction Details.
Crash Cushions (Impact Attenuators): Used where space limits preclude the use of the two standard end terminals, specified above.
Telescoping Guide Rail End Terminals: Used where there are back-to-back guide rails (usually within the median). Typically, this is used in conjunction with sign structures, where the support is located in the median. For details, see Sheet 64 of the Roadway Construction Details.

The standard for “trailing” traffic end terminations, or where it is unlikely that an end hit would occur (i.e., end of guide rail is outside “clear zone,” end of guide rail buried in cut, etc.):

Beam Guide Rail Anchorage: Standard beam anchorage terminal. For details, see Sheet 61 of Roadway Construction Details.
In-Line Beam Guide Rail Anchorage: Anchorage used, where end of guide rail is buried in a cut slope. For details, see Sheet 61 of Roadway Construction Details.

Many of the older safety systems used Breakaway Cable Terminals (BCT), or Eccentric Loader Terminals (ELT). These two end terminals did not pass the mandatory crash testing and no longer meet NJDOT standards.
<table>
<tr><th>Plan Title</th><th>Plan No.</th></tr>
<tr><td>Beam Guide Rail Anchorages</td><td>CD-612-4</td></tr>
<tr><td>Slotted Guide Rail Terminals & Extruder Terminals</td><td>CD-612-5</td></tr>
<tr><td>Controlled Release Terminals</td><td>CD-612-6</td></tr>
<tr><td>Median Guide Rail Treatment</td><td>CD-612-7</td></tr>
<tr><td>Beam Guide Rail End Treatment</td><td>CD-612-8</td></tr>
<tr><td>Beam Guide Rail Attachments</td><td>CD-612-9, 10, 11</td></tr>
<tr><td>Thrie Beam And W- Beam Terminal Connectors</td><td>CD-612-12</td></tr>
</table>
</td></tr>
<tr><td>Contact Log</td><td>Name: Greg Renman
Phone: (609) 530-5606
E-mail: greg.renman@dot.state.nj.us</td></tr>
<tr><td>References Used [Accessed Dec. 2009]</td><td>Bridge Design Manual http://www.state.nj.us/transportation/eng/documents/BDMM/
Standard Drawings http://www.state.nj.us/transportation/eng/CADD/E/index.-shtml#StandardDetailsEnglish
http://www.nj.gov/transportation/eng/CADD/E/RoadwayDetails/pdf/eRoadwayDetailsSet.pdf</td></tr>
</table>

NEW MEXICO	
Warrants	Railing Installation: ✓AASHTO Bridge Specifications require that railing be provided along the edges of all bridge structures for the protection of vehicles and pedestrians. ✓The policy of the NMDOT is to use concrete barriers (NMDOT Standard Drawings BBR-32 and BBR-42) on all new structures. The general rule is to use the 42-in. (Serial BBR-42) barrier on Interstate and U.S. highways, and the 32-in. (Serial BBR-32) barrier elsewhere. However, the height of railing to be used needs to be coordinated with the Design Team. ✓In an urban setting, where the speed limit is below 45 mph, metal railing may be used. Only Type A metal railing shown in the NMDOT Standard Serials, or other state's railing that has been crashed tested, may be used for vehicle traffic. Railing Transition: No information was found. Pedestrian Railings: ✓Pedestrian Railing is placed on the outer edge of a sidewalk to separate traffic and pedestrians, or on pedestrian bridges. ✓Combination Railing is designed to protect both vehicles and pedestrians, or bicycles (see NMDOT Standard Serials BMR-005). A combination railing in conjunction with a raised curb and sidewalk is used only on low speed highways.
Selection Criteria	Materials: The policy of the NMDOT is to use concrete barriers on all new structures, except in urban settings where the speed limit is ≤ 45mph, where metal railings are permitted. Height: The general rule is to use the 42-in. barrier on Interstate and U.S. Highways, and the 32-in. barrier elsewhere. Shape of face: Varies according to railing type. Compliance with NCHRP-350: Only crash tested railings can be used for vehicle traffic.
Inspection Procedures	No Bridge Inspection Manual was found on the internet. New Mexico DOT follows the NBIS and the FHWA Recording and Coding Guide for the appraisal of the Nations Bridges.
Railings	Concrete Railings: NMDOT Standard Drawings Division 500-Section 514 ✓32-in. Single Slope Bridge Barrier Railing ✓32-in. Jersey Type Bridge Barrier Railing ✓40-in. Jersey Type Bridge Barrier Railing ✓42-in. Single Slope Bridge Barrier Railing ✓48-in. Jersey Type Bridge Barrier Railing Metal Railings ✓Type A Metal Railing ✓Other state's railings that have been crash tested
Standard Drawings	**Plan Title** — **Plan No.** 32-in. Concrete Bridge Barrier Railing 32-in. Concrete Bridge Barrier Railing Standard Section and Details 32-in. Concrete Bridge Barrier Railing Transition Section Details 32-in. Concrete Bridge Barrier Railing Details at Joint Seals Barrier Railing General Details — BBR-01 Barrier Railing Standard Section Details — BBR-02 Barrier Railing Transition Section Details — BBR-03 Barrier Railing Details at Joint Seals — BBR-04

	40-in. Barrier Railing General Details 40-in. Barrier Railing Standard Section Details 40-in. Barrier Railing Transition Section Details 40-in. Barrier Railing Details at Joint Seals 42-in. Concrete Bridge Barrier Railing General Details 42-in. Concrete Bridge Barrier Railing Standard Section and Details 42-in. Concrete Bridge Barrier Railing Transition Section Details 42-in. Concrete Bridge Barrier Railing Details at Joint Seals 48-in. Concrete Bridge Barrier Railing General Details 48-in. Concrete Bridge Barrier Railing Standard Section Details 48-in. Concrete Bridge Barrier Railing Transition Section Details 48-in. Concrete Bridge Barrier Railing Details at Joint Seals
End Treatments	No information was found.
Contact Log	Name/Position: Ray Trujillo / State Bridge Engineer Phone: (505) 827-5448
References Used [Accessed Dec. 2009]	Bridge Procedures and Design Guide, September 2005 http://nmshtd.state.nm.us/main.asp?secid=14860 Bridge Design Standards http://www.nmshtd.state.nm.us/main.asp?secid=15060

NEW YORK	
Warrants	Railing Installation: The first choice in most design categories is a concrete barrier, or parapet. This preference is based on the concrete barrier's strength, durability, low initial cost, and low maintenance costs when compared to metal railing systems. Factors that may cause an alternative selection to be made are: ✓**Bridge Deck Drainage** - On bridges over waterways where concrete barriers would necessitate the use of scuppers, a curbless railing should be used. Generally, for most bridges, it will not be necessary to use scuppers with concrete barriers. It is usually possible to carry the deck drainage off the ends of the structure without scuppers, unless the bridge is very long, very wide, or it has a flat profile. The bridge deck hydraulics must be checked. ✓**Aesthetics** - In areas where the aesthetics of the railing/barrier is a prime concern, the Texas Type C411 concrete barrier is an option. However, the cost of this barrier is significantly higher than a standard barrier, and its use is restricted to situations where a service level of TL-2 (PL-1) applies. A barrier with an outside face treatment, using one of the many types of form liners, should also be considered. Concrete cover and bridge width must be increased when form liners are used. Concrete barrier can be colored by staining the cured concrete for an aesthetic effect. Color added to the concrete mix is not recommended because of the variability of results. Exposed aggregate finishes should be avoided because of maintenance concerns. A two-rail timber railing is also available for use in areas such as the Adirondack and Catskill Parks, where a rustic appearance is desired. In certain situations, it may be desirable to provide a view of scenic under features. An open railing system could be used in these situations. ✓**Visibility** - When intersections or driveways are close to the end of the bridge, an open railing system may be selected over a concrete barrier to increase visibility of oncoming traffic from the intersecting roadway. It should be pointed out that the visibility through the steel railings is limited and becomes even less with the addition of pedestrian fencing or permanent snow fence to the railing. This factor should only be a consideration in unusual circumstances. ✓**Snow Accumulation** - In areas with heavy snowfall, an open railing on bridges over waterways is sometimes considered to mitigate the effect of snow accumulation on the shoulders. The intent is to push snow through an open railing during snow plowing operations to reduce the need for maintenance forces to remove accumulated snow from the bridge shoulder. However, the ability to push snow through the relatively close spacing of the rails is limited at best. Bridges over highways and railroads will ordinarily carry a snow fence on the structure. Therefore, snow accumulation is usually not a factor in the railing/barrier decision on such bridges. Geometric design policy for new and replacement bridges ordinarily results in a shoulder wide enough to permit snow storage. The factor of snow accumulation driving a decision to use open railing rather than a concrete barrier should occur only in unusual circumstances. Table 6-1 of NYSDOT Bridge Design Manual shows the available railing and barrier options for the different design service levels. Current BD Sheets should be consulted for the details of the various systems. Railing Transition: Approved transitions from bridge railing and barrier to highway railing are shown in Table A2, obtained from NYSDOT Bridge Design Manual. If it is necessary to transition from corrugated beam highway rail to box beam highway rail (or vice versa), make the transition away from the bridge in accordance with the details shown on the Highway Standard Sheets.

Table A2. Bridge Railing to Highway Railing Transition.

Bridge Rail	Highway Rail	BD Sheet
Thrie Beam	Corrugated Beam	BD-RL1
Two Rail Curbless	Box Beam	BD-RL3
Three Rail Curbless	Box Beam	BD-RS4
Four Rail Curbless and with sidewalk	Box Beam	BD-RS4
Five Rail Curbless	Box Beam	BD-RS4
Two Rail with brush curb	Box Beam	BD-RS4
Timber Two Rail	Thrie Beam / Corrugated Beam	BD-RT1
Concrete Safety Shape	Box Beam	BD-RC1
Concrete Single Slope	Box Beam	BD-RC13
Concrete Vertical Wall	Box Beam	BD-RC6
Concrete F-Shape	Box Beam	BD-RC16
Texas Type	Thrie Beam/Corrugated Beam	BD-RC10
All Concrete Barriers	Corrugated Beam	BD-RC17, BD-RC18

The purpose of bridge railing/barrier transitions is to provide a smooth transition from the rigid bridge rail to the flexible highway guide rail without forming a snagging pocket. When driveways or other roadways are in close proximity to the end of the bridge and make the use of the full transition length impossible, the designer shall utilize as much of the transition as possible. The highway guide rail shall be terminated in accordance with the highway standard sheets where conditions permit.

Pedestrian Railings:

- ✓**Pedestrian Traffic (Sidewalk on Bridge)** - Bridges carrying a sidewalk must use a concrete parapet or four-rail railing at the fascia with a minimum height of 1.06 m above the sidewalk surface. It is presumed that bridges with a sidewalk do not carry bicycle traffic on the sidewalk. When a sidewalk is separated from vehicular traffic by a traffic railing, then a minimum 1.06-m high pedestrian railing or fencing must be used on the fascia.
- ✓**Pedestrian Traffic (No Sidewalk on Bridge)** - A railing or concrete barrier with a minimum height above the roadway of 1.06 m shall be used.

Selection Criteria

Materials: Concrete, metal, and timber

Height: Varies according to rail type. See Standard Drawings.

Shape of face: Varies according to railing type. See Standard Drawings.

Compliance with NCHRP-350: New railing and barrier systems must meet the requirements established in NCHRP 350. NCHRP 350 sets forth the crash test requirements and criteria for accepting railing systems.

The general descriptions of the service levels to be used are as follows:

- ✓TL-2 (PL-1)–Taken to be generally acceptable for most local and collector roads with favorable site conditions, work zones, and where a small number of heavy vehicles are expected and posted speeds are reduced.
- ✓TL-4 (PL-2)–Taken to be generally acceptable for the majority of applications on high-speed highways, expressways, and interstate highways with a mixture of trucks

	and heavy vehicles. ✓TL-5 (PL-3)–Taken to be generally acceptable for applications on high-speed, high-traffic volume and high ratio of heavy vehicles for expressways and interstate highways with unfavorable site conditions.
Inspection Procedures	NYSDOT Bridge Inspection Manual Ch 6: Deck Elements, contains information regarding the inspection of the condition of the bridge railings, not its structural or its functional adequacy. EVALUATION RATING 7- New or like-new condition. 5- Minor concrete spalls, mortar loss in stone work, minor section loss or bent members, or a few noncritical fence ties missing. 3- Concrete spalled with rebars exposed, stones loose or missing, bolts missing, small parts on rails or members missing, measurable section loss, or impact damage hindering full function of the rail or parapet. Concrete parapets and rails tipped from vertical. 1- Broken or missing sections of rail or parapet, so that it is totally ineffective.
Railings	TL-2 (Less than 500 AADT) 1. Thrie Beam 2. Steel Two Rail Curbless 3. Steel Three Rail Curbless 4. Steel Four Rail 5. Steel Five Rail Curbless 6. Steel Two Rail with Brush Curb 7. Timber Two Rail 8. 864 mm Safety Shape 9. 1.07 m Single Slope 10. 1.07 m F-Shape 11. 1.07 m Vertical Parapet 12. 1.07 m Texas-Type TL-2 (Less than 1500AADT) 1. Steel Two-Rail Curbless 2. Steel Three-Rail Curbless 3. Steel Four-Rail 4. Steel Two-Rail with Brush Curb 5. Steel Five-Rail Curbless 6. Timber Two-Rail 7. 864 mm Safety Shape 8. 1.07 m Single-Slope 9. 1.07 m F-Shape 10. 1.07 m Vertical Parapet 11. 1.07 m Texas-Type TL-2 (Greater than 1500AADT) 1. 864 mm Safety Shape 2. Steel Three-Rail Curbless 3. Steel Four-Rail 4. Steel Five-Rail Curbless 5. Steel Two-Rail with Brush Curb 6. 1.07 m Single-Slope

<table>
<tr><td></td><td>7. 1.07 m F-Shape
8. 1.07 m Vertical Parapet
9. 1.07 m Texas-Type
10. Timber Two-Rail

TL-4
1. 864 mm Safety Shape
2. Steel Three-Rail Curbless
3. Steel Four-Rail
4. Steel Five-Rail Curbless
5. Steel Two-Rail with Brush Curb
6. 1.0 m Single-Slope
7. 1.07 m F-Shape
8. 1.07 m Vertical Parapet
9. Timber Two-Rail

TL-5 and Controlled Access Interstates
1. 1.07 m Single-Slope [CIP and slipform options only]
2. 1.07 m F-Shape

Controlled Access Non Interstate
1. 864 mm Safety Shape
2. 1.07 m Single-Slope
3. 1.07 m F-Shape</td></tr>
<tr><td>Standard Drawings/ Standard Plans</td><td>Plan Title — Plan No.
Thrie Beam — BD-RL1
Steel Two-Rail Curbless — BD-RL3
Steel Three-Rail Curbless — BD-RS1
Steel Four-Rail — BD-RS1
Steel Five-Rail Curbless — BD-RS3
Steel Two-Rail with Brush Curb — BD-RS2
Timber Two-Rail — BD-RT1
864 mm Safety Shape — BD-RC1
1.07 m Single-Slope — BD-RC11
1.07 m F-Shape — BD-RC15
1.07 m Vertical Parapet — BD-RC2
1.07 m Texas-Type — BD-RC8</td></tr>
<tr><td>End Treatments</td><td>No information was found in NYSDOT Bridge Design Manual, or Standard Drawings.</td></tr>
<tr><td>Contact Log</td><td>Name: James Flynn
Phone: (518) 485-1148
E-mail: jhflynn@dot.state.ny.us</td></tr>
<tr><td>References Used [Accessed Dec. 2009]</td><td>NYSDOT Bridge Design Manual, 2006
https://www.nysdot.gov/portal/page/portal/divisions/engineering/structures/manuals/bridge_manual_4th_ed
NYSDOT Bridge Standard Drawings https://www.nysdot.gov/portal/page/portal/main/business-center/engineering/cadd-info/drawings/bridge-detail-sheets</td></tr>
</table>

NORTH CAROLINA	
Warrants	Railing Installation: Warrants for guardrail are to be in accordance with the "Roadside Design Guide" and with the guardrail warrant curves, included in Chapter 3 of NCDOT Roadway Design Manual. Generally, bridges with no sidewalks or no anticipated sidewalks should have a Jersey barrier rail. When a sidewalk or designated bikeway is justified, appropriate railings shall be used. Railing Transition: No was information found. Pedestrian Railings: No was information found.
Selection Criteria	Materials: Concrete Height: Varies according to railing type. (See Standard Plans.) Shape of face: Varies according to railing type. (See Standard Plans.) Compliance with NCHRP-350: All bridge railings shall conform to current AASHTO criteria and shall have been successfully crash tested in accordance with FHWA guidelines.
Inspection Procedures	No Bridge Inspection Manual was found. North Carolina DOT follows the NBIS and AASHTO.
Railings	Concrete Railings: ✓New Jersey (used on most bridges, even on low volume low speed roads) ✓Constant Slope
Standard Drawings / Standard Plans	**Plan Title** — **Plan No.** Double Faced Concrete Barrier - Types I, II, III and IV — 854.01 Double Faced Concrete Barrier - Types `T', `T1' and `T2 — 854.02 Concrete Median Barrier - Precast Permanent — 854.04 Concrete Median Transition Barrier — 854.05 Precast Reinforced Concrete Barrier - 41 in. Single Faced — 857.01 Guardrail Placement — 862.01 Guardrail Installation — 862.02 Anchoring End of Guardrail - for B-77 and B-83 Anchor Units — 862.04 Cable Guiderail — 865.01
End Treatments	When use of an impact attenuator or terminal end unit is indicated, the following guidelines need to be considered: 1. Only those items that have been crash tested and found to meet the requirements of NCHRP-350 will be considered for use, where there is a chance of hitting the guardrail “Head on” within the vehicle’s clear zone. 2. Each location must be evaluated to determine the appropriate width and type of attenuator, which will meet the site needs, geometric conditions, expected frequency of impact, and economy of installation and maintenance. (See 3-12, Table 1.) 3. The effects of impacts with respect to the safety of subsequent vehicles. a. Water-filled units should not be placed where expelled water will stand on or flow across the travel way. b. Sand-filled units should not be placed where the sand from impacted containers will spill into the travel way. 4. There may be a need for additional delineation to reduce the frequency of impacts (refer to TRR 1111, "Traffic Accident Analysis, Visibility Factors, and Motorists Information Needs"). 5. The availability and storage of repair parts should be evaluated. 6. Proprietary devices require special attention during final plan process on both State and Federal projects. Three comparable alternatives are desired for the final plans. If only

	one alternative is used, then written approval must be given by the FHWA Division Administrator (NHS projects) or State Highway Design Engineer (state funded or non-NHS projects). The approvals must be requested based on one of the following criteria: a. The device is the only alternative available to do the job, and its use is in the Public interest. b. The device is to be used for experimental purposes. Anchor units most commonly used are: 1. GRAU-350 2. M-350 3. CAT-1 4. AT-1 5. Terminal End Section.
Contact Log	Name/Position: Henry Black / Assistant State Bridge Maintenance Phone: (919) 733-4362 E-mail: hblack@dot.state.nc.us
References Used [Accessed Dec. 2009]	North Carolina DOT Roadway Design Manual 2002 http://www.ncdot.org/doh/preconstruct/altern/value/manuals/designmanual.html Roadway Standard Drawings 2006 http://www.ncdot.org/doh/preconstruct/ps/std_draw/06english/08/default.html

OKLAHOMA	
Warrants	*The Oklahoma DOT does not have a Bridge Design Manual. They use their Standard Drawings as a guide on what to use on State and County Bridges. Railing Installation: No information was found. Railing Transition: Details for Thrie beam to bridge parapet connection can be found on Appendix B, page B11 of the ODOT PONTIS Bridge Inspection Manual. Pedestrian Railings: No information was found.
Selection Criteria	Materials: Concrete and metal Height: Varies according to railing type. See Standard Drawings. Shape of face: Varies according to railing type. See Standard Drawings. Compliance with NCHRP-350: The Oklahoma DOT requires that all safety barriers used on bridges located on the NHS be in compliance with the NCHRP 350. Other highways that are not federally funded do not require such compliance.
Inspection Procedures	No Bridge Inspection Manual was found on the internet. ODOT follows the PONTIS Bridge Inspection Manual (2006), and the National Bridge Inspection Standards for the inspection of their bridges. ODOT PONTIS Bridge Inspection Manual Appendix B, presents in pages B5 and B6 cross sections of bridge rails that are currently acceptable (NBIS Item 36-1), and others that are obsolete and are no longer acceptable (NBIS Item 36-0).
Railings	Concrete Railings ✓TR3 ✓TR4 ✓42-in. F-Shape ✓Sloped Face Parapet Metal Railings ✓Tubular Metal Traffic Rail
Standard Drawings/ Standard Plans	*COUNTY BRIDGE STANDARD DRAWINGS* **Plan Title** — **Plan No.** Concrete Traffic Rail — CB-33E Tubular Metal Traffic Rail — CB-34E *STATE BRIDGE STANDARD DRAWINGS* **Plan Title** — **Plan No.** Concrete Traffic Rail (TR3) — B-001 Sloped Face Parapet — B-002 Concrete Traffic Rail (TR4) — B-003 42-in. F-Shaped Concrete Parapet — B-004
End Treatments	**Plan Title** — **Plan No.** Bridge End Guardrail — CB-30E Bridge End Guardrail Hardware — CB-31E
Contact Log	Name: Walter Peters Phone: (405) 521-2606 E-mail: wpeters@odot.org
References Used [Accessed Dec. 2009]	Standard Drawings, 1999 http://www.okladot.state.ok.us/bridge/standards.htm

<table>
<tr><th colspan="2">PENNSYLVANIA</th></tr>
<tr><td>Warrants</td><td>Railing Installation: Bridge railing may consist of single face concrete F-shape barrier, or other crash tested and approved railing system appropriate to the roadway (see DM-2, Chapter 12.9). Under most conditions, the concrete F-shape barrier provides the highest and least costly level of protection. Therefore, the concrete F-shape barriers are generally the preferred alternative. If the temporary bridge could cause hydraulics problems during flooding conditions, the use of an open metal railing (such as the PA 10M) is encouraged to minimize restrictions to water flow during high water episodes.
Provide bridge railings that meet the requirements of Test Level 5 (TL-5) of NCHRP Report 350, unless another test level is authorized by the Director, Bureau of Design. The Typical Concrete Barrier (shown in Standard Drawing BD-601M) provides a high level of safety and low maintenance cost. This barrier is considered the default bridge railing system, unless the Director, Bureau of Design, authorizes a different railing system due to environmental considerations, public request, or other requirements.

Railing Transition: The connection between the bridge railing and any guide rail on the approaches is to be smooth and of adequate strength, so that no "pockets" will be created if impacted by vehicles. See Set of Standard Drawings RC-50M, Sheets 1-16.

Pedestrian Railings: The minimum height of a pedestrian railing shall be 1.07 m {42 in.} measured from the top of the walkway. A pedestrian rail may be composed of horizontal and/or vertical elements. The clear opening between elements shall be such that a 150 mm {6 in.} diameter sphere shall not pass through.
When both horizontal and vertical elements are used, the 150 mm {6 in.} clear opening shall apply to the lower 685 mm {27 in.} of the railing, and the spacing in the upper portion shall be such that a 200 mm {8 in.} diameter sphere shall not pass through. A safety toe rail or curb should be provided. Rails should project beyond the face of posts.</td></tr>
<tr><td>Selection Criteria</td><td>Materials: Concrete, metal, and timber

Height: The required railing heights are reflected in the BD-601M, BD-610M, BD-615M, BD-617M, and BD-618M Standard Drawings.

Shape of face: Varies according to railing type. See Standard Drawings.

Compliance with NCHRP-350:
• Under any circumstance that Design Manual Part 2 does not provide criteria for the selection of the Test Level, then Test Level Five, TL-5, shall be used, except when otherwise directed by the Department.
• Test Levels 4 & 6 may be authorized by the Director of the Design Bureau on a case-by-case basis.
o TL-4 may be considered in the following cases:
1. Case I - Where favorable conditions of alignment, grade and speed exist and, hence, the probability of severe crashes is minimal.
2. Case II - Where the height required for railings satisfying TL-5 may hinder sight distance requirements.
3. Case III - Along the sides of bridges with sidewalks not separated from traffic with a crashworthy traffic railing.
o TL-6 may be considered for locations where the history of, or the potential for tanker truck rollover exists.
• For bridges on Very Low Volume Roads, it is permissible to utilize a reduced Test Level, provided the barrier is crash tested and acceptable to the FHWA.</td></tr>
<tr><td rowspan="2">Inspection Procedures</td><td>PennDOT uses the NBIS for the inspection of the bridge railings.
The Evaluation Rating used is later converted to the NBIS rating:</td></tr>
<tr><td><u>PennDOT / NBIS</u> <u>Description</u>
8 / 1 Good condition; meets current standards.</td></tr>
</table>

	6 / 1	Good condition; meets previous standards.
	4 / 0	Does not meet previous standards; considered adequate.

Railings

Concrete Railings
✓F-Shape
✓Vertical Wall

Combination Railings
✓PA Bridge Barrier

Timber Railing

Standard Drawings / Standard Plans

Plan Title	TL	Plan No.
Typical Concrete Barrier	5	BD-601M, Sheet 2
Alternate Concrete Barrier	4	BD-601M, Sheet 2
Split Concrete Glare Screen Median Barrier Detail	4	BD-601M, Sheet 2
Alternate Split Concrete Median Barrier Detail	4	BD-601M, Sheet 2
Concrete Glare Screen Median Barrier Detail	4	BD-601M, Sheet 3
Concrete Median Barrier Detail	4	BD-601M, Sheet 3
Vertical Wall Bridge Barrier at Alternate Sidewalk Detail	5	BD-601M, Sheet 4
PA Bridge Barrier	5	BD-610M
PA HT Bridge Barrier	5	BD-615M
PA Type 10M Bridge Barrier	4	BD-617M
Vertical Wall Bridge Barrier	5	BD-618M
Alternate Vertical Wall Bridge Barrier	4	BD-618M
Vertical Wall Bridge Barrier for Non-Composite Adjacent Box Beams	4	BD-618M
Alternate Concrete Barrier for Plank Beams	4	BD-661M, Sheet 3
Typical Barrier Reinforcement for Composite Adjacent Box Beams	5	BD-661M, Sheet 4
Vertical Wall Bridge Barrier for Composite Adjacent Box Beams	5	BD-661M, Sheet 5
Alternate Concrete Barrier for Non-Composite Adjacent Box Beams	4	BD-661M, Sheet 5
Timber Bridge Rail Details		BLC-556M

End Treatments

Crashworthy end treatments/crash cushions acceptable for use in Pennsylvania are listed below by type for a particular application. They are categorized by type as follows:

✓Type I - Anchored Backslope Terminal – See Std Drawing RC-54M, Sheets 5-7
✓Type II - Gating Flared Terminals
1. Slotted Rail Terminal (SRT-350)
2. Flared Energy Absorbing Terminal (FLEAT®-350)
3. Redirecting Gating End Terminal (REGENT)

✓Type III - Gating Parallel Terminals

	1. Extruder Terminal (ET-2000) 2. Sequentially Kinking Terminal (SKT-350) ✓Type IV - Gating Systems Used Where Two-Way Traffic Is Present 1. Crash-Cushion Attenuating Terminal (CAT-350) 2. Brakemaster® 350 3. Advanced Dynamic Impact Extension Module (ADIEM) ✓Type V - Non-Gating Terminals Used Where Two-Way Traffic Is Present *STANDARD* 1. QuadGuard 2. TRACC 3. TAU-II *REUSABLE* 4. QuadGuard Elite 5. REACT 350 6. REACT 350 (60 in.) 7. SCI100GM *EXTEND REUSABLE* 8. QuadGuard LMC ✓Type VI - Gating, Non-Redirective Crash Cushion Systems *SAND FILLED* 1. Energite III Module 2. Fitch Universal Module 3. Traffix *WATER FILLED* 4. ABSORB 350 ✓Miscellaneous Systems 1. The BarrierGate 2. Earth Berm Mounds 3. The DRAGNET®
Contact Log	See U21: Harold Rogers Phone: (717) 787 - 2881 E-mail: hrogers@state.pa.us
References Used [Accessed Dec. 2009]	Design Manual Part 4 (2000 Edition) http://www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/DesignHomepage?openframeset&frame=main&src=BQADinspection?OpenForm Design Manual Part 2 http://www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/DesignHomepage?openframeset&frame=main&src=HQADStandards?OpenForm Bridge Standard Drawings http://www.dot.state.pa.us/Internet/BQADStandards.nsf/bd2005?openform Roadway Standard Drawings http://www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/DesignHomepage?openframeset&frame=main&src=HQADStandards?OpenForm Bridge Safety Inspection Manual (2002 Edition) http://www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/DesignHomepage?openframeset&frame=main&src=BQADinspection?OpenForm

<table>
<tr><th colspan="3">PUERTO RICO</th></tr>
<tr><td>Warrants</td><td colspan="2">* The Puerto Rico Department of Transportation and Public Works does not have a Bridge Design Manual; they follow AASHTO LRFD Bridge Design Specifications, 2007.

Railing Installation: Bridge Parapets and their connection to metal barriers, including bridge end inlets, will be done in conformity with the Standard Plans of the Puerto Rico Highway Authority.

Railing Transition:

Plan Title — Plan No.
W-Beam Strong Post Single Face – Connection concrete bridge parapet — MB 17 of 28

Pedestrian Railings: No information was found.</td></tr>
<tr><td>Selection Criteria</td><td colspan="2">Materials: Concrete

Height: 32-in. (F-Shape)

Shape of face: F-Shape

Compliance with NCHRP-350: It is required that the railings used by the PR DOT be in compliance with the NCHRP-350 criteria.</td></tr>
<tr><td>Inspection Procedures</td><td colspan="2">The Puerto Rico DOT and Public Works is currently working on developing a Bridge Inspection Manual.

The Puerto Rico DOT&PW uses the NBIS, the AASHTO CoRe Element Manual, and the Inspectors follow Caltrans and Wyoming DOT’s Inspection Manual.</td></tr>
<tr><td>Railings</td><td colspan="2">Concrete Railings

• 32-in. F-Shape

Metal Railings

• Strong Post W-Beam (Open Railings for bridges susceptible to floods)</td></tr>
<tr><td>Standard Drawings</td><td>Plan Title
W-Beam Strong Post-Hardware
W-Beam Strong Post Assembly and Elevation Details
W-Beam Strong Post – Timber Blockout Details
W-Beam Strong Post – Timber Blockout Details

Concrete Barrier Type F Shape</td><td>Plan No.
MB 1-5A of 28
MB 6 of 28
MB 6A of 28
MB 6B of 28
MB 6C of 28
MB 6D of 28
CB 1 of 8</td></tr>
<tr><td>End Treatments</td><td colspan="2">Metal Barrier Terminals
✓Barrier Terminals Type MA and MA-MED–the metal barrier should be offset and flared as per the above table, and the barrier terminal buried and anchored in the cut slope. These barriers terminals shall be used on approach ends and on leaving ends when the leaving end may be impacted from the opposite direction of travel.
✓Barrier Terminals Type MB and MB-MED–the metal barrier should be offset and flared as per the above table. The blunt end will be anchored with a cable anchor, as indicated in the standard drawings. These barriers terminals shall be used on approach ends and on leaving ends when the end may be impacted from the opposite direction of travel.
✓Barrier Terminals Types MC–these terminals are intended for leaving ends with a minimum offset of 1.0 to 2.0 m, and used only where there is no or little probability of being impacted from the opposite direction. They shall have a blunt end similar to</td></tr>
</table>

types MB and MB-MED.

Concrete Barrier Terminals

- ✓Barrier Terminals CD and CD-MED shall consist of a long tapering or flare down of the concrete barrier, as defined in the standard plans. This terminal shall be used on low speed approach terminals.
- ✓Barrier Terminals CE and CE-MED shall consist of a short tapering or flare down of the concrete barrier, as defined in the standard drawings. They shall be used on leaving terminals when there is no, or little, probability of being impacted from the opposite direction.

Metal and Concrete Barrier Terminals

- ✓Barrier Terminal Impact Attenuator shall consist of the installation of sand filled impact attenuators to protect the barrier terminal, as defined in the standard plans for impact attenuators for the appropriate speed. May be used for metal and concrete barriers.
- ✓Barrier Terminal Proprietary shall consist of any of the proprietary terminals adopted by the agency and defined in the standard drawings. May be used for metal and concrete barriers.
- ✓Barrier Terminal Earth Berm shall consist of an earth berm to protect the barrier terminal, as defined in the standard drawings. May be used for metal and concrete barriers.

Proprietary Terminals

The FHWA and the PR Department of Transportation and Public Works have decided to use three proprietary terminals to use in the NHS System:

- ✓FLEAT 350: for flared installation inside the Clear Zone
- ✓SKT 350: for tangent installation inside the Clear Zone
- ✓QuadGuard® Elite: to be used as a crash cushion in conditions where you have traffic on both sides, such as a median, a gore area, or a toll station.

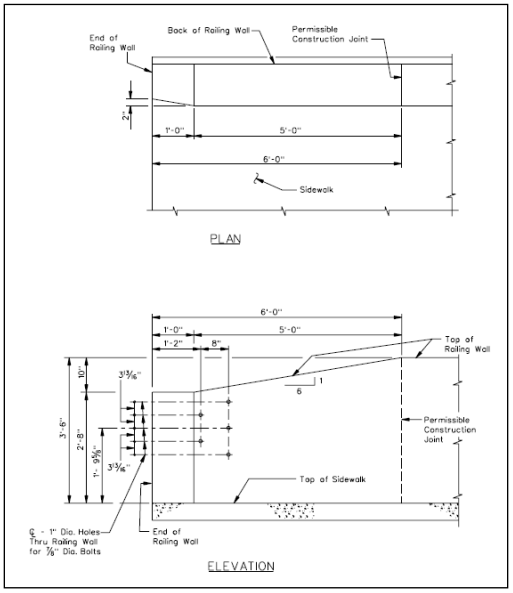
Plan Title	Plan No.
W-Beam Strong Post Terminal Type MA	MB 8 of 28
W-Beam Strong Post Terminal Type MB	MB 9 of 28
W-Beam Strong Post Terminal Type MC	MB 10 of 28
W-Beam Strong Post Double Face Terminal Type MA-MED	MB 20 of 28
W-Beam Strong Post Double Face Terminal Type MB-MED	MB 21 of 28
Impact Attenuator Modules	IA 1 of 2 / IA 2 of 2

Contact Log

Name: Manuel Coll
Phone: (787) 729-1529
E-mail: mcoll@act.dtop.gov.pr

References Used [Accessed Dec. 2009]

Design Directive No. 400
Design Directive No. 401
Design Directive No. 408
http://dtop.gov.pr/ACT/diseno/Directrices/DirectricesDiseno_indice.htm

SOUTH CAROLINA	
Warrants	Railing Installation: SCDOT typically uses the Jersey shape for the 32-in. rail instead of the other available concrete bridge rail shapes (e.g., F-shape, constant-slope shape, and vertical wall), with the exceptions of bridges with sidewalks and bridges where aesthetics and dead loads are very important. Railing Transition: The Road Design Section is responsible for designing and detailing the guardrail-to-bridge-rail transition for the approaching roadway. However, site conditions may present problems for the necessary transition. Therefore, the bridge designer should work with the Road Design Section to ensure compatibility between the guardrail-to-bridge-rail transition and the site. Transitions specified in the Bridge Design Manual: 1. 32-in. Concrete Parapet transition: The SCDOT standard concrete bridge parapet transition shall be used at all barrier ends, where a thrie beam guardrail bridge connector is required. 2. 42-in. Concrete wall: Figure 17.6-1 of the SCDOT Bridge Design Manual illustrates the transition that is required for the 42-in. concrete wall at all rail ends, where a thrie beam guardrail bridge connector is used. For concrete bridge rails with heights other than 42 in., the length of the transition shall be modified as necessary to maintain the 6:1 taper in Figure 17.6-1.  **Figure 17.6-1. End Transition for 42-in. Concrete wall.** Pedestrian Railings: At lower speeds, the sidewalk is separated from the adjacent roadway by a vertical curb, which is typically 6 in. high. However, at higher speeds, the vertical curb will interfere with the proper vehicular/bridge rail interaction. Therefore, the following will apply to the location of a bridge rail in combination with a sidewalk: ✓V ≤ 45 mph. The 42-in. concrete wall is typically located on the outside edge of the sidewalk. ✓V ≥ 50 mph. Place the 32-in. concrete bridge barrier parapet between pedestrians and traffic, i.e., between the roadway portion of the bridge deck and the sidewalk. The 32-in. concrete barrier must have a metal hand rail on top of the barrier to reach the required 42 in. height for a pedestrian rail. A 42-in. pedestrian rail is then used at the outside edge of the sidewalk. For this arrangement, the roadway and sidewalk portions of the bridge deck are at the same elevation. Pedestrian rails are used on bridges with sidewalks, where the roadway and sidewalk are

	separated by a barrier.
Selection Criteria	Materials: Concrete (typical), and metal (special circumstances) Height: Varies according to rail. (See Standard Drawings.) Shape of face: ✓Concrete: F-Shape, Vertical Wall ✓Metal: Varies according to railing type Compliance with NCHRP-350: Bridge railings in South Carolina are required to be in compliance with the NCHRP Report 350. TL-1, TL-2, and TL-6 have no applications in South Carolina; the test levels that apply in South Carolina are the following: ✓TL-3 (Test Level 3). Generally acceptable for a wide range of high-speed arterial highways with very low mixtures of heavy vehicles and with favorable site conditions. Performance crash testing is at 60 mph with a 1.55-kip passenger car and a 4.5-kip pickup truck. ✓TL-4 (Test Level 4). Generally acceptable for the majority of applications on high-speed highways, freeways, and expressways with a mixture of passenger cars, trucks, and other heavy vehicles. Performance crash testing is at 60 mph with a 1.55-kip passenger car and a 4.5-kip pickup truck, plus an 18-kip single-unit truck at 50 mph. ✓TL-5 (Test Level 5). Generally acceptable for the same applications as TL-4, plus where large trucks make up a significant portion of the vehicular mix.
Inspection Procedures	The South Carolina DOT uses the NBIS and AASHTO CoRe Element Manual for the Inspection of their bridge railings.
Railings	1. 32-in. Concrete Bridge Barrier Parapet: SCDOT typically uses this bridge rail on all bridges that do not include sidewalks. The 32-in. concrete bridge barrier parapet, which has the same face configuration as the typical SCDOT concrete median barrier, meets the performance criteria for a TL-4. SCDOT typically uses the Jersey shape for the 32-in. rail instead of the other available concrete bridge rail shapes (e.g., F-shape, constant-slope shape, vertical wall). The concrete bridge rail's advantages when compared to a metal beam rail include its superior performance when impacted by large vehicles, its relatively low maintenance costs, and its better compatibility with the bridge deck system (i.e., the concrete rail can be constructed integrally with the bridge deck). The concrete bridge rail's disadvantages include its higher dead weight. 2. 42-in. Concrete Wall: SCDOT typically uses this rail where sidewalks are present on the bridge. The 42-in. concrete wall is vertical, and its height conforms to the LRFD requirements for pedestrian rails; therefore, its use where sidewalks are present avoids the need to extend the height of a 32-in. concrete bridge rail to meet the height requirements of a pedestrian rail. The 42-in. concrete wall meets the TL-5 performance criteria, although SCDOT does not typically use this barrier for those highway facilities that may warrant consideration for the TL-5 rail. 3. Metal Beam Rail: SCDOT strongly discourages the use of any metal beam bridge rail system. Its use may only be considered where aesthetics or dead loads are very important. When compared to the concrete bridge rail, a metal beam rail's advantages include lower dead weight and providing a more open view of the surrounding scenery. The comparative disadvantages include a lesser ability to contain heavier vehicles, higher maintenance costs, and a more complex structural connection to the bridge deck system. 4. 32-in. Concrete Wall: For bridges that meet all of the following conditions: ✓60 ft or less in length; ✓straight wing walls (i.e., wing walls that are parallel to the centerline of bent); and ✓where sidewalks or bikeways are not provided, a 32-in. reinforced concrete wall with a vertical face shall be used.

Standard Drawings /Plans	No Railing Standard Drawings were found on the internet.
End Treatments	No information was found on the Bridge Design Manual, or the SCDOT Standard Drawings.
Contact Log	Name/Position: Lee Sloid / SCDOT Bridge Maintenance Phone: (803) 737-1494 E-mail: SCDOT_contact@scdot.org
References Used [Accessed Dec. 2009]	Bridge Design Manual (2006) http://www.scdot.org/doing/bridge/06design_manual.shtml

<table>
<tr><th colspan="2">TENNESSEE</th></tr>
<tr><td>Warrants</td><td>Railing Installation: No information was found.

Railing Transition:

Plan Title — Plan No.
Guardrail Attachment at Bridge Ends to Existing Concrete Slope Face Endpost 1989 — SBR 2-131, SBR 2-132
Guardrail Attachment at Bridge Ends to Existing Concrete Vertical Face Endpost 1989 — SBR 2-133, SBR 2-134
Guardrail Attachment to Existing Pier Protection 1991 — SBR 2-135

Pedestrian Railings: No information was found.</td></tr>
<tr><td>Selection Criteria</td><td>Materials: Concrete and metal

Height: Varies according to railing type. See Standard Drawings.

Shape of face: Varies according to railing type. See Standard Drawings.

Compliance with NCHRP-350: No information was found.</td></tr>
<tr><td>Inspection Procedures</td><td>No Bridge Inspection Manual was found on the internet.
TDOT follows the NBIS for the inspection of the bridge railings.</td></tr>
<tr><td>Railings</td><td>Concrete Railings
✓Single Slope
✓New Jersey

Metal Railing
✓W-Beam</td></tr>
<tr><td>Standard Drawings/ Standard Plans</td><td>Plan Title — Plan No.
Bridge Railing Concrete Parapet 1990 — STD 1-1
Bridge Railing Single Slope Concrete Parapet 2006 — STD 1-1SS
Standard Concrete Median Barrier — STD 1-3
Standard Single Slope Concrete Median Barrier 2006 — STD 1-3SS
Steel Slider Plate Assemblies for Concrete Median Barrier 1993 — STD 1-4
Bridge Mounted Interconnected Portable Barrier Rail 2005 — STD 2-1
Bridge Railing Concrete Parapet with Structural Tubing 1988 — STD 11-1
Standard Concrete Classic Rail 2007 — STD 11-2
W-Beam Barrier Posts Details and Specifications — S-GR-12
Barrier Rail Mounting Post Block-Outs with Vertical Adjustment Holes — S-GR-13
Barrier Rail Mounting Post for Plastic Block Outs with Horizontal Adjustment Holes — S-GR-13A
Guardrail Attachments to Concrete Decks of Box and Slab Culverts and Bridges — S-GR-22
Minimum Installation Length for Protective Guardrail At Bridge Ends — S-GR-24</td></tr>
<tr><td>End Treatments</td><td>The most desirable approach end terminal continues to be Item No. 705-04.02, Guardrail Terminal (Type 12). When it is not feasible to use this end terminal, a gating type approach end terminal shall be used.

✓<u>On the designated state highway system</u>, when using gating type approach end terminals, it is required to specify an end terminal that meets NCHRP 350 crash criteria. Item 705-04.07, Tangent Energy Absorbing Terminal (NCHRP 350, TL3) shall be used. End terminals that are specified under this pay item meeting these criteria include: the Extruder Terminal – ET-2000, the Sequential Kinking Terminal – SKT, the Beam Eating Steel Terminal – BEST, or approved equal. These terminals shall be</td></tr>
</table>

<table>
<tr><td></td><td>specified on the construction plans as type 38 terminals. They shall have a length of 50 ft.
✓On all other roads not on the designated state highway system, including side roads to state and U.S. highways, when the current design speed exceeds 40 miles per hour, the same type of terminal meeting the NCHRP 350 crash criteria is required as stated above.
✓On all low speed roads not on the designated state highway system, including side roads to state and U.S. routes, when the current design speed is 40 miles per hour or less, the Slotted Rail Terminal - SRT 75 (Type 21) terminal anchor, or equal shall be used.</td></tr>
<tr><td></td><td><table>
<tr><th>Plan Title</th><th>Plan No.</th></tr>
<tr><td>W-Beam Barrier Terminal Element Details</td><td>S-GR-15</td></tr>
<tr><td>Guardrail Terminal (Type In-Line) and Shoulder Line Detail</td><td>S-GR-18</td></tr>
<tr><td>Guardrail Terminal Anchors Type 12 and Type 13</td><td>S-GR-19</td></tr>
<tr><td>Details for Construction of Type 12 Guardrail Terminal Guardrail Terminal Anchor, Buried in Backslope Type 12</td><td>S-GR-19A</td></tr>
<tr><td>Alternate</td><td>S-GR-19B</td></tr>
<tr><td>Guardrail Terminal Anchor, Type 13Alternate</td><td>S-GR-19C</td></tr>
<tr><td>Length of Need and Terminal Requirements in Fills</td><td>S-GR-21</td></tr>
<tr><td>Guardrail Attachment to Bridge End for Low Volume Local Roads (ADT ≤ 400)</td><td>S-GR-23A</td></tr>
<tr><td>Guardrail Terminal Anchor (Type 21) Post Layout and Erection Details</td><td>S-GR-26</td></tr>
<tr><td>Guardrail Terminal Anchor (Type 21) Element Assembly Details</td><td>S-GR-27</td></tr>
<tr><td>Guardrail Terminal Anchor (Type 21) Post and Assembly Details</td><td>S-GR-28</td></tr>
</table></td></tr>
<tr><td>Contact Log</td><td>Name/Position: Terry Leatherwood
Jeff Jones / Director of Design
Ali Hangul / Standards and Quality Assurance
Phone: (615) 741-0806 / (615) 741-2212 / (615) 741-2806
E-mail: Terry.D.Leatherwood@state.tn.us
Jeff.C.Jones@state.tn.us
Ali.Hangul@state.tn.us</td></tr>
<tr><td>References Used [Accessed Dec. 2009]</td><td>Roadway Design Guidelines (2006)
http://www.tdot.state.tn.us/Chief_Engineer/assistant_engineer_design/design/DesGuide.htm
Standard Drawings
http://www.tdot.state.tn.us/Chief_Engineer/engr_library/stddrlib.htm</td></tr>
</table>

<table>
<tr><th colspan="2">TEXAS</th></tr>
<tr><td>Warrants</td><td>Railing Installation: Bridge railing is required for all bridges, except bridge-class culverts.
As informed by Engineer John Holt, although TxDOT does not mandate bridge rail for bridge class culverts, some form of protection for errant vehicles is required. In order of preference on bridge class culverts, they use safety end treatments, metal beam guard fence, and bridge rails.

Railing Transition: Bridge railing on any Texas bridge must connect with roadside guard railing, if it is present. The connection must comply with the railing transition details of the TxDOT Design Division Standards. Design speeds of 50 mph or greater require a TL-3 transition. Design speeds of 45 mph or less can use a TL-2 or TL-3 transition.

<table>
<tr><th>Plan Title</th><th>Plan No.</th></tr>
<tr><td>Metal Fence Guard Fence Transition</td><td>MBGF(TR)-05</td></tr>
<tr><td>Metal Beam Guard Fence Transition (TL-2)</td><td>MBGF(TL-2)-05</td></tr>
<tr><td>Metal Beam Guard Fence Transition (T101)</td><td>MBGF(T101)-05</td></tr>
</table>

Pedestrian Railings: (FHWA policy) A vehicular bridge with a design speed of 45 mph or less does not require a separator railing, if pedestrians use it.
(TxDOT Policy) Separator railing may be appropriate on lower speed bridges that are close to schools, or that have significant pedestrian traffic. Combination railing is designed for use on the outside of raised sidewalks when no separator railing is used on a facility with design speeds of 45 mph or less.</td></tr>
<tr><td>Selection Criteria</td><td>Materials: The TxDOT uses railings made of concrete, metal and concrete, and metal.

Height: Varies according to railing type. See Standard Drawings.

Shape of face: Varies according to railing type. See Standard Drawings.

Compliance with NCHRP 350: Design speeds of 50 mph and greater require a rail rated at least TL-3. Design speeds of 45 mph and less require a rail rated at least TL-2.</td></tr>
<tr><td>Inspection Procedures</td><td>There is no railing inspection procedure specified in the TxDOT’s Bridge Inspection Manual.</td></tr>
<tr><td>Railings</td><td>Concrete Railings
• Type T201 – TL-3
• Type C201-TL-2
• Type B201-Not crash tested (Bicycle-Pedestrians only)
• Type T203-TL-3
• Type C-203-TL-2
• Type T221-TL-3
• Type C221-TL-2
• Type T411 – TL-2
• Type C411-TL-2
• Type T501- TL-4
• Type T501SW-TL-4
• Type C501-TL-2
• Type T502-TL-4
• Type C502-TL-2
• Type T503-TL-4
• Type T504-TL-4
• Type SSTR – TL-3
• Type TT- TL-6

Metal Railings
• Type T101- TL-3</td></tr>
</table>

	• Type T421-TL-2 • Type T6 - TL-2 • Type PR-1 **Metal and Concrete Railing** • Type T4 (S) – Not crash tested • Type T4 (A) – TL-3 • Type C4 (S) – TL-3 • Type T401- TL-3 • Type T402 – TL-3 • Type C402 – TL-3 • Type T77 – TL-3 • Type HT- TL-5 • Type PR-2	
Standard Drawings/ Standard Plans	**Plan Title**	**Plan No.**
	Metal Beam Guard Fence	MBGF-03A
	Bridge End Details	BED-03
	Concrete Safety Barrier (F-Shape), Precast or Cast-in-Place (Type 1)	CSB(1)-04
	Concrete Safety Barrier (F-Shape), Joint Types for Precast Barrier	CSB(2)-04
	Concrete Safety Barrier (F-Shape), Precast or Cast-in-Place (Bridge)	CSB(3)-04
	Concrete Safety Barrier (F-Shape), Cast-in-Place Barrier at Light Pole (Type 2)	CSB(4)-04
	Concrete Safety Barrier (F-Shape), Bridge and Roadway with Illumination, Pole, Conduit, and Anchor Bolt Details	CSB(5)-04
	Concrete Safety Barrier (F-Shape), Cast-in-Place at Fixed Objects (Type 3)	CSB(6)-04
	Concrete Safety Barrier (F-Shape), Precast Barrier Pinned to Bridge Deck	CSB(7)-04
	Concrete Safety Barrier (F-Shape), Precast (10 foot) Barrier (Type 4)	CSB(8)-04
	Precast Concrete Traffic Barrier, Type 2	PCTB(1)-04
	Precast Concrete Traffic Barrier, Type 2	PCTB(2)-04
	Precast Concrete Traffic Barrier, Type 2	PCTB(3)-04
	Concrete Barrier Rail (Portable and Precast)	CBR (P&P)-04
	Single Slope Concrete Barrier, Type 1 (Bridge)	SSCB(1)-99
	Single Slope Concrete Barrier, Type 2	SSCB(2)-00A
	Single Slope Concrete Barrier, Type 3 (Cast-in-Place at Bridge Ends or Median Obstructions)	SSCB(3)-02
	Single Slope Concrete Barrier, Type 4 (Cast-in-Place, Bridge and Roadway with Illumination)	SSCB(4)-00
	Low Profile Concrete Barrier (Portable and Precast)	LPCB(1)-92
End Treatments	**Plan Title**	**Plan No.**
	Single Guardrail Terminal (ET-2000 PLUS) (Wood Post)	SGT(7)-03A
	Single Guardrail Terminal (ET-2000 PLUS) (Hinged Breakaway Steel Post)	SGT(7)HB-03A
	Single Guardrail Terminal (SKT-350) (Wood Post)	SGT(8)-03A
	Single Guardrail Terminal (SKT-350) (Hinged Steel Post)	SGT(7)-03A
	Single Sided Crash Cushion (BEAT-SSCC)	SSCC-03A
	Crash Cushion Attenuating Terminal Details (2 Sheets)	CATGR(1)-97
	Crash Cushion Attenuating Terminal Details (2 Sheets)	CATCB(1)-97
	Brakemaster® System Terminal Details	BRST(1)-94

	Brakemaster® System Terminal Details	BRST(2)-94
	Quadguard® System (Narrow)	QUAD(N)-99
	Quadguard® System (Wide)	QUAD(W)-99
	Quest System (Wide)	QUEST-06
	Quadguard® (ELITE) System (Narrow)	QGELITE(N)-99
	Quadguard® (ELITE) System (Wide)	QGELITE(W)-99
	Reusable Energy Absorbing Crash Terminal (Narrow REACT 350)(2 Sheets)	REACT(N)-05
	Reusable Energy Absorbing Crash Terminal (Wide REACT 350)	REACT(W)-03
	Trinity Attenuating Crash Cushion (Narrow TRACC® Systems) (FASTRACC, TRACC, SHORTRACC)	TRACC(N)-05
	Trinity Attenuating Crash Cushion (Wide TRACC® Systems) (FASTRACC, TRACC, SHORTRACC)	TRACC(W)-05
	Barrier Systems Attenuating Crash Cushion (Narrow)	TAU-II(N)-05
	Barrier Systems Attenuating Crash Cushion (Wide)	TAU-II(N)-05
	Barrier System Attenuating Crash Cushion (ABSORB 350 System)(For temp. work zone use only)	ABSORB-05
	Smart Cushion (Narrow)	SMTC(N)-06
	Smart Cushion (Wide)	SMTC(W)-06
Contact Log	Name: John Holt Phone: (512) 416-2212 E-mail: jholt@dot.state.tx.us	
References Used [Accessed Dec. 2009]	TxDOT Bridge Railing Manual, 2006 http://onlinemanuals.txdot.gov/txdotmanuals/rlg/index.htm TxDOT Roadway Standards http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/standard/rdwylse.htm	

UTAH	
Warrants	Railing Installation: When parapets are used on bridges and approach slabs, use 42-in. high single-slope parapets, unless approved otherwise by the Deputy Bridge Engineer for Design. Railing Transition: Place any transitions between bridge parapet and roadway barriers on the roadway section, not on the approach slab. For design speeds over 40 mph, a crash tested guardrail transition is required. See Standard Plans for details of the railing transitions used by the Utah DOT (UDOT). **Plan Title** — **Plan No.** Precast Concrete Constant Slope Transition Section For Crash Cushion And W-Beam Guardrail — BA 3B W-Beam Guardrail Transition — BA 4B W-Beam Guardrail Transition Curb Section — BA 4C W-Beam Median Barrier Transition — BA 4R Pedestrian Railings: Use a concrete parapet between the roadway and the sidewalk for design speeds greater than 40 mph. A raised sidewalk protected by curb and gutter may be used for design speeds of 40 mph or less. When curb and gutter is used, a concrete parapet meeting the AASHTO requirements for combination traffic and pedestrian railing is required on the outside edge of sidewalk.
Selection Criteria	Materials: Concrete (UDOT currently uses only concrete parapets on bridges.) Height: Use 42-in. high single-slope parapets, unless approved otherwise by the Deputy Bridge Engineer for Design. Shape of face: Single slope parapets are generally used by UDOT, unless approved otherwise by the Deputy Bridge Engineer for Design. Compliance with NCHRP-350: No information was found.
Inspection Procedures	National Bridge Inspection Standards AASHTO Guide for Commonly Recognized Structural Elements
Railings	Concrete Railings ✓Constant Slope ✓New Jersey Shape
Standard Drawings / Standard Plans	The Standard Drawings for UDOT parapets were provided by Engineer Ray Cook, since they are not available in UDOT's website. **Plan Title** — **Sheet No.** Parapet Details (Constant Slope) — 1 Parapet End Details (Constant Slope) — 2 Parapet Details (New Jersey Shape) — 3 Median Parapet Details (New Jersey Shape) — 4 Parapet End Details (New Jersey Shape) — 5-6 Parapet Transition Details (New Jersey Shape) — 7-8 The following are two plans from UDOT Roadway Barrier Standards, which can be used for box culvert structures, according to information provided by Mr. Ray Cook. **Plan Title** — **Plan No.** W-Beam Guardrail Nested Guardrail 25 ft Span — BA 4O W-Beam Guardrail With Precast Barrier For Span > 25 ft — BA 4P
End Treatments	Protect the ends of bridge parapets within the clear zone from traffic impacts. If an attenuator is used, do not locate it on the bridge or the approach slab, unless there is no alternative.

	Plan Title	Plan No.
	Precast Concrete Barrier Terminal For Speed ≤ 40 mph	BA 1C
	W-Beam Guardrail Buried In Backslope Terminal	BA 4I
	W-Beam Guardrail Buried In Backslope Terminal w/Rub Rail	BA 4J
	W-Beam Guardrail Buried In Backslope Terminal Anchor	BA 4K
Contact Log	Name / Position: Richard Miller / UDOT Bridge Design Chris Potter / Bridge Operations Phone: (801) 957-8556 / (801) 633-6225 E-mail: richardmiller@utah.gov, cpotter@utah.gov	
References [Accessed Dec. 2009]	UDOT Structure Design Manual Section 3.3.4 http://www.udot.utah.gov/main/f?p=100:pg:12302720542229821131:::1:T,V:1730 UDOT 2005 Standard Drawings (Updated 2008) http://www.udot.utah.gov/main/f?p=100:pg:0::::T,V:1941,	

VIRGINIA	
Warrants	Virginia DOT does not have a Bridge Design Manual; they follow AASHTO Bridge Design Specifications. Railing Installation: No information was found. Railing Transition: No information was found. Pedestrian Railings: No information was found.
Selection Criteria	Materials: Concrete and metal Height: Varies according to railing type. See Standard Drawings. Shape of face: Varies according to railing type. See Standard Drawings. Compliance with NCHRP-350: According to AASHTO Bridge Design Specifications, 2007, all railings used on new and rehabilitation projects should be in compliance with NCHRP-350.
Inspection Procedures	The inspections are conducted in accordance with National Bridge Inspection Standards. The Bridge Inspector Reference Manual is also used as a guide for inspecting bridge rails.
Railings	Concrete Railings ✓Kansas Corral ✓F-Shape Metal Railings ✓Illinois 2399 ✓BR27C Series ✓BR27D Series
Standard Drawings	**Plan Title** — **Plan No.** **CONCRETE RAILING (KANSAS CORRAL)** Railing With Curbing (2 ft-3 in. height) — *BCR-1 -1 Railing Without Curbing (2 ft-3 in. height) — *BCR-2 -1 Railing With Curbing (2 ft-8 in. height) — *BCR-3 -1 Railing Without Curbing (2 ft-8 in. height) — *BCR-4 -1 **STEEL RAILING (ILLINOIS 2399)** Railing with Terminal Wall and U-Back Wing on Abut. — *BIR-1 -1 Railing with Terminal Wall on Abutment — *BIR-2 -1 Railing – Miscellaneous Details — *BIR-3 -1 **PARAPET DETAILS** F-Shape with Terminal Wall and U-Back Wing on Abut — *BPB-3A -1 F-Shape with Terminal Wall on Abutment — *BPB-3B -1 **STEEL RAILING (BR27C-SERIES)** Railing with Terminal Wall and U-Back Wing on Abut. — *BR27C-1 -1 Railing with Terminal Wall on Abutment — *BR27C-2 -1 Railing – Miscellaneous Details — *BR27C-3 -1 Railing with Terminal Wall and U-Back Wing on Abut. — *BR27C-4 -1 Railing with Terminal Wall on Abutment — *BR27C-5 -1 Railing with Terminal Wall and U-Back Wing on Abut. — *BR27C-6 -1 Railing with Terminal Wall on Abutment — *BR27C-7 -1 Railing with Terminal Wall and U-Back Wing on Abut. — *BR27C-8 -1

	Railing with Terminal Wall on Abutment	*BR27C-9 -1	
	Railing with Terminal Wall and U-Back Wing on Abut.	*BR27C-10 -1	
	Railing with Terminal Wall on Abutment	*BR27C-11 -1	
	STEEL RAILING (BR27D-SERIES)		
	Railing with Terminal Wall and U-Back Wing on Abut.	*BR27D-1 -1	
	Railing with Terminal Wall on Abutment	*BR27D-2 -1	
	Railing – Miscellaneous Details	*BR27D-3 -1	
	Railing with Terminal Wall and U-Back Wing on Abut.	*BR27D-4 -1	
	Railing with Terminal Wall on Abutment	*BR27D-5 -1	
	Railing with Terminal Wall and U-Back Wing on Abut.	*BR27D-6 -1	
	Railing with Terminal Wall on Abutment	*BR27D-7 -1	
End Treatments	**Plan Title**	**Plan No.**	**Page No.**
	Terminal Treatment for W-Beam Guardrail	GR-6	501.09-501.10
	Breakaway Cable Terminal- 4 ft Flare	GR-7	501.11-501.13
	Guardrail Terminal Installation Site Preparations for GR-7	GR-SP	501.16-501.17
	Alternate Breakaway Cable Terminal- No Flare	GR-9	501.18
	Trailing End Terminal Treatment	GR-11	501.21
	Cast in Place Concrete Median Barrier 12-ft Terminal Section	MB-9A	501.49
	Precast Concrete Median Barrier 12-ft Terminal Section	MB-9A PC	501.50
Contact Log	Name: Ahmad Anwar Phone: (804)786 -2853 E-mail: anwar.ahmad@VDOT.virginia.gov		
References Used [Accessed Dec. 2009]	Manual of the Structure and Bridge Division-Volume V-Part 3 Current Details http://www.virginiadot.org/business/bridge-manuals.asp		

<table>
<tr><th colspan="2">WASHINGTON</th></tr>
<tr><td>Warrants</td><td>
Railing Installation: The WSDOT Bridge and Structures standard for new bridge traffic barriers is a 32-in. high F-Shape concrete barrier. This shall be used on all interstate, major highway routes, and over National Highway System (NHS) routes.

Use of a Single Slope concrete bridge traffic barrier shall be limited to when there is Single Slope concrete barrier on the approach grade to a bridge, or for continuity within a corridor. The Single Slope bridge traffic barrier is 34 in. high to be consistent with the heights being used on grade applications. (See WSDOT Design Manual Section 710 for additional background and criteria.)

Use the taller 42-in. high bridge traffic barriers on interstate or freeway routes, only in the following circumstances:
• Accident history suggests a need.
• Large trucks make up a significant portion of the ADT.
• Adverse roadway geometrics increase the possibility of hitting the traffic barrier at a high angle (such as on ramps for freeway to freeway connections with sharp curvature in the alignment).
• Protection of schools, businesses or other important facilities below the bridge.

Railing Transition: Transition details are shown in Standard Plans C-3 thru C-3c.
✓Transitions must be nested (two layers). In most cases, this will be thrie-beam. W-beam is allowed only when there is insufficient bridge rail height to accommodate the thrie-beam transition.
✓Post spacing should decrease in the transition, resulting in gradual stiffening as a vehicle moves along the transition from a flexible guardrail to the more stiff concrete bridge rail.
✓Type III transitions (hollow steel post) are not acceptable on new and rehabilitation projects. They may remain in place when retrofitting a bridge rail, if the conditions are met and do not create a snagging hazard.

Plan Title — Plan No.
Guardrail Transition Sections — C-3, C-3A, C-3B, C-3C
Concrete Barrier Transition, Type 2 to Bridge F-Shape — C-8F
Concrete Barrier Transition, Type 2 to Single Slope — C14-B
Single Slope Concrete Barrier Transition Section — C-14D

Pedestrian Railings: WSDOT pedestrian and bike/pedestrian railings are designed in accordance with Chapter 13 in the AASHTO LRFD Bridge Design Specifications.

The pedestrian crash tested rail system presented below offers a simple to build concrete alternative to the New Jersey and F-Shape configurations. This system was crash tested under both NCHRP 230 and 350. Since the traffic face geometry is better for pedestrians and bicyclists, WSDOT uses this system primarily in conjunction with a sidewalk. For complete details, see Appendix 10.2-A4.

Plan Title — Plan No.
Pedestrian Barrier Details — 10.2-(A4-1-A4-3)
</td></tr>
<tr><td>Selection Criteria</td><td>
Materials: Concrete and metal

Height: The preferred height is 32 in. When circumstances require it, the use of a 42-in. height barrier is allowed.

Shape of face: Varies according to railing type.

Compliance with NCHRP-350: WSDOT's bridge traffic barrier standard test level is a TL-4.
</td></tr>
<tr><td>Inspection Procedures</td><td>
See the Washington State Bridge Inspection Manual, December 2006.
http://www.wsdot.wa.gov/publications/manuals/fulltext/m36-64/BridgeInspection.pdf
</td></tr>
</table>

<table>
<tr><td>Railings</td><td>
TL-2
✓Weak Post Guardrail: This bridge traffic barrier is a crash tested weak post rail system. It was developed by Southwest Research Institute and reported in NCHRP Report 239 for low volume rural roadways with little accident history. We have utilized this design on some of our short concrete spans and on our timber bridges. A failure mechanism is built into this rail system such that upon a 2-kip applied impact load the post will break away from the mounting bracket. The thrie beam guardrail will contain the vehicle by virtue of its ribbon strength. This failure mechanism assures minimum damage, if any at all, to the bridge deck and stringers. For complete details, see Appendix 10.4-A1.
✓Texas T-411Aesthetic Concrete Baluster

TL-4
✓F-Shape
✓Single Slope
✓Pedestrian Barrier
✓Oregon 2-Tube Curb Mounted
TL-5
✓F-Shape 42 in.
✓Single Slope 42 in.
</td></tr>
<tr><td>Standard Drawings / Standard Plans</td><td>
Appendix 10 of WSDOT’s Bridge Design Manual
<table>
<tr><th>Plan Title</th><th>Plan No.</th></tr>
<tr><td>Shape F Traffic Barrier Detail 1 of 3</td><td>10.2-A1-1</td></tr>
<tr><td>Shape F Traffic Barrier Detail 2 of 3</td><td>10.2-A1-2</td></tr>
<tr><td>Shape F Traffic Barrier Detail 3 of 3</td><td>10.2-A1-3</td></tr>
<tr><td>Shape F Traffic Barrier on Flat Slab Details 1 of 3</td><td>10.2-A2-1</td></tr>
<tr><td>Shape F Traffic Barrier on Flat Slab Details 2 of 3</td><td>10.2-A2-2</td></tr>
<tr><td>Shape F Traffic Barrier on Flat Slab Details 3 of 3</td><td>10.2-A2-3</td></tr>
<tr><td>Traffic Barrier Shape F 42 in. Sheet 1 of 3</td><td>10.2-A5-1</td></tr>
<tr><td>Traffic Barrier Shape F 42 in. Sheet 2 of 3</td><td>10.2-A5-2</td></tr>
<tr><td>Traffic Barrier Shape F 42 in. Sheet 3 of 3</td><td>10.2-A5-3</td></tr>
<tr><td>Traffic Barrier - Shape F Luminaire Anchorage Detail</td><td>10.2-A7-1</td></tr>
<tr><td>Traffic Barrier - Single Slope Luminaire Anchorage Detail</td><td>10.2-A7-2</td></tr>
<tr><td>Single Slope Traffic Barrier Details 1 of 3</td><td>10.2-A3-1</td></tr>
<tr><td>Single Slope Traffic Barrier Details 2 of 3</td><td>10.2-A3-2</td></tr>
<tr><td>Single Slope Traffic Barrier Details 3 of 3</td><td>10.2-A3-3</td></tr>
<tr><td>Traffic Barrier - Single Slope 42 in. Sheet 1 of 3</td><td>10.2-A6-1</td></tr>
<tr><td>Traffic Barrier - Single Slope 42 in. Sheet 2 of 3</td><td>10.2-A6-2</td></tr>
<tr><td>Traffic Barrier - Single Slope 42 in. Sheet 3 of 3</td><td>10.2-A6-3</td></tr>
</table>
WSDOT Design Standards
<table>
<tr><th>Plan Title</th><th>Plan No.</th></tr>
<tr><td>Concrete Barrier Type 2</td><td>C-8</td></tr>
<tr><td>Concrete Barrier Type 4 and Transition Section</td><td>C-8A</td></tr>
<tr><td>Single Slope Barrier Pre-Cast Type</td><td>C-13</td></tr>
<tr><td>Single Slope Barrier Pre-Cast Type, Single Sided Section</td><td>C-13B</td></tr>
<tr><td>Single Slope Concrete Barrier (Dual Face)</td><td>C-14A</td></tr>
<tr><td>Single Slope Concrete Barrier Terminal</td><td>C-14C</td></tr>
<tr><td>Single Slope Concrete Barrier Vertical Back</td><td>C-14E</td></tr>
<tr><td>Single Slope Concrete Barrier (Splitting or merging)</td><td>C-14F</td></tr>
<tr><td>Single Slope Concrete Barrier Placement (Taper for pier wrap)</td><td>C-14G</td></tr>
</table>
</td></tr>
</table>

End Treatments	Acceptable guardrail terminals are: 1) Buried terminals (See Standard Plans C-4 and C-4a.) 2) Bent back, slotted terminals with anchor cables (See Design Manual Figure 710-13.) 3) Square terminals with end piece designed to turn over when impacted (See Design Manual Figure 710-13.) 4) Attenuator style terminals (don't need to be slotted) (See Design Manual Section 720.) 5) Inertial barriers (barrels filled with sand) (See Design Manual Section 720.) 6) Median bullnose terminals (See Standard Plan C-4f.).
Contact Log	Name/Position: Ryan Collins/Bridge and Structures Engineer Phone: (360) 705-7210 E-mail: COLLINSR@wsdot.wa.gov
References Used [Accessed Dec. 2009]	Bridge Design Manual http://www.wsdot.wa.gov/eesc/bridge/bdm/ Washington State Bridge Inspection Manual, December 2006. http://www.wsdot.wa.gov/publications/manuals/fulltext/m36-64/BridgeInspection.pdf WSDOT Standard Plans, 2008 http://www.wsdot.wa.gov/Design/Standards/Plans.htm#SectionC

WISCONSIN	
Warrants	Railing Installation: Railings must meet the criteria for TL-3 or greater to be used on all roadways. Railings meeting TL-2 criteria may be used on roadways, where the speed is 45 mph or less. The application of the railings used by the WisDOT is stated in the Bridge Manual. Standard Railing Details are generally employed as follows: 1. The "LF" railing is preferred on state and interstate highway bridges, except for some limited short span structures. An LF or solid parapet is preferred on all grade separation structures and railroad crossings to minimize snow removal falling on the traffic below. These railings meet crash test criteria for TL-4. 2. The "HF" railing is used where there is high truck traffic and curved horizontal alignment, creating more potential for overtopping the railing. These railings meet crash test criteria for TL-4. 3. Type "H" aluminum or steel railings are detailed on the Vertical Face Parapets "A" for sidewalks. If the structure has a sidewalk on one side only, the Sloped Face Parapet without railing is used on the side opposite the sidewalk. The Sloped Face Parapet is the recommended safety barrier adjacent to sidewalks on structures, where the traffic speed is 45 mph or greater. Meets criteria for TL-4. 4. Type "F" steel railings are not allowed on the National Highway System (NHS). Type “F” railing may be used on non-NHS roadways with speeds of 45 mph or less. This railing facilitates drainage and snow removal but is usually more expensive than the Sloped Face Parapet, if drains are not required at the ends of the bridge. Approach roadway beam guard railing is not required for bridges carrying less than 300 ADT. In order to meet AASHTO Specifications, three or more posts are attached to the Type "F" railing. May be used when TL-2 criteria is required. 5. Type “M” steel railings are used on state maintained bridges, where the District insists on an open railing. It is similar to the Type “F” but has a higher crash test rating. Used in place of the Type “W” rail on girder type structures. Meets criteria for TL-4. 6. Type "W" railings may be used on all functional classes of Wisconsin highway structures. Generally, Type "W" railing is considered when the highway approach requires standard beam guard and if the structure is 80 ft or less in length. Type "W" railing is used on bridge widenings when parapet dead load is a concern. Meets criteria for TL-3. The Type “W” rail shall only be used on concrete slab structures. The use of this railing on girder type structures shall be discontinued. 7. Aesthetic railings may be used if crash tested, according to Section 30.1. The Texas style parapet, Type “TX,” has been crash tested but it is very expensive. Form liners to simulate the openings would reduce the cost of this parapet. Meets criteria for TL-2. 8. The Standards show some combination Railings that are approved as aesthetic railings, Type “C1” through “C6.” The aesthetic additions are at least 5 in. from the crash tested rail face and do not present a snagging potential. Meets criteria for TL-2. 9. The “51F” railing may only be used on the median side, when it provides a continuation of the approach 51-in. high median barrier. 10. The Type “PF” tubular railings are not allowed on the National Highway System (NHS). Type “PF” railing may be used on non-NHS roadways with speeds of 45 mph or less. This railing is similar to the Type “F” railing with two main differences. The height of this rail meets the requirements for pedestrian facilities. This is a solid rail type that can be used on a grade separation structure. May be used when TL-2 criteria is required. 11. Approach beam guard railing is not required for box culverts carrying less than 300 ADT. If this is the case, the box culvert beam guard railing is terminated with

	a buffer section. Railing is not required on box culverts, if there is a clear zone as defined in Facilities Development Manual 11-15-1. Non-Traversable hazards or fixed objects should not be constructed or allowed to remain within the clear zone. When this is not feasible, the use of a traffic barrier to shield the hazard or obstacle may be warranted. The barrier shall be provided only when it is cost effective, as defined in Facilities Development Manual Procedure 11-45-1. 12. When the structure approach beam guard is extended across the box culvert, refer to Standard Detail, Box Culvert Details for additional information. The minimum dimension between end of box and face of guard rail provides an acceptable rail deflection to prevent a vehicle wheel from traversing over the end of the box culvert. In almost every case, the timber posts with offset blocks and standard beam guard are used. Type "W" railing may be used for maintenance and box culvert extensions to mitigate the effect of structure modifications. Railing Transition: **Plan Title** — **Plan No.** Steel Thrie Beam Structure Approach, Connection to Square End and Vertical Faced Parapets — 14B20-6b Steel Thrie Beam Structure Approach, Connection to Sloped End Parapets — 14B20-6c Steel Thrie Beam Structure Approach, Connection to Bridge Railing Type “F” and “W” — 14B20-7d Steel Thrie Beam Structure Approach, Connection to Bridge Railing Type “M” — 14B20-8e Pedestrian Railings: **Plan Title** — **Plan No.** Combination Railings Types “C1-C-6” — W-30.17 Combination Railings Details — W-30.18
Selection Criteria	Materials: Concrete, metal (aluminum and steel), and timber Height: Varies according to railing type. (See Standard Drawings.) Shape of face: Varies according to railing type. (See Standard Drawings.) Compliance with NCHRP-350: All bridge railings must have passed the crash tests, as recommended in the NCHRP report 350 for Bridge Railings. In order to use railings other than Bridge Office Standard railing details, the railings must conform to crash tested rails, which are available from the FHWA office. Any railings that are not crash tested must be reviewed by FHWA when they are used on bridge, culvert, retaining wall, etc.
Inspection Procedures	Found in: Wisconsin Structure Inspection Manual (available as CD, or paper copy).
Railings	Concrete Railings: ✓Vertical Face Parapet “A” ✓Sloped Face Parapet “LF” ✓Sloped Face Parapet “HF” ✓Vertical Face Parapet “TX” ✓Sloped Face Parapet “51F” Metal Railings: ✓Tubular Steel Railing Type “F” ✓Tubular Steel Railing Type “H” ✓Steel Railing Type “W” ✓Tubular Steel Railing Type “M”

	✓Tubular Aluminum Railing Type “H” ✓Railing Tubular PF <u>Timber Railing</u>	
Standard Drawings / Standard Plans	**Plan Title**	**Plan No.**
	Tubular Steel Railing Type F	W-301
	Steel Railing Type W	W-302
	Aluminum Tubular Railing Type H	W-304
	Steel Tubular Railing Type H	W-305
	Vertical Face Parapet A	W-307
	Sloped Face Parapet “LF”	W-3012
	Sloped Face Parapet “HF”	W-3013
	Tubular Steel Railing Type “M”	W-3016
	Vertical Face Parapet “TX”	W-3019
	Sloped Face Parapet “51F”	W-3020
	Railing Tubular PF	W-3022
	Railing Tubular PF Details	W-3023
	Timber Railing Attached to Concrete Slab	W-3024
	Timber Railing Attached to Concrete Slab Details	W-3025
End Treatments	**Plan Title**	**Plan No.**
	Steel Plate Beam Guard, Class "A" End Treatment with Anchorage For Steel Plate Beam Guard	14B17-3
	Steel Plate Beam Guard Energy Absorbing Terminal	14B24-4a ,b & c
	Steel Thrie Beam Bullnose Terminal	14B26-1a,b,c,d,&e
Contact Log	Name: Shiv Gupta Phone: (608) 266 - 5164 E-mail: shiv.gupta@dot.state.wi.us	
References Used	Bridge Manual http://on.dot.wi.gov/dtid_bos/extranet/structures/LRFD/index.htm Wisconsin DOT Facilities Development Manual (Ch16: Std. Detail Drawings) http://roadwaystandards.dot.wi.gov/standards Standard Details http://on.dot.wi.gov/dtid_bos/extranet/structures/LRFD/index.htm	

Appendix B: Bridge Traffic Safety Features Inspection Forms

The inspection forms were developed in this study to assist inspectors in the assessment of traffic safety barriers in bridges.

BRIDGE TRAFFIC SAFETY FEATURES INSPECTION FORM

SITE IDENTIFICATION	State	Road No.	County / Township
	Year Built	Year Reconstructed	Inspection Date
	Road Functional Class	AADT / Date of AADT	Number of Lanes
	Posted Speed V_P (mph)	Design Speed V_D (mph)	Roadway Type ☐ Divided ☐ Undivided
	Mileposts / Mileposts From _____ To _____	Direction of Traffic ☐ Highway traffic not carried ☐ 1-way traffic ☐ 2-way traffic ☐ One-lane bridge 2-way traffic	Inspector: _____ E-mail: _____ Phone: _____
BRIDGE INFORMATION	NBI Structure No.	Bridge Material	Type of Service
	Bridge Length (ft)	Number of Spans	Pavement Type
	Bridge Roadway Width (ft)	Number of Lanes	Pavement Markings EDGE: LEFT ☐ YES ☐ NO RIGHT ☐ YES ☐ NO CENTER: ☐ YES ☐ NO
	Shoulder Width L _____ft ☐ Not present R _____ft ☐ Not present	Sidewalk Width L _____ft ☐ Not present R _____ft ☐ Not present	

PLAN VIEW OF BRIDGE AND APPROACH ROADWAY CONFIGURATION

Direction of Inspection ☐ NB ☐ SB ☐ WB ☐ EB

*** Only for bridges with one-way traffic** ☐ Left Side ☐ Right Side

Section 3A BRIDGE ENTRY INFLUENCE ZONE

Length of Influence Zone

Intersection ☐ YES ☐ NO

Type: ☐ T-intersection ☐ Four-leg intersection ☐ Other

Horizontal Curve ☐ YES ☐ NO

Radius: _____
Superelevation: _____
Length: _____

Vertical Curve ☐ YES ☐ NO

Type ☐ Crest ☐ Sag

Visibility of Bridge ☐ YES ☐ NO If NO, indicate the available sight distance _____ ft

Section 4A BRIDGE EXIT INFLUENCE ZONE

Length of Influence Zone

Intersection ☐ YES ☐ NO

Type: ☐ T-intersection ☐ Four-leg intersection ☐ Other

Horizontal Curve ☐ YES ☐ NO

Radius:_____
Superelevation:_____
Length:_____

Vertical Curve ☐ YES ☐ NO

Type ☐ Crest ☐ Sag

Sight Obstructions ☐ YES ☐ NO If YES, describe _____

Section 5A APPROACH ROADWAY INFORMATION

Traveled Way Width (ft)

Shoulder Width
L _____ft ☐ Not present
R _____ft ☐ Not present

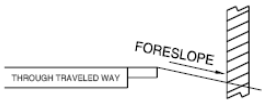
Sidewalk Width
L _____ft ☐ Not present
R _____ft ☐ Not present

Roadway Grade (%)

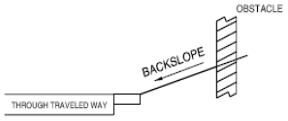
Pavement Type

Pavement Markings
EDGE:
L ☐ YES ☐ NO
R ☐ YES ☐ NO
CENTER: ☐ YES ☐ NO

Foreslope: L ____ R _____



Backslope: L _____ R: _____

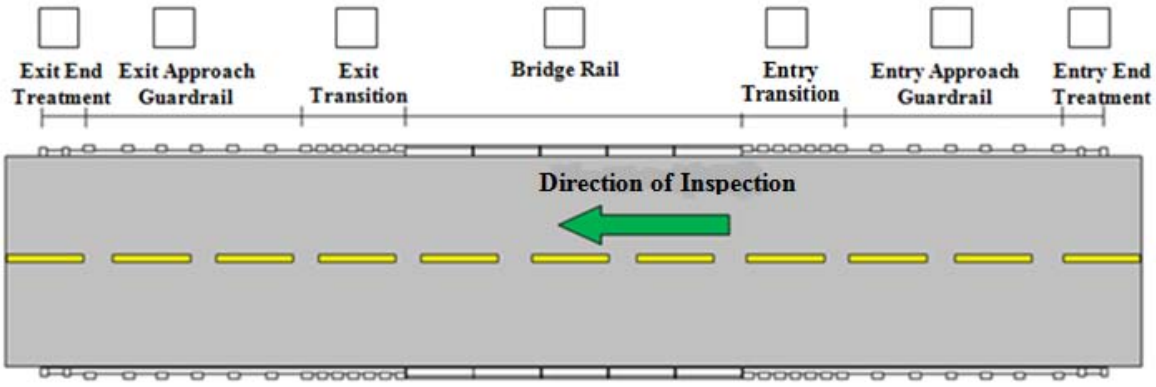


Existing Clear Zone _____ft

Required Clear Zone _____ft

EXISTING TRAFFIC SAFETY FEATURES ON THE BRIDGE

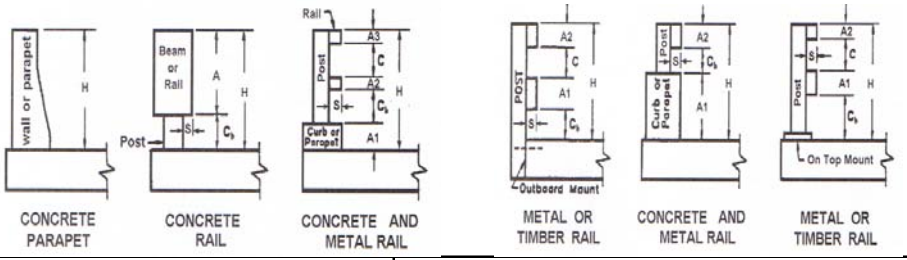
Complete the requested information in the next sections corresponding to the existing safety features.



ENTRY END TREATMENT	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
ENTRY APPROACH GUARDRAIL	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
	Flare Rate			☐ YES ☐ NO
	Lateral Offset			☐ YES ☐ NO
	Length of Need			☐ YES ☐ NO
ENTRY TRANSITION	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO
BRIDGE RAILING	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Lateral Offset			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Sketch of Bridge Railing			**Check the snagging potential and the post setback criteria of existing bridge rails on section 13.**

EXIT TRANSITION	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO
EXIT APPROACH GUARDRAIL	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
	Flare Rate			☐ YES ☐ NO
	Lateral Offset			☐ YES ☐ NO
	Length of Need			☐ YES ☐ NO
EXIT END TREATMENT	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO

Section 13A: CHECKS FOR BRIDGE RAILING COMPLIANCE WITH NCHRP 230 CRITERIA
(*Applies only for existing bridge railings approved by NCHRP 230 criteria)



Railing Contact Width ∑ A=_____ A_1=_____ A_2 = _____ A_3 =_____ ∑ A/H=_____	Vertical Clear Opening C =_____ Post Setback Distance S =_____

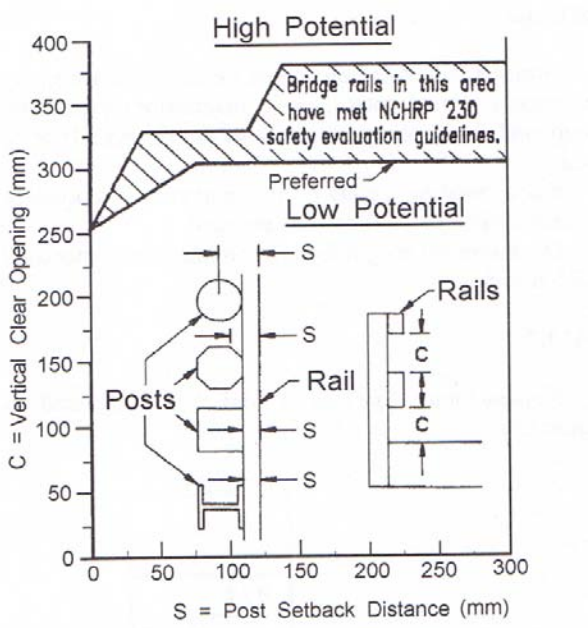


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

Use Figure A13.1.1-2

SNAGGING POTENTIAL

☐ LOW

☐ MEETS NCHRP 230

☐ HIGH

Use Figure A13.1.1-3

POST SETBACK CRITERIA

☐ NOT RECOMMENDED

☐ MEETS NCHRP 230

☐ PREFERED

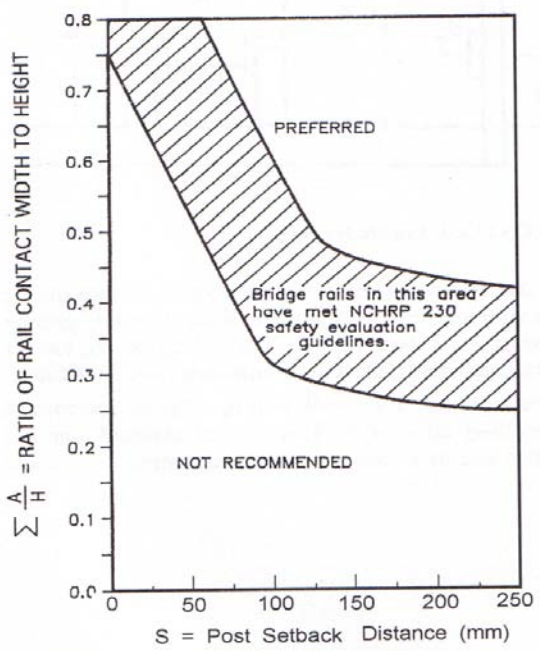


Figure A13.1.1-3 Post Setback Criteria.

Direction of Inspection ☐ NB ☐ SB ☐ WB ☐ EB

*** Only for bridges with one way traffic** ☐ Left Side ☐ Right Side

Section 3B BRIDGE ENTRY INFLUENCE ZONE

Length of Influence Zone

Intersection ☐ YES ☐ NO

Type: ☐ T-intersection ☐ Four-leg intersection ☐ Other

Horizontal Curve ☐ YES ☐ NO

Radius: _____
Superelevation: _____
Length: _____

Vertical Curve ☐ YES ☐ NO

Type ☐ Crest ☐ Sag

Visibility of Bridge ☐ YES ☐ NO If NO, indicate the available sight distance _____

Section 4B BRIDGE EXIT INFLUENCE ZONE

Length of Influence Zone

Intersection ☐ YES ☐ NO

Type: ☐ T-intersection ☐ Four-leg intersection ☐ Other

Horizontal Curve ☐ YES ☐ NO

Radius:_____
Superelevation:_____
Length:_____

Vertical Curve ☐ YES ☐ NO

Type ☐ Crest ☐ Sag

Site Obstructions ☐ YES ☐ NO If YES, describe _____

Section 5B APPROACH ROADWAY INFORMATION

Roadway Width

Shoulder Width
L _____ ☐ Not present
R _____ ☐ Not present

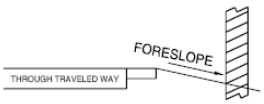
Sidewalk Width
L _____ ☐ Not present
R _____ ☐ Not present

Roadway Grade

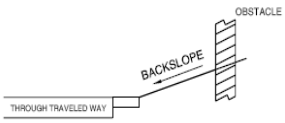
Pavement Type

Pavement Markings
EDGE:
L ☐ YES ☐ NO
R ☐ YES ☐ NO
CENTER: ☐ YES ☐ NO

Foreslope: L ____ R _____

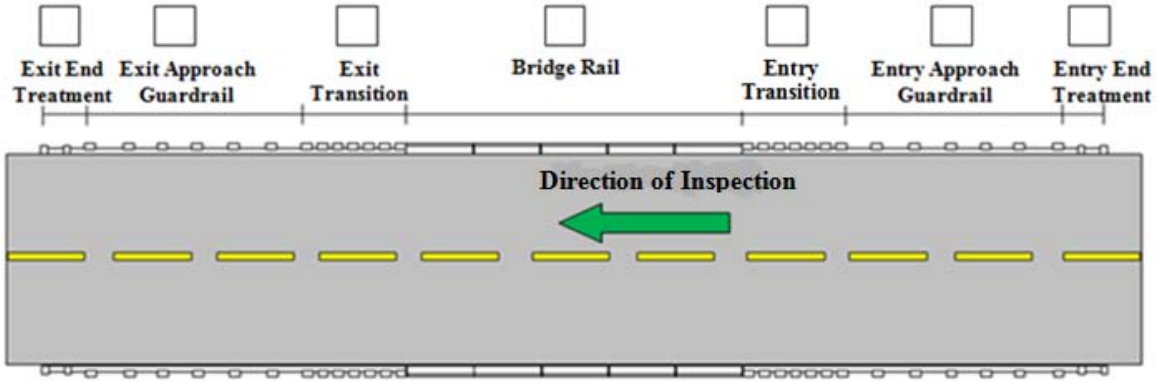


Backslope: L _____ R: _____



Existing Clear Zone: _____
Required Clear Zone (See Table 3.1 of AASHTO *Roadside Design Guide*)
_____

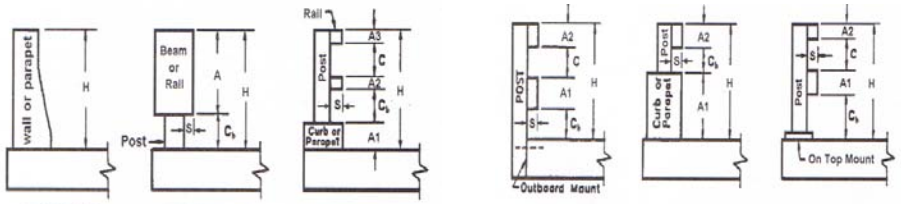
CHECK THE EXISTING TRAFFIC SAFETY FEATURES ON THE BRIDGE BEING INSPECTED
(Fill out the information in the following sections that correspond to the existing safety features)



ENTRY END TREATMENT	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
ENTRY APPROACH GUARDRAIL	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
	Flare Rate			☐ YES ☐ NO
	Lateral Offset			☐ YES ☐ NO
	Length of Need			☐ YES ☐ NO
ENTRY TRANSITION	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO
BRIDGE RAILING	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Lateral Offset			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Sketch of Bridge Railing			**Check the snagging potential and the post setback criteria of existing bridge rails on section 13.**

EXIT TRANSITION	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO
EXIT APPROACH GUARDRAIL	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
	Flare Rate			☐ YES ☐ NO
	Lateral Offset			☐ YES ☐ NO
	Length of Need			☐ YES ☐ NO
EXIT END TREATMENT	Type: _____	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO

Section 13B: CHECKS FOR BRIDGE RAILING COMPLIANCE WITH NCHRP 230 CRITERIA
(*Applies only for existing bridge railings approved by NCHRP 230 criteria)



Railing Contact Width ∑ A=_____ A_1=_____ A_2 = _____ A_3 =_____ ∑ A/H=_____	Vertical Clear Opening C =_____ Post Setback Distance S =_____

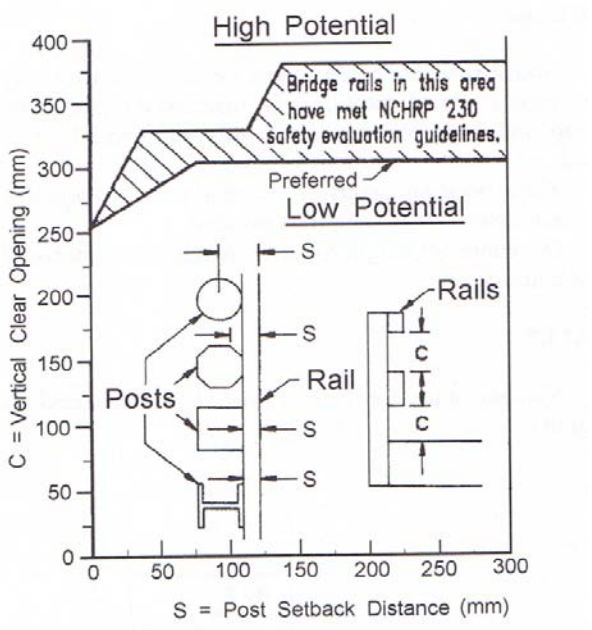


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

Use Figure A13.1.1-2

SNAGGING POTENTIAL

☐ LOW

☐ MEETS NCHRP 230

☐ HIGH

Use Figure A13.1.1-3

POST SETBACK CRITERIA

☐ NOT RECOMMENDED

☐ MEETS NCHRP 230

☐ PREFERED

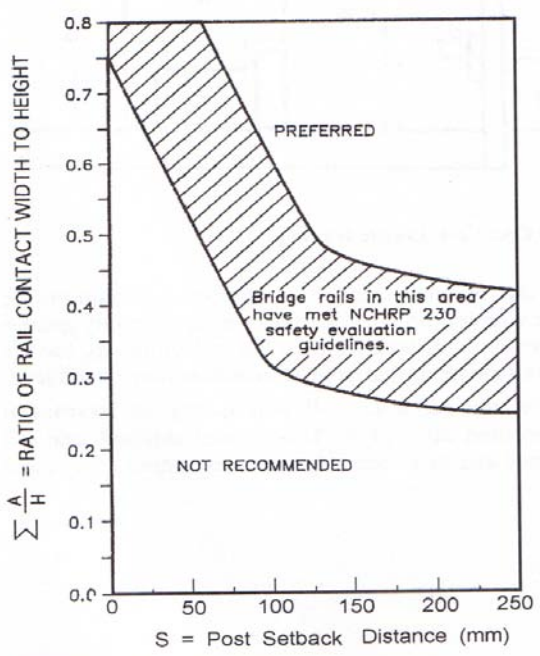


Figure A13.1.1-3 Post Setback Criteria.

Assessment of Traffic Safety Features			
ection of Inspection ☐ NB ☐ SB ☐ WB ☐ EB		Direction of Inspection ☐ NB ☐ SB ☐ WB ☐ EB	
ly for bridges with one way traffic ☐ Left Side ☐ Right Side		***Only for bridges with one way traffic** ☐ Left Side ☐ Right Side	
Element	**Rating**	**Element**	**Rating**
ry End Treatment	_____	Entry End Treatment	_____
ry Approach Guardrail	_____	Entry Approach Guardrail	_____
ry Transition	_____	Entry Transition	_____
lge Railing	_____	Bridge Railing	_____
: Transition	_____	Exit Transition	_____
: Approach Guardrail	_____	Exit Approach Guardrail	_____
: End Treatment	_____	Exit End Treatment	_____

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14. ABSTRACT

This report presents the results of the initial phase of a research study with the objective of documenting the current state-of-the-practice, at the national level and for the 32 states and the Commonwealth of Puerto Rico having military installations, related to the requirements, selection criteria, and inspection process for bridge safety barriers. The focus of the study was directed at identifying policies and recommended practices related to low speed, low volume road environments.

This report includes basic policies and guidelines from pertinent Federal Highway Administration (FHWA) and American Association of State Highway and Transportation Officials (AASHTO) documents that deal with aspects of roadway geometric design, roadside design, and safety barrier practices and their relation to bridge safety. Information is included about FHWA-approved crashworthy bridge railing systems used by some states.

State-specific tables that summarize the relevant information about the requirements and practices related to bridge safety barriers are included in this report. The tables were developed based on the review performed from the documents collected from each of the 33 jurisdictions and from FHWA and AASHTO sources.

An inspection procedure and field forms were developed for bridge inspectors to use in performing an evaluation of traffic safety features on bridges. The procedure and forms were developed from a comprehensive review of documents and current practices and include elements that are necessary for the consideration of traffic and user safety on public roads. Future research phases could include validation of the inspection process and use of the forms through implementation exercises and consideration of existing roadway conditions in military installations.

15. SUBJECT TERMS

Bridge railing
Low volume road
Traffic safety
Low speed traffic
Railing

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