METHODOLOGY FOR THE EVALUATION OF SAFETY APPURTENANCES FOR BRIDGES ON LOW SPEED RURAL ROADS

By

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ABSTRACT

Bridges are vital elements of the transportation infrastructure. There are over 600,000 bridges in the United States and Puerto Rico, which are required to be inspected in accordance with the National Bridge Inspection Standards, and reported on the National Bridge Inventory. The inspection of bridges has concentrated primarily on the structural aspects of the bridge, leaving the traffic safety components on the bridge and its approaches as a secondary concern.

This thesis presents a methodology for the inspection and evaluation of safety appurtenances on bridges located in low speed rural roads. The methodology consists of a detailed step by step process for the collection of field data, complemented with a series of inspection sheets. The data sheets are a reflection of the field inspection process, with the intent to ease and standardize the process. The information gathered in the data sheets is concentrated on three major areas: the safety appurtenances, the bridge, and the approach roadways. As part of the development of the inspection process, the elements that play a major role on the structural and functional adequacy of the safety appurtenances were identified, following an extensive review of the principal traffic safety and bridge inspection standards and guidelines developed by FHWA, AASHTO, and thirty three State DOTs. These factors are: the test level, the height, the post spacing, the lateral offset, the anchorage, the grading, and the length of need. Other criteria considered in the traffic safety evaluation of bridges are: the change in roadway width between the bridge and the approach road, the horizontal alignment, the bridge sight distance and the roadway clear zone.

The product of the inspection process is a traffic safety feature rating for the safety inspection elements (bridge railing, transition, approach guardrail, and end treatment) and the identification of possible safety treatments for typical bridge safety related issues. A descriptive rating was developed to assess the compliance of the elements considered in the safety evaluation of the bridge with the established standards. A rating is assigned to each of the traffic safety features on the bridge and it consists of five categories: excellent, good, average, deficient, and not applicable. The safety rating is related to the bridge and the evaluation of the existing operational situation in the bridge, and serves as an indicator of the need to identify and implement potential safety treatments.

The step by step inspection methodology developed in this thesis complements the process associated to Item 36 of the FHWA *Recording and Coding Guide* [1995], and can be used by transportation agencies in Puerto Rico and the United States to comply with the NBIS requirement that establishes the need for the proper safety evaluation and inspection of all highway bridges located on public roads.

RESUMEN

Los puentes son elementos vitales de la infraestructura de transportación. Existen sobre 600,000 puentes en los Estados Unidos y Puerto Rico, los cuales se requieren sean inspeccionados de acuerdo con los Estándares Nacionales de Inspección de Puentes, NBIS, por sus siglas en inglés, para ser reportados en el Inventario Nacional de Puentes, NBI, por sus siglas en inglés. La inspección de puentes se ha concentrado principalmente en los elementos estructurales, dejando el componente de seguridad del tráfico del puente y sus carreteras de acceso en un segundo plano.

Esta tesis presenta una metodología para la inspección y evaluación de dispositivos de seguridad en puentes localizados en carreteras rurales de baja velocidad. La metodología consiste en un proceso detallado paso a paso para la recopilación de datos en el campo, complementado con una serie de hojas de inspección. Las hojas de datos son un reflejo del proceso de inspección en el campo, con la intención de simplificar y estandarizar el proceso. La información recolectada en las hojas de campo se concentra en tres áreas principales: los dispositivos de seguridad, el puente, y las carreteras de acceso. Como parte del desarrollo del proceso de inspección, los elementos que tienen un rol importante en la funcionalidad y estructura de los dispositivos de seguridad fueron identificados, como resultado de un extenso repaso de los estándares principales de seguridad e inspección y las guías desarrolladas por FHWA, AASHTO y treinta y tres Departamentos de Transportación de diferentes estados. Estos factores son: el nivel de prueba, la altura, el espaciado de los postes, la distancia lateral, el anclaje, la pendiente del suelo, y la longitud de necesidad. Otros

criterios a considerarse en la evaluación de seguridad de tráfico en puentes son: el cambio en el ancho de la carretera del puente y sus accesos, la alineación horizontal, la distancia de visibilidad del puente, y el área libre al borde de la carretera.

El producto del proceso de inspección es la clasificación de los dispositivos de seguridad (barrera de puente, transición, barrera de la carretera de acceso, y el terminal), y la identificación de posibles tratamientos de seguridad para deficiencias típicas relacionadas con la seguridad en puentes. Se desarrolló una clasificación descriptiva para evaluar el cumplimiento de los elementos considerados en la evaluación de seguridad de tráfico en el puente con los estándares establecidos. Se asignará una clasificación a cada dispositivo de seguridad en el Puente; esta consiste de cinco categorías: excelente, bueno, promedio, deficiente y no aplica. La clasificación de seguridad esta relacionada con el Puente y la evaluación de la situación operacional existente en el mismo; sirve como un indicador de la necesidad de identificar e implementar tratamientos de seguridad potenciales.

La metodología de inspección detallada desarrollada en esta tesis complementa el proceso asociado con el Artículo 36 de FHWA *Recording and Coding Guide* [1995], y puede ser utilizada por agencias de transportación en Puerto Rico y los Estados Unidos para cumplir con los requerimientos del NBIS, el cual establece la necesidad de una evaluación e inspección de seguridad adecuada de todos los puentes localizados en carreteras públicas.

To my loved ones . . .

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Last, but not least, I would like to thank my family, my mother Wanda, my grandmother Rosa, my sisters and brother, and my grandfather who is not here today, but who I know will be very proud to see what I have accomplished. They are my foundations and without them none of this would be possible. I would like to give special thanks to Peter, whose love and support has been a pillar of strength in times when it was most needed.

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TABLE OF CONTENTS

Page

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TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF FIGURES (CONTINUED)

Page

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
Pounds (force)	4.448222	Newtons
Pounds (force) per foot	14.59390	Newtons per meter
Pounds (force) per inch	175.1268	Newtons per meter
Pounds (mass)	0.45359237	Kilograms
Square feet	0.09290304	Square meters
Square inches	6.4516 E-04	Square meters
Square miles	2.589998 E+06	Square meters

Unless stated otherwise all measurements and dimensions that appear in this work are presented using US Customary Units.

LIST OF ACRONYMS

AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ATSSA	American Traffic Safety Services Association
AHP	Analytical Hierarchy Process
BTS	Bureau of Transportation Statistics
BTSFR	Bridge Traffic Safety Feature Rating
CIAPR	Colegio de Ingenieros y Agrimensores de Puerto Rico
CFR	Code of Federal Regulations
DOT	Department of Transportation
FHWA	Federal Highway Administration
FLH	Federal Lands Highway
HVMT	Highway Vehicles Miles Traveled
LRFD	Load and Resistance Factor Design
LRFR	Load and Resistance Factor Rating
MUTCD	Manual on Uniform Traffic Control Devices
NBI	National Bridge Inventory
NBIS	National Bridge Inspection Standards
NCHRP	National Cooperative Highway Research Program

LIST OF ACRONYMS (CONTINUED)

NHTSA	National Highway Traffic Safety Administration
PDO	Property Damage Only
PR	Puerto Rico
PR-DTPW	Puerto Rico Department of Transportation and Public Works
RDG	Roadside Design Guide
RPM	Raised Pavement Marker
SSD	Stopping Sight Distance
TRB	Transportation Research Board
TL	Test Level
USC	United States Code
vpd	Vehicles per Day
VMT	Vehicle Miles Traveled

1 INTRODUCTION

Bridges are vital elements of the highway transportation system. The bridge design has a significant effect in the operation, service quality, and safety of road networks. Bridges and their approaches are generally recognized as high frequency sites for severe, single-vehicle crashes [FHWA, 1998]. One third of fatal crashes in the United States highway network in 2006 were a result of a single vehicle run of the road crash, and nearly 25 percent were related to bridges or culverts [NHTSA, 2007]. Improving highway safety is a primary focus of transportation agencies. An integrated effort by the Federal Highway Administration (FHWA), the State Departments of Transportation, the local transportation agencies, and the automobile industry, contributed to the decline of the rate of fatalities from 5.5 to 1.52 fatalities per 100 million highway vehicle miles traveled (HVMT), from 1966 to 2001. FHWA continues its goal to improve highway safety by making it the first of its three "Vital Few", along with environmental stewardship and streamlining, and congestion mitigation. The three areas directly related to infrastructure safety identified by FHWA are the reduction of fatalities at intersections, pedestrian related fatalities, and those resulting from roadway departures. FHWA's plan for the period of 2002-2007 was to address such safety issues in order to achieve a 10 percent reduction in fatalities during this period [Ostensen, 2003].

1.1 Motivation

The Title 23 of the Code of Federal Regulation (CFR), Section 650 Subpart C-National Bridge Inspection Standards (NBIS) establishes the need for the proper safety evaluation and inspection of all highway bridges [NARA, 2005]. This requirement applies to all structures defined as highway bridges located on public roads. A public road is defined as any road or street under the jurisdiction of, maintained by a public authority, and open to public travel. In summary, each State DOT, local transportation agency or private owner is responsible for developing their own bridge inspection policies and procedures.

Currently the Puerto Rico Department of Transportation and Public Works (PR-DTPW) uses the guidelines of the American Association of State Highway and Transportation Officials (AASHTO) and Pontis for their bridge management activities in support of the National Bridge Inventory (NBI). Pontis is a bridge management system that assists transportation agencies to make sound, fact-based decisions about maintenance, rehabilitation, and replacement of structures. However the PR-DPTW has not yet developed a Bridge Inspection Manual to uniform and to regulate the local procedures and protocols for the evaluation and inspection of bridge structures in the island's road network.

Rural roads were responsible for 47.2 percent of the total fatalities resulting from crashes in Puerto Rico's highways in 2005, despite the fact that only 6.7 percent of the total vehicle miles traveled (VMT) were through these roads. The fatality rate for the rural highway system in 2005 was 165 fatalities per 100 million VMT, twelve times the rate of the urban highway system, which was 13.2 deaths per 100 million VMT [Colucci and Figueroa, 2006]. This significant difference in the fatality rate can be partially attributed to the particular roadway geometric design principles of each highway system. The American Association of State Highway and Transportation Officials (AASHTO), *Policy on Geometric Design of Highways and Streets* [2004], which applies to the United States and Puerto Rico, provides criteria for the design and construction of highways according to their functional classification [AASHTO, 2004]. The AASHTO functional classification concept suggest that as the Average Annual Daily Traffic (AADT) and the design speed increases, the roadway design is enhanced by including additional cross section elements and geometric improvements to satisfy the mobility and safety needs of the users. These considerations are suggested for roads of lower functional classifications (e.g. lower AADT), such as collector and local rural roads, based on engineering judgment. Economic considerations in the design of typical local rural roads, particularly in low volume roads, may affect the decisions related to roadway geometry and cross-section components.

It is necessary for road and bridge safety inspectors to be familiarized with the design considerations of the highway type and the local bridge site conditions being evaluated in order to perform an assessment of safety appurtenances on the bridge system. In highway design, the functional classification of the road, the traffic volume, and the design speed are factors that influence different aspects of design, including but not limited to the road alignment, maximum grades, minimum width of traveled way, clear zone and other safety related specifications, such as the placement, selection and performance evaluation of roadside barriers, and bridge railings, among other traffic safety appurtenances. The term traffic safety appurtenance is generally used when referring to traffic barriers, for bridges the FHWA has adopted the term traffic safety features, which applies to all components of the bridge railing system. Throughout this work, with the intention of being consistent with this terminology, the author will use the term traffic safety features when referring to safety appurtenances on bridges.

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

1.2 Objectives

The main objective of this thesis is to develop a detailed methodology that could be used as guidance for engineers to perform the inspection and evaluation of traffic safety and traffic safety features in bridges on low speed rural roads. The methodology will assist bridge engineers, both designers and inspectors, by providing them with a guide for the execution of routine inspections of bridges, based on the NBIS regulations and relevant FHWA and AASHTO policies and guidelines. The methodology includes the development and validation of a field inspection sheets with the purpose of the data collection and the analysis of the safety level of the current conditions for the bridge and approach roadways. An implementation exercise of the inspection procedure was performed using five bridges located on rural roads located in western Puerto Rico. The implementation example included the assignment of the safety rating to the bridge's traffic safety features and the identification of general safety treatments or countermeasures that could be used for mitigating typical major deficiencies of bridge railing systems.

The research study has the following specific objectives:

1. Perform a literature review of existing policies and specifications related to the roadway geometry and roadside design for low-speed rural roads, developed by AASHTO and FHWA.

2. Perform a literature review of existing bridge safety barrier systems that have been tested and approved for operating conditions similar to those typical of low speed rural roads. The review will focus on identifying the typical design features and characteristics of the barriers.

3. Perform a literature review of existing regulations, selection criteria, performance characteristics, and inspection procedures of bridge safety barriers, particularly for low speed rural road conditions, developed by Federal Agencies or State Departments of Transportation.

4. Develop a detailed methodology for the safety evaluation of bridge railings, transition sections, approach guardrails and end terminals on bridges on low-speed rural roads.

5. Create field inspection data sheets that can be used by bridge engineers and inspectors for the safety evaluation of the appurtenances on bridges and their approach roadways.

6. Perform inspection examples to validate the adequacy and comprehensiveness of the methodology and the field inspection data sheets.

7. Present examples of the implementation of the inspection process, the data collection, and the identification of safety treatments.

1.3 Scope

The scope of this thesis is toward the safety evaluation of bridges and approach roadways on low speed rural roads. This research will be circumscribed to two lane rural roads with a posted speed of 45 mph or less. Only roads classified as collector or local roads with level or rolling terrain were considered; arterials or interstate highways were not included in this study.

The methodology developed in this research study is related to the traffic safety evaluation of bridges and the functional and structural adequacy of the railing systems. The methodology does not include the evaluation of the physical condition of the elements of the railing system, but on the determination of its functional and structural adequacy. The research study does not include temporary bridge structures and does not take into consideration railing upgrade.

The bridges selected for the application exercises performed in this study are selected from Puerto Rico's Bridge Inventory 2008 and are all located in the western area of Puerto Rico.

1.4 Expected Benefits

This research provides a step by step methodology for the evaluation of traffic safety features for bridges of low speed rural roads in Puerto Rico and the United States. Although the implementation examples were performed using data collected from local bridges located in rural roads of western Puerto Rico, the methodology can be applied in bridges on similar conditions in other jurisdictions. The current requirements for bridge design and inspection, together with the increasing use of rural roads might raise tort liability concerns in the presence of adverse site conditions with high crash risk potential. The consideration of safety barriers on secondary or tertiary rural roads using recommended guidelines or practices established for high speed, high truck traffic conditions might lead to cost effectiveness issues on low speed road conditions. These issues are dealt 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 methodology developed in this research is intended to assist Puerto Rico's DTPW and local transportation agencies by providing them with a practical uniform method for inspecting the safety level of rural bridges and its approach roadways as part of their bridge management activities. The methodology is described in detail to serve as a training tool for bridge designers and inspectors to guide them in the process of making relevant design decisions that will improve the overall safety of the rural highway and bridge network and improve the data collection process for routine inspections under the NBIS procedures.

1.5 Organization of the Thesis

In this section the author presents the organization of the research study presented in this document. The second chapter of this thesis consists in a description of the tasks performed throughout the development of this work. The third chapter consists in a general review of manuals, specifications and guidelines related to the geometric design and roadside design of low speed rural local and collector roads; it also presents the current regulations for the inspection of traffic safety features on bridges.

Chapter four presents the developed inspection protocol for traffic safety features on bridges and the inspection sheets created for the field data collection. In the next chapter the author presents the application exercise used to validate the comprehensiveness of the inspection protocol and the inspection sheets. The group of bridges selected for the exercise, were inspected following the developed protocol and using the inspection sheets created. A detailed description of the inspection and evaluation of each bridge is presented.

In Chapter six the author presents the conclusions of the work performed in this research, and Chapter seven and eight present the author's recommendation and future research that can be done to enhance the scope of this work and further develop it.

1.6 Definitions of Terms

This section presents the definition of some terms that will be used throughout the extent of this document.

- Appurtenance: Real and personal property owned by transportation agencies located on, near or under the roadways and streets. For the purpose of this thesis, a road appurtenance is associated to devices such as, guardrails, road signs, etc.

- Barrier [AASHTO, 2006]: A device which provides a physical limitation through which a vehicle would not normally pass. It is intended to contain or redirect an errant vehicle.

- Bridge [NARA, 2005]: 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 20ft between undercopings of abutments, or spring lines of arches, or extreme ends of openings for multiple boxes.

- Bridge Approach Guardrail [AASHTO, 2007]: Roadside guardrail system preceding the structure and attached to the bridge rail system that is intended to prevent a vehicle from impacting the end of the bridge railing or parapet.

- Bridge Railing [AASHTO, 2006]: Longitudinal barrier intended to prevent a vehicle from running off the edge of a bridge or culvert.

- Collector road [AASHTO, 2004]: Collect traffic for movement between arterial streets and local roads, and provide access to abutting properties. Travel distances are shorter than on arterials.

- Crashworthy [AASHTO, 2007]: A 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.

- End Treatment [AASHTO, 2006]: The designed modification of the end of a roadside or median barrier

- Local Road [AASHTO, 2004]: Provides access to adjacent land or properties (farms, residences, etc), and serves travel over relatively short distances.

- Low speed road [AASHTO, 2004]: a road with a design speed of 45 mph or less.

- Public road [NARA, 2005]: Any road or street under the jurisdiction of and maintained by a public authority and open to public travel.

- Transition section [AASHTO, 2006]: A section of barrier between two different barriers or, more commonly, where a roadside barrier is connected to a bridge railing or to a rigid object such as a bridge pier. It should produce a gradual stiffening of the approach rail so vehicular pocketing, snagging, or penetration at the connection can be avoided.

The terms presented below, represent the definitions of some documents revised for the development of this work. They are presented in the order in which they should prevail for implementation purposes.

- Standards: An established norm or requirement. It is usually a formal document that establishes uniform engineering or technical criteria, methods, processes and practices.

- Specification: Explicit set of requirements to be satisfied by a material, product, or service. A singular documented need of what a particular product or service should be or do.

- Policy: Deliberate plan of action to guide decisions and achieve rational outcome(s). However, the term may also be used to denote what is actually done, even though it is unplanned. Policy differs from rules or law; while law can compel or prohibit behaviors, policy merely guides actions toward those that are most likely to achieve a desired outcome.

- Guide: Provides direction or advice as to a decision or course of action. Document that presents recommended practices, not requirements.

2 RESEARCH METHODOLOGY

This chapter presents the research methodology followed to accomplish the objectives of this work, Figure 1. It consists of five mayor tasks; a general description of each of the stages will be presented as a prelude of the more detailed descriptions presented in later chapters.

The first task consisted in performing a comprehensive literature review of the pertinent Federal and State policies, regulations and guidelines for the selection and placing of bridge railings on low speed roads. The documentation includes topics such as the clear zone concept, warrants for the placement of safety barriers, types of bridge railings, railing crash testing criteria, examples of approved crash tested railings, National Bridge Inspection Standards requirements, and current methods used in the United States for the traffic safety evaluation of bridges. Chapter Three presents in detail each of the topics mentioned above.

The next stage consisted of two tasks; the first one was the development of guidelines for the selection of traffic safety features for bridges on low speed rural roads in Puerto Rico. The methodology was developed based on the literature reviewed in task one and with the application of engineering judgment taking into consideration the different aspects of design, such as, road geometry, environment, average daily traffic, posted speed, signing, and other elements that play an important role in providing road safety. The second task consisted in developing a bridge railing system inspection protocol that will allow bridge engineers (inspectors) to collect data in the field for the proper safety inspection of bridges. Chapter Four discusses in detail the inspection protocol, and the inspection sheets developed.

The third task of the methodology consisted of selecting a total of five bridges and implementing in such bridges the inspection protocol developed in this work. Two lane rural roads from the Western area of Puerto Rico were identified to be used in the application of the bridge traffic safety features' inspection protocol. PR-DTPW Bridge Design Office provided Puerto Rico's 2008 Bridge Inventory, which was used to identify and select the bridges. After careful analysis of the bridge inventory, all bridges that complied with the scope of this study, such as: rural, collector or local, speed limit ≤45mph, level or rolling terrain, and located in the Western area of Puerto Rico were identified. Road maps and aerial photographs were used for the identification of the type of terrain, and also to identify the location of the bridge sample selected. Field visits were carried out to collect information concerning the characteristics of the bridge and its approaching roadways. The application examples serve inspectors as a guide and provide detailed examples of real scenarios and the proper way to perform an evaluation of traffic safety features on bridges located in low speed rural roads. Chapter Five presents the application examples of the inspection protocol, including all the information gathered in the field, the inspection sheets, and the pictures taken during the field inspection exercise.

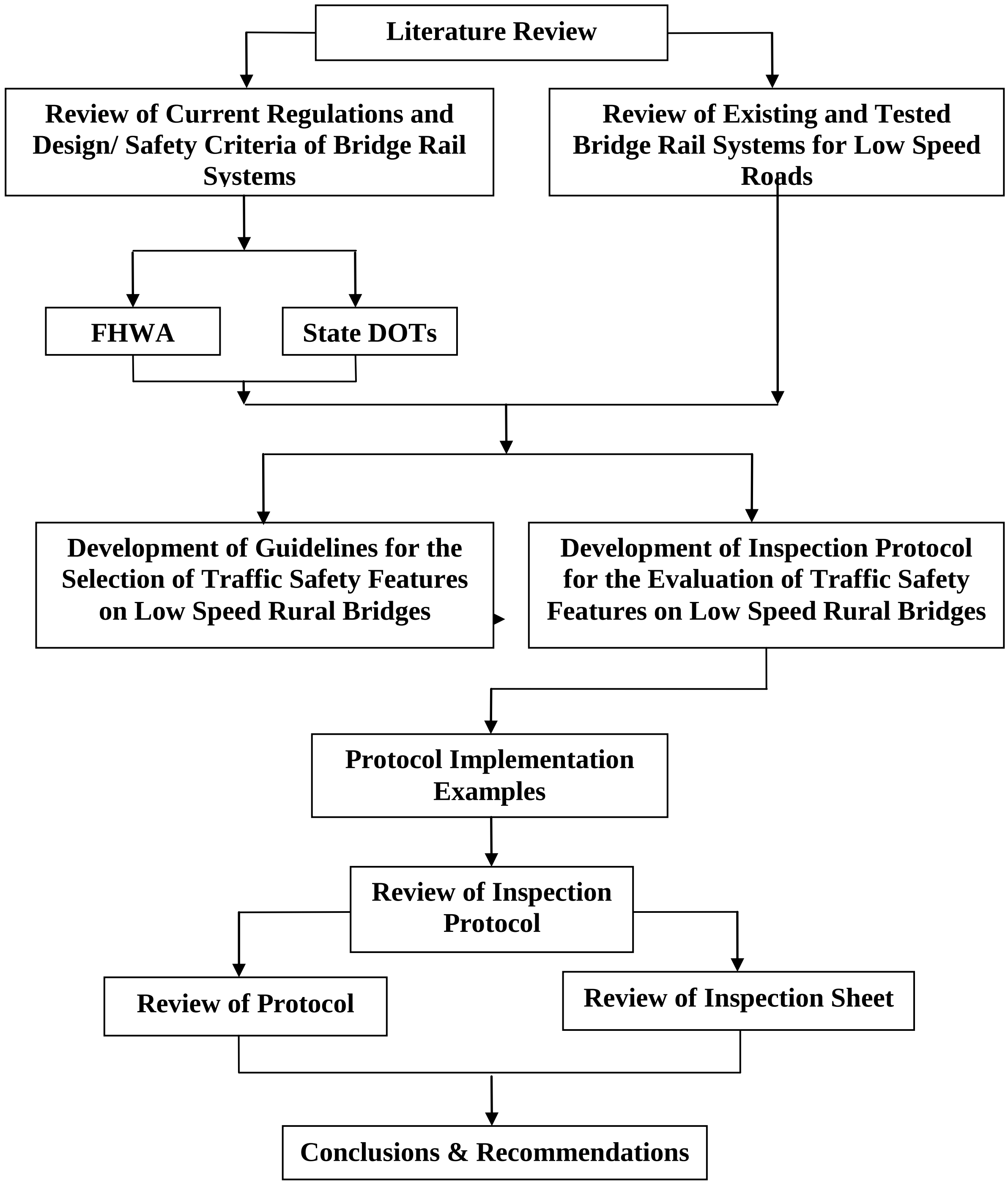


Figure 1. Research Methodology

The next task performed was the review of the inspection protocol. In this task the information gathered during the field inspections was used to assess the comprehensiveness of both the inspection protocol and the inspection sheets. Changes were done to the original inspection sheets and the inspection protocol in order to ease the process in the field and also to add items that were not considered initially, and that were found to be essential for the evaluation of traffic safety features on bridges. The results of this task are the final inspection protocol and inspection sheets.

The final stage of the methodology consists of the conclusions and the recommendations for future works that can further enhance the evaluation of traffic safety features on low speed rural bridges. Chapter Seven presents the conclusions and recommendations of this work.

3 LITERATURE REVIEW

3.1 Introduction

The purpose of this chapter is to present a general review of major manuals, specifications, and guidelines related with geometric design, roadside design and bridge inspections. The intent of this chapter is to present major differences in geometric and roadside design guidelines of specific roadway elements and also to present a review of the existing standards for the inspections of bridges and their traffic safety features.

A review of the geometric design elements presented in AASHTO's *Green Book*, and a review of the main roadside design aspects, and their relation to bridge safety, included in the AASHTO *Roadside Design Guide* (RDG) [2006], and the Federal Lands Highways *Barrier Guide* [2005] are presented in this chapter. Another crucial part of this chapter is the discussion of existing regulations and standards for the inspection of traffic safety features on bridges available in FHWA *National Bridge Inspection Standards* (NBIS) [2005], FHWA *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* [1995], and AASHTO *Manual for Condition Evaluation and LRFR of Highway Bridges* [2003]. Is not the intent of this chapter to provide a comprehensive review of all the geometric design, roadside design and bridge inspection concepts provided in these references; for the complete information and guidelines regarding any of these concepts, readers are referred to the above mentioned documents.

3.2 Geometric Design Policies Related to Bridges

3.2.1 Classification of Highways

Classification schemes for highway networks include the administrative classes in the National Highway System (NHS), the classification by jurisdiction (Interstates, U.S. highways, State roads, County roads, City streets) and the AASHTO's functional classification. The functional classification concept is defined by AASHTO [2004] as the process by which streets and highways are grouped into arterials, collectors, and local roads according to the character of service they are intended to provide.

Arterial roads are facilities where the main movements take place, providing high mobility, while operating under high volume and high speed conditions, offering service to mayor points of interest in rural and urban areas, and requiring the highest and more demanding design specifications.

Collector roads are facilities that move traffic between arterial and local roads, providing a balance between mobility and accessibility, and typically serving moderate traffic volumes.

Local roads include all facilities that provide terminal access to farms, residences, businesses, and other properties; typically operating under low volume and low speed conditions. Local roads constitute approximately 70 percent of the total roadway mileage in the United States, while carrying 13 percent of the total VMT of travel [BTS, 2007].

The extent of the local road system is one of the principal reasons for the need to develop appropriate and cost efficient guidelines for such roads, which because of their traffic conditions and geographical locations result in challenges to engineers in the application of current roadside safety policies and guidelines developed by AASHTO.

3.2.2 Minimum Bridge Roadway Width

Key elements in the roadway's cross section of low volume roads include the traveled way and shoulder widths. Table 1 presents the minimum bridge clear roadway width indicated by AASHTO [2004] for new and reconstructed bridges on local roads.

Table 1. Minimum Clear Roadway Widths and Design Loadings for New and Reconstructed Bridges [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.

In roads with ADT of less than 100 vpd, one-lane bridges can be provided as long as the designer understands this type of structure can operate effectively. Where one-lane bridges are to be designed, their minimum width should be 15 ft, and their maximum width, recommended by AASHTO, should be 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.

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. Table 2 presents acceptable minimum roadway widths for cases where a safety problem related to the width of an existing bridge is identified.

Table 2. Minimum Clear Roadway Widths and Design Loadings for Existing Bridges [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].

The need for widening an existent bridge structure will have to be established 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, and the concerns from local residents and the police.

3.2.3 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, superelevation, and side friction is essential for the design of horizontal curves in the proximity of bridges. Newman [AASHTO, 2001] indicates that since the horizontal curve design criteria are based on conservative driver comfort levels, the values presented in AASHTO [2004] can be lowered for low volume roads with no negative implication on safety.

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.

3.2.4 Sight Distance

Sight distance is defined as 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, composed of the brake reaction distance and the braking distance, provides a sufficiently long distance to allow a road user that is traveling at the design speed to perceive and avoid colliding with a two foot tall object on its path. A 2.5 seconds reaction time and a deceleration rate of 11.2 ft/s2 are values suggested by AASHTO [2004] to calculate SSD values. AASHTO SSD formula is presented in Figure 2. The alignment design of approach roadways to bridges must provide adequate sight distance in order to promote safe operating conditions on local roads.

Metric	US Customary	
$d = 0.278Vt + 0.039\frac{V^2}{a}$	$d = 1.47Vt + 1.075\frac{V^2}{a}$	**(3-2)**
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]

3.3 Roadside Design Guidelines

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 RDG [2006] presents six (6) strategies for reducing roadside obstacles that represent the proper approach to be taken by the designer 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 the roadside design are the determination of the clear zone width and establishing the need for the installation of traffic barriers when the roadside clear zone cannot be provided.

3.3.1 Clear Zone

The clear zone is the lateral distance, starting from the edge of the traveled way, available for the safe use of errant vehicles. Table 3 presents the AASHTO RDG [2006] recommended clear zone values; which provide limited information for low speed road conditions. The desired clear zone width depends on the traffic volume, the roadway design speed, and the side slopes. 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; and 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 appropriate clear zone distance is not provided.

Table 3. Recommended Clear Zone Values [AASHTO RDG, 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.

Federal Lands Highways [2005] developed guidance for the identification of clear zone distances for low-speed roads. Table 4 presents the recommended clear zone values for roads with speeds below 40 mph as an extension AASHTO RDG [2006] recommended values.

Table 4. 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.

Correction factors for the recommended clear zone values on the high side of horizontal curves 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.

The designer is encouraged to modify the roadside design to site-specific conditions, considering trade-offs between cost effectiveness and safety. In analyzing the need for appropriate clear zones, the designer should consider the location crash history, the expected growth of traffic, and the presence of heavy vehicles. AASHTO [2001] provides the following additional guidelines in exercising engineering judgment on the site specific safety evaluation to decide the appropriate or necessary clear zone.

1. A clear recovery area of 6 ft should be considered at locations that present low cost and minimal social and environmental impacts;
2. 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;

3.3.2 Safety Barrier Warrants

The decision to install a traffic barrier is based on the established warrants that provide guidance to the designer in evaluating the potential safety and operational benefits of traffic control devices or safety features [AASHTO, 2007]. 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. The bridge owner is responsible for all the safety features and functions of a bridge and for developing appropriate warrants for the bridge sites.

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

The identification of fixed objects or roadside features and their 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. Tables 5 to 8 present the severity classification of four groups of potential roadside hazards to be used as guide in the warranting process of safety barriers.

Table 5. 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 6. 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 7. 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 8. 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

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 a function of the vehicle's speed and the relative seriousness of a crash. Severity is measured by the mix of likely crash types: fatal, injury and property-damage-only (PDO) and is measured by a severity index using a zero (0) to ten (10) scale. All the severity indices are estimated at 100 km/h (62mph), but generally will have the same relative meaning at lower speeds [FLH, 2005]. FLH [2005] suggests corrective measures for each of the three severity classes.

Group 1 hazards are estimated to have a severity index of below 3.0 (fatalities are unlikely). The low crash severity implication of these hazards suggests that accepting the risk and leaving the hazard could be appropriate for some locations, if it is not possible avoiding having these conditions in the clear zone by applying low cost corrective actions.

Group 2 hazards have a severity index of 3.0 to 4.9 (some possibility of serious injury and fatality, but probably less severe than barriers). Currently acceptable roadside barriers are estimated to have a severity index of 4.9 [FLH, 2005], therefore these hazards generally do 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 5.0 and higher (may be more severe than a crash into a barrier). The need for possible use of roadside barriers is justified if it is too expensive or impractical to eliminate either the hazard or make it crashworthy. If a barrier is not warranted or an alternate treatment is less expensive than a barrier, treat as a Group 2 hazard.

Note that bridge piers, abutments, and railing ends are classified in the high severity group. The consequences of drivers' going over the edge of the structure or hitting the abutment or railing end, if unshielded, are severe; therefore railings are generally warranted [AASHTO, 2006] in those situations.

3.3.3 Bridge Railing System

A bridge railing system, as shown on Figure 3, can be composed of four elements: the bridge rail, the transition, the standard section or approach guardrail, and the end terminal.

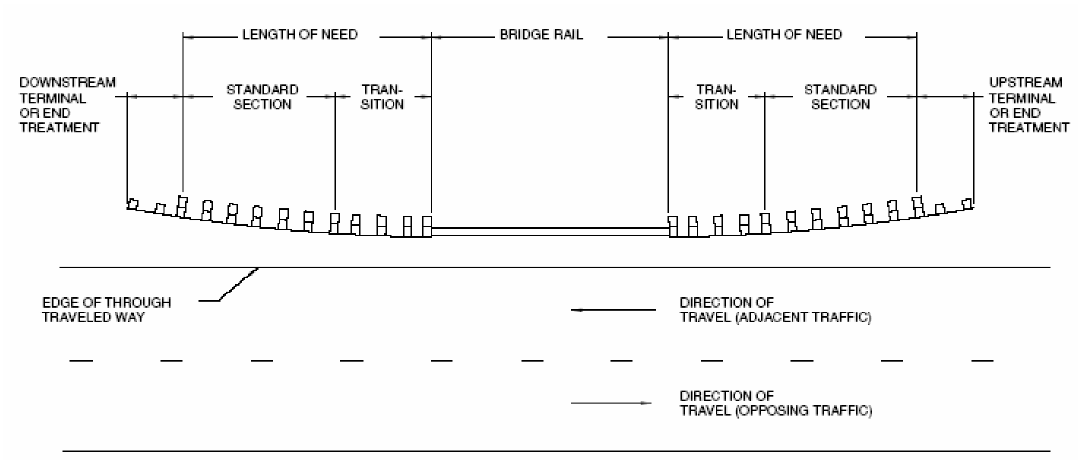


Figure 3. Typical Setting of Bridge Safety Barriers [AASHTO, 2006]

The bridge rail is an integral part of the bridge structure, intended to prevent a vehicle from running off the edge of it. Bridge rails are typically designed to have no deflection when struck by a vehicle, and should 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 approach guardrail is a longitudinal barrier preceding the structure and is attached to the bridge rail to prevent a vehicle from hitting a hazard in front or at the side of the structure, or from impacting the end of the bridge railing or parapet.

A transition section is needed when the type and materials, and deflection capabilities of the bridge rail and the approach guardrail differ. This section provides a gradual stiffening of the approach guardrail in order to prevent vehicles from snagging, pocketing or penetrating it. Transitions might not be required in urban or suburban roadways with speeds of 45 mph or less AASHTO RDG [2006], and where compatible bridge railing and approach guardrail designs are provided.

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.

3.3.4 Bridge Railing Warrants & Selection Guidelines

A bridge railing should be chosen to satisfy the concerns of the warrants as completely and practical as possible [AASHTO, 2007]. Bridge railing warrants should contain information regarding its level of performance.

After the determination that a barrier is warranted, it is the responsibility of the designer to select the appropriate barrier system that provides the required level of protection at the lowest cost.

The first factor to consider in the selection of a bridge railing is its performance capability. *AASHTO LRFD Bridge Design Specifications* require that a bridge railing be crash tested to NCHRP Report 350 test criteria. Table 9 presents the criteria of the six performance levels in NCHRP Report 350. The test levels (TL-1 to TL-6) identify the barrier's performance capability based on the vehicle weight, and the impact speed and angle.

Table 9. NCHRP 350 Test Matrix of Safety Devices

Test Level	Test Vehicle	Nominal Impact Speed, mph [kph]	Nominal Impact Angle (degrees)
TL-1	700C	31 [50]	20
	820C	31 [50]	20
	2000P	31 [50]	25
TL-2	700C	43 [70]	20
	820C	43 [70]	20
	2000P	43 [70]	25
TL-3	700C	62 [100]	20
	820C	62 [100]	20
	2000P	62 [100]	25
TL-4	8000S	50 [80]	15
TL-5	36,000V	50 [80]	15
TL-6	36,000T	50 [80]	15

In the case of existent structures, built before the development of NCHRP Report 350 criteria, designed following *AASHTO Standard Specifications for Highway Bridges* criteria or structures that may have been crash tested under *NCHRP Report 230: Recommended Procedures for the Safety Performance Evaluation of Highway Safety Appurtenances* [1981], their use may be acceptable based on an evaluation of their in-service performance. FHWA developed a railing level equivalency table which indicates the appropriate conversion between the levels used on each of these sources (NCHRP 350, AASHTO, and NCHRP 230), as shown on Table 10.

Table 10. Railing Level Equivalency Table [FHWA, 1997]

BRIDGE RAILING TESTING CRITERIA	**ACCEPTANCE EQUIVALENCIES**					
NCHRP REPORT 350	TL-1	TL-2	TL-3	TL-4	TL-5	TL-6
NCHRP REPORT 230		MSL-1 MSL-2*		MSL-3		
AASHTO GUIDE SPECIFICATIONS		PL-1		PL-2	PL-3	
AASHTO LRFD BRIDGE SPECIFICATIONS		PL-1		PL-2	PL-3	

* This is the performance level usually cited when describing a barrier as tested under NCHRP Report 230. It is close to a TL-3, but adequate TL-3 performance cannot be assured without a pickup truck test.

The test level chosen for the bridge railing shall be the responsibility of the authority in charge of the design of the bridge, and it should be selected in accordance with the site conditions. The most common test level selected for bridge railings on highways is TL-3. The following applications are suggested in AASHTO RDG [2006] for local roads:

1. TL-1: Work zones with low posted speed and low volume local streets. AASHTO (2006) does not recommend the use of TL-1 railings, since operating speeds could exceed the 31 mph TL-1 criteria.
2. TL-2: Work zones, and most local and collector roads with low posted speeds and with a low number of heavy vehicles expected

The selected test level of a bridge railing can control factors such as the height, and the shape of face. The height of the railing can prevent vehicles with high center of gravities, such as trucks, from rolling over it. Bridge railings should be at least 27 in. (685 mm) for TL-3 [AASHTO, 2007]. A vertical concrete safety shape is preferred where there is high number of heavy truck traffic, since other safety shapes can cause the vehicle to rollover.

When selecting a bridge railing system the type of service of the facility where it's going to be installed (highway, pedestrian, combination highway-pedestrian) need to be considered. Bridges with pedestrian facilities should avoid the use of curbs higher than eight inches in front of bridge rails. The installation of raised sidewalks is reserved for low speed roads. Both situations require the use of a combination barrier at the outer edge of the sidewalk, as shown in Figure 4.

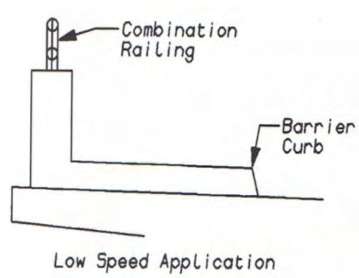


Figure 4. Combination Railing Application for Low Speed Highways [AASHTO, 2007]

Other factors to consider in the railing selection are the barrier's deflection capability, the side slope conditions, the compatibility with existing systems, costs, maintenance, field performance, and aesthetics.

The available deflection distance will dictate the type of barrier to be used. Bridge rails are typically designed to have no deflection when struck by a vehicle. For approach guardrails, 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, a semi rigid or rigid barrier is the adequate choice.

The side slope conditions also influence the approach roadway barrier type selection. AASHTO *RDG* recommends that the slope of the area adjacent to the barrier is 1V:10H; otherwise a flexible or semi-rigid barrier should be used. Barriers should never be placed on slopes steeper than 1V:6H.

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

Documenting the in-service performance of bridge railings will help designers determine if the railing is working properly and also to keep records of its maintenance and the life-cycle costs. A bridge railing's field experience can be the determining factor for its selection in a particular project.

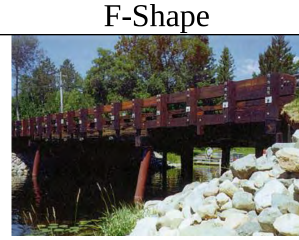
3.3.5 Crashworthy Bridge Railings

The FHWA maintains a website that includes a list of approved bridge railings, longitudinal barriers, transition sections, and end treatments according to the crash test requirements of NCHRP Reports 350 and 230. The FHWA acceptance letters as well as links to barrier manufacturers' websites for information on proprietary systems can be accessed at http://safety.fhwa.dot.gov/roadway_dept/road-_hardware.htm. Additional information about crashworthy safety barriers can be found at the following websites:

1. FHWA Safety, http://safety.fhwa.dot.gov/roadway_dept/road_hardware/bridgerailings.htm
2. TXDOT Bridge Railing Manual, http://onlinemanuals.txdot.gov/txdotmanuals/rlg/index.htm
3. Worcester Polytechnic Institute Online Guide to Bridge Railings, http://civil-ws2.wpi.edu/Documents/Roadsafe/Guides/bridgeRailGuide/index.php?action=browse&all=1&sort=see_through&by=desc

The FHWA *Bridge Rail Guide* [2005] presents the test level, general information and typical costs for a total of ninety three crashworthy bridge railings. The railings are grouped into six types: W-beam rails, Thrie-beam rails, metal tube rail, vertical concrete parapets, F-shape concrete barriers, and timber rails, as shown on Table 11.

Table 11. Bridge Railing Types [FHWA, 2005a]

Bridge Railing Type	Picture
W-Beam Rail	 Texas T101
Thrie Beam Rail	 Washington 10 Gauge Thrie Beam
Metal Tube Rail	 Foothills Parkway Aluminum Bridge Rail
Vertical Concrete Parapet	 Kansas Corral Rail
F-Shape Concrete Barrier	 F-Shape
Timber Rail	 Timber Rail 3

The guide includes five W-beam railings, four complying with TL-2 and one with TL-3; six Thrie beam railings ranging from TL-2 to TL-6. The metal tube railing section has thirty railings that comply with test levels starting from TL-2 to TL-5. The concrete rail section includes 36 vertical concrete parapet railings, varying from TL-2 to TL-6, and five F-shape concrete barriers, four complying with TL-4 and one TL-5. The timber bridge rail section contains ten rails which are mostly utilized in parks or in areas where the vehicle volume and the operating speeds are low. The timber railings are mostly TL-1 or above, except for the timber curbs used on longitudinal timber decks which are considered below TL-1.

A review of the existing regulations, selection criteria, and inspection procedures, regarding traffic safety features on low speed, low volume bridges, developed by Federal Agencies and the DOTs of 32 States and Puerto Rico was performed. The review indicated that in all 32 States and Puerto Rico bridge railings are always warranted. The states mostly differ in the selection criteria and the types of railings commonly used. A table that presents a summary of the documents revised for each of these states and Puerto Rico, accompanied by four sample tables, which illustrate a summary of the information collected for particular states is presented in Appendix A.

A total of 58 percent of the jurisdictions reviewed require the use of bridge railings that meet particular NCHRP 350 test levels, while the other 42 percent have no written guidance specifying the bridge railing test level. Out of the 58 percent of the jurisdictions that have a test level requirement, 53 percent require the use of bridge railings that meet TL-4 criteria; and the remaining 47 percent have various TL specified for particular site conditions. Only 24 percent of the jurisdictions reviewed allow the use of TL-2 bridge railings on low speed roads without previous approval or coordination.

When analyzing the types of railings preferred for use by the states, 32 out of the 33 states prefer to use concrete railings on their bridges; Alaska is the only State that has a metal railing, the Two Tube Metal Railing, as their standard bridge railing. However, 24 out of the 32 states that prefer using concrete railings also allow the installation of metal railings in their bridges. Alabama, Arkansas, Georgia, Iowa, Kansas, Mississippi, North Carolina, Puerto Rico, and Utah are the states that only allow concrete railings in their bridges. The states of Hawaii, New York, Pennsylvania and Wisconsin are the only states that have timber railing details in their standard drawings, which means that these types of railings are permitted.

Alaska, North Carolina, Oklahoma, Puerto Rico, and Virginia have not developed local guidelines for the selection and inspection of bridge railings. These agencies follow directly the design requirements established in AASHTO LRFD *Bridge Design Specifications* [2007] and the FHWA *NBIS* [2005]. Jurisdictions that don’t have standard drawings, and details of approved railings refer to FHWA guidance for bridge railings and other safety features.

3.3.6 Approach Guardrails

Approach guardrails are roadside barriers attached to the bridge railing end by a transition section, with the purpose of preventing a vehicle from impacting an unshielded bridge railing end. Often an approach guardrail is the most important safety feature at a bridge or large culvert location.

Approach guardrails should be structurally and functionally adequate. To be structurally adequate they should be properly connected to the bridge rail; they must not separate from the bridge in the event of a crash. Also, they should 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. 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 [FHWA, 1998]. Figure 5 presents the approach guardrail length of need. The length of need is the appropriate length of barrier required to shield an obstacle within the established clear zone. The AASHTO RDG [2006] provides the methodology for the calculation of the length of need of approach guardrails and provides also guidelines for the placement of longitudinal barriers, the side slopes and terrain grading, particularly for highway conditions.

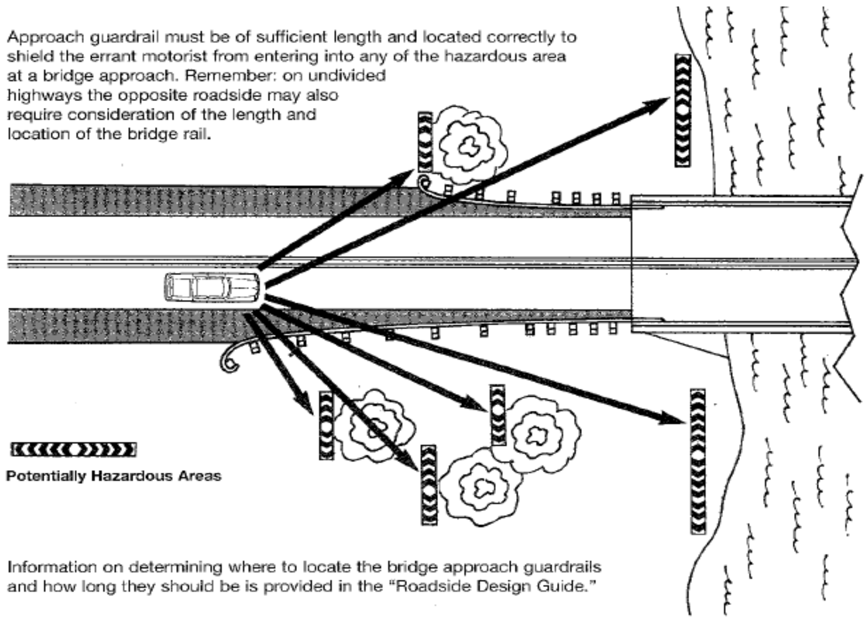


Figure 5. Approach Guardrail Length of Need [FHWA, 1998]

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 6 presents examples of proper or improper alignment of approach guardrails.

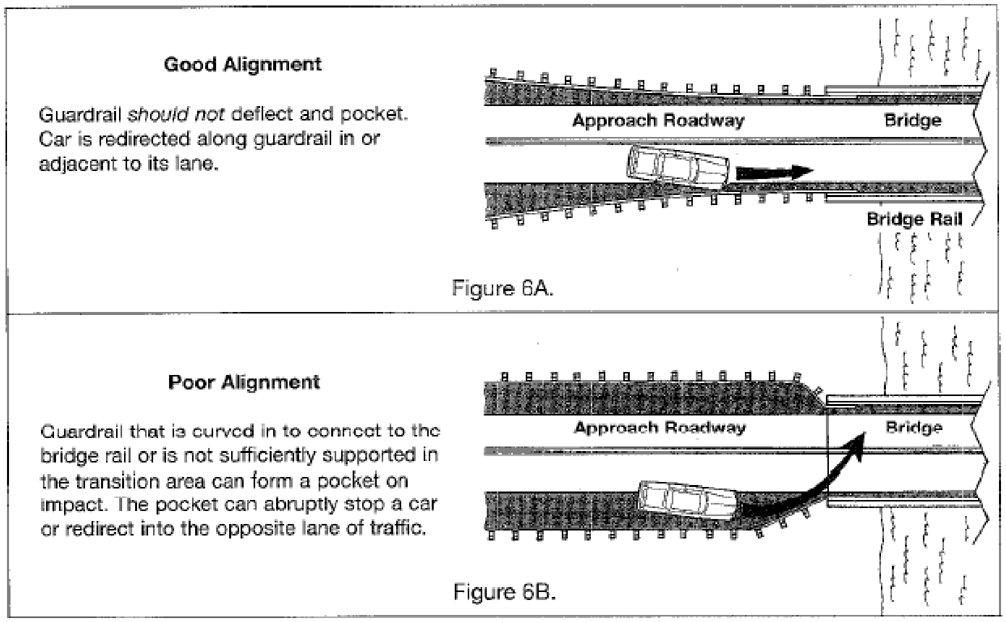


Figure 6. Approach Guardrail Alignment [FHWA, 1998]

Approach guardrails are an integral part of the bridge railing system, but they are not always warranted. The installation of approach guardrails in bridge length culverts or in urban areas with sidewalks and a high number of intersections, and in restricted low speed highways may not be cost effective or it may not be possible. AASHTO *Bridge Design Specifications* [2007] presents several alternatives for urban areas where city streets and/or sidewalks prevent the 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.

3.3.7 Transitions

A transition segment is barrier section between two barrier types, where a roadside barrier is connected to a bridge railing or to a rigid object such as a bridge pier. The transition section should produce a gradual stiffening of the approach guardrail to avoid vehicular pocketing, snagging or penetration at the connection [AASHTO, 2006].

The AASHTO RDG [2006] provides the following guidance about the proper installation and performance of the transition section.

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 rail.

FHWA provides the description, the name of the manufacturer, the NCHRP 350 TL and the standard plans of twenty approved crashworthy transition designs. For approved crash tested transition details designers can visit FHWA website and search for bridge rail transition sections.

3.3.8 End Treatments & Crash Cushions

An end treatment is the designed modification of the end of a roadside or median barrier, and crash cushions are protective devices that prevent errant vehicles from impacting fixed objects by gradually decelerating the vehicle to a safe stop [AASHTO, 2006]. 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 its abrupt deceleration. Most end treatments and all crash cushions have the capability of gradually decelerating an impacting vehicle until it comes to a safe stop for a head-on impact or, redirecting it away from the object of concern for side impacts.

All end treatments and crash cushions should be in compliance with NCHRP Report 350 criteria. Table 12 presents NCHRP Report 350 TL for end treatments and crash cushions.

Table 12. NCHRP 350 Test Levels for End Terminals and Crash Cushions

Test Level	Test Vehicle	Test Speed	Impact Angle
TL-1	820kg / 2000lbs	50km/h (30mph)	0º, 15º, 20º
TL-2	2000kg /4400lbs	70km/h (45mph)	0º, 15º, 20º
TL-3	2000kg / 4400lbs	100km/h (60mph)	0º, 15º, 20º

The use of a crashworthy end treatment is necessary 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, should have the same redirective capabilities within its length of need as the standard roadside barrier, and must have proper anchorage.

Crash cushions are practical 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: exit ramp gores where a bridge railing end requires shielding, steep downgrades on routes having high truck traffic, and in construction and maintenance zones. The AASHTO RDG [2006] provides additional guidance about the properties and proper placement of end treatments and crash cushions.

3.4 Bridge Inspections

Bridge inspections are performed periodically to evaluate the bridge performance, to initiate maintenance actions, and to establish priorities for repair and evaluation programs. 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.

The NBIS are a set of regulations developed by the FHWA which establishes standards for the proper safety inspection and evaluation of all highway bridges in accordance with Title 23 USC 151 [2005]. These standards apply to all structures defined as highway bridges located on public roads. Bridge inspections should be performed in accordance with the inspection procedures presented in the AASHTO *Manual for Condition Evaluation* [1994], as amended by the 1995, 1996, 1998, 2000, 2001, and 2003 interim revisions.

The intervals at which inspections are performed should not exceed two years; in the case where the bridge owner wishes to inspect the bridge at intervals greater than two years, without exceeding 4 years, a detailed written plan which includes the reason supporting this decision must be presented to the Federal and State agencies for approval [AASHTO, 2003].

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 (10) years of experience in bridge inspections and shall successfully complete a FHWA-approved bridge inspection training course. The bridge inspection organization is responsible for: 1) 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.

The information gathered by each State's bridge inspection organization is then submitted to the FHWA to be included in the National Bridge Inventory (NBI). The NBI is a database that contains information about approximately 600,000 bridges located on public roads in the United States, 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 FHWA *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* is used by the State, Federal and other agencies in recording and coding the data elements that comprise the NBI database. The coded items in this guide are an integral part of the database that is used to meet federal reporting requirements in Title 23 of the Code of Federal Regulations.

3.4.1 Bridge Railing Inspection Procedure

According to the AASHTO's *Manual for Condition Evaluation of Bridges* [2003] the inspection of the bridge railings should focus on the condition, the adequacy of the geometry and its structural capacity.

Item 36, Traffic Safety Features, of FHWA *Recording and Coding Guide* [1995], corresponds to the evaluation of the bridge railing system and is a four digit code composed of four segments, one for each of the bridge railing system element: rail, transition, approach guardrail, and approach guardrail ends (or end treatments), as shown on Table 13.

Table 13. Code for the Evaluation of Traffic Safety Features in the NBI [FHWA, 1995]

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

1. Bridge Railing:
   a. Verify the rail height, material, strength and geometric features since these factors affect the proper functioning of the bridge railing.
   b. Railings should be in compliance with NCHRP Report 350 criteria. For existing bridges, railings designed in accordance with the AASHTO *Standard Specifications for Highway Bridges* or crash tested under NCHRP Report 230 may be acceptable after an evaluation of their in-service performance.
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 the designer may choose to install larger posts.

3. Approach Guardrail

    a. Verify the structural adequacy and 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 reporting of these safety features is based on a 0 (zero), 1 (one) or N (Not applicable) rating, as shown on Table 14. Collision damage and deterioration of the elements are not considered when coding this item.

Table 14. Rating Codes for Traffic Safety Features [FHWA, 1995]

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

4 DEVELOPMENT OF INSPECTION PROTOCOL

4.1 Introduction

This chapter presents the procedure created for the inspection of traffic safety features on bridges. The inspection protocol was developed by performing a comprehensive review of the existing guidelines and manuals developed by AASHTO, and FHWA in relation to the inspection of bridges and their safety features.

The intention of this work is to present a procedure for inspecting and evaluating both the structural and functional adequacy of the existing traffic safety features on a bridge. The inspection sheets developed serve as a guide to follow in the recollection of information in the field. Inspectors are recommended to follow the inspection protocol and the field data collection sheets in order to ease the inspection and the evaluation process.

4.2 Guidelines for the Installation of Traffic Safety Features on Bridges

The AASHTO *Roadside Design Guide* [2006] establishes the need for bridge railing systems that are composed of four elements: bridge railing, transition section, approach guardrail, and end treatment. Although the installation of a bridge railing system with all of the elements will be the safest design option, this does not always result in cost efficient designs for low speed low volume road facilities, encouraging engineers to use their judgment when site conditions require it, with the purpose of reaching a balance between safety and costs.

Economic restrictions could dictate the safety measures taken in particular situations, providing the safest design possible based on the available resources. There might be situations in which the entire bridge railing system is not provided on each side of the bridge and on each direction of traffic. There are many different approaches that can be taken when trying to achieve traffic safety; therefore it is important for designers to understand the site's environment in order for them to find adequate solution(s) for a particular safety problem.

Prior to performing an inspection of the traffic safety features on a bridge, an inspector is responsible for understanding the selection criteria of the different elements in a bridge railing system. Such information is a key element in the evaluation of traffic safety features on bridges. This section presents a guide for the selection of these safety features. The guide can be used on the design stage of a project or can also be used, as is the case of this work, for determining if the existing traffic safety features on the bridge being inspected are the correct safety treatment for the site conditions. It is important that both designers and inspectors have an understanding of these guidelines before performing an assessment of the traffic safety features on a new or existing bridge.

The following guidelines for the selection of traffic safety features on bridges are to be used when designing or evaluating low speed rural local bridges. These guidelines are based on the literature reviewed from AASHTO, FHWA, and several State DOTs.

1. Current bridge design specifications require the use of bridge railings on all bridges open to public travel to protect road users from running off the edge of a bridge or culvert, for this reason a bridge rail is always warranted.

2. The need for the installation of an approach guardrail is determined by the condition of the approach roadway's roadside (lateral slopes, objects within the required clear zone distance), and by the need to protect road users from encroaching on the roadside and falling into a stream, a highway, a railroad track or any other potentially fatal hazard that can be located underneath the bridge structure. Check if the existing clear zone conforms to the recommended values established in AASHTO RDG, 2006 presented in Table 3, or in the case of facilities with speeds below 35mph the evaluator can also use the values recommended by FLH presented in Table 4. The designer should also check if the lateral extent of the area of concern is already protected.

3. When the installation of an approach guardrail has been warranted, if such system differs in rigidity from the bridge railing type, then the installation of a transition section is required. A transition section is not required when the approach guardrail and the bridge rail have the same rigidity (e.g. rigid system, semi-rigid system).
    a. On two lane bridges that carry two way traffic the installation of a transition section in both the entry and exit of the structure is recommended.
    b. On two lane one way bridges the installation of an exit transition section may not be necessary. Although the entire transition section may not be provided,

the installation of a connection between different barrier systems is always recommended.

4. Impacting the unshielded end of a roadside barrier can have serious consequences, for this reason barrier end treatments are always warranted. A crash tested end treatment should be selected and installed.

5. The minimum setting for low speed road facilities, under favorable bridge site and approach roadway conditions, could include only the bridge railing and the end treatments 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.

6. The Test Level selected for each one of the bridge railing system elements present in the bridge should be in accordance with the established standards, where available, or the existing site conditions. Factors to consider are: design speed, design vehicle, % of heavy vehicles, geometric design conditions, and type of service on the bridge (e.g. highway traffic, pedestrian traffic, combination highway-pedestrian traffic).

   a. The use of TL-1 is not recommended, except on very extreme situations, such as very low volume roads, with low speed, and limited or no presence of heavy vehicle traffic. Such designs are considered impractical, since they are tested for speeds of 30 mph and operating speeds almost always exceed that level [AASHTO, 2006].

b. Low speed roads with a low percentage of heavy vehicles can use elements that comply with NCHRP Report 350 TL-2 and above.

c. Low speed roads with a high percentage of heavy vehicles have a minimum requirement of railing elements compliant with NCHRP Report 350 TL-4.

d. Bridges with highway-pedestrian traffic located on low speed roads require the use of a combination railing, as shown on Figure 4. The minimum height for a pedestrian railing should be 42"; railings of this height are generally TL-4 or TL-5.

e. The installation of a bridge railing system element that complies with TL-5 or above in a low speed two lane road will not be cost effective, unless extremely unfavorable site conditions or a site specific safety problem have been identified.

4.3 Bridge Traffic Safety Features Assessment

According to the NBIS each State DOT and Federal agency is responsible for inspecting or causing to be inspected all highway bridges that are located in public roads which are fully or partially located within the State's or Federal agency's responsibility [Federal Register, 2005].

A complete bridge inspection includes the inspection of its traffic safety features, as it's demonstrated by Item 36 of FHWA's *Recording and Coding Guide* [1995]. As previously discussed the proper inspection of traffic safety features on bridges requires the evaluation of many factors. This work is focused on developing an inspection protocol for performing the assessment of traffic safety features on bridges that will help inspectors determine the functionality of the existing bridge railing system. The developed protocol is discussed in this section and is shown on Figure 7. The protocol includes the following five steps.

1. **Bridge Identification**

   Bridges are selected for inspection when one of two things has occurred; the first is the bridge's scheduled inspection time and the second is the identification of a specific deficiency or problem, where the need to prioritize and perform an unscheduled inspection has been recognized. Before performing an inspection to a particular bridge, the previous inspection reports should be analyzed and the necessary information gathered. Previous reports will give inspectors an idea of what they can encounter on the field during the inspection, and also the knowledge of previous findings that might require a more detailed inspection in the field. When performing the initial inspection, where previous reports have not been prepared, the 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. The experience has demonstrated that on occasions, DOTs create a subdivision inside their Bridge Design Office, which is responsible for the design and inspection of traffic safety features on bridges.

2. Field Inspection Data Collection

After selecting the bridge to be inspected the next step consists in going to the field to gather information about the site and the existing traffic safety features on the bridge. The information collected in the field by the inspectors will be documented in the inspection sheets. Section 4.4 of this chapter presents the field inspection data collection process and offers a detailed section by section description of the how to gather information, the type of information required and the manner in which the inspection should unfold in the field.

3. Inspection Data Analysis

After all the information in the field has been collected with regards to the site, the bridge, the approach roadway, and the traffic safety features, the inspector is responsible for analyzing the information obtained in the field, and whether or not it complies with the original bridge design plans, the agency standard plans or the recommended values given in standards and guides such as AASHTO *Green Book*, AASHTO *Bridge Design Specifications*, AASHTO *Roadside Design Guide*, and FHWA *Bridge Rail Guide*, among others.

Figure 7. Bridge Safety Features Assessment

4. **Bridge Traffic Safety Feature Rating**

After performing the inspection and analyzing the data obtained, each traffic safety feature on the bridge will be assigned a safety rating. This rating was created by performing a series of judgments based on the literature reviewed for this work and taking into consideration the traffic safety features' compliance with each of the items considered in its evaluation with the established design guidelines. The development of the rating and a detailed description of the rating process are presented in Section 4.5 of this chapter.

5. **Identification of Potential Treatments**

After the analysis of the field data has been performed and each traffic safety feature has been assigned a rating, it is the responsibility of the engineer to identify possible solutions to any deficiency encountered in the bridge's field inspection. The safety treatment(s) recommended will depend on the site condition and the particular deficiency identified in the field. This work provides information about typical treatments that improve road safety and that can be applied on bridges and their influence zones. These treatments are presented in Section 4.6 of this chapter.

4.4 Field Inspection Data Collection

The utilization of inspection sheets has proven to be a great asset in the field, when performing any kind of inspection. In order to make a sound evaluation of a particular situation a certain amount of information, specific to the kind of inspection being performed, is required. Inspection sheets should be a reflection of the inspection process, and as such, they should help ease the process and reduce the time it takes to perform it. The comprehensiveness of the inspection sheets will determine the thoroughness of the evaluation to be performed with the information gathered. As part of this work, inspection sheets were developed for the assessment of traffic safety features on low speed rural bridges, and they are presented in Appendix B.1.

The field inspection will be subdivided into two parts of data collection. The first part corresponds to general information about the site and the bridge; this information will only filled out once throughout the inspection process. The second part corresponds to information that varies with the direction of inspection, such as 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 second part of the inspection should be performed twice, once 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. The inspection protocol is presented on Figure 8; detailed instructions on the proper way to carry out the inspection and fill out the inspection sheets are presented below.

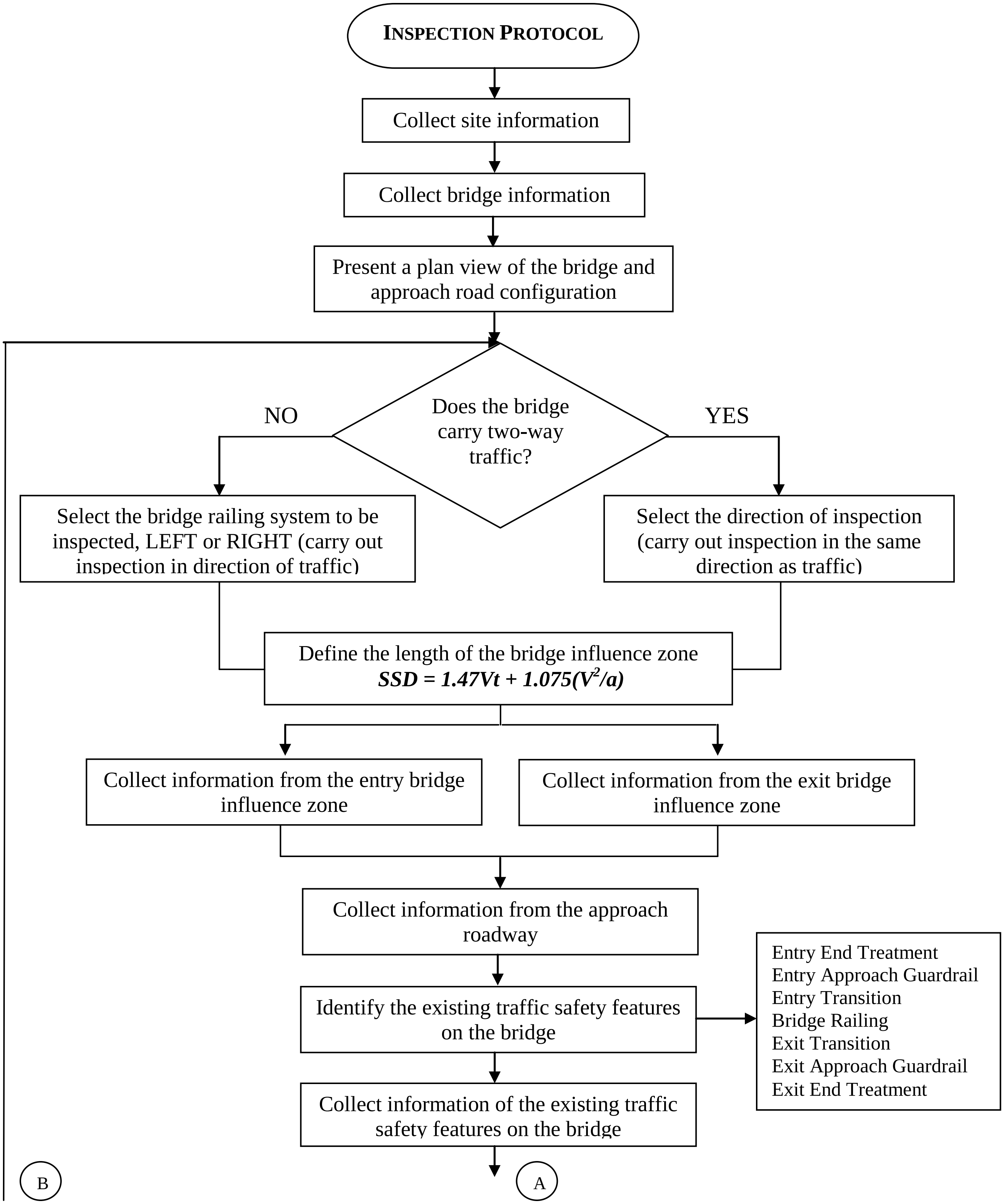


Figure 8. Inspection Protocol

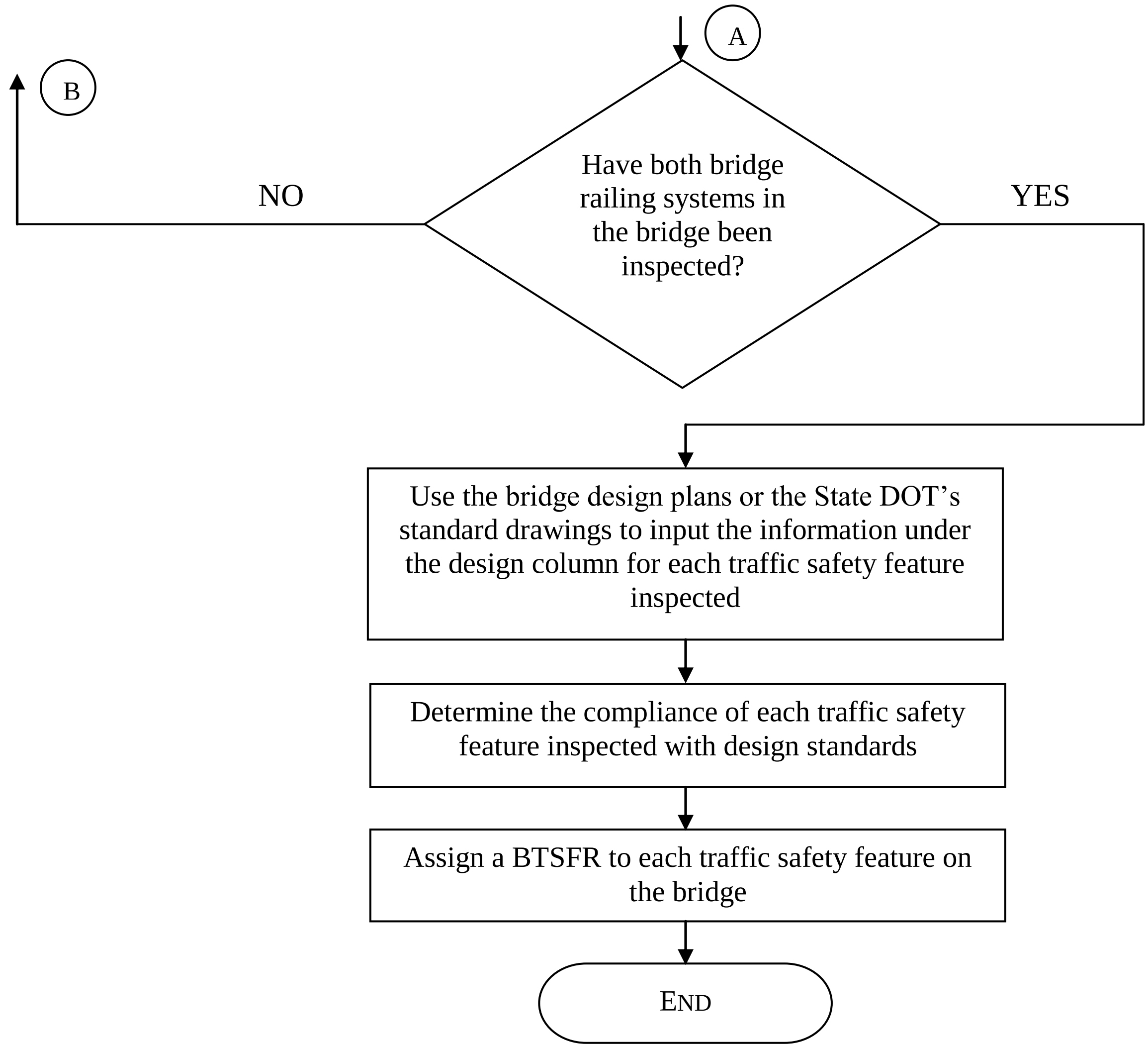


Figure 8. Inspection Protocol (Continued)

PART ONE: GENERAL SITE AND BRIDGE INFORMATION

1. **Section One: Site Identification**

   The information required in this section pertains to the highway in which the bridge is located, such as State, route number, municipality or county, year built and year reconstructed, functional classification of road, number of lanes, ADT, year of ADT, posted and design speed, highway type, starting and ending kilometers of the bridge, direction of traffic, and information regarding the person in charge of performing the inspection.

a. Functional Classification: In this section the inspector should identify the functional classification of the roadway where the bridge is located. The road should be classified into one of the following categories, obtained from FHWA *Recording and Coding Guide* [1995]:

i.	RURAL	01	Principal Arterial- Interstate
		02	Principal Arterial – Other
		03	Minor Arterial
		04	Major Collector
		05	Minor Collector
		06	Local
ii.	URBAN	11	Principal Arterial – Interstate
		12	Principal Arterial–Other (Freeway-Expressways)
		14	Other Principal Arterial
		16	Minor Arterial
		17	Collector
		19	Local

This section of the inspection sheet can be filled out in the office, since it is all information that should be available in previous inspection files. It is important to be aware of which of the items in this section have changed since the last inspection was performed. For example, the ADT in the inspection report should always be the latest value available.

2. **Section Two: Bridge Information**

The information in this section will allow the identification of the bridge in the National Bridge Inventory. It consists of the following: NBI structure number, bridge material, length, number of spans, type of service, bridge roadway width, number of lanes, pavement type, pavement markings, shoulder width, and sidewalk width.

a. NBI Structure Number: The identification number assigned to a bridge structure by its owner. This number should not change throughout the life of the bridge.

b. Bridge Material: The material used for the construction of the bridge. According to the FHWA [1995], the bridge material should be identified as any of the following:

   i. Concrete
   ii. Concrete continuous
   iii. Steel
   iv. Steel continuous
   v. Prestressed concrete
   vi. Prestressed concrete continuous
   vii. Wood or Timber
   viii. Masonry

ix. Aluminum, Wrought Iron, or Cast Iron

x. Other

c. Type of Service: Service provided by the bridge structure. The type of service in the bridge should be identified as any of the following, in accordance with FHWA [1995]:

i. Highway

ii. Railroad

iii. Pedestrian - bicycle

iv. Highway - railroad

v. Highway – pedestrian

vi. Overpass structure at an interchange or second level of a multilevel interchange

vii. Third level (Interchange)

viii. Four level (Interchange)

ix. Building or plaza

x. Other

3. Plan View of Bridge and Approach Roadway Configuration

Aerial photographs, roadway horizontal alignment or design plan where the configuration of the bridge and the approach roadway can be observed clearly should be presented. If none of these tools are available then a sketch of the configuration should be prepared by the inspector in the area provided.

4. **Direction of Inspection**

When performing inspections of safety features on bridges, it is important to comprehend that they function as a system; in order to evaluate them properly the inspection should consider the complete system. A bridge should have two railing systems, and for this reason individual inspection of each of them should be performed. The identification of the direction in which the inspection is being performed is crucial.

Inspections to 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). Individual inspections should be performed to each system; the inspector should indicate in this section which system is being inspected.

5. **Section Three & Four: Bridge Entry and Exit Influence Zones**

The bridge influence zone is the road area starting at each end of the bridge structure. It is the area in which drivers should be aware of the presence of the bridge structure and are able to take the necessary precautions to ensure their safety.

Before completing this section the inspector or the agency responsible for the maintenance of the bridge site is in charge of defining the length of the bridge influence zone. The length of this zone is determined by using the stopping sight distance (SSD) equation provided in AASHTO *Green Book* [2004], as shown on

Figure 2, where the recommended values for *t* and *a*, are 2.5 s and 11.2 ft/s^2 respectively. SSD is the length of roadway ahead that is visible to the driver; it should be enough to enable a vehicle traveling at or near the design speed to stop before reaching a stationary object in its path [AASHTO, 2004].

In low speed roads the value of SSD corresponding to a road with speed of 45 mph is 360 ft for a level road. This SSD value can be assigned to the length of the bridge influence zone when inspecting low speed roads ($V \leq 45$mph). For terrain with longitudinal grades, upgrades or downgrades, higher than 3 percent AASHTO [2004] recommends that the SSD value be modified to take into account the effect of grade on vehicle speeds. For higher speeds or when smaller bridge influence zones are justified, SSD values for level roads can be calculated by substituting the desired speed of the road where the bridge is located in the SSD equation or by using the values on Table 15 provided on AASHTO [2004].

Two influence zones are defined, the entry and the exit influence zones. Each one will vary according to the direction in which the inspection is being carried out. The entry influence zone in one direction will be the exit influence zone in the opposite direction of traffic. When inspecting bridges that carry one-way traffic, there will be only one entry and one exit influence zone, which means that section three and four will only be completed once throughout the inspection.

Table 15. SSD values [AASHT0, 2004]

Metric					US Customary				
Design speed (km/h)	Brake reaction distance (m)	Braking distance on level (m)	Stopping sight distance: Calculated (m)	Stopping sight distance: Design (m)	Design speed (mph)	Brake reaction distance (ft)	Braking distance on level (ft)	Stopping sight distance: Calculated (ft)	Stopping sight distance: Design (ft)
20	13.9	4.6	18.5	20	15	55.1	21.6	76.7	80
30	20.9	10.3	31.2	35	20	73.5	38.4	111.9	115
40	27.8	18.4	46.2	50	25	91.9	60.0	151.9	155
50	34.8	28.7	63.5	65	30	110.3	86.4	196.7	200
60	41.7	41.3	83.0	85	35	128.6	117.6	246.2	250
70	48.7	56.2	104.9	105	40	147.0	153.6	300.6	305
80	55.6	73.4	129.0	130	45	165.4	194.4	359.8	360
90	62.6	92.9	155.5	160	50	183.8	240.0	423.8	425
100	69.5	114.7	184.2	185	55	202.1	290.3	492.4	495
110	76.5	138.8	215.3	220	60	220.5	345.5	566.0	570
120	83.4	165.2	248.6	250	65	238.9	405.5	644.4	645
130	90.4	193.8	284.2	285	70	257.3	470.3	727.6	730
					75	275.6	539.9	815.5	820
					80	294.0	614.3	908.3	910

Note: Brake reaction distance predicated on a time of 2.5 s; deceleration rate of 3.4 m/s^2 [11.2 ft/s^2] used to determine calculated sight distance.

After defining the length of the bridge's influence zone and indicating it in the sheet, the inspector is responsible for identifying the presence of intersections, horizontal curves, vertical curves, or a combination of any of these elements within the area. In section three, the visibility of the bridge from the end of this zone will be recorded with the purpose of determining if the bridge has the adequate SSD. If the bridge is not visible from this point, the distance at which the bridge is visible within the influence zone should be recorded. This information will serve inspectors to verify the compliance of the bridge site with AASHTO's sight distance requirements.

Section four corresponds to the bridge exit influence zone. In this section the inspector should indicate any obstructions to the drivers' sight which limit visibility to the end of the influence zone while exiting the bridge. The inspector is also responsible for indicating the presence of any geometric elements such as horizontal, vertical curves and intersections in this zone.

6. **Section Five: Approach Roadway Information**

A description of the geometric characteristics of the approach roadway should be given in this section. Information such as, approach roadway width, shoulder width, sidewalk width, roadway grade, pavement type, pavement markings, side slopes, and existing and required clear zones, should be provided.

a. Side slopes: The slopes in the roadside can be classified as foreslopes or backslopes, as shown on Figure 9. Identify the slopes in the roadside of the approach as either one of these and enter the magnitude of the slope for both sides of the approach road (left - right).

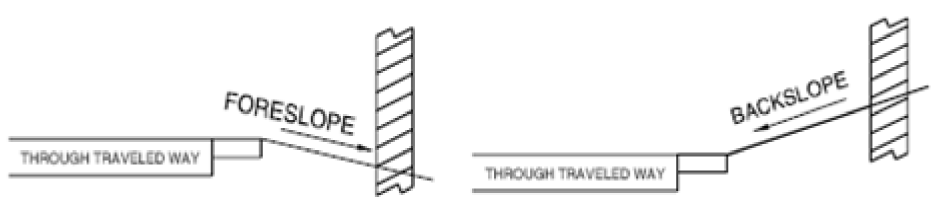


Figure 9. Types of Roadside Slopes [AASHTO, 2006]

In certain situations the inspector can encounter a drainage channel within the clear zone. The evaluation of these features will also be taken into consideration under this section. The evaluation of vee, rounded, and trapezoidal channels is performed by using Figures 3.6 and 3.7 of AASHTO

RDG [2006]. When a drainage channel is encountered in the field the inspector is asked to enter the information in the area provided with the only difference being that for this particular situation there will be values placed on both the foreslope and backslope boxes for the side in which the channel is present (Left or Right), since all drainage channels have both a foreslope and a backslope section. If there are drainage channels on both sides of the road then all L and R blanks will be filled out on both boxes. Unfavorable drainage channel slope combinations are considered a low severity hazard according to the severity classifications presented in Chapter 3.

b. Clear Zone: The clear zone should be measured in the field and later compared with the recommended values presented in Table 3. The clear zone should be measured in the area that is not protected by a safety barrier, if the entire approach roadway within the influence zone is protected by a barrier then the inspector should indicate 0 as the existing clear zone or he can also in

*This chart is applicable to all Vee ditches, rounded channels with a bottom width less than 8ft [2.4m] and trapezoidal channels with bottom widths less than 4ft [1.2m]

ıan 40mph the values in Table 4 developed by FLH can be used.

7. Checks for Existing Traffic Safety Features on the Bridge being Inspected

A schematic of a bridge and approach roadway with all of the components of a bridge railing system is presented. Each component has a check box for identifying the existing traffic safety features in the bridge site. After completing these task the inspector should proceed to fill out only the sections that correspond to each of the existing traffic safety features in the bridge in the order in which they appear in the field (entry end treatment, entry approach guardrail, entry transition, bridge rail, exit transition, exit approach guardrail, exit end treatment).

8. Section Six: Entry End Treatment

In this section the inspector should identify the type of end treatment, check the anchorage and the grading between the traveled way and the terminal.

a. Type and Test Level: The inspector should identify the existing end treatment and its Test Level. He should verify that it complies with the end treatment in the design plans. If design plans are not available, the inspector should verify that the TL of the treatment is consistent with what is required for the type of road being inspected. FHWA can be a great tool for this task, since it provides standard plans for crash tested end treatments. When the end treatment does not correspond to any existing crash tested design, the inspector should write in the design column for all items of the section NA (Not applicable), and proceed to check NO in the compliance column of each item.

b. Anchorage: For impacts within the approach guardrail's length of need, the end treatment should have the same redirectional characteristics as the standard guardrail, this means that it should be properly anchored [AASHTO, 2006]. The inspector should verify that the anchorage system has been properly installed according to its design and that it has not been impacted, bent, or is missing any bolts or cables. In this item the inspector should indicate the following:

i. Functional: Represents that the anchor is properly installed, it's not missing any elements, and has minor or no impacts preventing it from working properly. Corresponds to a YES under the compliance column.

ii. Damaged: Represents that the end treatment has been impacted or that design elements are missing or not installed accordingly. The anchorage has become loose or unattached. Under this condition the end treatment will not work properly. Corresponds to a NO under the compliance column.

iii. Not present: The existing end treatment type requires the installation of an anchorage system and none is provided. Without an anchorage system the existing end treatment is not considered functionally adequate, which corresponds to a NO under the compliance column.

iv. NA (Not Applicable): There are different types of end treatments which are composed of different parts. If after revision of the bridge design plans, or the DOT standard plans its determined that the existing end treatment does not require the installation of an anchorage system, the inspector should place in both the existing and design columns the letters NA (Not applicable) and proceed to check YES under the compliance column.

c. Grading: The grading between the traveled way and the terminal should be essentially flat (no greater than 1V:10H in any direction). Figures 10 and 11 present the preferred grading for flared and non flared guardrail end treatment. If grading for end treatment does not meet these requirements than it's considered as not in compliance.

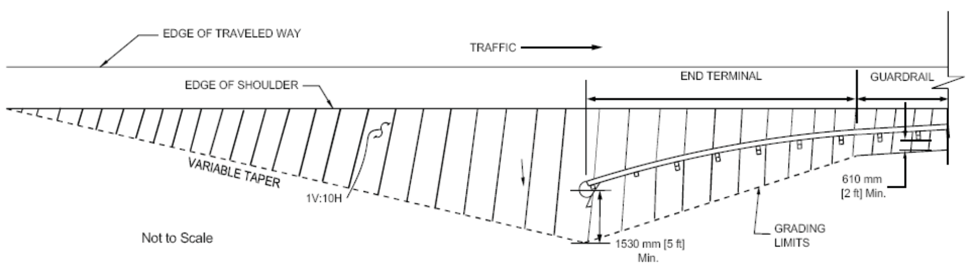


Figure 10. Grading for Flared Guardrail End Treatment [AASHTO, 2006]

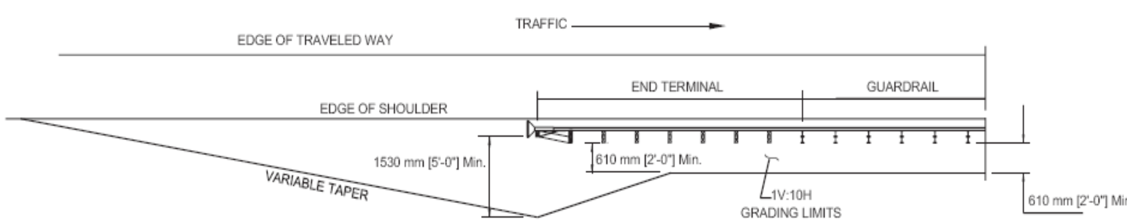


Figure 11. Grading for Non-Flared Guardrail End Treatment [AASHTO, 2006]

9. Section Seven: Entry Approach Guardrail

In this section, the type of the approach guardrail should be determined and the height, post spacing, grading, flare rate, lateral offset, and length should be measured.

a. Type and Test Level: The inspector should identify the existing approach guardrail and its Test Level, and verify its compliance with the design plans, if design plans are not available the inspector should verify that the TL of the guardrail is consistent with what is required for the type of road being inspected. A source that can help in determining the guardrail's TL is FHWA website which provides a list of crash tested guardrails and their standard plans. This information can be used by the inspector to determine the compliance of the existing approach guardrail. When the approach guardrail does not correspond to any existing design, the inspector should write in the design column for all items in the section NA (Not applicable), and proceed to check NO in the compliance column of each item.

b. Height: The inspector should measure the height of the existing approach guardrail in the field and determine if its height is in compliance with what is established in the design plans or the DOT standard plans for the barrier type. Barriers are crash tested at their design height; any change could affect their crashworthiness.

c. Post Spacing: The inspector should measure the spacing between the posts of flexible or semi rigid barrier systems. The distance measured should be from center to center of adjacent posts. Determine the compliance of the post spacing with the design standard. The post spacing criteria controls the barrier's deflection distance; the available deflection distance at the site can be a controlling factor in the selection of a barrier's post spacing. AASHTO's RDG [2006] presents the results of field test carried out by Kansas DOT to determine the deflection of a W-Beam guardrail with different post spacing being impacted at angles of 15º and 25º by a 4,400 lb sedan at 60 mph. These values can be used to determine the compliance of the existing post spacing of W-Beam guardrails in the field. When the approach guardrail is a rigid system that does not have any post elements, the inspector should write in both the existing and design columns NA (Not applicable), which corresponds to a YES in the compliance column.

d. Grading: The recommended grading for the installation of approach guardrails is 1V:10H or flatter. If a barrier is to be placed on a slope steeper than 1V:10H, a flexible or semi rigid barrier should be used. No barrier should be placed on a slope steeper than 1V:6H [AASHTO, 2006], however the installation of barriers at slope of 1V:6H are not recommended. The inspector is responsible for evaluating the site conditions and determining the compliance of the existing grading when is value is between 1V:10H and 1V:6H.

e. Flare Rate: The variable offset distance of a barrier to move it farther from the traveled way; AASHTO [2006] presents the suggested maximum flare rate values; these vary according to the design speed and whether or not the guardrail is installed within the shy distance. The inspector should determine if the existing flare rate of the approach guardrail complies with the maximum values presented in Table 5.7 of AASHTO [2006].

f. Lateral Offset: A roadside barrier should be placed as far as possible from the edge of the traveled way, in order to give drivers a better chance of regaining control of the vehicle without impacting the barrier, and also to provide better sight distance. The distance at which an object or roadside barrier is perceived by drivers as an obstacle is the shy line offset. Suggested values for this distance are presented in AASHTO [2006] Table 5.5; the inspector should determine the compliance of the existing lateral offset of the approach guardrail using the values in this table.

g. Length of need: Represents the total length of a roadside barrier needed to shield an area of concern [AASHTO, 2006]. The inspector should measure the length of the existing approach guardrail in the field and calculate the design value of the length of need by using Equation 1. This information will allow the inspector to determine the compliance of the length of the approach guardrail with the calculated value. When the approach guardrail is a W-Beam with an approved end treatment, consideration should be given to the fact that most W-Beam end terminals are designed to contain and redirect vehicles striking at or beyond the third post, 12.5 ft from the face of the terminal. The measured length of the approach guardrail should not consider this distance. The length of need is expressed as:

$$\boldsymbol{X} = \frac{\boldsymbol{L_A} + \left({}^{\boldsymbol{b}}/_{\boldsymbol{a}}\right)(\boldsymbol{L_1}) - \boldsymbol{L_2}}{\left({}^{\boldsymbol{b}}/_{\boldsymbol{a}}\right) + \left({}^{\boldsymbol{L_A}}/_{\boldsymbol{L_R}}\right)} \qquad \mathbf{1}$$

Where:

X = length of need,

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, and

(a:b) = flare rate.

10. Section Eight: Entry Transition

A transition is only required when the semi rigid approach barrier joins a rigid bridge railing. In this section, information regarding the type, length, height, post spacing, and the connection of the entry transition should be documented.

a. Type and Test Level: The inspector should identify the existing transition and its Test Level, and verify its compliance with the design plans. If design plans are not available the inspector should verify that its TL is consistent with what is required for the type of road being inspected. FHWA website provides a list of crash tested transitions and their standard plans that can help inspectors determine the transition's TL. After the information has been obtained the inspector should determine the compliance of the existing transition. If the transition does not correspond to any existing crash tested design, the inspector should write in the design column for all items in the section NA (Not applicable), and proceed to check NO in the compliance column of each item.

b. Length: The length of a transition is determined by its design; the inspector should verify the bridge design plans or the DOT's standard plans. Generally the transition length should be 10 to 12 times the difference in the lateral deflection of the two systems in question [AASHTO, 2006]. After obtaining the information in the field and comparing it with the design values the inspector should determine the compliance of the transition length.

c. Height: The transition should maintain the same height as the approach guardrail. The inspector should measure the height of the transition and compare it with the design height to determine its compliance.

d. Post spacing: The stiffness of the transition should increase smoothly and continuously from the less rigid to the more rigid system. There are various ways of achieving this, decreasing the post spacing is one of them. The inspector should verify the design plans which establish the adequate post spacing reduction to be used according to the transition type. The transition installed should meet the post spacing requirements of its design. The inspector should determine the compliance of the transition's post spacing with the design standard.

e. Connection: 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, and as such its installation is required. The inspector should verify that 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 missing any bolts or nuts, or the connection has become loose or separated. The inspector should indicate the following:

   i. Functional: Represents that the connection is properly installed, it's not missing any elements, has minor or no impacts preventing it from working properly, and has not become unattached. Corresponds to a YES under the compliance column.

   ii. Damaged: Represents that the connection between barrier systems has been impacted, design elements are missing or have not been installed accordingly, or the connection has become loose or unattached. Under this condition the transition will not be functional. Corresponds to a NO under the compliance column.

iii. Not installed: The transition does not have a connection to the bridge rail. Without a connection, the guardrail can pull out leaving the bridge end unprotected. Corresponds to a NO under the compliance column.

11. Section Nine: Bridge Railing

A bridge railing is always warranted, under no circumstances a bridge should be left unshielded. In this section, information should be gathered about the type, TL, height, post spacing, and length of the bridge railing system.

a. Type and Test Level: The inspector should identify the existing bridge railing and its Test Level and verify its compliance with the design plans. If design plans are not available he should verify that the TL is consistent with what is required for the location of the bridge being inspected. To determine the TL the inspector can check FHWA *Bridge Rail Guide* [2005a], which provides details of crash tested bridge railings. If for any reason the existing bridge railing system can't be found in the above mentioned document, or on any other list for crash tested bridge railings available, the checks on Section Thirteen should be performed. These checks will verify the existing bridge railing's compliance with NCHRP Report 230 criteria. After the TL has been identified the inspector should determine the compliance of the existing bridge railing. When the bridge rail does not correspond to any existing design and the checks in section 13 demonstrate the railing's high snagging potential or its inadequate post setback criteria then the inspector should write in the design column for all items in the section NA (Not applicable), and proceed to check NO in the compliance column for each item.

b. Height: The inspector should measure the height of the existing bridge railing in the field and compare it with the design height. A change in height can affect the railing's crashworthiness. The inspector should compare the existing bridge railing's height with the design value and determine its compliance.

c. Post Spacing: The inspector should measure the spacing between the posts of flexible or semi rigid barrier systems and compare it with the design post spacing. The distance measured should be from center to center of adjacent posts. The existing and design values will be used to determine the compliance of the post spacing in the existing bridge railing. When the bridge rail is a rigid system that does not have any post elements, the inspector should write in both the existing and design columns NA (Not applicable), which corresponds to a YES in the compliance column.

d. Lateral Offset: A roadside barrier should be placed as far as possible from the edge of the traveled way, in order to give drivers a better chance of regaining control of the vehicle without impacting the barrier, and also to provide better sight distance. The distance at which an object or roadside barrier is perceived by drivers as an obstacle is the shy line offset. Suggested values for this distance are presented in AASHTO [2006] Table 5.5; the inspector should determine the compliance of the existing lateral offset of the bridge railing using the values in this table.

e. Length: The primary function of a bridge railing is to prevent an errant vehicle from going over the side of the bridge structure, for this reason a bridge railing should extend through the length of the entire bridge including the abutments. The length of the bridge railing can be obtained from the design plans and verified in the field; when design plans are not available the length of rail can be determined by measuring it in the field starting from the abutments. The inspector should determine the compliance of the bridge railing's length by verifying that it extends from beginning to end of the structure.

f. Sketch of Bridge Railing

   In this section, the inspector is asked to sketch the bridge rail, and provide its dimensions. For a formal preparation of the inspection sheet a picture of the bridge rail can be provided along with a sketch.

12. Section Ten: Exit Transition

The exit transition is the section installed at the exit of the bridge structure according to the direction in which the inspection is being conducted. This element is not always required on one-way traffic low speed roads, although consideration should be given to the amount of traffic, and the crash history of the site; careful consideration should be given to locations where safety problems have been identified.

All parameters considered in this section are the same as the ones in Section 8 and they should be measured and evaluated accordingly.

13. Section Eleven: Exit Approach Guardrail

The approach guardrail located on the exit of the bridge is used to prevent vehicles in the opposing traffic lane from encroaching on the area located adjacent to the bridge's exit. All parameters considered in this section are the same as the parameters in Section 7 and should be measured and evaluated accordingly. For calculating the adequate length of need of this guardrail, the equation remains the same, but the values used to calculate it will now be measured from the inner edge of the travel lane or the center of the traveled way if there are no pavement markings.

14. Section Twelve: Exit End Treatment

The exit end treatment is the end treatment installed at the end of the exit approach guardrail. All parameters considered in this section are the same as the ones in Section 6 and they should be measured and evaluated accordingly.

15. Section Thirteen: Checks for Bridge Railing Compliance with NCHRP 230

Existing bridge railings designed to criteria contained in the AASHTO *Standard Specifications for Highway Bridges* and that may have been crash tested under previous guidelines may be acceptable for use on new or reconstruction projects through evaluation of their in-service performance [AASHTO, 2006]. In this section, railings that cannot be found on FHWA *Bridge Rail Guide* or that do not have an FHWA letter of approval establishing they have met NCHRP Report 350 criteria should be tested to verify their compliance with NCHRP Report 230 crash testing guidelines.

In order to verify a bridge railing's compliance with NCHRP Report 230 the following information should be collected in the field: 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 12.

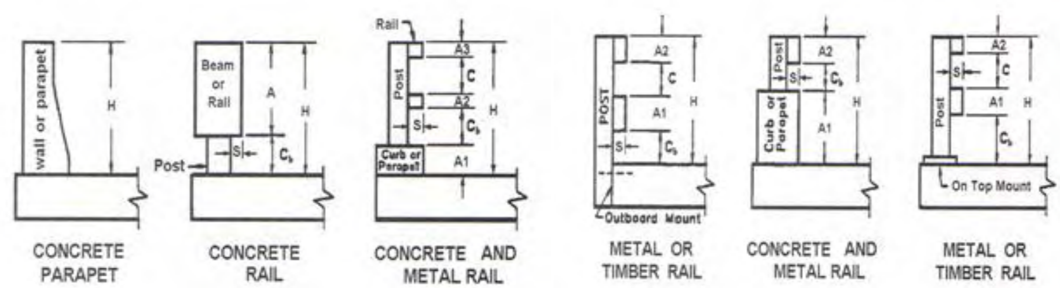


Figure 12. Measurements of Typical Bridge Railings

After collecting this information in the field, two checks must be performed using the figures shown below. Figure 13 should be used to verify that the vertical clear opening (C), and the post setback criteria, S, should be within or below the shaded area, indicating that the railing meets NCHRP 230 criteria or that the potential for vehicles snagging on the railing post is low. In Figure 14 the combination of ΣA/H and the post setback, S, should be within or above the shaded area, indicating that the design post setback distance meets NCHRP Report 230 criteria or that the design is preferred. The inspection sheet provides these figures for evaluating existing bridge railings, and allows inspectors to indicate in the sheets their findings.

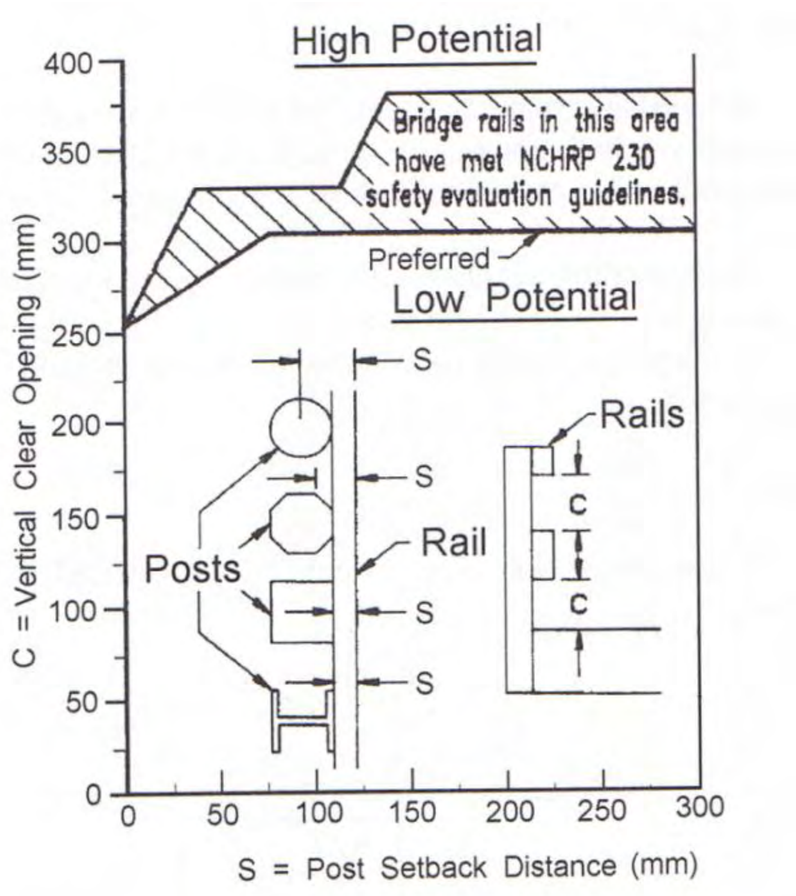


Figure 13. Check for Bridge Railing Snagging Potential [AASHTO, 2007]

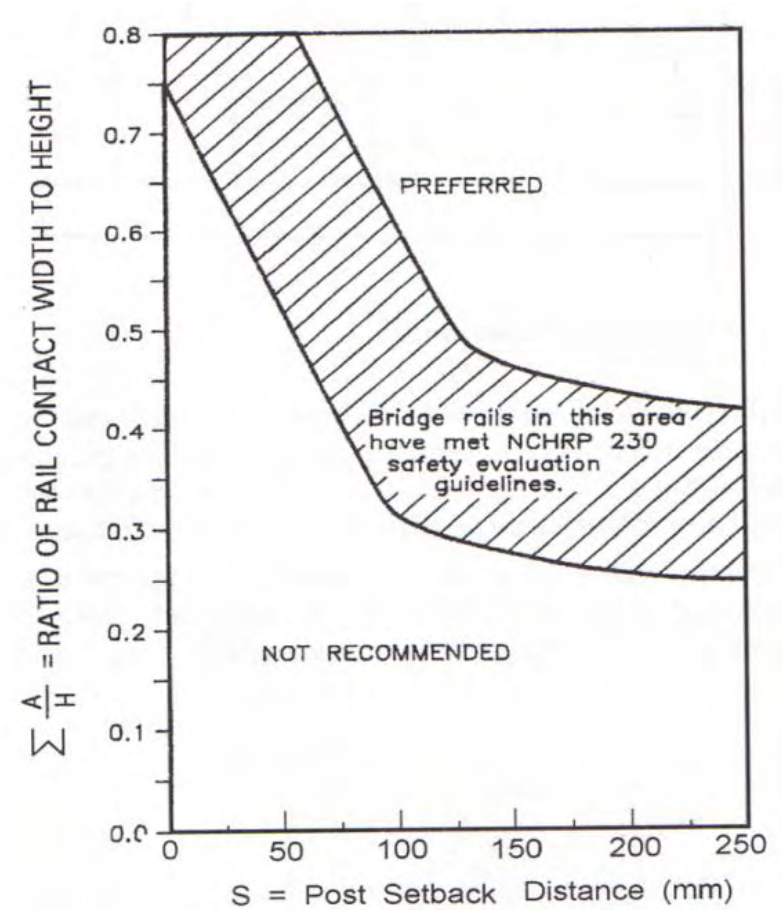


Figure 14. Check for Bridge Railing Post Setback Criteria [AASHTO, 2007]

4.5 Rating for Bridge Traffic Safety Features

This work is intended to provide a methodology for carrying out traffic safety inspections of bridges located on low speed rural roads. In the creation of this methodology a series of factors emerged as essential in the proper traffic safety evaluation of bridges; these factors are the geometry alignment of the roadway, the bridge sight distance, the change in roadway width, the clear zone, and the traffic safety features. When determining the degree of traffic safety on a bridge all of these factors play an important role; but should be evaluated from two different perspectives. The geometry alignment, the bridge sight distance, the change in roadway width, and the clear zone, all represent characteristics of the site which can be identified as potential causes for accidents, while traffic safety features are treatments for safety deficiencies identified during the design or maintenance stage of a particular bridge. This work will focus on the evaluation of the traffic safety features on bridges and will use the information obtained during the inspection with regards to the other factors in the identification of potential safety treatments and in the assignment of ratings to the traffic safety features. Further studies can focus on the creation of an overall rating of traffic safety on bridges, by combining all of these factors.

The bridge traffic safety feature rating (BTSFR) presented in this section is a descriptive rating. The decisions taken during the creation of this rating were based on the literature review carried out for this work and on the application of engineering judgment. This rating is determined by the amount of items that are in compliance in the corresponding traffic safety feature section of the inspection sheets. Sections six thru twelve of the inspection sheets correspond to the bridge's traffic safety features (end treatment, approach guardrail, transition, and bridge rail), each of these features, with the exception of the bridge rail, are evaluated for both the entry and exit segments of the bridge. Each section considers a series of items for its evaluation; each item represents a factor that has an effect in the element's functional and structural adequacy. The number of factors considered for the evaluation of each section are, three for the end treatment, seven for the approach guardrail, and five factors each for the transition and the bridge railing sections.

After gathering the data in the field, the inspector is in charge of comparing the information collected with the corresponding design values. In order for a traffic safety feature item not to be in compliance one of three things must happen, the first is that the information obtained in the field for the existing feature differs from the design values, the second is that the feature does not correspond to any existing crash tested design, and the third is that the feature is required, and is currently not installed.

Each category of the BTSFR represents the following:

1. Excellent: A bridge traffic safety feature under this category must meet all of the design criteria. This rating represents that the element is in full compliance and at the moment of the inspection is found to be structurally and functionally adequate.

2. Good: A bridge traffic safety feature under this category has at most one item that needs attention. For a traffic safety feature to be rated in this category the inspector must determine the severity of a crash that will result from the item that's not in compliance, taking into consideration the type of hazard that the feature is protecting and how the level of protection will be affected by the element that is not in accordance with the design value. If the element does not affect the proper function of the feature or if its function is affected but the hazard being protected is classified as low severity, then the element can be assigned this rating. If under any circumstance the hazards protected are of moderate or high severity the inspector must lower the rating to average or deficient. The severity of the hazard that the

feature is protecting must be determined, before assigning a rating. This category does not apply to end treatments. A feature in this category can remain in place.

3. Average: If more than one, but less than half of the items of the feature do not meet design standards, the feature will be classified in this category; with the exception of the end treatment, in which case if only one of the items considered in its evaluation is not in compliance is considered to be average. Bridge traffic safety features classified as average may be considered functional for some site conditions. Further analysis will be required to determine if the feature may be considered functional under favorable site conditions (low speed, low ADT, low % trucks, recoverable side slopes, and good geometric conditions). For a feature to be rated as average, all of the items that are not in compliance must not affect the features function, which is to protect road users from potential hazards that may result in crashes with severe injuries or fatalities. The severity of the hazard that the feature is protecting must be determined by the inspector; if the hazard(s) has low to moderate severity the feature can be rated as average. The inspector may assign a higher or lower rating to the feature, good or deficient, if considered necessary. Traffic safety features in this category could require work or the identification of adequate safety treatments. If the issues encountered are not critical and do not require immediate attention, the inspector can report his findings and program the needed work along with existing scheduled work.

4. Deficient: In order for a bridge traffic safety feature to be classified as deficient, half or more than half of the items evaluated have to be found not in compliance. An element can also be considered deficient if any of the items considered for its evaluation is found not in compliance and can result on high severity crashes that lead to fatalities or severe injuries. Deficient features are not functionally or structurally adequate and require immediate attention. Inspectors are responsible for identifying any deficiency encountered and evaluating possible short and long term treatments, which could include the removal and reinstallation of the feature.

5. NA: Represents that the traffic safety feature is not required and has not been installed. For a traffic safety feature to have this classification it represents that for the particular site conditions the feature is not required. This category does not apply to the bridge railing. If the element is required but has not been installed, then it should be classified as deficient.

An application of the Bridge Traffic Safety Feature Rating where the issues presented have a low probability of high or moderate severity crashes with fatalities or severe injuries is presented in Tables 16-19; these tables can be used to illustrate the rating process for these particular cases.

Table 16. BTSFR for End Treatments

# ITEMS IN COMPLIANCE	RATING
3 items in compliance	EXCELLENT
2 items in compliance	AVERAGE
1 item in compliance	DEFICIENT

Table 17. BTSFR for Approach Guardrail

# ITEMS IN COMPLIANCE	RATING
7 items in compliance	EXCELLENT
6 items in compliance	GOOD
4 or 5 item in compliance	AVERAGE
3 items or less in compliance	DEFICIENT

Table 18. BTSFR for Transition

# ITEMS IN COMPLIANCE	RATING
5 items in compliance	EXCELLENT
4 items in compliance	GOOD
3 item in compliance	AVERAGE
2 items or less in compliance	DEFICIENT

Table 19. BTSFR for Bridge Railing

# ITEMS IN COMPLIANCE	RATING
5 items in compliance	EXCELLENT
4 items in compliance	GOOD
3 item in compliance	AVERAGE
2 items or less in compliance	DEFICIENT

4.6 Safety Treatments

The identification of issues that represent potential safety hazards to the road users is essential for the evaluation of traffic safety on bridges. The field inspection when carried out adequately will allow inspectors to identify safety deficiencies and determine the severity of the issues encountered. When adverse conditions such as: sharp horizontal curves, steep longitudinal grades, limited sight distance to and from the bridge, change in roadway width between the approach and the bridge, steep side slopes, and less than recommended clear zone values are encountered, and the existing traffic safety features on the bridge have an average or deficient rating, there is a need for the identification and implementation of potential safety treatments. These treatments will be directed at the specific deficiencies encountered during the inspection.

Traffic safety on bridges can be improved in three main areas: bridge, approach roadway and operational improvements [FHWA, 1998]. The first corresponds to the enhancements that can be made to elements that are structurally and/or functionally inadequate in the bridge structure, such as: the bridge rail, sidewalks, snag points in the bridge rail or bridge rail end, and delineation of narrow bridges. The second type is the improvements to elements in the approach roadway, such as the approach guardrail and transition elements, drainage features, curbs and sidewalks. The third type of improvements, correspond to the operational aspects of the approach road and the bridge, under this category are the improvements to road signs and markings to inform drivers about changes in geometry and traffic operating conditions. In this section a series of low cost safety treatments will be presented that can be effective for certain safety problems.

4.6.1 Signs

The appropriate placement and installation of signs can result in significant safety improvements. Signs provide regulation, warning, and guidance information to drivers; they should be used where justified by engineering judgment or studies [FHWA, 2003]. Signs can be classified as regulatory, warning and guide; regulatory signs notify road users of traffic laws and regulations, warning signs notify about situations that might not be apparent to the user, and finally guide signs provide geographical, recreational, or cultural information. A sign should have high visibility (day and night) and have adequately sized letters and/or symbols that make it legible. The visibility of a sign is determined by its retroreflectivity; all signs should be retro reflective and show the same shape and color both day and night. Signs should be designed in accordance with the sizes, shapes, colors, and legends in the *Standard Highway Signs* book.

A study in Mendocino County, California consisted in identifying potential signing and marking deficiencies in county roads; these deficiencies were identified and improvements were implemented. The implementation and upgrading of signs and markings on areas identified as hazardous resulted in a significant decrease in crashes. When comparing the cost of the program to the savings as a result of the decrease in the percentage of crashes, the savings were outstanding ($12.58 -$23.73 millions) [ATSSA, 2006]. Signs when placed strategically can provide very useful information to drivers; a well informed driver can make reasonable and timely decisions that can prevent accidents. The following is a list of several signs that can be used to improve traffic safety on bridges; for more information about signs the reader is referred to FHWA's *Manual on Uniform Traffic Control Devices* (2003).

1. Speed limit sign (R2-4): Shall be located at points of change from one speed limit to another, beyond mayor intersections, at locations where it is necessary to remind road users of the speed limit that is applicable, at entrances to the State and at jurisdictional boundaries of metropolitan areas. Providing a speed limit sign can be very effective for the safety of road users since it informs drivers of the maximum allowable speed for a particular location. When there is a change in roadway alignment or a reduction of the total roadway width in the bridge with respect to the approach roadway's width the installation of the speed limit sign is needed to remind road users of the established maximum speed for that particular location.

Figure 15. Speed Limit Sign [FHWA, 2003]

2. Horizontal alignment signs (W1-1 thru W1-5, W1-11, W1-15): These signs can be used when there are adverse changes in horizontal alignment in any of the bridge

influence zones. There are various signs that can be selected in accordance with the degree of change in the horizontal alignment, for example W1-11 represents a change in the alignment of 135 degrees or more, W1-15 represents a 270 degrees change. When either of these signs is installed the use of W1-8 chevron sign on the outer edge of the curve is recommended.

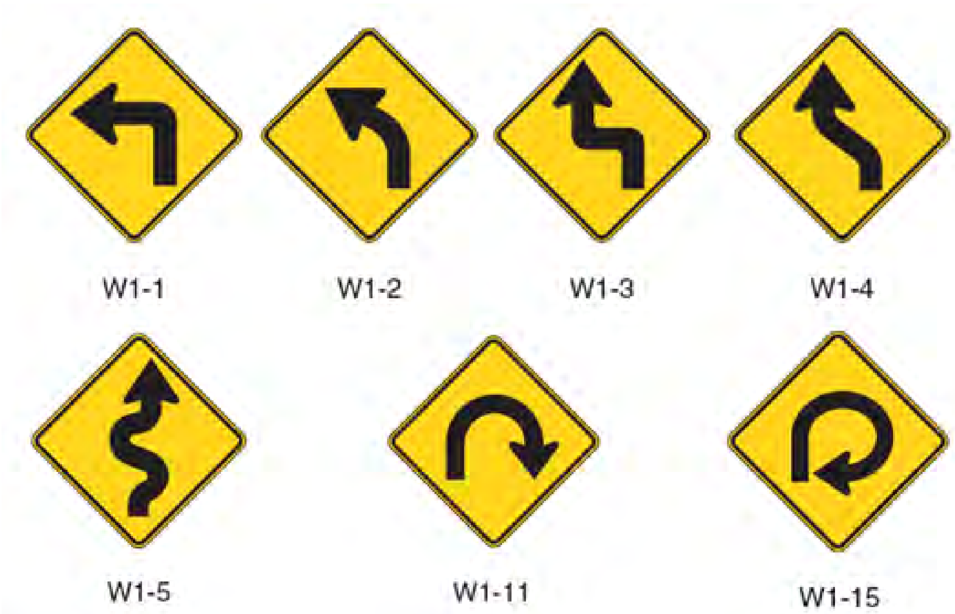


Figure 16. Horizontal Alignment Signs [FHWA, 2003]

3. Chevron alignment sign (W1-8): This sign is used when adverse horizontal alignment is present on the bridge influence zones. This sign is installed on the outside of the horizontal curve and is generally used in addition to any of the horizontal alignment signs presented in Figure 16, since it provides additional emphasis and guidance for a change in horizontal alignment.

W1-8

Figure 17. Chevron Sign [FHWA, 2003]

4. Combination horizontal alignment /intersection sign (W1-10): This sign can be used when there is an intersection located on the outside of a horizontal curve on any of the bridge influence zones. This sign will warn drivers of the existence of the intersection particularly when no adequate visibility distance is provided prior to its location.

W1-10

Figure 18. Combination Horizontal Alignment / Intersection Sign [FHWA, 2003]

5. Narrow bridge sign (W5-2): Should be used in advance of any bridge or culvert having a two way roadway width of (16 ft - 18 ft), or any bridge or culvert having a roadway width less than the width of the approach roadway. It may be used in advance on the bridge when the approach shoulders are narrowed or eliminated. Spanish is the official language used on all messages displayed in signs in PR, therefore the corresponding sign will read "Puente Estrecho"

W5-2

Figure 19. Narrow Bridge Sign [FHWA, 2003]

6. One lane bridge sign (W5-3): Should be used on two lane roadways in advance of a bridge or culvert that has a roadway width of less than 16 ft, or a bridge that has a clear roadway width of 18 ft with a high percentage of truck traffic or limited sight distance in the approach road. In Puerto Rico messages on signs should be in Spanish and it should read "Puente de un carril".

W5-3

Figure 20. One Lane Bridge Sign [FHWA, 2003]

7. Speed reduction zones sign (W3-5, W3-5a): Informs road users of a reduced speed zone ahead. It is used when engineering judgment indicates the need for advance notice of the upcoming speed zone ahead.

Figure 21. Speed Reduction Signs [FHWA, 2003]

4.6.2 Pavement Markings

Pavement markings provide guidance and information to road users; they can be used as supplemental information to other traffic control devices as signs and signals or on their own to convey regulation, warnings, and guidance while allowing minimal diversion of attention from the roadway.

The width of a pavement marking is normally between 4 – 6 inches; a wide line is considered to have at least twice the normal width of the marking (up to 12 inches). The use of wide pavement markings can denote emphasis, and as such may command more attention while providing the driver with information about his location with respect to other vehicles in the same and/or the opposing direction of travel, and with respect to the traveled way limits. In 1981 Morris County, New Jersey installed 8 inch edge lines on all county roads, being the first report of application of wider edge marks in the US. In a before-after crash study three years later, the county reported a decrease of 10 percent in all fatality and injury crashes [ATSSA, 2006]. Soon after, a research study performed by FHWA recommended the use of 8 inch edge lines on roadways with ADT between 2000-5000vpd, roadway width of 24 ft and frequent rainfall.

Edge line markings serve as visual references during adverse visibility conditions, such as weather. On two lanes - two way roads, edge lines shall consist of normal solid white lines. This type of pavement marking is not mandated for rural local roads; however their use is recommended on rural collectors with a minimum traveled way width of 20 ft and an ADT of 3,000 vpd or greater. An engineering study can be carried out to determine the need of these markings on roads not classified as freeways, expressways, or rural arterials.

Centerline markings are used to delineate the separation of traffic traveling in opposite directions, their color is yellow. These markings should be placed on rural arterials and collectors that have 18 ft or more in width, and an ADT or 3,000 vpd or greater. They should also be placed when an engineering study indicates the need.

4.6.3 Raised Pavement Markers

A raised pavement marker (RPM) is a safety device used on roads as a supplement or substitute pavement markings. They are at least 0.4 inch high and mounted on the road surface. These devices come in multiple colors: white, yellow, red, and blue, the same colors as the pavement markings the supplement or substitute. There are two types: retro reflective and non retro reflective. Retro reflective markers can be used on their own as a substitute of pavement markings; the surface of retro reflective raised pavement markers makes the device clearly visible at long distances, at night and in rainy weather. Non retro reflective should be used in conjunction with retro reflective markers and never on their own, since they are hardly noticeable.

Figure 22. Retro Reflective RPMs

RPMs can be used for additional delineation and to enhance drivers' ability to track the roadway at night and during adverse weather conditions. They provide audible and tactile warning to drivers that traverse them, making them very effective on the edge and centerline of two lane rural roads with high crash rates attributed to run off the road, encroachment, and head on crashes [ATSSA, 2006].

4.6.4 Object Markers

Object markers are safety devices used to mark obstructions within or adjacent to the roadway. Using a retro reflective object marker can help drivers avoid hitting an obstruction that's within the roadway or close enough to the traveled way for a vehicle to impact it. There are three types of object markers, as shown on Figures 23 thru 25; each of these can be used individually or as an arrangement of more than one to emphasize a potentially hazardous object.

Figure 23. Type 1 Object Markers [FHWA, 2003]

Figure 24. Type 2 Object Marker [FHWA, 2003]

Figure 25. Type 3 Object Marker [FHWA, 2003]

Object markers type 1 and 3 are used when the obstructions are within the roadway; these markers shall be used in conjunction with approach markings for obstructions. When obstructions are adjacent to the roadway type 2 and 3 object markers may be used, taking into consideration that the inner edge of the marker shall be aligned with the inner edge of the obstruction.

The mounting height of the object marker when the object is in the roadway or 8 ft or less from the shoulder is 4 ft from the surface of the nearest travel lane. When the object is 8 ft or more from the shoulder the mounting height should be at least 4 ft above the ground [FHWA, 2003].

4.6.5 Delineators

Delineators are devices mounted on the road surface or along the edge of a road used to channelize traffic in areas where the alignment might be confusing or unexpected. Since they are used to delineate the road alignment they are considered guidance devices rather than warning devices. They provide drivers with a better idea of the sharpness of the curve before entering it while at the same time providing continuous tracking information that allows the driver to position their vehicle in the travel lane as they traverse the curve. For information about the appropriate spacing of delineators in curved alignments refer to MUTCD [2003].

Figure 26. Application of Delineators in Curved Alignment [ATSSA, 2006]

The retro reflective units in these devices are capable of retro reflecting lights under normal weather conditions from a distance of 1,000 ft. Delineators should be mounted on suitable supports with the top of the highest reflector placed 4 ft from the surface of the edge of the roadway and placed 2 ft – 8 ft from the outer edge of the shoulder. When a guardrail is present the placement of the delineators can be altered to behind, on top or in the innermost edge of the guardrail.

Delineators can be used in the approach roadway to a bridge when the approach and/or bridge are on a curved alignment, when there is limited sight distance, on narrow bridges and where the travel path can be confusing.

4.6.6 Rumble Strips

Rumble strips alert drivers about possible dangers by causing a tactile vibration and audible rumbling, transmitted through the wheels into the car body. They can be applied in the direction of travel to alert drivers when they leave their lane and encroach on the roadside or invade the opposing lane, or in a transverse position to the direction of travel to warn drivers about an upcoming hazard. They consist of intermittent narrow areas of rough textured slightly raised or depressed road surface. The spacing between the strips is reduced as the driver gets closer to the potentially dangerous condition.

The use of rumble strips is not recommended in areas with sharp horizontal or vertical curves, on pedestrian crossings or on bicycle routes.

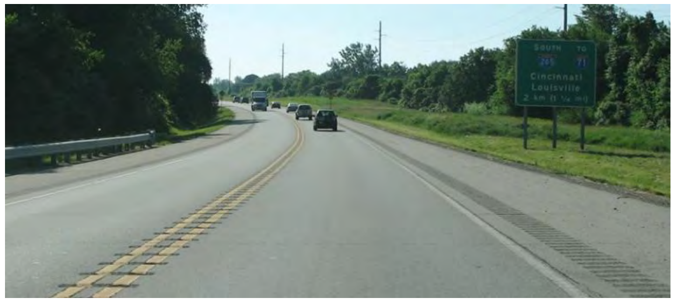


Figure 27. Application of Edge and Centerline Rumble Strips

4.6.7 Maintenance and Removal of Vegetation

Vegetation can restrict sight distance, thus creating a major safety problem. In bridges, the adequate sight distance is primordial, especially when the bridge is narrow, there are pedestrians crossing, and there are sharp curves on the bridge or on its approach roadways. Good sight distance allows drivers to be prepared and take action in a timely manner in the event of any abrupt changes that may present.

The lack of maintenance can allow vegetation to partially or completely cover regulatory, warning, or guidance signs that are installed in the road with the purpose of providing important information to drivers. Also foliage can cover guardrails which can become a hazard to drivers if they are not aware of their existence. These are just some of the reasons that maintenance and removal of vegetation in the roadside is of great importance for the safety of the road users.

Figure 28. STOP Sign Partially Covered by Foliage

The creation of a maintenance program by the counties or regional transportation agencies can result in the scheduling of maintenance work to all roads that require it. As discussed before, maintenance can result in improvements to sight distance, visibility to signs and roadside barriers.

5 APPLICATION OF INSPECTION PROTOCOL

5.1 Introduction

This chapter presents five application exercises in which bridges were selected from the western area of Puerto Rico. The primary objective of presenting these application exercises, is demonstrating the proper approach to be taken when performing an inspection of traffic safety features on low speed rural bridges. The inspection protocol presented in Chapter 4 was used on each of the selected bridges, and a complete inspection was performed. This chapter presents the bridge selection method, the data collected in the field using the inspection sheets and the evaluation of each bridge according to the information collected.

5.2 Bridge Selection Process

Puerto Rico's Bridge Inventory is a compilation of information with regards to bridges in Puerto Rico; there are a total of 2,166 bridges in the 2008 Inventory. This data base contains information regarding the bridge's identification number, its location (road, km., municipality), year it was built, functional classification, number of lanes, Average Daily Traffic (ADT), owner, maintenance responsibility, service type, bridge width, number of spans, material, design, length, condition ratings (deck, superstructure, substructure, channel, channel protection, and culverts), appraisal ratings (structural evaluation, deck geometry, and waterway adequacy), sufficiency rating, clearance, scour critical, and inspection date. The 2008 Inventory was made available for this project through Dr. Manuel

Coll, director of PR-DTPW Bridge Office to be utilized in the process of selecting bridges for the application exercise.

The selection process consisted initially in identifying all the bridges whose characteristics comply with the scope of this work, such as: located in the Western area of Puerto Rico, roads functionally classified as rural local or rural collector, only structures that comply with Title 23 CFR definition of bridge, and no culverts. The speed (posted or design) and the terrain characteristics of the road where the bridge is located are not present in the bridge inventory, therefore they could not be directly considered in the selection process. The speed and the terrain characteristics of the road were both checked in the field prior to the inspection exercise, in order to determine the bridge applicability for this work. In the case of the terrain the municipalities that were considered to be located in the mountainous area of PR were eliminated from consideration, such as: Las Marias, and Maricao. After scrutinizing the inventory 72 bridges were identified as relevant for this study.

A total of five bridges were needed for the application exercise. It was important that the bridges selected would present different scenarios, in order to make the exercise diverse, and to present how to proceed under different situations in the field. For this reason three characteristics were identified, which were intended to be included in the bridges selected, these characteristics are: functional classification (rural local, rural minor collector, rural major collector), type of service (highway, highway-pedestrian), and material (concrete, and steel). Each one of these characteristics should be on at least one of the five bridges.

5.3 Field Tools

The field inspection for each of the five bridges selected requires the collection of different elements of the approach roadways, the bridge, and the traffic safety features. Among the data to be collected are the widths of the roadway, bridge roadway width, width of the shoulders, sidewalk's width, barrier's height, post spacing, barrier's lateral offsets, clear zone distances, lateral slopes, longitudinal slopes, transversal slopes, etc. To measure these elements in the field the inspector will use a series of tools. For this work the following tools were used:

1. Reflective safety jackets
2. Odometer
3. Tape Measure
4. Electronic Level
5. Road characterization sheet
    a. Used to collect information about the traveled way width, the shoulder, the clear zone, the transversal slope, the longitudinal slope, and the lateral slope on different points of the bridge and its influence zones. The purpose of this sheet is to obtain these measurements in points in which changes are perceived either in the roadway's cross section, in the grade or in the roadside clear zone, and lateral slopes. The inspector can choose to take these measurements at preselected distance when the bridge's influence zone does not have any perceivable changes. On the bridge structure, information can be

taken on the extremes and in the middle. This sheet will be presented on Appendix B.2.

6. Roadside measures sheet

   a. The purpose of this sheet is the collection of information with regards to potential roadside hazards in the approach roadway and the presence of traffic control devices. It can be used to document the presence of any obstacle or potential hazard to the road users within the required clear zone, such as non recoverable or critical slopes. Problems regarding the condition of any of the traffic safety features in the bridge can also be indicated in this sheet, for instance, missing posts or bolts, and impacted sections of guardrail. This sheet will be presented on Appendix B.2.

5.4 Application Examples

This section presents the cases of the five bridges chosen for the inspection of their traffic safety features, using the selection method presented above. The intention is to implement the inspection protocol developed in this work, on existing low speed rural bridges located on local or collector roads in Puerto Rico. Each example presents the application of the inspection protocol for traffic safety features on bridges from start to finish. Consideration should be given to the fact that the situation on each of the selected bridges varies; it was the author's intention to present different scenarios that would require a different approach when performing the inspection and when completing the inspection sheets. The purpose of this exercise is to present such differences and also making a point to state that although the inspection sheets were created to be comprehensive, there are special situations that can be encountered in the field which may present the need to improvise and collect information about a particular situation that was not contemplated during the creation of the original inspection sheets. The complete analysis performed using the information collected during the inspection exercise is presented in this section. The completed inspection's data collection sheets for each of the inspected bridges, is presented in Appendix C.

5.4.1 Application Example #1: NBI Structure Number #465

Description:

1. General: The Bridge is located at km 1.2 of PR-329 in the municipality of San Germán. This road has an ADT of 1,200 vpd, and is an undivided highway functionally classified as rural local. During the inspection no posted speed limit sign was present on the roadway in either direction. In Puerto Rico the maximum legal speed limit in unsigned rural roads is 45 mph, as established in PR Vehicle's and Traffic Law No. 22 of 2000, Article 5.02. This speed will be assumed as the posted speed for the road.
2. Bridge: The NBI structure number is 465. The material of the structure is concrete, and the bridge serves vehicular traffic only, no sidewalks provided for pedestrian traffic. The length of the bridge is 30.18 ft, and the roadway width is 16.8 ft. The pavement surface is asphalt and it has only edge pavement markings.

3. Approach Roadway:

   a. Eastbound: The total roadway width is 16.33 ft. This road does not have shoulders or sidewalks. The pavement surface is asphalt. During the field inspection a positive 2.33 percent grade was measured. The roadside slopes for both the left and right sides of the road are foreslopes, 1V:5H and 1V:9H respectively. Guardrail has been installed throughout the total length of the influence zone.

   b. Westbound: The total roadway width is 17.9 ft. The road does not have any shoulder or sidewalks. The pavement material is asphalt. A roadway grade of negative 1.9 percent was measured during the field inspection. The roadside slopes in the left and right side of the road are 1V:4H and 1V:11H respectively. Guardrail has been installed throughout the total length of the bridge influence zone.

<u>Findings</u>:

1. Direction of Inspection: <u>Eastbound</u>

   a. No speed limit sign was found in the vicinity of the bridge or throughout the length of PR-329.

   b. There is no visibility of the bridge from the limits of the bridge influence zone, defined using the SSD for a 45 mph road which is 360 ft. The point at which the bridge is visible by a driver traveling in its lane is located at a distance of approximately 96 ft from the bridge. The existing SSD is much less than the design value, which represents that drivers do not have adequate visibility of the bridge. This can result dangerous especially in situations in which the bridge roadway width is less than the approach roadway width, and also when the geometric alignment of the road is a reverse curve.

c. At a distance of 99 ft a “Puente Estrecho” sign has been installed, to convey that the bridge roadway width is less than the approach roadway width. See Figure 29A.

d. The entry approach guardrail has several variations within its length of need, the system starts as a weak post guardrail, then at 187.5 ft becomes a strong post guardrail and then at a distance of 100 ft from the bridge the posts change to concrete; see Figure 29B. The entry approach guardrail has a total of 8 concrete posts, with one damaged; such posts are not acceptable in the installation of a W-Beam guardrail, since these systems are crash tested with metal or wood posts. The concrete posts used in this installation can act as potential hazards to road users. This finding led to the entry approach guardrail TL being found non compliant.

e. There is a utility post located a distance of 44 ft from the bridge structure, the post is located right behind the guardrail at a distance of 13inches, shown on Figure 29C. The maximum dynamic deflection of a W-Beam weak post is 6.5 ft and of a W-Beam strong post is 3 ft. The distance at which the utility post is located behind the guardrail is inadequate.

f. The entry approach guardrail and the bridge rail are not connected. There is a space of 1.5 ft between the safety features, shown on Figure 29D, and there is no reduction in post spacing.

Figure 29. Issues Encountered on Bridge #465 Eastbound Approach

g. The bridge rail is not a crash tested design. The rail is composed of a 15 inch high concrete element with a W-Beam weak post mounted on top, as shown on Figure 30A. The concrete element has a 3.5 inch high step; the total height of the bridge rail is 35.5 inches.

h. There is a local track to the right that starts at the end of the bridge rail. There is a section of W-Beam guardrail that follows the bridge rail in the direction of the local track, but this section is only 12.5 ft, attached to concrete posts and its height is only 11 inches, see Figure 30B.

i. The exit approach guardrail continues after the local track. A group of mail boxes are located at the beginning of the guardrail, right behind the approach guardrail terminal, as shown on Figure 30C. This guardrail has two concrete posts at the other end.

j. There's a utility post located behind the guardrail at a distance of 70 ft from the start. The guardrail appears to have been impacted and it has become encrusted in the utility post, shown on Figure 30D. The closeness at which the post was installed does not allow for the guardrail to achieve its maximum deflection in the case of an impact. Utility posts are considered a hazard for road users and for this reason they should be shielded or located beyond the required clear zone distance for the road, in order for a vehicle that encroaches on the roadside not to impact it.

k. The exit approach guardrail ends without an end treatment, see Figure 30E.

l. At a distance of 192 ft from the bridge and 92 ft from the end of the exit approach guardrail, a W-Beam strong post guardrail installation starts. This W-Beam guardrail starts with a blunt end, as shown on Figure 30F. These types of terminals can be very dangerous because of their capability of penetrating the passenger's compartment.

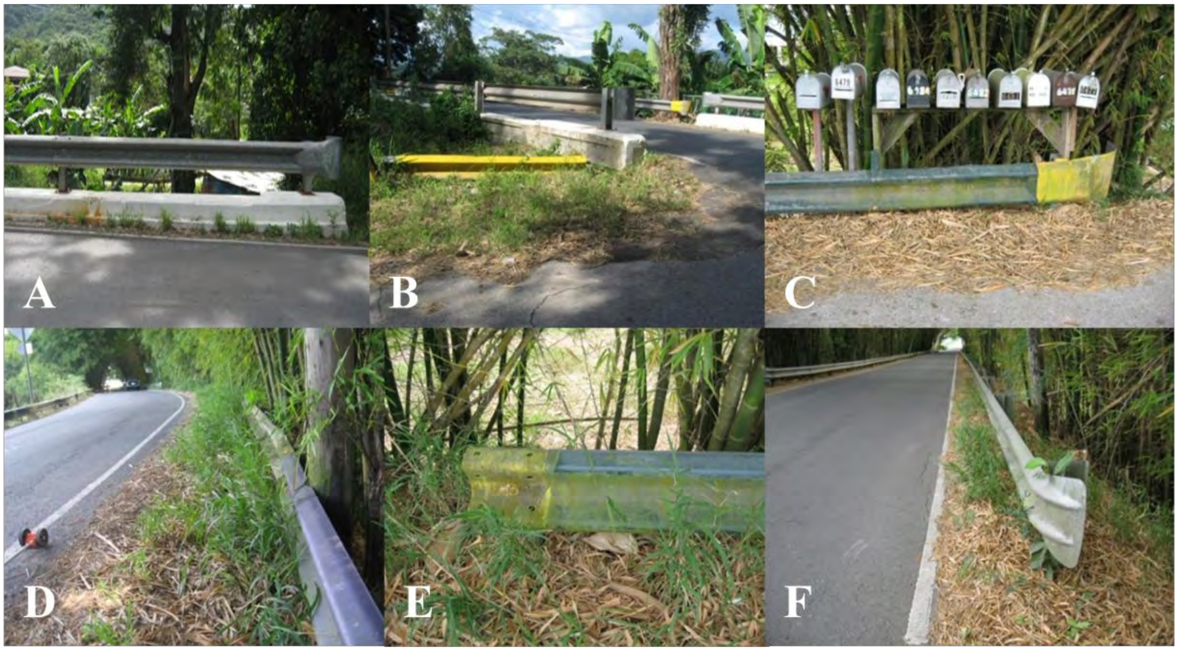


Figure 30. Issues Encountered on Bridge #465 Eastbound Approach (Continued)

2. Direction of Inspection: <u>Westbound</u>

   a. There is a W-Beam guardrail system that extends through the approach roadway, and is installed in precedence to the approach guardrail, see Figure 31A. This system ends in a blunt end terminal, which are very hazardous to road users because of their capability of penetrating the passenger's compartment. The start of the bridge approach guardrail is located at a distance of five feet from the blunt end terminal of the approach roadway's guardrail. The bridge's approach guardrail has an end treatment type MB. This end treatment appears to have been bent.

b. There is a “Puente Estrecho” (Narrow Bridge) sign located at a distance of 59 ft from the bridge, to indicate that the bridge roadway width is less than the approach roadway width, as shown on Figure 31B.

c. The entry approach guardrail has a total of 9 concrete posts out of the total 15 posts in the guardrail’s length of need.

d. The entry approach guardrail is damaged, it appears there are various sections of guardrail that have been impacted, approximately 40 ft; a post is missing and two posts have been pushed back, one of them has separated from the rail and broken in pieces, as shown on Figure 31C.

e. The point at which the bridge is visible by drivers is located 105 ft from the bridge. The SSD for a road with a speed of 45 mph is 360 ft, this situation does not comply with AASHTO’s *Green Book* [2004] SSD requirements.

f. The entry approach guardrail and the bridge rail are not connected, see Figure 31D. There is a space of 2 ft between the safety features, and there is no reduction in post spacing.

g. The bridge rail is not a crash tested design; its composed of a 15 inch high concrete element with a 3.5 inch step, mounted on top of the concrete element there is a 20.5 inch high W-Beam weak post.

h. There exit approach guardrail is a W-Beam strong post segment, that is not connected to the bridge rail. This segment of guardrail ends with a bent terminal at the start of the local track and it does not extend through the entrance, making this not the proper installation of the element, shown on Figure 31E.

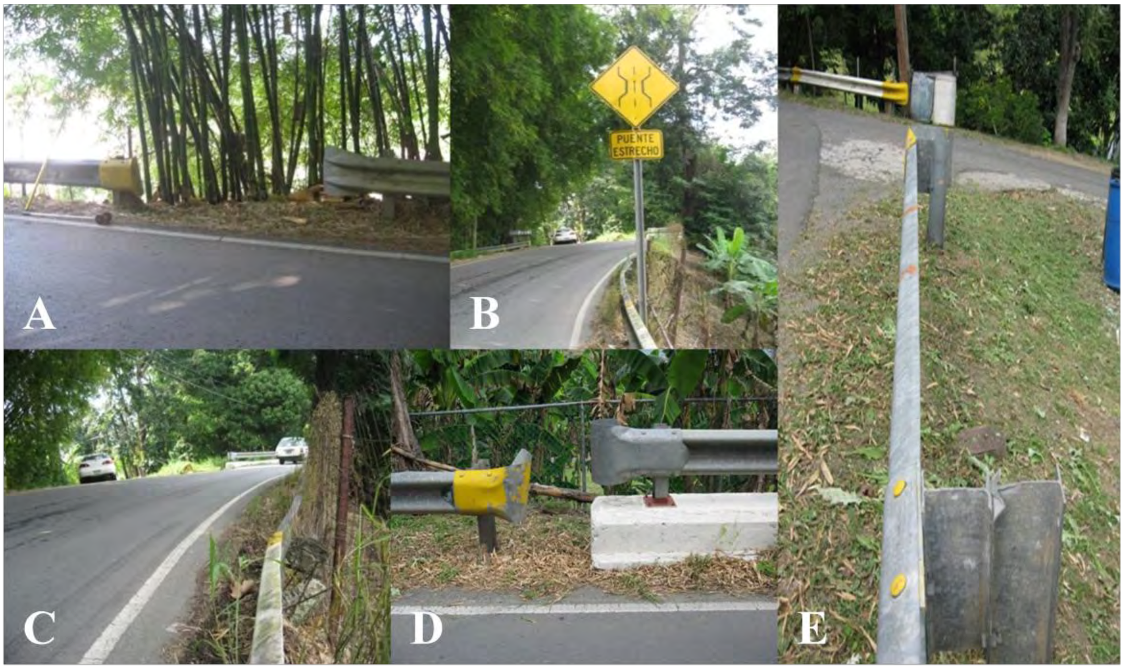


Figure 31. Issues Encountered on Bridge #465 Westbound Approach

i. The approach guardrail continues at the other extreme of the local track, where the guardrail begins with a blunt end, and posts made of concrete instead of metal throughout the first four sections of guardrail. The following sections correspond to a strong post W-Beam with steel posts. The height of the approach guardrail in this section is 15 inches.

j. Behind the last 200 ft of exit approach guardrail there is a critical slope of 1V:1H that is located approximately 2 ft behind the guardrail.

Evaluation

This section presents all factors considered in the safety evaluation of bridge #465. The evaluation will consist of two parts; the first part is the evaluation of safety elements that are related to the geometry alignment, sight distance, roadway width and clear zone. The second part consists in the evaluation of the bridge's traffic safety features. The evaluation of these factors is performed twice, once for each direction of inspection. The last page of the inspection sheets contains a table in which to enter the rating assigned to each traffic safety feature.

Direction of Evaluation: Eastbound

1. Change in approach roadway and bridge roadway width

   The bridge roadway width is 16.8 ft, and the eastbound approach roadway width is 16.3 ft. This represents that there is no significant change in roadway width between the bridge and the eastbound approach.

2. Entry sight distance

   The required SSD for a road with a posted speed of 45 mph is 360 ft. During the inspection the point of visibility of the bridge from the approach roadway was measured and it was determined to be 96 ft. This distance does not comply with the value of SSD presented by AASHTO [2004].

3. Exit sight distance

There is no visibility of the end of the exit influence zone from the bridge. The degree of curvature and the radius of the curve do not allow drivers exiting the bridge a clear view of the area.

4. Geometry Alignment

The bridge is located in an inverted curve. The road's horizontal alignment consists of two sharp curves with radius of 189 ft and 290 ft respectively. There are no vertical curves in the bridge site.

5. Clear Zone

Guardrail is installed throughout the entire bridge influence zone, both in the entry and exit of the bridge.

$\underline{\text{BTSFR}_{\text{EB}}}$

1. Entry End Treatment

The entry approach guardrail has an entry end treatment type MB, this feature is TL-2 and placed on a 1V:10H grade, however the anchorage system is not present. The feature complies with two out of three elements and the element that is not in compliance has a low probability of producing a high severity crash. After the evaluation, the end treatment was found average.

2. Entry Approach Guardrail

The entry approach guardrail is a W-Beam, the installation varies from weak post to strong post and at some point near the beginning of the bridge rail a total segment of guardrail is installed with concrete posts (8 in total). This situation deemed the guardrail's TL not compliant, since W-Beams are crash tested with steel or wood posts. In the evaluation of the existing guardrail's criteria, four out of the seven items to consider were found not in compliance, and these are: TL, height, grading, and lateral offset. Two factors were considered not effective at providing adequate protection to road users from the hazard they are intended to shield, which could result in the probability of a high severity crash. The first is the height which is only half of the design value for that particular guardrail, which can allow a driver to go over the guardrail, and the second is the grading which is 1V:6H; according to the RDG [2006] W-Beam guardrails have a tendency to bend backward and ramp the vehicle, when installed on 1V:6H slopes. After evaluating the situation the approach guardrail is rated as deficient.

3. Entry Transition

There is no entry transition installed. The guardrail presents no connection to the bridge rail and no reduction in post spacing. Since the approach guardrail and the bridge railing element are two different systems, a transition segment should be installed; therefore the entry transition is considered deficient.

4. Bridge Railing

The existing bridge railing is not a crash tested design. It consists of a concrete element that is 15 inches high with a W-Beam strong post system mounted on top. The total height of the rail is 35.5 inches. The concrete element of the rail has a 3.5 inch step that can produce a vaulting effect. Since there are no design criteria to which we can compare the traffic safety feature, the bridge railing is found deficient, with zero elements in compliance.

5. Exit Transition

There is a local track located at the end of the bridge rail. At the entrance to the local track there is a section of guardrail that was installed to protect oncoming traffic from penetrating the side of the structure. This section of guardrail is not connected to the bridge rail. This feature is found to be deficient.

6. Exit Approach Guardrail

The exit approach guardrail eastbound should be installed in two positions, at the entrance to the local track, and it should continue after the clearance of the local track. In this case the installation at the entrance to the local track consists of only one section of guardrail, and it does not comply with most of the items considered. The installation of the guardrail after the local track opening starts with an MB end treatment, that has been pulled out to fit in the space behind it a group of mailboxes, as shown before on Figure 30C. This W-Beam guardrail consists of mainly steel posts, but has two concrete posts at its end. The guardrail was classified as average but after evaluation it was determined that its height does not allow the feature to effectively protect road users, thus resulting in the probability of high severity crashes.

7. Exit End Treatment

No end treatment was installed. The end treatment was found to be deficient.

Direction of Inspection: <u>Westbound</u>

1. Change in approach roadway and bridge roadway width

The bridge roadway width is 16.8 ft, and the eastbound approach roadway's width is 17.9 ft. This represents that the bridge roadway width is less than the roadway width of the westbound approach; this reduction in roadway width can be a potential hazard for drivers.

2. Entry sight distance

The required SSD for a road with a posted speed of 45 mph is 360 ft. During the inspection the point of visibility of the bridge from the approach roadway was measured and it was determined to be 146 ft. This distance does not comply with the value of SSD presented by AASHTO.

3. Exit sight distance

There is no visibility of the end of the exit influence zone from the bridge. The degree of curvature and the radius of the curve do not allow drivers exiting the bridge a clear view of the area.

4. Geometry Alignment

The bridge is located in an inverted curve. The road's horizontal alignment consists of two sharp curves with radius of 290 ft and 189 ft respectively. There are no vertical curves in the bridge site.

5. Clear Zone

Guardrail is installed throughout the entire bridge influence zone, both in the entry and exit of the bridge.

$\underline{BTSFR_{EB}}$

1. Entry End Treatment

The entry approach guardrail has an entry end treatment type MB, this feature is TL-2 and placed on a 1V:10H grade, however the anchorage system is not present. Not installing the anchorage system does not prevent the feature from performing its primary function which is preventing the road user from impacting the unprotected end of a guardrail, thus causing severe and probably fatal crashes as a result of penetration, vaulting or rolling. After the evaluation, the end treatment was found to be average.

2. Entry Approach Guardrail

The entry approach guardrail is a W-Beam, the installation varies from weak post to strong post and at some point near the beginning of the bridge rail a total segment of guardrail is installed with 9 concrete posts in total. This situation deemed the guardrail's TL not compliant, since W-Beams are crash tested with steel or wood posts. In the evaluation of the existing guardrail's criteria, four out of the seven items to consider were found not in compliance, and these are: TL, height, grading, and lateral offset. Two factors were considered poor at providing adequate protection to road users from crashes that may result in severe injuries or crashes. The first is the height which is too low when compared to the design value for that particular guardrail, which can allow a driver to go over the guardrail. The second factor is the slope which is 1V:5H; an unacceptable value because of its safety consequences. The feature was found to be deficient.

3. Entry Transition

There is no entry transition installed. The guardrail presents no connection to the bridge rail and no reduction in post spacing. Since the approach guardrail and the bridge railing element are two different systems, a transition segment should be installed; therefore the entry transition is considered deficient.

4. Bridge Railing

The existing bridge railing is not a crash tested design. It consists of a concrete element that is 15 inches high with a W-Beam strong post system mounted on top. The total height of the rail is 35.5 inches. The concrete element of the rail has a 3.5 inch step that can produce a vaulting effect. Since there are no design criteria to which we can compare the traffic safety feature, the bridge railing is found to be deficient, with zero elements in compliance.

5. Exit Transition

There is no entry transition installed. The exit approach guardrail presents no connection to the bridge rail and no reduction in post spacing. Since the exit approach guardrail and the bridge railing element are two different systems, a transition segment should be installed; therefore the exit transition is considered deficient.

6. Exit Approach Guardrail

The exit approach guardrail will be considered in two sections, the section of guardrail that should continue through the entrance of the local track, and the guardrail that starts after the clearance of the local track. In this case the approach guardrail installation does not continue through the entrance to the local track, instead it stops at the edge of it, which does not constitute the proper installation. The second section starts with a blunt end terminal that is flared through the entrance, and has four concrete posts. The feature does not comply with three of the seven items considered in its evaluation. The guardrail was classified as average; after evaluation it was determined that its height does not give proper protection to road users, and the installation of concrete posts will not provide adequate safety, these elements will not be effective at preventing severe injuries or fatalities, that will result from a vehicle encroaching on the roadside to the hazardous area they are intended to protect. The feature was deemed deficient.

7. Exit End Treatment

    The entry approach guardrail has an entry end treatment type MB, this feature is TL-2 and placed on a 1V:19H grade, however the anchorage system is not present. Not installing the anchorage system does not prevent the feature from performing its primary function which is preventing the road user from impacting the unprotected end of a guardrail, resulting in severe and probably fatal crashes as a result of penetration, vaulting or rolling. After the evaluation, the end treatment was found to be average.

Recommended Safety Treatments:

This bridge presents a series of safety problems that are associated with the horizontal alignment of the road, the sight distance, and the overall compliance of its traffic safety features. With the purpose of improving the overall traffic safety in this bridge and its influence zones the following safety improvements are recommended:

1. The installation of a speed limit sign in both approaches is very important to indicate the safe speed at which drivers should traverse this road. Currently without the installation of a speed limit sign, the speed for a road located in a rural area where there are no speed limit signs installed is 45 mph; this speed is too high for this particular location, the geometry alignment, the limited sight distance, and the width of the roadway does not allow a driver traveling at that speed to be safe.

2. Installation of signs to warn drivers about the different conditions they can encounter ahead and also to guide users through them.
    a. Reverse curve
    b. Combination Horizontal Alignment/Intersection sign (W1-10)
    c. Chevrons Alignment sign (W1-8) or the One-Direction Large Arrow sign (W1-6)

   * The use of too many signs is not recommended since providing drivers with too much information can confuse them, for this reason only one sign between the reverse curve and the combination horizontal/intersection alignment sign may be installed. For this decision the inspector must use his engineering judgment to determine which information is more critical and will result more helpful to drivers.

3. The installation of a type 1 or type 3 object marker at the end of the bridge railing.

4. Removal and reinstallation of mailboxes currently located behind the exit approach guardrail. For adequate lateral placement and mailbox separation recommendations refer to AASHTO *A guide for erecting mailboxes on highways* [1994].

5. Traffic safety features (Eastbound)
    a. Removal of concrete posts and installation of steel posts for the entry approach guardrail.
    b. Lifting the entry approach guardrail to its original design height of 30.38 inches.

c. Removing the existing bridge railing and reinstalling a crash tested bridge rail.
d. Installing an adequate transition between the existing approach guardrail and the new bridge rail.
e. Reinstallation of the section of exit guardrail that goes into the entrance to the local track. The new installation should have the correct height, post type, and length of need.
f. Installation of a crash tested end treatment at the exit approach guardrail.

6. Traffic safety features (Westbound)
   a. Removal of concrete posts and installation of steel posts for the entry approach guardrail.
   b. Lifting the entry approach guardrail to its original design height of 30.38 inches.
   c. Removing and reinstalling a crash tested bridge rail at the bridge.
   d. Installing an adequate transition between the existing entry and exit approach guardrails and the new bridge rail.
   e. Extend the existing installation of the exit approach guardrail through the entrance of the local track, to provide adequate shielding of the hazardous area behind the bridge rail.
   f. Reinstallation of the section of the exit approach guardrail that start at the end of the local track clearance tom provide the adequate height and to eliminate all concrete posts from the installation.

5.4.2 Application Example #2: NBI Structure Number #63

Description:

1. General: The Bridge is located at km 0.55 of PR-115 in the municipality of Añasco. This road has an ADT of 8,000 vpd, and is an undivided highway functionally classified as rural major collector with a posted speed of 35 mph.

2. Bridge: The NBI structure number is 63. The material of the structure is concrete, and the bridge serves vehicular traffic only, no sidewalks provided for pedestrian traffic. The length of the bridge is 27.6 ft, and the total roadway width is 29.4 ft with left and right shoulder widths of 3.7 ft and 3.5 ft, respectively. The pavement surface is asphalt and it has both edge and centerline pavement markings.

3. Approach Roadway:
   a. Northbound: The total roadway width is 24 ft. This road does not have shoulders or sidewalks. The pavement surface is asphalt. The roadside slopes for both the left and right sides of the road are 1V:12H foreslopes. There is an approach guardrail installation but it does not extend through the entire length of the influence zone. There are no adverse geometry alignment conditions in this site; the approach is a tangent section.
   b. Southbound: The total roadway width is 24 ft. The road has left and right shoulder widths of 2.3 ft and 2 ft, respectively. The pavement material is asphalt. The roadside slopes in the left and right side of the road are 1V:12H

and 1V:14H respectively, in foreslopes. An approach guardrail has been installed but it does not extend throughout the total length of the bridge influence zone.

<u>Findings</u>:

1. Direction of Inspection: <u>Northbound</u>

   a. Two metal tubes filled with concrete are located at a distance of 15 ft from the traveled way in the right side of the approach road, 156 ft from the bridge, as shown on Figure 32A. The distance were they were found is within AASHTO's recommended clear zone value, which is 14 ft – 16 ft, and surpasses the value recommended by FLH in their *Barrier Guide* [2005b], which is 12 ft – 14 ft.

   b. The bridge approach guardrail is covered by vegetation, and is almost imperceptible by drivers, see Figure 32B.

   c. The approach guardrail transition has a reduction in post spacing that is not as required by its design. The correct installation of the transition should start with the connection, transition into 4 posts spaced at 1 ft 7 inches and the two posts spaced at 3 ft 1 inch. The current installation has the connection and 4 posts spaced at 3 ft 1 inch.

   d. Located 28 ft after the bridge at the exit approach there is a concrete hectometer that is 10 inches behind the guardrail, as shown on Figure 32C. The W-Beam strong post has a maximum dynamic deflection of 6 ft 3inches.

The installation of the structure behind the guardrail does not allow it to deflect appropriately.

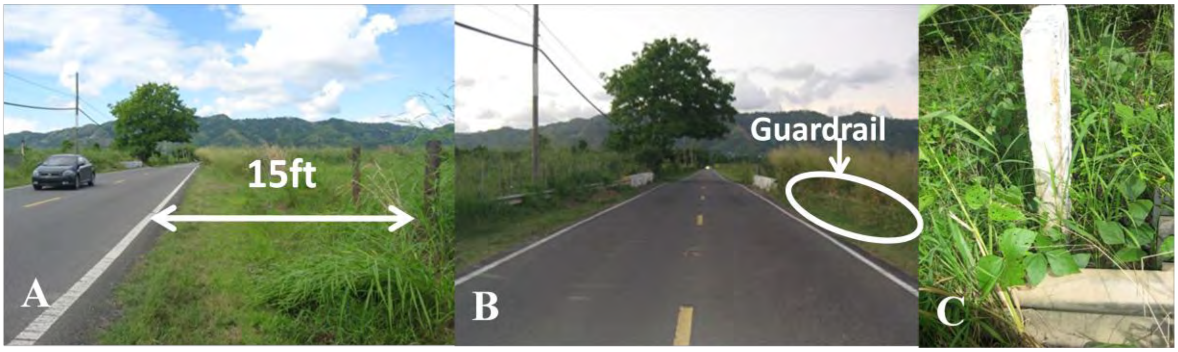


Figure 32. Issues Encountered on Bridge #63 Northbound Approach

2. Direction of Inspection: Southbound

    a. There is a 6 inch diameter tree at the bridge entry influence zone, 259 ft from the bridge. The tree is located 11 ft away from the traveled way.

    b. There are utility poles installed 10 ft from the traveled way, at the right side of the road at a distance of 352 ft and 200 ft from the roadway. The lateral distance at which they are installed does not comply with the recommended clear zone values of AASHTO or FLH.

    c. At 83ft from the bridge there is an entrance to a private estate.

    d. At a distance of 36 ft from the bridge right behind the approach W-Beam there is a tree that has a diameter of 20 inches, the trees appears to have grown around the guardrail post installation, as shown on Figure 33. Such incident will prevent the section of guardrail from working properly.

Figure 33. Tree Behind Approach Guardrail

e. At the exit influence zone there is considerable amount of vegetation surrounding the exit guardrail, to the point that there are some areas of the feature completely covered by it.

Evaluation

This section presents all factors considered in the safety evaluation of bridge #63, for both directions in which the inspection was performed, northbound and southbound. The ratings assigned to each traffic safety feature during evaluation will be presented in the last page of the inspection sheets.

Direction of Evaluation: Northbound

1. Change in approach roadway and bridge roadway width

The bridge roadway width is 29.4 ft, and the northbound approach roadway width is 24 ft. This represents that bridge roadway is wider than the approach roadway and this does not represent a safety concern.

2. Entry sight distance

The approach roadway and bridge configuration is a relatively flat tangent section, which means that drivers have adequate view of the bridge roadway before entering it. During the inspection no visibility problems related to the alignment or to possible obstructions to drivers' sight were encountered.

3. Exit sight distance

The bridge is located in a tangent section of roadway. There are no obstructions to the drivers' sight line when exiting the bridge.

4. Geometry Alignment

The bridge is located in a relatively flat tangent section. There are no adverse geometric design elements in the bridge influence zones.

5. Clear Zone

The approach guardrail does not extend throughout the entire bridge influence zone. When evaluating the clear zone in both sides of the road, it was determined that the right side of the road complies with AASHTO recommended clear zone values, while the left side has a clear zone of 10.3 ft, which is below the 14 ft recommended by AASHTO and the 12 ft recommended by FLH.

$BTSFR_{NB}$

1. Entry End Treatment

The entry approach guardrail has an entry end treatment type MB, this feature is TL-2 and placed on a 1V:35H grade, however the anchorage system is not present. The feature complies with two out of three elements and the element that is not in compliance will not have an adverse effect in the overall protection of the road user. After the evaluation, the end treatment was found to be average.

2. Entry Approach Guardrail

The entry approach guardrail is a strong post W-Beam with steel blocks. Only one of the seven items considered in its evaluation was found not in compliance, and it is the height. The required height of the W-Beam strong post is 27 inches and the height measured in the field was 25 inches. Although height is a very important factor in providing adequate protection to drivers, in this case since the difference in height is not considerable, the guardrail will be rated as good.

3. Entry Transition

The existing entry transition has a total of two items that were found not in compliance during the inspection, the first is the height and the second is the post spacing. The height of the transition is 25 inches, 2 inches below the design height. The reduction in the post spacing is not in accordance with the PR-DTPW standard plans. Instead of having a gradual reduction with two posts spaced at 3 ft 1 inch, 4 posts spaced at 1 ft 7 inches and then the connection to the bridge rail; the transition installed consists of 4 posts spaced at 3 ft 1 inch and then the connection. The difference in height may not be regarded as a considerable safety risk, however the difference in post spacing does not provide the gradual stiffening of the approach guardrail. After evaluation and in accordance with the bridge traffic safety feature rating, the transition is considered as average.

4. Bridge Railing

The existing bridge railing is a New Jersey barrier that complies with all elements evaluated during inspection. This feature is rated as excellent.

5. Exit Transition

The existing entry transition has a total of two items that were found not in compliance during the inspection, the first is the height and the second is the post spacing. The height of the transition is 22 inches, 5 inches below the design height. The reduction in the post spacing is not in accordance with the PR-DTPW standard plans. Instead of having a gradual reduction with two posts spaced at 3 ft 1 inch, 4 posts spaced at 1 ft 7 inches and then the connection to the bridge rail; the transition installed consists of 4 posts spaced at 3 ft 1 inch and then the connection. The difference in height is considerable, and the difference in post spacing does not provide the gradual stiffening required by this type of transition; however after an evaluation of the safety risks taking into consideration the elements of the site and in accordance with the bridge traffic safety feature rating, the transition is considered as average.

6. Exit Approach Guardrail

There is only one item that was found not in compliance during the inspection and that is the height, which is 20 inches, 7 inches below the design height. This difference in height is considerable, and could be considered a risk for vehicles that impact it. The major concern in this case is the probability of a vehicle impacting the guardrail and rolling over it because of its height. When considering all other elements of the site, such as, the geometry alignment, the sight distance, the change in roadway width, and the clear zone, we can determine that they do not represent potential safety risks. The feature was assigned a rating of good.

7. Exit End Treatment

The exit approach guardrail has an exit end treatment type MB, this feature is TL-2 and placed on a 1V:13H grade, however the anchorage system is not present. The feature complies with two out of three elements and the element that is not in compliance will not have an adverse effect in the overall protection of the road user. After the evaluation, the end treatment was found to be average.

Direction of Evaluation: Southbound

1. Change in approach roadway and bridge roadway width

    The bridge roadway width is 29.4 ft, and the southbound approach roadway width is 24 ft. This represents that bridge roadway is wider than the approach roadway and this does not represent a safety concern.

2. Entry sight distance

    The approach roadway and bridge configuration is a relatively flat tangent section, which means that drivers have adequate view of the bridge roadway before entering it. During the inspection no visibility problems related to the alignment or to possible obstructions to drivers' sight were encountered.

3. Exit sight distance

    There are no obstructions to the drivers' sight line when exiting the bridge.

4. Geometry Alignment

    The bridge is located in a relatively flat tangent section. There are no adverse geometric design elements in the bridge influence zones.

5. Clear Zone

    The approach guardrail does not extend throughout the entire bridge influence zone. When evaluating the clear zone in both sides of the road, it was determined that the left side of the road complies with AASHTO recommended clear zone values, while the right side has a clear zone of 10.4 ft, which is below the 14 ft recommended by AASHTO and the 12 ft recommended by FLH.

$\underline{\text{BTSFR}_{SB}}$

1. Entry End Treatment

The entry approach guardrail has an entry end treatment type MB, this feature is TL-2 and placed on a 1V:24H grade, however the anchorage system is not present. The feature complies with two out of three elements and the element that is not in compliance will not have an adverse effect in the overall protection of the road user. After the evaluation, the end treatment was found to be average.

2. Entry Approach Guardrail

The entry approach guardrail is a strong post W-Beam with steel blocks. Only one of the seven items considered in its evaluation was found not in compliance, and it is the height. The required height of the W-Beam strong post is 27 inches and the height measured in the field was 24 inches. Although height is a very important factor in providing adequate protection to drivers, in this case since the difference in height is not considerable, the guardrail will be rated as good.

3. Entry Transition

The existing entry transition has a total of two items that were found not in compliance during the inspection, the first is the height and the second is the post spacing. The height of the transition is 24 inches, 3 inches below the design height.

The reduction in the post spacing is not in accordance with the PR-DTPW standard plans. Instead of having a gradual reduction with two posts spaced at 3 ft 1 inch, 4 posts spaced at 1 ft 7 inches and then the connection to the bridge rail; the transition installed consists of 4 posts spaced at 3 ft 1 inch and then the connection. The difference in height may not be regarded as a considerable safety risk; however the difference in post spacing does not provide the gradual stiffening of the approach guardrail. After evaluation and in accordance with the bridge traffic safety feature rating, the transition is considered as average.

4. Bridge Railing

The existing bridge railing is a New Jersey barrier that complies with all elements evaluated during inspection. This feature is rated as excellent.

5. Exit Transition

The existing entry transition has a total of two items that were found not in compliance during the inspection, the first is the height and the second is the post spacing. The height of the transition is 25 inches, 2 inches below the design height, this difference is not considerable. The reduction in the post spacing is not in accordance with the PR-DTPW standard plans. Instead of having a gradual reduction with two posts spaced at 3 ft 1 inch, 4 posts spaced at 1 ft 7 inches and then the connection to the bridge rail; the transition installed consists of 4 posts spaced at 3 ft 1 inch and then the connection. The difference in post spacing does not provide the gradual stiffening required by this type of transition; however after an evaluation of the safety risks taking into consideration the elements of the site and in accordance with the bridge traffic safety feature rating, the transition is considered as average.

6. Exit Approach Guardrail

   There is only one item that was found not in compliance during the inspection and that is the height, which is 25 inches, 2 inches below the design height. This difference in height is not considerable, and does not represent a major safety concern. The feature was assigned a rating of good.

7. Exit End Treatment

   The exit approach guardrail has an exit end treatment type MB, this feature is TL-2 and placed on a 1V:12H grade, however the anchorage system is not present. The feature complies with two out of three elements and the element that is not in compliance will not have an adverse effect in the overall protection of the road user. After the evaluation, the end treatment was found to be average.

<u>Recommended Safety Treatments:</u>

After an evaluation of bridge #63 and all the elements associated with geometry alignment, sight distance, change in roadway width, clear zone, and the overall compliance of its traffic safety features, it was determined that this bridge does not present major safety problems. In response to some of the specific problems identified during the inspection the following safety improvements are recommended:

1. Schedule maintenance work to remove all vegetation from the surroundings of the approach guardrail, in order for the road users to be aware of its presence.
2. Remove the hectometer located behind the exit approach guardrail in the northbound direction.
3. Remove the tree that has grown around the entry approach guardrail in the southbound direction and perform the necessary work to the guardrail in order for it to function effectively.
4. Perform a crash analysis of the site and determine if there is a need to remove and reinstall the transitions in accordance with the PR-DTPW standard plans, or if they can remain in place.

5.4.3 Application Example #3: NBI Structure Number #2231

Description:

1. General: The Bridge is located at km 17 of PR-125 in the municipality of San Sebastián. This road has an ADT of 2,300 vpd, and is an undivided highway functionally classified as rural minor collector with a posted speed of 35 mph.

2. Bridge: The NBI structure number is 2231. The material of the structure is prestressed concrete, and the bridge serves vehicular traffic only, no sidewalks provided for pedestrian traffic. The length of the bridge is 102.33 ft, and the total roadway width is 29.6 ft with left and right shoulder widths measured from the westbound approach of 3.3 ft and 4.3 ft, respectively. The pavement surface is asphalt and it has edge pavement markings, but they have worn off.

3. Approach Roadway:
    a. Eastbound: The total roadway width is 25.4 ft, with left and right shoulder widths of 3.8 ft and 1.8 ft respectively. The pavement surface is asphalt. The roadside of the eastbound approach roadway consists of a vee channel on the left side of the road, and a 6 inch curb on the right side. The foreslope of the vee channel is 1V:6H and the backslope is 1V:7H. There is an approach guardrail installation but it does not extend through the entire length of the influence zone because of the presence of entrances for

houses and private estates. There are no adverse geometry alignment conditions in this approach; the approach is a tangent section.

b. Westbound: The total roadway width is 27.5 ft. The road has left and right shoulder widths of 2.8 ft and 2.2 ft, respectively. The pavement material is asphalt. The roadside slopes in the left and right side of the road are 1V:10H and 1V:14H foreslopes respectively. An approach guardrail has been installed and it extends throughout the total length of the bridge influence zone.

Findings:

1. Direction of Inspection: Westbound

   a. The edge pavement markings are worn out and are barely visible throughout the entire length of the bridge influence zones (entry and exit) at both approaches and on the bridge.

   b. There is an entrance to a private estate that extends 37 ft located at the eastbound entry approach 309 ft from the bridge, as shown on Figure 34A.

   c. There is a concrete hectometer located 5 inches at the front of the approach guardrail, see Figure 34B. This 2.5 ft concrete structure can represent a potential hazard for road users.

   d. The post spacing of the transition between the W-Beam and the New Jersey barrier is not in accordance with the PR-DTPW standard plans. According to the standard plans the transition should consist of the connection to the bridge rail, 4 posts spaced at 1 ft 7 inches, and 2 posts spaced at 3 ft 1 inch. The transitions installed in the field, in the entry east approach and west approach have the connection and 5 posts spaced a 3 ft 1 inch each.

e. There is a Vee channel in front of the exit approach guardrail that has a 1V:6H foreslope and a 1V:7H backslope. According to AASHTO's RDG [2006] these values of slope change are inside the preferred channel cross section.

f. There is a house entrance at a distance of 128 ft from the bridge that extends for 12 ft.

g. At the exit bridge influence zone there is a warning sign "PRECAUCION ENTRADA Y SALIDA DE CAMIONES 100MTS" placed on a utility post instead of on the adequate sign post, as shown on Figure 34C.

Figure 34. Issues Encountered on Bridge #2231 Westbound Approach

2. Direction of Inspection: Eastbound

    a. There is an entrance to a private estate that extends 20 ft located at a distance of 350 ft from the bridge.

    b. Starting at a distance of 250 ft from the bridge and extending for 30 ft, there is a 1V:2H cut slope, as shown on Figure 35A.

    c. There is a house located at the entrance to the bridge. The house has a 6 inch curb, as shown on Figure 35B. According to AASHTO *Green Book* [2004] curbs should be between 4 inches - 6 inches high and they should have an offset distance of at least 1 ft. This curb complies with those values.

    d. There is a steel block missing from one of the W-Beam posts located 29 ft from the bridge at the exit influence zone, as shown on Figure 35C.

Figure 35. Issues Encountered on Bridge #2231 Eastbound Approach

Evaluation

This section presents all factors considered in the safety evaluation of bridge #2231, for both directions in which the inspection was performed, westbound and eastbound, and it also presents the evaluation and rating assigned to each traffic safety feature on the bridge. The ratings assigned to each traffic safety feature during this evaluation will be documented in the last page of the inspection sheets.

Direction of Evaluation: Westbound

1. Change in approach roadway and bridge roadway width

   The bridge roadway width is 30.5 ft, and the westbound approach roadway width is 27.5 ft. This represents that bridge roadway is wider than the approach roadway, which does not represent a safety concern.

2. Entry sight distance

   The bridge structure cannot be perceived by drivers from the limit of the entry influence zone, which are located at a distance of 360 ft from the bridge, however since this distance was determined by calculating the SSD for a speed of 45 mph and the posted speed in this bridge is 35 mph the inspector can recalculate the SSD for a 35 mph and determine that it is 250 ft, and measure in the field the distance at which the bridge is visible to drivers traveling in their lane. The distance measured in the field during inspection was 250 ft, with this information the inspector can determine that the bridge sight distance at the entry influence zone is in compliance. No safety concerns related to sight distance.

3. Exit sight distance

   At the exit influence zone there are no problems related to sight distance, since the road is straight and relatively flat. There are no obstructions to the drivers' line of sight when exiting the bridge that can result in safety problems.

4. Geometry Alignment

   There is a horizontal curve with radius of 1309.3 ft and a length of 446.48 ft at the entry influence zone; however the radius of this curve complies with AASHTO's criteria for minimum radius. The minimum radius for a curve with a posted speed of 35 mph and a superelevation of 6% is 340 ft. At the exit influence zone the road is a tangent section, no presence of sharp horizontal curves or steep vertical curves, no adverse changes in alignment. Overall the existing geometric alignment features are not adverse and do not represent a potential safety hazard for drivers.

5. Clear Zone

   The entry approach guardrail extends throughout the entire bridge entry influence zone. At the exit influence zone the approach guardrail complies with its length of need, however it does not extend throughout the entire influence zone. At the end of the guardrail there is a house entrance and the house fence extends through the rest of the influence zone. There is a vee channel that extends through the entire bridge exit influence zone, the channel cross section was evaluated using RDG [2006] and it was found in compliance with the preferred cross section.

$\underline{\text{BTSFR}_{WB}}$

1. Entry End Treatment

    The entry approach guardrail has an entry end treatment type MB, this feature is TL-2 and placed on a 1V:14H grade, however the anchorage system is damaged. The feature complies with two out of three elements and the element that is not in compliance will not have an adverse effect in the overall protection of the road user. After the evaluation, the end treatment was found to be average.

2. Entry Approach Guardrail

    The entry approach guardrail is a strong post W-Beam with steel blocks. Only one of the seven items considered in its evaluation was found not in compliance, and it is the height. The required height of the W-Beam strong post is 27 inches and the height measured in the field was 24 inches. Although height is a very important factor in providing adequate protection to drivers, in this case since the difference in height is not considerable, the guardrail will be rated as good.

3. Entry Transition

The existing entry transition has a total of two items that were found not in compliance during the inspection, the first is the height and the second is the post spacing. The height of the transition is 24 inches, 3 inches below the design height. The reduction in the post spacing is not in accordance with the PR-DTPW standard plans. Instead of having a gradual reduction with two posts spaced at 3 ft 1 inch, 4 posts spaced at 1 ft 7 inches and then the connection to the bridge rail; the transition installed consists of 5 posts spaced at 3 ft 1 inch and then the connection. The difference in height may not be regarded as a considerable safety risk, however the difference in post spacing does not provide the gradual stiffening of the approach guardrail. After evaluation and in accordance with the bridge traffic safety feature rating, the transition is considered as average.

4. Bridge Railing

The existing bridge railing is a New Jersey barrier that complies with all elements evaluated during inspection. This feature is rated as excellent.

5. Exit Transition

There is no transition installed at the westbound exit of the bridge. Since the bridge is located on a two lane rural road, the installation of the transition at the exit approach is very important to avoid pocketing. This incident occurs when a guardrail is not sufficiently stiffened at its transition section, or like in this case when there is no transition, this causes the guardrail to deflect and strike the end of the bridge railing, which can result in severe injury or death. For this reason the installation of a transition in this particular case is required, which deems the transition deficient.

Figure 36. Westbound View of Approach Guardrail on Bridge #2231

6. Exit Approach Guardrail

All items in the exit approach guardrail are found in compliance with design values, for this reason the feature will be rated as excellent.

7. Exit End Treatment

The exit approach guardrail has an exit end treatment type MB, this feature is TL-2 and placed on a 1V:14H grade, however the anchorage system is not present. The feature complies with all elements considered for its evaluation, which represents that the exit end treatment will be rated as excellent.

Direction of Evaluation: <u>Eastbound</u>

1. Change in approach roadway and bridge roadway width

   The bridge roadway width is 30.5 ft, and the westbound approach roadway width is 25.4 ft. This represents that bridge roadway is wider than the approach roadway, which does not represent a safety concern.

2. Entry sight distance

   There are no problems related to sight distance at the entry influence zone, since the road is straight and relatively flat. There are no obstructions to the drivers' line of sight that can prevent a driver from being aware of the existence of the bridge or any event that may result in safety problems.

3. Exit sight distance

   The limit of the exit influence zone is not visible to drivers because of the existence of a horizontal curve. However the length of the bridge exit influence zone was determined using the value of SSD for a road with a posted speed of 45 mph. During inspection the point of visibility was measured and it was determined to be 270 ft from the bridge. When calculating the SSD for a road with a posted speed of 35 mph, the value obtained was 250 ft. The distance measured in the field is in compliance with AASHTO [2004] SSD criteria. No safety concerns related to sight distance.

4. Geometry Alignment

The entry influence zone consists of a tangent road section, without any sharp horizontal curves or steep vertical curves, no adverse changes in alignment. There is a horizontal curve with radius of 1309.3 ft and a length of 446.48 ft at the entry influence zone; this curve limits drivers' line of sight to the influence zone limits, however is still in compliance with the SSD requirements for this road. Overall the existing geometric alignment features are not adverse and do not represent a potential safety hazard for drivers.

5. Clear Zone

At the entry influence zone the approach guardrail complies with its length of need, however it does not extend throughout the entire influence zone. At the end of the guardrail there is a driveway and the house fence extends up to 250 ft from the bridge, after the driveway ends there is a 6inch high curb. Located 250 ft from the bridge and extending for 30 ft there is a roadside area that has a 1V:2H backslope, this slope is critical and should be shielded. Due to the restrictions of the surroundings the entry influence zone does not comply with AASHTO [2006] recommended clear zone value, which is 12ft - 14 ft. The approach guardrail at the exit influence zone extends 46 ft past the influence zone limits; there are no safety concerns related to clear zone in this area.

$\underline{BTSFR_{EB}}$

1. Entry End Treatment

   The entry approach guardrail has an entry end treatment type MB, this feature is TL-2 and placed on a 1V:7H grade. The recommended slope for the placement of end terminals is 1V:10H or flatter, since the end treatment does not comply with the recommended grading, but complies with the other two items considered in its evaluation the feature was found to be average.

2. Entry Approach Guardrail

   The entry approach guardrail is a strong post W-Beam with steel blocks. There were two items found not in compliance during evaluation, the height and the length of need. The measured height of the W-Beam strong post was 26 inches, 1 inch below the design height which is 27 inches. Although height is a very important factor in providing adequate protection to drivers, in this case the difference in height is not considerable. The approach guardrail does not comply with the required length of need due to the existence of a house access, which does not allow the installation of the total length of guardrail required, however there is a house gate that does not allow the encroachment of a vehicle into the area of concern. After applying engineering judgment it was determined that the guardrail will be rated as good.

3. Entry Transition

The existing entry transition has a total of two items that were found not in compliance during the inspection, the first is the height and the second is the post spacing. The height of the transition is 26 inches, 1 inch below the design height. The reduction in the post spacing is not in accordance with the PR-DTPW standard plans. Instead of having a gradual reduction with two posts spaced at 3 ft 1 inch, 4 posts spaced at 1 ft 7 inches and then the connection to the bridge rail; the transition installed consists of 5 posts spaced at 3 ft 1 inch and then the connection. The difference in height may not be regarded as a considerable safety risk however the difference in post spacing does not provide the gradual stiffening of the approach guardrail. After evaluation and in accordance with the bridge traffic safety feature rating, the transition is considered as average.

Figure 37. Eastbound Entry Transition of Bridge #2231

4. Bridge Railing

The existing bridge railing is a New Jersey barrier that complies with all elements evaluated during inspection. This feature is rated as excellent.

5. Exit Transition

There is no transition installed at the eastbound exit of the bridge. Since the bridge is located on a two lane rural road, the installation of the transition at the exit approach is very important to avoid pocketing. This incident occurs when a guardrail is not sufficiently stiffened at its transition section, or like in this case when there is no transition, this causes the guardrail to deflect and strike the end of the bridge railing, which can result in severe injury or death. For this reason the installation of a transition in this particular case is required, which deems the transition deficient.

6. Exit Approach Guardrail

All items in the exit approach guardrail are found in compliance, except for its height which is 26 inches instead of 27 inches as established in its design, since the difference in height is not significant the feature will be rated as good.

7. Exit End Treatment

The exit approach guardrail has an exit end treatment type MB, this feature is TL-2 and placed on a 1V:10H grade. The feature complies with all elements considered for its evaluation, which represents that the exit end treatment will be rated as excellent.

Recommended Safety Treatments:

The results of the evaluation performed to bridge #2231 and all the elements associated with geometry alignment, sight distance, change in roadway width, clear zone, and the overall compliance of its traffic safety features, showed some points that need some improvements. The following safety improvements are recommended:

1. Removal of the concrete hectometer located at the front of the entry approach guardrail in the westbound direction.
2. Maintenance work to repaint edge pavement markings that have worn off and are barely visible during the day much less during the night.
3. Repair work to the entry transition sections, in order to provide the adequate post spacing for the existing transition design.
4. Installation of the exit transition sections at the bridge.

5.4.4 Application Example #4: NBI Structure Number #2740

Description:

1. General: The Bridge is located at km 13.6 of PR-102 in the municipality of Cabo Rojo. This road has an ADT of 5,900 vpd, and is an undivided highway functionally classified as rural major collector. No speed limit sign was found in the bridge site; however after an inspection of the road the speed limit for PR-102 was found to be 35mph.

2. Bridge: The NBI structure number is 2740. The material of the structure is concrete, and the bridge serves both vehicular and pedestrian traffic. Sidewalks are provided on both sides of the bridge, the width of the sidewalks is 4 ft. The length of the bridge is 50.18 ft, and the total roadway width is 24 ft without any shoulders. The pavement surface is concrete and it has edge and centerline pavement markings.

3. Approach Roadway:
   a. Southbound: The total roadway width is 20.4 ft, without any shoulders. The roadside slopes are 1V:29H and 1V:20H foreslopes. The approach area is surrounded by houses and restaurants, which doesn't allow the installation of an approach guardrail. The pavement surface is asphalt, it has edge pavement markings. There are no adverse geometry alignment conditions in this approach; the approach is a tangent section.

b. Northbound: The total roadway width is 20.8 ft, without any shoulders. The pavement material is asphalt with edge pavement markings. The roadside slopes are 1V:43H and 1V:77H foreslopes. To the left of the approach area there are restaurants and houses, while on the right there is an area designated for vehicular parking, this situation does not allow the installation of an approach guardrail in the bridge influence zone.

<u>Findings</u>:

1. Direction of Inspection: <u>Southbound</u>
   a. There are utility posts located at 322 ft and 274 ft from the bridge at the entry influence zone. The distance between their installation and the traveled way is 6.5 ft, which is not in compliance with the 12 ft - 14 ft recommended by AASHTO [2006]. Each utility post has a 14 inch high by 14 inch wide concrete base, as shown on Figure 38A.
   b. There is a house entrance at 305 ft from the bridge in the entry influence zone. The entrance to the house has a concrete wall with a metal tube fence. The metal tube fence at the entrance is located behind the wall creating a possible snagging point for a vehicle in case of a crash, see Figure 38B. Object markers have been placed on the wall as a safety measure.
   c. There is a 14 inch diameter tree trunk located 6 ft from the traveled way, at 294 ft from the bridge in the entry influence zone.

d. In the bridge entry influence zone at a distance of 258 ft from the bridge there is a local track that provides access to approximately 3 houses, see Figure 38C.

e. The sidewalk installed on the bridge extends 5 ft and 5.5 ft outside of the bridge structure in the entry and exit influence zones respectively.

f. There is a 12 ft high, 8inches thick concrete wall located 96 ft from the bridge at the exit influence zone.

g. At 148 ft from the bridge starts a 4 ft sidewalk with a 4 inch curb that continues until the end of the exit influence zone. At the beginning of the sidewalk there is a 4 ft diameter tree located on its right side, see Figure 38D.

Figure 38. Issues Encountered on Bridge #2740 Southbound Approach

2. Direction of Inspection: Northbound

    a. There is a parking area located throughout the entire right side of the entry influence zone.

    b. At 327 ft from the bridge and 2.2 ft from the traveled way there is a utility post.

    c. There are a group of trees, two utility posts, and two metal garbage bins located 5.3 ft from the traveled way on the entry influence zone, see Figure 39A.

    d. There is a T intersection located at the start of the bridge, see Figure 39B.

    e. There are two groups of mailboxes located at 200 ft and 294 ft from the bridge in the exit influence zone, see Figures 39C and 39D. The first group consists of 8 mailboxes placed on wood planks between two trees; and the second group consists of 8 mailboxes placed on wood planks on top of a tree trunk and a steel post.

    f. Tree located 4 ft from the traveled way at 334 ft from the bridge in the exit influence zone, see Figure 39E.

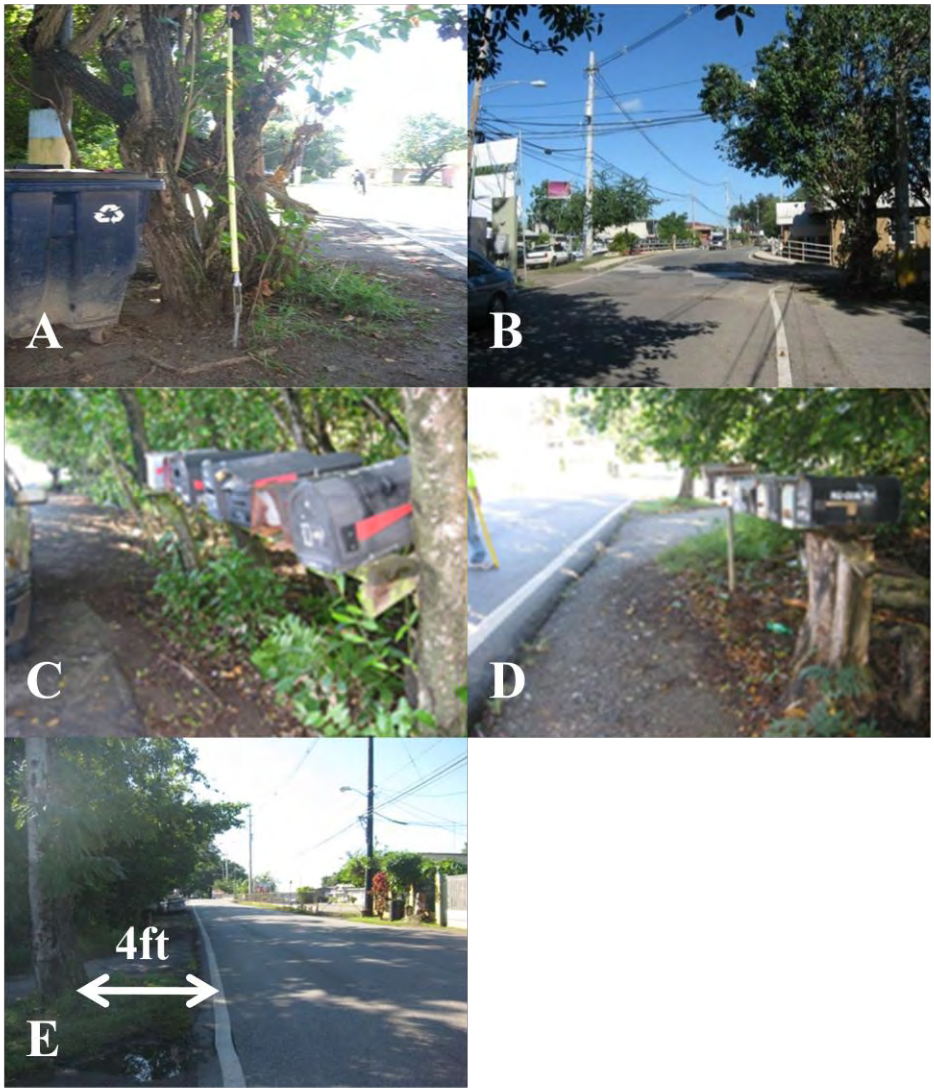


Figure 39. Issues Encountered on Bridge #2740 Northbound Approach

Evaluation

This section presents all factors considered in the safety evaluation of bridge #2470, for both directions in which the inspection was performed, southbound and northbound, such as the geometry alignment, bridge sight distance, change in roadway width, clear zone and the traffic safety features. The evaluation of the traffic safety features performed in this section will have as a result the rating assigned to each feature. These ratings will be documented in the last page of the inspection sheets.

Direction of Evaluation: Southbound

1. Change in approach roadway and bridge roadway width

   The bridge roadway width is 24 ft, and the approach roadway width is 20.4 ft. This represents that bridge roadway is wider than the approach roadway, which does not represent a safety concern.

2. Entry sight distance

   There are no obstructions to the drivers' sight from the limits of the entry influence zone to the bridge; the approach road is a tangent section that does not interfere with drivers' line of sight.

3. Exit sight distance

   At the exit influence zone there is a horizontal curve, however this geometric design element does not obstruct the visibility of drivers to the limit of the influence zone. There are no problems related to sight distance at the exit influence zone that can result in safety problems.

4. Geometry Alignment

   The entry influence zone presents no adverse geometry alignment since the road is a relatively flat tangent section. At the exit influence zone there is a horizontal curve with radius of 1553.41 ft and a length of 563.11 ft. This curve does not represent an abrupt change in road alignment and as such is not considered to be a potential safety risk. Overall the existing geometric alignment features are not adverse and do not represent a potential safety hazard for drivers.

5. Clear Zone

There is no approach guardrail in either the entry or the exit influence zones for this bridge. The location of the bridge does not allow the installation of an approach guardrail. There are houses, restaurants and parking lots at the side of the road in each influence zone. The house and restaurant fences and walls extend through the side of the road. The provided clear zone distance does not comply with the 12 ft - 14 ft recommended by AASHTO [2006].

$\underline{\text{BTSFR}_{\text{SB}}}$

1. End Treatment, Approach Guardrail and Transitions (Entry & Exit)

There are no end treatments, approach guardrails, and transitions installed on this bridge. In this particular situation where the bridge is located on an area that prevents the installation of such features AASHTO's *Bridge Design Specifications* [2007] recommends one of the following measures: extending the bridge rail, providing a barrier curb, restricting speed, adding signing, and providing a recovery area. When evaluating the circumstances on bridge 2740 we see that the bridge railing has been placed on a raised sidewalk with a 6 inch high curb, and this sidewalk extends well beyond the installation of the bridge rail. In the southbound approach the sidewalk extends at its entry 59.5 ft and at its exit 67 ft. The installation of a barrier curb complies with AASHTO's recommendations, and for this reason the absent features will not be found deficient, instead the inspector will write on the inspection the letter NA that represents that the feature has not been installed, but is still in accordance with AASHTO's guidelines.

2. Bridge Railing

The existing bridge railing is a 3 tube curb mount. This railing is TL-4 and complies with all elements evaluated during inspection. This feature is rated as excellent.

Figure 40. Bridge Railing 3 Tube Curb Mount

Direction of Evaluation: <u>Northbound</u>

1. Change in approach roadway and bridge roadway width

   The bridge roadway width is 24 ft, and the approach roadway width is 20.8 ft. This represents that bridge roadway is wider than the approach roadway, which does not represent a safety concern.

2. Entry sight distance

   There are no obstructions to the drivers' sight from the limits of the entry influence zone to the bridge. The approach road is a soft curve that does not interfere with drivers' line of sight.

3. Exit sight distance

   The exit influence zone consists of a relatively flat tangent section of road that does not obstruct the visibility of drivers from the bridge to the limits of the influence zone. There are no problems related to sight distance when a driver is leaving the bridge and entering the exit influence zone that can result in safety problems.

4. Geometry Alignment

   There is a horizontal curve with radius of 1553.41 ft and a length of 563.11 ft at the entry influence zone. The curve presents a soft transition with no abrupt changes in alignment that can cause a driver to be unaware of his surroundings. The geometry alignment of the exit influence consists of a relatively flat tangent road section. Overall the existing geometric alignment features are not adverse and do not represent a potential safety hazard for drivers.

5. Clear Zone

There is no approach guardrail in either the entry or the exit influence zones for this bridge. The location of the bridge does not allow the installation of an approach guardrail. There are houses, restaurants and parking lots located at the side of the road, the house and restaurant fences and walls extend throughout the entire length of the influence zones. The provided clear zone distance does not comply with the 12 ft - 14 ft recommended by AASHTO [2006].

$\underline{BTSFR_{NB}}$

1. End Treatment, Approach Guardrail and Transitions (Entry & Exit)

There are no end treatments, approach guardrails, and transitions installed on this bridge. When evaluating the circumstances on bridge 2740 we see that the bridge railing has been placed on a raised sidewalk with a 6 inch high curb, and this sidewalk extends well beyond the installation of the bridge rail. In the northbound entry influence zone the sidewalk extends 57 ft all the way into the intersecting road, and at the exit influence zone it extends 7 ft. The installation of a barrier curb complies with AASHTO's *Bridge Design Specifications* [2007] recommendations, and for this reason the absent features will not be found deficient, instead the inspector will write on the inspection sheets the letter NA that represents that the feature has not been installed, but is still in accordance with AASHTO's guidelines.

2. Bridge Railing

   The existing bridge railing is a 3 tube curb mount. This railing is TL-4 and complies with all elements evaluated during inspection. This feature is rated as excellent.

<u>Recommended Safety Treatments:</u>

After carrying out the evaluation of bridge #2470 and all of the safety elements considered during inspection, such as the geometry alignment, sight distance, change in roadway width, clear zone, and the overall compliance of its traffic safety features, the following safety improvements are recommended:

1. Installation of speed limit sign.
2. Remove and reinstall the mailboxes located on the northbound exit influence zone in accordance with AASHTO *Guide for Erecting Mailboxes on Highways*.
3. Install type 2 object markers on the utility posts and the concrete wall that are within the recommended clear zone.

5.4.5 Application Example #5: NBI Structure Number #481

Description:

1. General: The Bridge is located at km 0.1 of PR-411 in the municipality of Rincón. This road has an ADT of 12,100 vpd, and is an undivided highway functionally classified as rural local with posted speed of 35 mph.

2. Bridge: The NBI structure number is 481. The material of the structure is concrete, and the bridge serves vehicular traffic only. The length of the bridge is 45.92 ft, and the total roadway width is 17 ft without any shoulders. The pavement surface is asphalt and it has edge pavement markings.

3. Approach Roadway:
    a. Northbound: The total roadway width is 17 ft, without any shoulders. The roadside slopes are 1V:10H backslope on the right side of the approach and a vee channel on the left side with 1V:5.2H and 1V:4.5H slope changes. On the right side of the approach area there is a house access and on the right side there is a 3.5 ft high wall that represents the limits of a gas station, such set up does not allow the installation of approach guardrails. The pavement surface is asphalt, it has edge pavement markings. There are no adverse geometry alignment conditions in this approach; the approach is a tangent section.

b. Southbound: The total roadway width is 17 ft, without any shoulders. The pavement material is asphalt with edge pavement markings. There are vee channels on both sides of the road, the change in slopes of the left channel is 1V:8H and 1V:6H, and on the right channel is 1V:7H, and 1V:4H. There are houses at both sides of the southbound approach, and an intersecting road located exactly before the start of the bridge. There is a section of W-Beam guardrail installed at the entrance to the intersecting road, but is only 12.5 ft long and does not have a transition or an end treatment. There is no approach guardrail installed on the left side of the southbound approach. There is a horizontal curve on this approach; the curve has a radius of 2,700 ft and a length of 422 ft, however it does not limit visibility to the bridge or from the bridge towards the approach.

Findings:

1. Direction of Inspection: Northbound
    a. The entry influence zone has a length of 240 ft, the limits of this zone is defined by PR-411 intersection with PR-115.
    b. There is a concrete utility posts located 120 ft from the bridge, and 5 ft from the traveled way. Three feet behind the post there is a speed limit sign. See Figure 41A
    c. There is a house access located 65 ft from the bridge in the entry influence zone, see Figure 41B.

d. There is a type 3 object marker installed in front of the bridge railing end terminal at the entry influence zone, as shown on Figure 41C.

e. There is a vee channel that extends throughout the entire exit influence zone. The slopes of the channel are 1V:8H foreslope and 1V:6H backslope. The channel's slope change was checked with Figure 3.6 of RDG [2006] and they are within the preferred channel cross section.

Figure 41. Issues Encountered on Bridge #481 Northbound Approach

2. Direction of Inspection: Southbound

    a. There is a vee channel that extends throughout the entire entry influence zone. The slopes of the channel are 1V:7H foreslope and 1V:4H backslope. The channel's slope change was checked with Figure 3.6 of RDG [2006] and they are within the preferred channel cross section.

    b. There is an intersecting road prior to the bridge, shown on Figure 42A.

    c. There is a W-Beam guardrail shielding the area of concern to prevent southbound traffic or traffic coming from the intersection to go behind the bridge and fall into the stream below, as shown on Figure 42B. The W-Beam consists of one 12.5 ft section without a transition or an end treatment.

    d. Since there is no approach guardrail in this bridge the bridge railing starts with a sloped concrete end treatment, see Figure 42C.

    e. There is a vee channel that extends throughout the entire entry influence zone. The slopes of the channel are 1V:5.2H foreslope and 1V:4.5H backslope. The channel's slope change was checked with Figure 3.6 of RDG [2006] and they are within the preferred channel cross section.

Figure 42. Issues Encountered on Bridge #481 Southbound Approach

Evaluation

This section presents all factors considered in the safety evaluation of bridge #481, for both directions in which the inspection was performed, northbound and southbound. The evaluation of such factors as the geometry alignment, bridge sight distance, change in roadway width, clear zone and the traffic safety features. As a result of the evaluation of the traffic safety features a safety rating will be assigned to each feature. These ratings will be documented in the last page of the inspection sheets.

Direction of Evaluation: Northbound

1. Change in approach roadway and bridge roadway width

    The bridge roadway width and the approach roadway width are both 17 ft. According to AASHTO [2004] the minimum clear roadway width for a bridge with over 2,000 vpd is equal to the approach roadway width, which means that the bridge roadway width is in compliance.

2. Entry sight distance

    There are no obstructions to the drivers' sight from the limits of the entry influence zone, which in this case represent a distance of 240 ft from the bridge, at the point where PR-411 starts. The approach road is a tangent section that does not interfere with drivers' line of sight.

3. Exit sight distance

    At the exit influence zone there is a horizontal curve, however this geometric design element does not obstruct the visibility of drivers to the limit of the influence zone. There are no problems related to sight distance at the exit influence zone that can result in safety problems.

4. Geometry Alignment

    The entry influence zone presents no adverse geometry alignment since the road is a relatively flat tangent section. There is a horizontal curve with radius of 2700 ft and a length of 422 ft at the exit influence zone. Overall the existing geometric alignment features are not adverse and do not represent a potential safety hazard for drivers.

5. Clear Zone

There is no approach guardrail in either the entry or the exit influence zones for this bridge. The location of the bridge does not allow the installation of an approach guardrail. There are accesses to houses at the side of the road in each influence zone. The house gates extend through the side of the road. The provided clear zone distance does not comply with the 14 ft - 16 ft recommended by AASHTO [2006].

$\underline{BTSFR_{NB}}$

1. Entry End Treatment

The sloped concrete end treatment has not met NCHRP Report 350 criteria, however its use is allowed on locations where the posted speed is less than 40 mph and the space is limited by right of way constraints [AASHTO, 2006]. The recommended length of the tapering of this end treatment is 20 ft, with 30 ft - 40 ft being the desirable length, with a height at the end of the taper of no more than 4 inches. In this case the taper length is 5 ft and there is no vertical distance from the end of the taper and the pavement surface. After careful evaluation of this feature and taking into consideration the road's ADT, and the high probability of a vehicle mounting the treatment and creating a vaulting effect the feature was assigned a deficient rating.

2. Entry & Exit Approach Guardrails

There are no approach guardrails, and transitions installed. In this particular situation where the bridge is located on an area that prevents the installation of such features AASHTO's *Bridge Design Specifications* [2007] recommends one of the following measures: extending the bridge rail, providing a barrier curb, restricting speed, adding signing, and providing a recovery area. When evaluating the circumstances on bridge 481 we see that the bridge railing has been extended at the entry but not at the exit, and that the posted speed is low. The absent entry and exit approach guardrails will not be found deficient, instead the inspector will write on the inspection sheets the letter NA that represents that the feature has not been installed, due to the circumstance of the approach roadside environment, but are still in accordance with AASHTO's guidelines.

3. Entry & Exit Transitions

Transitions are only required when the existing approach guardrails and bridge railings have different rigidity. In this case since there are no approach guardrails installed on the entry or exit of the bridge, the transition is not required. Write NA on the inspection sheets which represents that the feature has not been installed but is not required.

4. Bridge Railing

The existing bridge railing is vertical concrete parapet. This railing is TL-4, but does not comply with the required height and the suggested lateral offset. The difference in height is 8 inches which is considerable, and the available lateral offset is 1.3 ft, compared to distance suggested in the RDG, which ranges from 3.6 ft to 4.6 ft. The feature will be assigned a rating of average.

5. Exit End Treatment

No exit end treatment was provided. This safety feature is very important on two lane-two way roads where oncoming vehicles from the opposing direction of traffic can impact the unshielded end of the bridge railing. This feature will be rated as deficient.

Direction of Evaluation: <u>Southbound</u>

1. Change in approach roadway and bridge roadway width

The bridge roadway width and the approach roadway width are both 17 ft. According to AASHTO [2004] the minimum clear roadway width for a bridge with over 2,000 vpd is equal to the approach roadway width, which means that the bridge roadway width is in compliance.

2. Entry sight distance

There are no obstructions to the drivers' sight from the limits of the entry influence zone. The approach road is a horizontal curve that does not limit drivers' line of sight. There are no problems related to sight distance at the entry influence zone that can result in safety problems.

3. Exit sight distance

   The exit influence zone is a tangent section of road that presents no adverse geometric alignment and does not obstruct the visibility of drivers to the limit of the influence zone. There are no problems related to sight distance at the exit influence zone that can result in safety problems.

4. Geometry Alignment

   There is a horizontal curve with radius of 2,700 ft and a length of 422 ft at the entry influence zone, which does not represent an abrupt change in alignment for drivers. At the exit influence zone the road is a relatively flat tangent section. Overall there are no adverse geometric alignment conditions in the location of the bridge.

5. Clear Zone

   There are no approach guardrails in either the entry or the exit influence zones for this bridge. The provided clear zone distance at the entry influence zone varies from 14.2 ft - 16.7 ft, and at the exit is 9.1 ft. The clear zone provided at the entry complies with the 14ft - 16 ft recommended by AASHTO [2006], while the clear zone at the exit doesn't.

$\underline{BTSFR_{SB}}$

1. Entry End Treatment

    The sloped concrete end treatment has not met NCHRP Report 350 criteria, however its use is allowed on locations where the posted speed is less than 40mph and the space is limited by right of way constraints [AASHTO, 2006]. The recommended length of the tapering of this end treatment is 20 ft, with 30 ft - 40 ft being the desirable length, with a height at the end of the taper of no more than 4 inches. In this case the taper length is 5 ft and there is no vertical distance from the end of the taper and the pavement surface. After careful evaluation of this feature and taking into consideration the road's ADT, and the high probability of a vehicle mounting the treatment and being vaulted, the feature was assigned a deficient rating.

2. Entry Approach Guardrail

    There is an approach guardrail installed at the entrance to the intersection. It consists of a 12.5 ft section of W-Beam guardrail. This guardrail does not comply with three out of the seven elements considered in its evaluation, the height, the grading, and the length of need. The height and the length of need are two significant elements since they can effectively avoid vehicles encroaching on the area of concern and in this case falling into the stream below. For this reason after the evaluation the feature was deemed deficient.

3. Entry Transition

No entry transition was provided between the entry approach guardrail and the bridge railing. The feature rating is deficient.

Figure 43. Bridge Railing and Approach Guardrail of Bridge #481

4. Bridge Railing

The existing bridge railing is vertical concrete parapet. This railing is TL-4, but does not comply with the required height or the suggested lateral offset. The difference in height is 8 inches which is considerable, and the available lateral offset is 1.3 ft, compared to distance suggested in the RDG, which ranges from 3.6 ft to 4.6 ft. The feature will be assigned a rating of average.

5. Exit Approach Guardrail

In this particular situation where the bridge is located on an area that prevents the installation of such features AASHTO's *Bridge Design Specifications* [2007] recommends one of the following measures: extending the bridge rail, providing a barrier curb, restricting speed, adding signing, and providing a recovery area. When evaluating the circumstances on bridge 481 we see that the bridge railing has been extended at the exit, to the point where it is not possible for a vehicle to encroach on the side of the bridge a fall on the stream below. Also the bridge is located in a road with a posted speed of 35 mph, considered to be low speed. After evaluation the absent exit approach guardrail will not be found deficient, instead the inspector will write on the inspection sheets the letter NA that represents that the feature has not been installed, due to the circumstance of the approach roadside environment, but is still in accordance with AASHTO's guidelines.

6. Exit Transition

Transitions are only required when the existing approach guardrails and bridge railings have different rigidity. In this case since there is no approach guardrail installed on the exit of the bridge, the transition is not required. Write NA on the inspection sheets which represents that the feature has not been installed but is not required.

7. Exit End Treatment

    No exit end treatment was provided. This safety feature is very important on two lane two way roads where oncoming vehicles from the opposing direction of traffic can impact the unshielded end of the bridge railing. This feature will be rated as deficient.

Recommended Safety Treatments:

After carrying out the evaluation of bridge #481 and all of the safety elements considered during inspection, such as the geometry alignment, sight distance, change in roadway width, clear zone, and the overall compliance of its traffic safety features, the following safety improvements are recommended:

1. Flaring the existing bridge railing end treatments (entry northbound and entry southbound) to avoid the vaulting effect. Since AASHTO allows the use of this type of end treatment on low speed roads with space restrictions, this treatment does not necessarily need to be removed instead flaring the element away from traffic may result in a reasonable safety measure.
2. Installation of end treatments on the exit bridge railing ends (exit northbound and exit southbound), to avoid oncoming traffic from the opposite direction to impact the unshielded end of a bridge rail.
3. Where there is an intersection close to a bridge, AASHTO [2006] suggests the use of curved guardrails that were crash tested to NCHRP Report 230. Install a

curved guardrail at the intersection located prior to the southbound bridge entry and provide the required transition.

4. Installations of type 2 object markers on the concrete utility post located on the northbound approach.
5. Install a W5-2 “Puente Estrecho” sign.

6 CONCLUSIONS

The inspection process developed in this thesis was a result of an extensive literature review that included the standards, manuals and guides of AASHTO, FHWA, 33 DOTs in the United States, and Puerto Rico. This review revealed that although many states have standards and manuals that establish the need for inspecting traffic safety features on bridges in accordance with the NBIS and FHWA *Recording and Coding Guide* [1995], none of them provide information regarding how to perform such inspections, and most importantly all the elements that should be considered in their evaluation.

Transportation agencies, state and local, in the United States and Puerto Rico should include in their bridge inspection manuals, when available, a section that presents the adequate process for performing these inspections. The Bridge Inspection Manual should include a uniform procedure for the performance of inspections of traffic safety features on bridges, to ensure that at the national level all inspectors are considering the same elements at the moment of carrying out such inspections. Having a national procedure for inspecting traffic safety features on bridges will ensure uniformity and result in a more accurate rating assignment to each feature at the national level.

The bridge railing, the approach guardrail, the transition, and the end treatment are the traffic safety features on a bridge. These features provide safety to road users from potential hazards that may result more harmful than impacting the safety feature itself. The approach guardrail, the transition, and the end treatment can be installed in the entry and exit influence zones of the bridge. There are a total of two bridge railing systems on a bridge, and each one can have up to seven components, one bridge railing, two approach guardrails, two transition sections, and two end treatment. The current state of the practice establishes that only the most critical element of each is reported. The methodology created on this work allows for all bridge railing system components to be inspected and reported. Inspecting all components of the bridge railing system allows inspectors to identify any deficiencies present.

The evaluation of traffic safety on bridges should concentrate in three major aspects: the bridge, the approach roadway, and the traffic safety features. The information collected will allow the inspectors to evaluate issues such as the change in roadway width between the bridge and the approach roadways, the available clear zone, the roadway alignment, the bridge sight distance, and the structural and functional adequacy of the existing traffic safety features.

Inspectors should have a minimum set of knowledge requirements before being able to perform evaluations of traffic safety features on bridges. They should also have an understanding of the function of each feature and the situations for which they are considered warranted. Bridge railings and their corresponding end treatments are always warranted, since the consequences of leaving the sides of the bridge unshielded and the end of a barrier unprotected can be potentially severe for road users. The installation of the approach guardrail will be determined by the characteristics of the site, such as the roadside slopes and the presence of roadside hazards. The transition section is considered part of the approach guardrail; this feature is only needed when the bridge railing and the approach guardrail are different barrier systems with different strength and deflection capabilities. If these systems have similar strength capabilities or are simply the same, a transition may not be required; however these systems should always be connected, there should be no unshielded space between barrier systems.

The minimum setting for low speed road facilities, under favorable bridge site and approach roadway conditions, could include only the bridge railing and the end treatments. 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.

Knowledge of the overall site conditions will allow inspectors to make educated judgments with regard to the traffic safety features' adequacy in a particular situation. Factors such as ADT, posted speed, functional classification, climate, and location play an important role in the evaluation of these features. Bridge design plans, and DOT standard plans are required when performing an assessment, since they are used to evaluate the compliance of the existing traffic safety features. The overall compliance of the criteria considered in the evaluation of a traffic safety feature will determine its BTSFR (Bridge Traffic Safety Feature Rating), a descriptive rating created to determine the degree of safety that the traffic safety feature provides. According to this rating, a feature can be classified as excellent, good, average, deficient or not applicable. Each rating will determine if the feature can remain in place, if it needs repair, or if it needs to be removed and replaced by a feature that is compliant.

7 FUTURE WORK

Future research could include the development of an overall bridge traffic safety rating that will incorporate all the factors that have an effect in a bridge's traffic safety. This rating could be based on a numeric scale and would reflect the average safety condition based on all elements considered during inspection; it would combine elements associated with frequency of crashes, and severity of crashes. The elements associated with frequency of crashes are the horizontal alignment, the bridge sight distance, the clear zone and the change in roadway width; while the elements associated with the severity of a crash are the traffic safety features. For the development of this rating, an AHP model can be used to assign weights to all elements considered. The result will be a rating that will allow the comparative analysis of bridges at the network level, and provide a ranking scheme for transportation officials to determine the relative safety needs of the bridges in their jurisdiction. The AHP is a structured technique that provides a comprehensive and rational framework for structuring a problem, representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions; the decisions made can be based on concrete data or on the decision maker's judgments about the elements' relative meaning and importance.

Other research could include the performance of a detailed safety study of rural bridges in Puerto Rico. The study should reflect the crash history of bridges in rural areas in PR, and establish crash trends by causes, vehicle types, posted speed, etc. The results will be used for the development and calibration of crash performance functions to be applied in the inspection process to evaluate the safety effects of possible safety treatments.

A speed study can be performed with the purpose of developing a speed prediction model. Road operating speeds will be gathered in both the approach roadway and the bridge for determining the effect of the change in roadway width in driver's speed. The model developed could be used in the inspection process to provide a scientific approach for estimating the reduction in speed that could be associated with safety.

Additional research could focus on expanding the scope of this work to include in the inspection process other elements such as: signs, pavement markings, and other traffic control devices. Studies to further develop this methodology could focus on including applications such as: bridges with high percentage of truck traffic and bridges located on areas with extreme weather.

Developing a procedure for carrying out nighttime traffic safety inspections on bridges could be considered in other research, as a supplement of the methodology created in this work, with the purpose of demonstrating the importance of such inspections and the safety benefits that can be obtained from them.

REFERENCES

American Association of State Highway and Transportation Officials (1994) *A guide for erecting mailboxes on highways,* Washington D.C.

American Association of State Highway and Transportation Officials (2004) *A Policy on Geometric Design of Highways and Streets*, Washington, D.C.

American Association of State Highway and Transportation Officials (2001) *Guidelines for Geometric Design of Very Low Volume Local Roads (ADT ≤400 vpd)*, Washington, D.C.

American Association of State Highway and Transportation Officials (2007) *LRFD Bridge Design Specifications*, Washington, D.C.

American Association of State Highway and Transportation Officials (2003) *Manual for Condition Evaluation and Load and Resistance Factor Rating (LRFR) of Highway Bridges,* Washington, D.C.

American Association of State Highway and Transportation Officials (2006) *Roadside Design Guide,* Washington, D.C.

American Traffic Safety Services Association (2006) *Low Cost Local Road Safety Solutions,* Virginia.

Bureau of Transportation Statistics (2007) *National Transportation Statistics 2007*, Washington, D.C.

Colucci, Benjamín y Figueroa, Alberto M. (2006) ‘El Estado de la Infraestructura Vial y la Seguridad en Puerto Rico’, *Dimensión Revista del CIAPR*, 7-11.

Federal Highway Administration (2005a) Bridge Rail Guide, http://www.fhwa.dot.gov/bridge/bridgerail/index.cfm , Date accessed March 2008.

Federal Highway Administration (2005b) *Barrier Guide for Low Volume and Low Speed Roads*, Publication No. FHWA-CFL/TD-05-009, Central Federal Lands Highway Division.

Federal Highway Administration (1998) *Improving Highway Safety at Bridges on Local Roads and Streets*.

Federal Highway Administration (2003) *Manual on Uniform Traffic Control Devices for Streets and Highways*, Washington, D.C.

Federal Highway Administration (1995) *Recording and Coding Guide for the Structures Inventory and Appraisal of the Nation's Bridges*, Report No. FHWA-PD-96-001, Washington, D.C.

Federal Highway Administration Roadside Hardware, http://safety.fhwa.dot.gov/roadway_dept/road_hardware/longbarriers.htm, Date accessed January 2009.

National Archives and Records Administration (2005) *Code of Federal Regulations*, Title 23, Washington, D.C.

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, D.C.

Ostensen, George A. (2003) ‘Saving Lives: A Vital FHWA Goal’, *FHWA Public Roads*, Volume 66, No. 4.

APPENDIX A. DOCUMENTS REVISED FOR 32 STATES AND PR

The following table presents the list of documents and sources that were obtained from 32 states and Puerto Rico regarding their existing regulations, selection criteria, and inspection procedures for traffic safety features on bridges. The documents and sources listed below were reviewed, and the information obtained was a valuable component in the development of this work.

STATE	**DOCUMENTS REVISED**
Alabama	ALDOT Structures Design and Detail Manual [January 2008] ALDOT Standard Drawings [2008]
Alaska	Standard Drawings [2003] (Section G: Guardrail, Median Barriers and Crash Cushions)
Arizona	Railing Standard Drawings Bridge Design Guidelines
Arkansas	Arkansas DOT Bridge Inspection Manual [2008] FHWA Bridge Railing Website Information provided by Phil Brand from Arkansas DOT's Bridge Division
California	Standard Specifications [2006] Standard Plans [2006] Chapter 7 of Traffic Manual Caltrans Element Level Inspection Manual [2000] Revised 2007
Colorado	Bridge Design Manual [1992] Standard Drawings [2006]
Georgia	GDOT Bridge and Structures Design Policy Manual [2005] Revised 2007 GDOT English Construction Standards
Hawaii	Design Criteria for Bridges and Structures [2008] Bridge Inspection Program [2008] Statewide Policy for Permanent Highway Safety Hardware [1999] FHWA website
Indiana	INDOT Design Manual [Last update 2005]
Iowa	Iowa DOT LRFD Bridge Design Manual - Railing Section [Revised 2008] Iowa DOT Traffic Barriers Standard Drawings Iowa DOT Bridge Railings Standard Drawings
Kansas	KDOT Design Manual-Volume III Bridge Section [Revised 2008] Bridge Standard Drawings & Road Standard Drawings
Kentucky	Standard Plans, Bridge Series Standard Plans, Roadway Series
Louisiana	LADOT Bridge Design Manual
Maryland	Guidelines for Traffic Barrier Placement and End Treatment Design [2006] Standard Drawings [2007]
Massachusetts	Part I Bridge Design Manual [2005] Part II Bridge Design Manual [2005]

Michigan	Michigan Bridge Design Manual Bridge Standard Plans Road Standard Plans
Mississippi	GoMDOT Roadside Design Manual [2001] Roadway Design Standard Drawings
Missouri	MoDOT Engineering Policy Guide (Sections 606, 617 & 751) MoDOT Standards for Construction MoDOT Bridge Standard Drawings
Nevada	Standard Plans for Road and Bridge Construction [2007] NDOT Bridge Design Manual, Railing Section [2008]
New Jersey	Bridge Design Manual Standard Drawings
New Mexico	Bridge Procedures and Design Guide [2005] Bridge Design Standards
New York	NYSDOT Bridge Design Manual [2006] NYSDOT Bridge Standard Drawings
North Carolina	North Carolina DOT Roadway Design Manual [2002] Roadway Standard Drawings [2006]
Oklahoma	Standard Drawings [1999] ODOT PONTIS Bridge Inspection Manual [2008]
Pennsylvania	Design Manual Part 4 [2000] Design Manual Part 2 [2000] Bridge Standard Drawings Roadway Standard Drawings Bridge Safety Inspection Manual [2002]
Puerto Rico	Design Directive No. 400 [1998] Design Directive No. 401 [1998] Design Directive No. 408 [2005]
South Carolina	Bridge Design Manual (2006)
Tennessee	Roadway Design Guidelines [2006] Standard Drawings
Texas	TxDOT Bridge Railing Manual [2006] TxDOT Roadway Standards
Utah	UDOT Structure Design Manual Section 3.3.4 UDOT 2005 Standard Drawings [Updated 2008]
Virginia	Manual of the Structure and Bridge Division-Volume V-Part 3 Current Details
Washington	Bridge Design Manual Washington State Bridge Inspection Manual [2006] WSDOT Standard Plans [2008]
Wisconsin	Bridge Manual Wisconsin DOT Facilities Development Manual (Ch16: Std. Detail Drawings) Standard Details

The tables presented in this section correspond to four of the states that were reviewed. Each table corresponds to a state and contains a summary of the most important information regarding the state's warrants for railing installation, selection criteria, inspection procedures, types of railings and end treatments approved for use, and the standard drawings or plans for all safety features approved by the state. The tables include contact information of the Officials from each state that were contacted, and they also include the documents and links used to collect the information required. In this section we will present the tables of California, Hawaii, Puerto Rico, and Texas.

<table>
<tr><td></td><td>CALIFORNIA</td></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 4.3m.
3. There is less than a 6 hour 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.
<u>Plan Title</u> — <u>Plan No.</u>
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</td></tr>
</table>

	Metal Beam Guard Railing-Connections to Bridge Railings with 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 found
Selection Criteria	Materials: Concrete and Metal Height: Varies according to barrier type Shape of face: Varies according to barrier type Compliance with NCHRP-350: No Information found
Inspection Procedures	Use CALTRANS Element Level Inspection Manual
Railings	Chain Link Railing Cable Railing Metal Beam Railing Metal Railing Steel Bridge Railing Concrete Railing
Standard Drawings/ Standard Plans	<u>Metal Railings</u> **<u>Plan Title</u>** **<u>Plan No.</u>** California ST-30 B11-65 California ST-40 B11-66,67 California ST-10 B11-68,69,70 <u>Concrete Railings</u> **<u>Plan Title</u>** **<u>Plan No.</u>** 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:
	  ○ Bury the end of a concrete barrier in a cut slope
	  ○ Extend the end of a concrete barrier at a 1:20 or flatter flare to a point outside the clear recovery zone
	  ○ 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

	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 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'-6" height and follow AASHTO LRFD Bridge Design Specifications.
Selection Criteria	Materials: Concrete & 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 http://safety.fhwa.dot.gov/roadway_dept/road_hardware/bridgerailings.htm
End Treatments	All guardrail end terminals, buried guardrail end terminals, and crash cushions must receive approval from the FHWA and Staet 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 a the standard 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 is similar to the ET-2000 and the SKT-350, but is shorter in length (37.6" versus 50'). The fleat should be installed with a 2'-6"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 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 SRT350and "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. ○ If less than 50% of the existing SRT 350 and "GREAT" system needs repair, one may 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. http://safety.fhwa.dot.gov/roadway_dept/road_hardware/term_cush.htm
Contact Log	Name/Position: Paul Santo / Bridge Design Engineer Phone: (808) 692-7611 E-mail: paul.santo@hawaii.gov
References Used	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/road_hardware/bridgerailings.htm http://safety.fhwa.dot.gov/roadway_dept/road_hardware/term_cush.htm

	PUERTO RICO
Warrants	* 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 found
Selection Criteria	Materials: Concrete Height: 32" (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
Inspection Procedures	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
Railings	Concrete Railings • 32" F-Shape Metal Railings • Strong Post W-Beam (Open Railings for bridges susceptible to floods)
Standard Drawings	**Plan Title** — **Plan No.** W-Beam Strong Post-Hardware — MB 1-5A of 28 W-Beam Strong Post Assembly and Elevation Details — MB 6 of 28

	W-Beam Strong Post – Timber Blockout Details MB 6A of 28 W-Beam Strong Post – Timber Blockout Details MB 6B of 28 MB 6C of 28 MB 6D of 28 Concrete Barrier Type F Shape CB 1 of 8
End Treatments	**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 meters, and used only were there is no or little probability of being impacted from the opposite direction. They shall have a blunt end similar to 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 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 a 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 3 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. **<u>Plan Title</u>** **<u>Plan No.</u>** 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/Position: Manuel Coll Phone: (787) 729-1529 E-mail: mcoll@act.dtop.gov.pr
References Used	Design Directive No. 400 Design Directive No. 401 Design Directive No. 408

	TEXAS
Warrants	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, we 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. **<u>Plan Title</u>** **<u>Plan No.</u>** Metal Fence Guard Fence Transition MBGF(TR)-05 Metal Beam Guard Fence Transition (TL-2) MBGF(TL-2)-05 Metal Beam Guard Fence Transition (T101) MBGF(T101)-05 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.
Selection Criteria	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.
Inspection Procedures	There's **NO** railing inspection procedure specified in the TxDOT's Bridge Inspection Manual

Railings	**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 • 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	**Plan Title** Metal Beam Guard Fence Bridge End Details	**Plan No.** MBGF-03A BED-03

Plans	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	**<u>Plan Title</u>**	**<u>Plan No.</u>**
	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/Position: John Holt Phone: (512) 416-2212 E-mail: jholt@dot.state.tx.us
References Used	TxDOT Bridge Railing Manual, 2006 ftp://ftp.dot.state.tx.us/pub/txdot-info/gsd/manuals/des.pdf TxDOT Roadway Standards http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/standard/rdwylse.htm

APPENDIX B. BRIDGE INSPECTION SHEETS

APPENDIX B.1 BRIDGE TRAFFIC SAFETY FEATURES INSPECTION SHEET

BRIDGE TRAFFIC SAFETY FEATURES INSPECTION SHEETS

Section 1 **SITE IDENTIFICATION**	State	Route No.	Municipality / County
	Year Built	Year Reconstructed	Inspection Date
	Road Functional Class	Average Daily Traffic (ADT)	Year of ADT
	Posted Speed (V_P)	Design Speed (V_D)	Highway Type ☐ Divided ☐ Undivided
	From – To (Milepost / Milepoint) _________ --- _________	Inspector: E-mail: Phone:	Direction of Traffic ☐ Highway traffic not carried ☐ 1-way traffic ☐ 2-way traffic ☐ One lane bridge two-way traffic
Section 2 **BRIDGE INFORMATION**	NBI Structure #	Bridge Material	Type of Service
	Bridge Length	Number of Spans	Pavement Type
	Bridge Roadway Width	Number of Lanes	Pavement Markings EDGE: L ☐ YES ☐ NO R ☐ YES ☐ NO CENTER: ☐ YES ☐ NO
	Shoulder Width L _______ ☐ Not present R _______ ☐ Not present	Sidewalk Width L _______ ☐ Not present R _______ ☐ 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

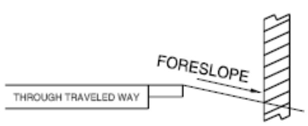
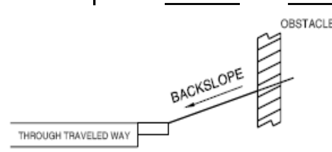
Section 3A BRIDGE ENTRY INFLUENCE ZONE

Length of Influence Zone	Horizontal Curve ☐ YES ☐ NO	Vertical Curve ☐ YES ☐ NO
Intersection ☐ YES ☐ NO Type ________________	Radius: ________ Superelevation: ________ Length: ________	Type ☐ Crest ☐ Sag
	Visibility of Bridge ☐ YES ☐ NO	If NO, indicate the available sight distance ________________

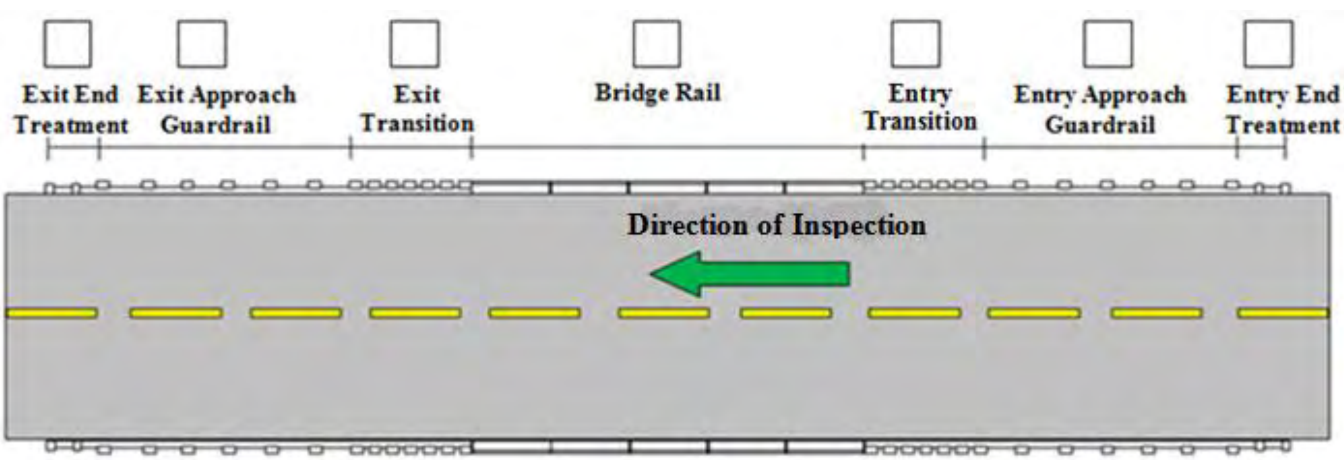
Section 4A BRIDGE EXIT INFLUENCE ZONE

Length of Influence Zone	Horizontal Curve ☐ YES ☐ NO	Vertical Curve ☐ YES ☐ NO
Intersection ☐ YES ☐ NO Type ________________	Radius:_______ Superelevation:_______ Length:________	Type ☐ Crest ☐ Sag
	Sight Obstructions ☐ YES ☐ NO	If YES, describe ________________

Section 5A 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 AASHTO *Roadside Design Guide*) ________________

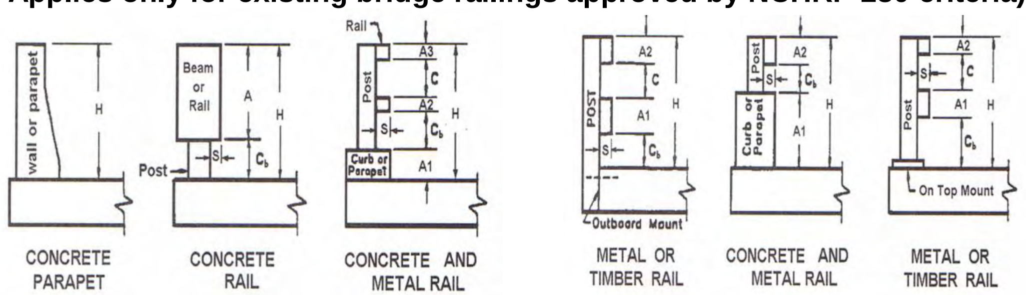
CHECK THE EXISTING TRAFFIC SAFETY FEATURES ON THE BRIDGE BEING INSPECTED
(Fill out the information in the following sections that correspond to the existing safety features)



Section 6A ENTRY END TREATMENT	Type: ___________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
Section 7A 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
Section 8A ENTRY TRANSITION	Type: ___________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO
Section 9A 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.**

	Type: ___________	EXISTING	DESIGN	COMPLIANCE
Section 10A EXIT TRANSITION	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO
Section 11A 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
Section 12A 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 =__________

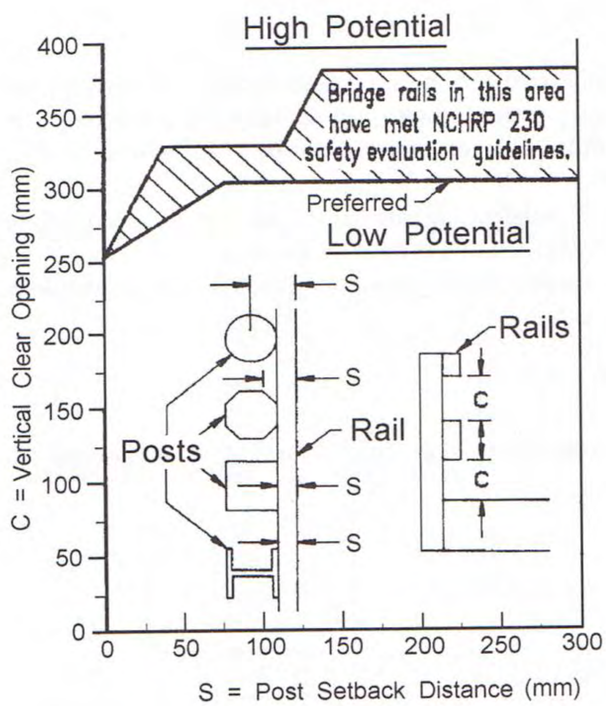


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

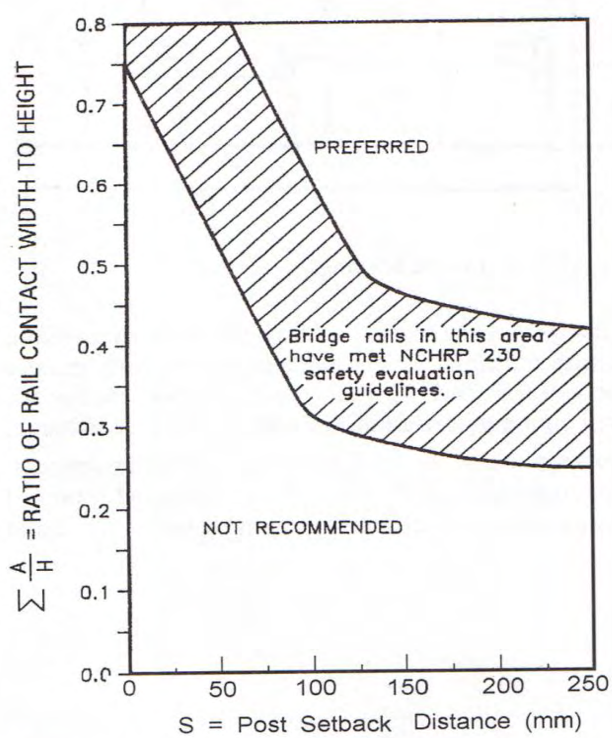
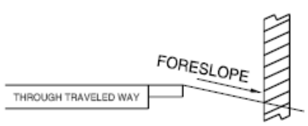
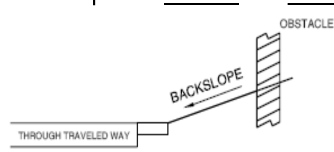
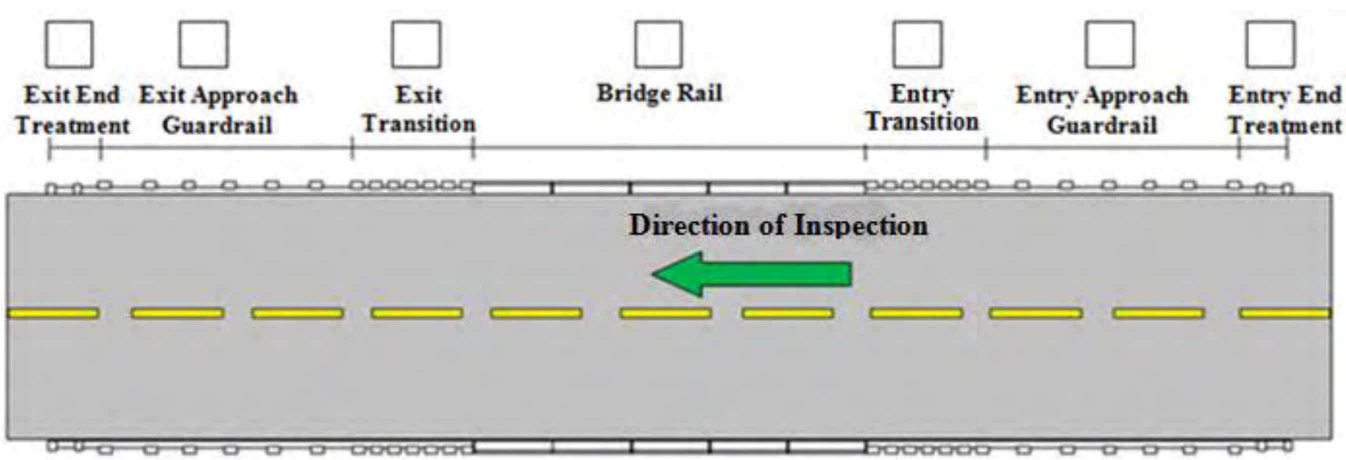


Figure A13.1.1-3 Post Setback Criteria.

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	Horizontal Curve ☐ YES ☐ NO Radius: ________ Superelevation: ________ Length: ________	Vertical Curve ☐ YES ☐ NO Type ☐ Crest ☐ Sag
	Intersection ☐ YES ☐ NO Type ________________	Visibility of Bridge ☐ YES ☐ NO	If NO, indicate the available sight distance ________________
Section 4B BRIDGE EXIT INFLUENCE ZONE	Length of Influence Zone	Horizontal Curve ☐ YES ☐ NO Radius:_______ Superelevation:_______ Length:________	Vertical Curve ☐ YES ☐ NO Type ☐ Crest ☐ Sag
	Intersection ☐ YES ☐ NO Type ________________	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)



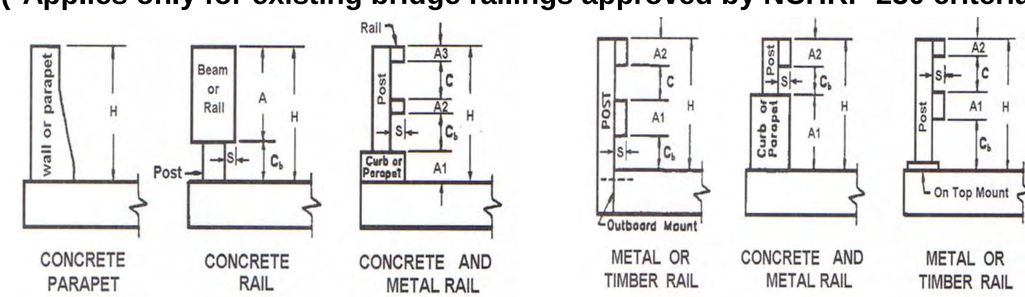
		EXISTING	DESIGN	COMPLIANCE
Section 6B ENTRY END TREATMENT	Type: ____________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
Section 7B ENTRY APPROACH GUARDRAIL	Type: ____________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
	Flare Rate			☐ YES ☐ NO
	Lateral Offset			☐ YES ☐ NO
	Length of Need			☐ YES ☐ NO
Section 8B ENTRY TRANSITION	Type: ____________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO
Section 9B 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.**

Section 10B EXIT TRANSITION	Type: ___________	EXISTING	DESIGN	COMPLIANCE
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO

Section 11B 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

Section 12B 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 =__________

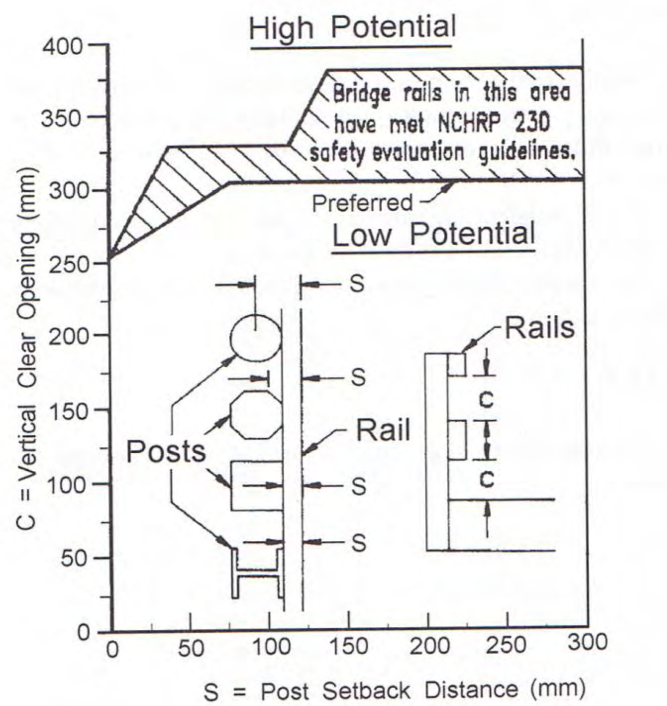


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

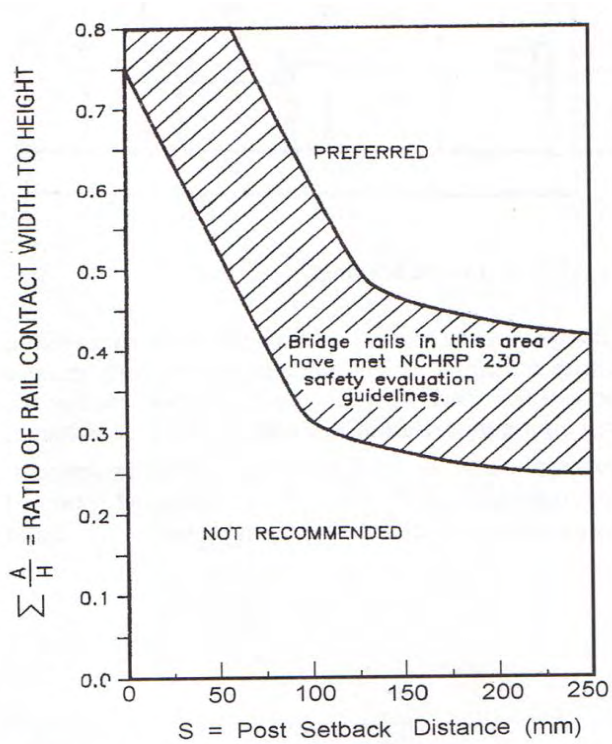


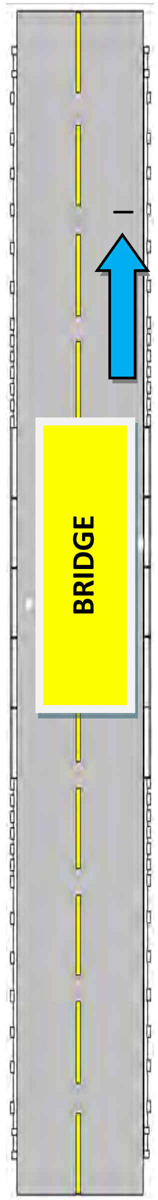
Figure A13.1.1-3 Post Setback Criteria.

<table>
<tr><th colspan="4">Assessment of Traffic Safety Features</th></tr>
<tr><td colspan="2">Direction of Inspection
☐ NB ☐ SB ☐ WB ☐ EB</td><td colspan="2">Direction of Inspection
☐ NB ☐ SB ☐ WB ☐ EB</td></tr>
<tr><td colspan="2">*Only for bridges with one way traffic
☐ Left Side ☐ Right Side</td><td colspan="2">*Only for bridges with one way traffic
☐ Left Side ☐ Right Side</td></tr>
<tr><td><u>Element</u></td><td><u>Rating</u></td><td><u>Element</u></td><td><u>Rating</u></td></tr>
<tr><td>Entry End Treatment</td><td>____</td><td>Entry End Treatment</td><td>____</td></tr>
<tr><td>Entry Approach Guardrail</td><td>____</td><td>Entry Approach Guardrail</td><td>____</td></tr>
<tr><td>Entry Transition</td><td>____</td><td>Entry Transition</td><td>____</td></tr>
<tr><td>Bridge Railing</td><td>____</td><td>Bridge Railing</td><td>____</td></tr>
<tr><td>Exit Transition</td><td>____</td><td>Exit Transition</td><td>____</td></tr>
<tr><td>Exit Approach Guardrail</td><td>____</td><td>Exit Approach Guardrail</td><td>____</td></tr>
<tr><td>Exit End Treatment</td><td>____</td><td>Exit End Treatment</td><td>____</td></tr>
</table>

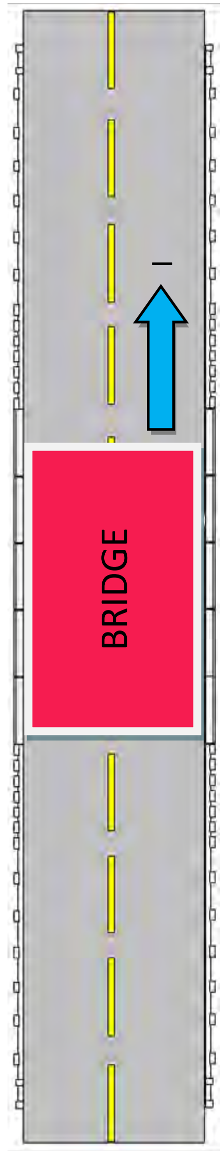
APPENDIX B.2 ROAD CHARACTERIZATION AND ROADSIDE MEASURES SHEET

Municipality: ____________________ Road:_____________ km_______ Date:____________________ Inspector: __________________________

LAT. S	LS	TS	TW	CZ	SH	DISTANCE		DISTANCE	SH	CZ	TW	TS	LS	LAT. S



Municipality: ________________ Road: _________ Km_____ Date: ____________________ Inspector: __________________________

NOTES	FIXED OBJECT	DISTANCE		DISTANCE	FIXED OBJECT	NOTES

APPENDIX C. COMPLETED INSPECTION SHEETS FOR THE APPLICATION EXAMPLES

BRIDGE TRAFFIC SAFETY FEATURES INSPECTION SHEETS

Section 1 **SITE IDENTIFICATION**	State Puerto Rico	Route No. 329	Municipality / County San Germán
	Year Built 1940	Year Reconstructed Not available in PR Bridge Inventory	Inspection Date 11-25-2008
	Road Functional Class Rural Local	Average Daily Traffic (ADT) 1200 vpd	Year of ADT Not available in PR Bridge Inventory
	Posted Speed (V_P) Not posted (Assume 45 mph)	Design Speed (V_D) Not available in PR Bridge Inventory	Highway Type ☐ Divided ☒ Undivided
	From – To (Milepost / Milepoint) _km 1.23 --- __________	Inspector: Elizabeth Negrón E-mail: xxxx@xxxxxx.com Phone: (xxx) xxx-xxxx	Direction of Traffic ☐ Highway traffic not carried ☐ 1-way traffic ☒ 2-way traffic ☐ One lane bridge two-way traffic
Section 2 **BRIDGE INFORMATION**	NBI Structure # 465	Bridge Material Concrete	Type of Service Highway
	Bridge Length 30.18 ft	Number of Spans 1	Pavement Type Asphalt
	Bridge Roadway Width 16.83 ft	Number of Lanes 2	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
	Shoulder Width L _______ ☒ Not present R _______ ☒ Not present	Sidewalk Width L _______ ☒ Not present R _______ ☒ Not present	

PLAN VIEW OF BRIDGE AND APPROACH ROADWAY CONFIGURATION

Direction of Inspection	* Only for bridges with one-way traffic
☐ NB ☐ SB ☐ WB ☒ EB	☐ Left Side ☐ Right Side

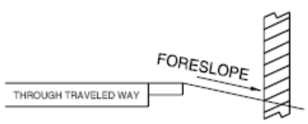
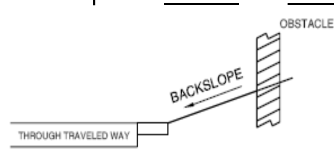
Section 3 BRIDGE ENTRY INFLUENCE ZONE

Length of Influence Zone 360 ft	Horizontal Curve ☒ YES ☐ NO Radius: 189.64 ft Superelevation: None Length: 136 ft	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☒ YES ☐ NO Type local track	Visibility of Bridge ☐ YES ☒ NO	If NO, indicate the available sight distance Required: 250 ft Existing: 96 ft

Section 4 BRIDGE EXIT INFLUENCE ZONE

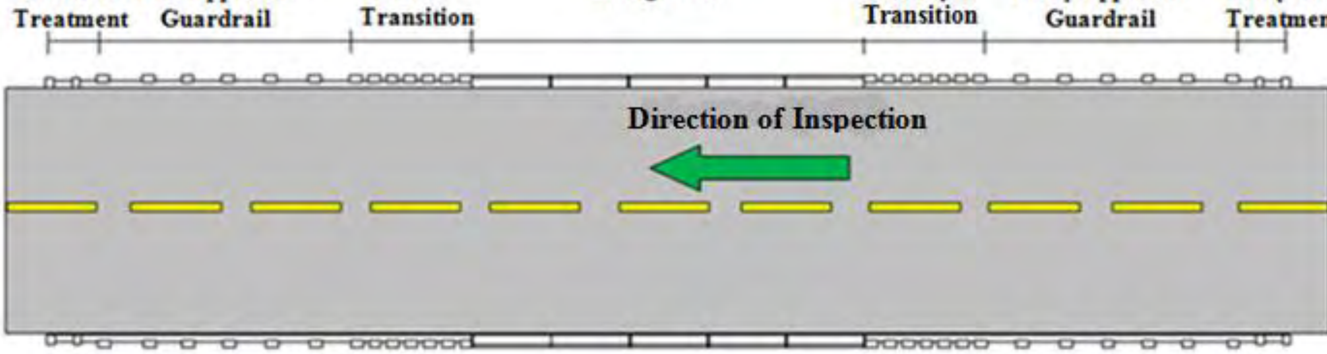
Length of Influence Zone 360 ft	Horizontal Curve ☒ YES ☐ NO Radius:290.07 ft Superelevation: None Length:194.56 ft	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☒ YES ☐ NO Type local track	Sight Obstructions ☒ YES ☐ NO	If YES, describe horizontal curve and trees

Section 5 APPROACH ROADWAY INFORMATION

Roadway Width 16.33 ft	Shoulder Width L _______ ☒ Not present R _______ ☒ Not present	Sidewalk Width L _______ ☒ Not present R _______ ☒ Not present
Roadway Grade 2.1%	Pavement Type Asphalt	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
Foreslope: L 1V:5H R 1V:6H  	Backslope: L ______ R: ________  	Existing Clear Zone: Guardrail installed Required Clear Zone (See Table 3.1 AASHTO *Roadside Design Guide*) L=12 ft-14 ft R=10 ft-12 ft

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)

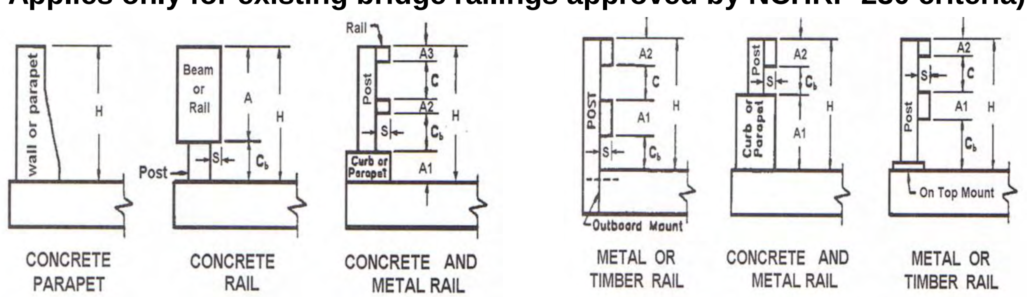
☐	☒	☐	☒	☐	☒	☒
Exit End Treatment	Exit Approach Guardrail	Exit Transition	Bridge Rail	Entry Transition	Entry Approach Guardrail	Entry End Treatment



Section 6 **ENTRY END TREATMENT**	Type: MB	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Anchorage	Not present	Functional	☐ YES ☒ NO
	Grading	1V:10H	1V:10H or flatter	☒ YES ☐ NO
Section 7 **ENTRY APPROACH GUARDRAIL**	Type: W-Beam weak post	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	Non compliant (8 concrete posts)	TL-2	☐ YES ☒ NO
	Height	15 inch	30.38 inch	☐ YES ☒ NO
	Post Spacing	12 ft 6 inch	12 ft 6 inch	☒ YES ☐ NO
	Grading	1V: 6H	1V:10H or flatter	☐ YES ☒ NO
	Flare Rate	N/A	Max 1V:7H-1V:8H	☒ YES ☐ NO
	Lateral Offset	3.25 ft	Min. 4.6 ft	☐ YES ☒ NO
	Length of Need	356 ft	138.2 ft Adjusted value:150 ft	☒ YES ☐ NO
Section 8 **ENTRY TRANSITION**	Type: Not installed	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	Not installed	NA	☐ YES ☒ NO
	Length	Not installed	NA	☐ YES ☒ NO
	Height	Not installed	NA	☐ YES ☒ NO
	Post Spacing	Not installed	NA	☐ YES ☒ NO
	Connection	Not installed	NA	☐ YES ☒ NO
Section 9 **BRIDGE RAILING**	Type: Not crash tested design	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	NA	NA	☐ YES ☒ NO
	Height	35.5 inch	NA	☐ YES ☒ NO
	Post Spacing	12 ft 6 inch	NA	☐ YES ☒ NO
	Lateral Offset	0	NA	☐ YES ☒ NO
	Length	41.5 ft	NA	☐ YES ☒ NO
	Sketch of Bridge Railing 			**Check the snagging potential and the post setback criteria of existing bridge rails on section 13.**

		EXISTING	DESIGN	COMPLIANCE
Section 10 EXIT TRANSITION	Type: <u>Not installed</u>	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	NA	NA	☐ YES ☒ NO
	Length	NA	NA	☐ YES ☒ NO
	Height	NA	NA	☐ YES ☒ NO
	Post Spacing	NA	NA	☐ YES ☒ NO
	Connection	NA	NA	☐ YES ☒ NO
Section 11 EXIT APPROACH GUARDRAIL	Type: <u>W-Beam Weak Post</u>	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Height	15.5 inch	30.38 inch	☐ YES ☒ NO
	Post Spacing	12 ft 6 inch	12 ft 6 inch	☒ YES ☐ NO
	Grading	1V: 8H	1V:10H or flatter	☐ YES ☒ NO
	Flare Rate	N/A	Max 1V:7H-1V:8H	☒ YES ☐ NO
	Lateral Offset	13.57 ft	Min. 4.6 ft	☒ YES ☐ NO
	Length of Need	100 ft	91.4 ft Adjusted value: 100ft	☒ YES ☐ NO
Section 12 EXIT END TREATMENT	Type: <u>Not installed</u>	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	NA	NA	☐ YES ☒ NO
	Anchorage	NA	NA	☐ YES ☒ NO
	Grading	NA	NA	☐ YES ☒ NO

Section 13: 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 =__________

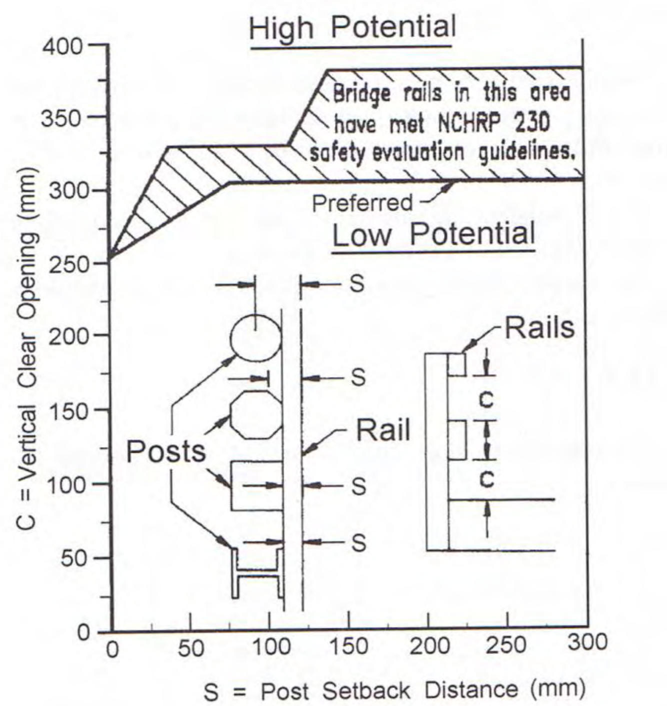


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

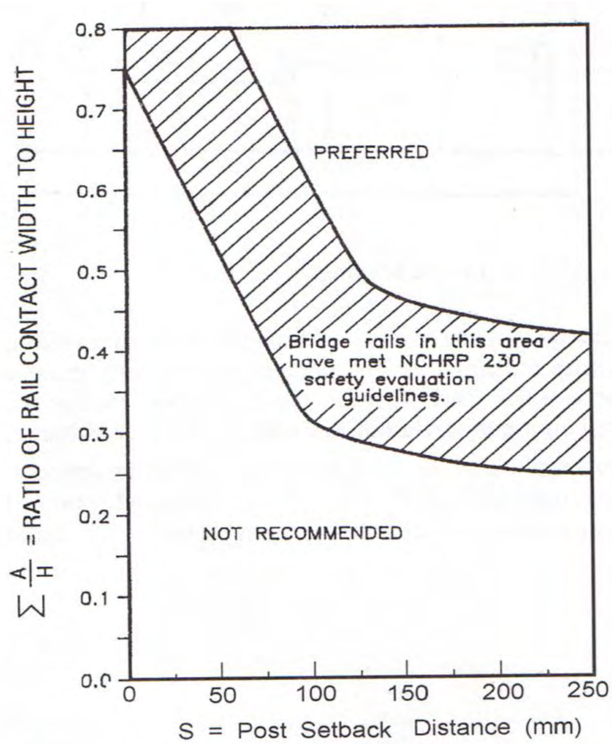


Figure A13.1.1-3 Post Setback Criteria.

Direction of Inspection	* **Only for bridges with one way traffic**
☐ NB ☐ SB ☒ WB ☐ EB	☐ Left Side ☐ Right Side

Section 3 BRIDGE ENTRY INFLUENCE ZONE

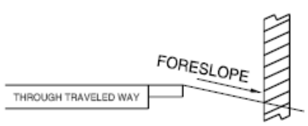
Length of Influence Zone 360 ft	Horizontal Curve ☒ YES ☐ NO Radius: 290.07 ft Superelevation: None Length: 194.56 ft	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☒ YES ☐ NO Type Local track	Visibility of Bridge ☐ YES ☒ NO	If NO, indicate the available sight distance 146 ft

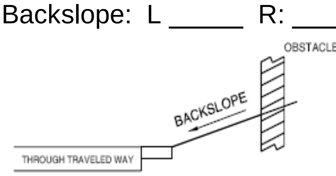
Section 4 BRIDGE EXIT INFLUENCE ZONE

Length of Influence Zone 360 ft	Horizontal Curve ☒ YES ☐ NO Radius:189.64 ft Superelevation: None Length:136 ft	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☒ YES ☐ NO Type Local track	Site Obstructions ☒ YES ☐ NO	If YES, describe horizontal curve

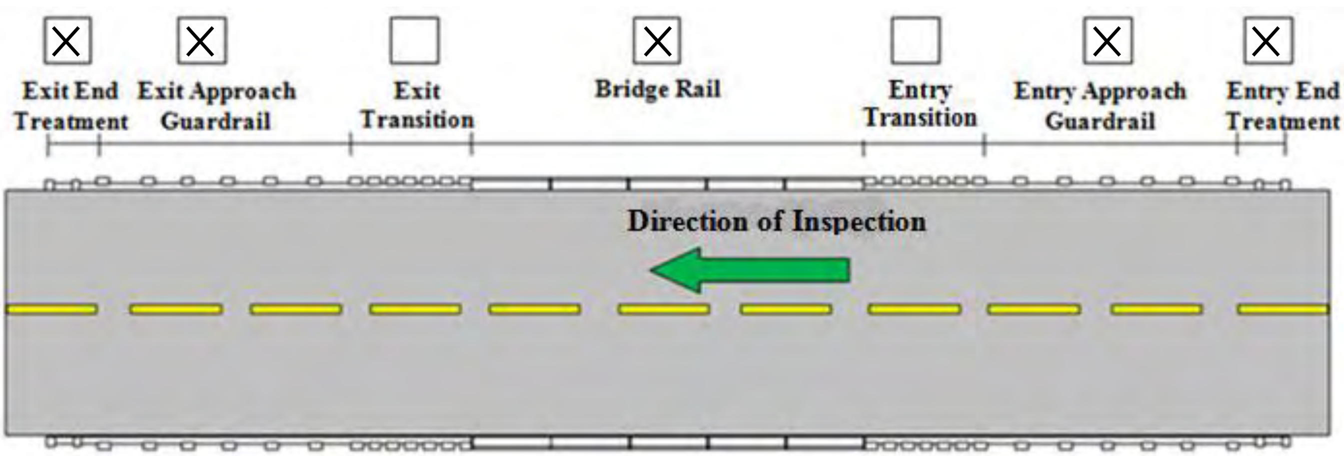
Section 5 APPROACH ROADWAY INFORMATION

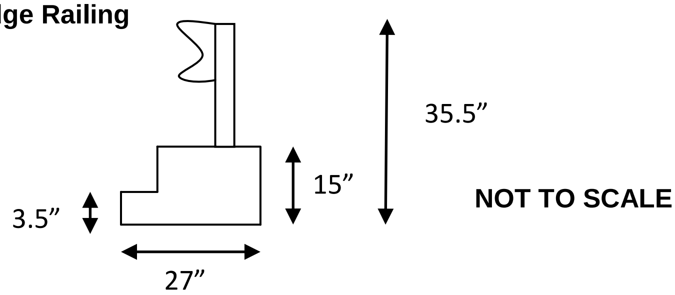
Roadway Width 17.9 ft	Shoulder Width L ______ ☒ Not present R ______ ☒ Not present	Sidewalk Width L ______ ☒ Not present R ______ ☒ Not present
Roadway Grade -1.9 %	Pavement Type Asphalt	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
Foreslope: L 1V:4H R1V:11H	Backslope: L _____ R: _______	Existing Clear Zone: Guardrail installed Required Clear Zone (See Table 3.1 of AASHTO *Roadside Design Guide*) L=12-14 ft R=10-12 ft





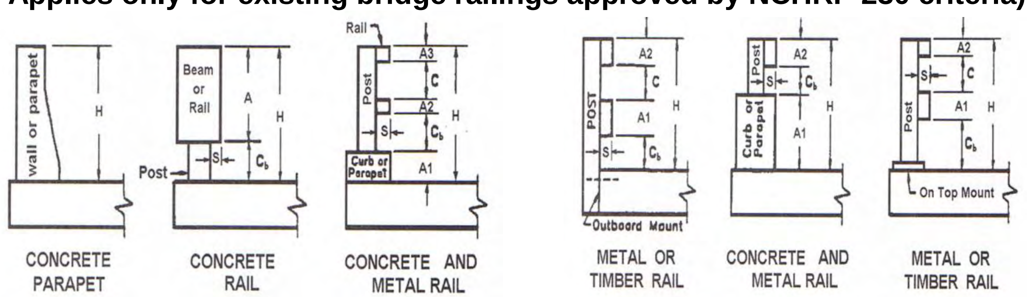
CHECK THE EXISTING TRAFFIC SAFETY FEATURES ON THE BRIDGE BEING INSPECTED
(Fill out the information in the following sections that correspond to the existing safety features)



		EXISTING	DESIGN	COMPLIANCE
Section 6 ENTRY END TREATMENT	Type: MB	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Anchorage	Not present	Functional	☐ YES ☒ NO
	Grading	1V: 10H	1V: 10H or flatter	☒ YES ☐ NO
Section 7 ENTRY APPROACH GUARDRAIL	Type: W-Beam weak post	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	Not compliant (9 concrete posts)	TL-2	☐ YES ☒ NO
	Height	18.4 ft	30.38 ft	☐ YES ☒ NO
	Post Spacing	12 ft 6 inch	12 ft 6 inch	☒ YES ☐ NO
	Grading	1V: 5H	1V: 10H or flatter	☐ YES ☒ NO
	Flare Rate	N/A	Max. 1V:16H	☒ YES ☐ NO
	Lateral Offset	2.2 ft	Min. 4.6 ft	☐ YES ☒ NO
	Length of Need	187.5 ft	147 ft Adjusted value 150 ft	☒ YES ☐ NO
Section 8 ENTRY TRANSITION	Type: Not installed	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	NA	NA	☐ YES ☒ NO
	Length	NA	NA	☐ YES ☒ NO
	Height	NA	NA	☐ YES ☒ NO
	Post Spacing	NA	NA	☐ YES ☒ NO
	Connection	NA	NA	☐ YES ☒ NO
Section 9 BRIDGE RAILING	Type: Not crash tested design	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	NA	NA	☐ YES ☒ NO
	Height	35.5 inch	NA	☐ YES ☒ NO
	Post Spacing	12 ft 6 inch	NA	☐ YES ☒ NO
	Lateral Offset	0	NA	☐ YES ☒ NO
	Length	41.4 ft	NA	☐ YES ☒ NO
	Sketch of Bridge Railing 			**Check the snagging potential and the post setback criteria of existing bridge rails on section 13.**

Section 10 EXIT TRANSITION	Type: Not installed_	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	NA	NA	☐ YES	☒ NO
	Length	NA	NA	☐ YES	☒ NO
	Height	NA	NA	☐ YES	☒ NO
	Post Spacing	NA	NA	☐ YES	☒ NO
	Connection	NA	NA	☐ YES	☒ NO
Section 11 EXIT APPROACH GUARDRAIL	Type: W-Beam weak post	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	Not compliant (4 concrete posts)	TL-2	☐ YES	☒ NO
	Height	15 inch	30.38 inch	☐ YES	☒ NO
	Post Spacing	12 ft 6 inch	12 ft 6 inch	☒ YES	☐ NO
	Grading	1V:19H	1V:10H or flatter	☒ YES	☐ NO
	Flare Rate	N/A	Max. 1V:16H	☒ YES	☐ NO
	Lateral Offset	3.8 ft	Min. 4.6 ft	☐ YES	☒ NO
	Length of Need	336 ft	106.56 ft Adjusted value:112.5 ft	☒ YES	☐ NO
Section 12 EXIT END TREATMENT	Type: MB	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	TL-2	TL-2	☒ YES	☐ NO
	Anchorage	Not installed	Functional	☐ YES	☒ NO
	Grading	1V:19H	1V:10H or flatter	☒ YES	☐ NO

Section 13: 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 =__________

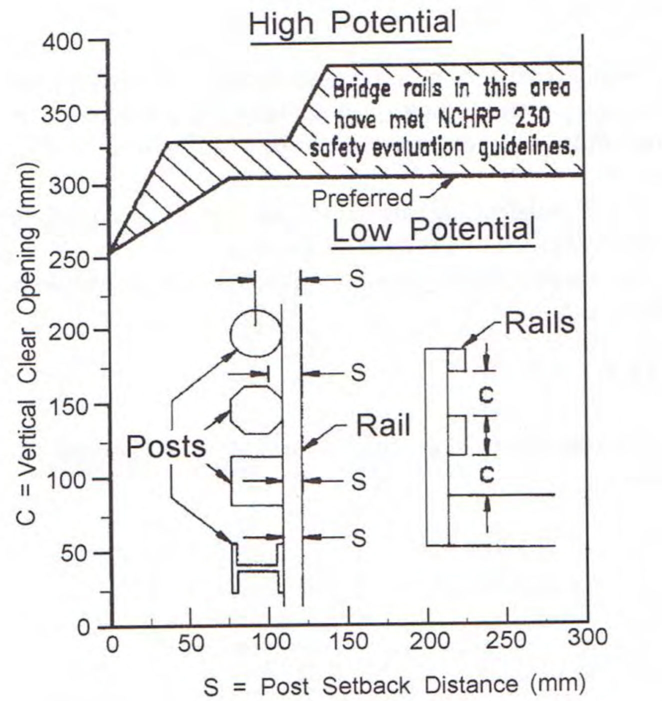


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

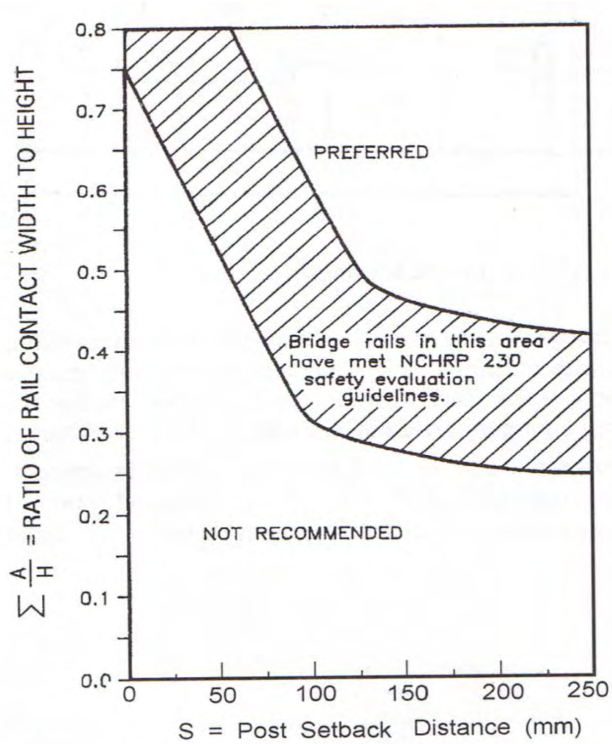


Figure A13.1.1-3 Post Setback Criteria.

Assessment of Traffic Safety Features			
Direction of Inspection ☐ NB ☐ SB ☐ WB ☒ EB		Direction of Inspection ☐ NB ☐ SB ☒ WB ☐ EB	
***Only 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**
Entry End Treatment	**Average**	Entry End Treatment	**Average**
Entry Approach Guardrail	**Deficient**	Entry Approach Guardrail	**Deficient**
Entry Transition	**Deficient**	Entry Transition	**Deficient**
Bridge Railing	**Deficient**	Bridge Railing	**Deficient**
Exit Transition	**Deficient**	Exit Transition	**Deficient**
Exit Approach Guardrail	**Average**	Exit Approach Guardrail	**Deficient**
Exit End Treatment	**Deficient**	Exit End Treatment	**Average**

BRIDGE TRAFFIC SAFETY FEATURES INSPECTION SHEETS

Section 1 **SITE IDENTIFICATION**	State Puerto Rico	Route No. 115	Municipality / County Añasco
	Year Built 1915	Year Reconstructed No information on PR Bridge Inventory	Inspection Date 11-19-2008
	Road Functional Class Rural Major Collector	Average Daily Traffic (ADT) 8000	Year of ADT No information on PR Bridge Inventory
	Posted Speed (V_P) 35mph	Design Speed (V_D) No information on PR Bridge Inventory	Highway Type ☐ Divided ☒ Undivided
	From – To (Milepost / Milepoint) __km 0.55_ --- __________	Inspector: Elizabeth Negrón E-mail: xxxx@xxxxxx.com Phone: (xxx) xxx-xxxx	Direction of Traffic ☐ Highway traffic not carried ☐ 1-way traffic ☒ 2-way traffic ☐ One lane bridge two-way traffic
Section 2 **BRIDGE INFORMATION**	NBI Structure # 63	Bridge Material Concrete	Type of Service Highway
	Bridge Length 27.6ft	Number of Spans 1	Pavement Type Asphalt
	Bridge Roadway Width 29.4ft	Number of Lanes 2	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☒ YES ☐ NO
	Shoulder Width L _3.7ft_ ☐ Not present R _3.5ft_ ☐ Not present	Sidewalk Width L _______ ☒ Not present R _______ ☒ 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 3 BRIDGE ENTRY INFLUENCE ZONE

Length of Influence Zone
360ft

Intersection
☐ YES ☒ NO

Type ________________

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 4 BRIDGE EXIT INFLUENCE ZONE

Length of Influence Zone
360ft

Intersection
☐ YES ☒ NO

Type ________________

Horizontal Curve
☐ YES ☒ NO

Radius:_______
Superelevation:_______
Length:________

Vertical Curve
☐ YES ☒ NO

Type
☐ Crest ☐ Sag

Sight Obstructions
☐ YES ☒ NO If YES, describe ________________

Section 5 APPROACH ROADWAY INFORMATION

Roadway Width
24ft

Shoulder Width
L ______ ☒ Not present
R ______ ☒ Not present

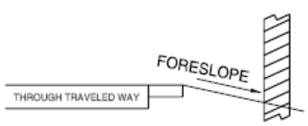
Sidewalk Width
L ______ ☒ Not present
R ______ ☒ Not present

Roadway Grade
+ 0.2%

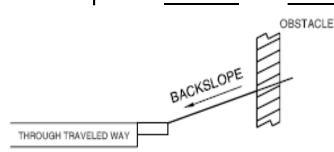
Pavement Type
Asphalt

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

Foreslope:L1V:12H R 1V:12H

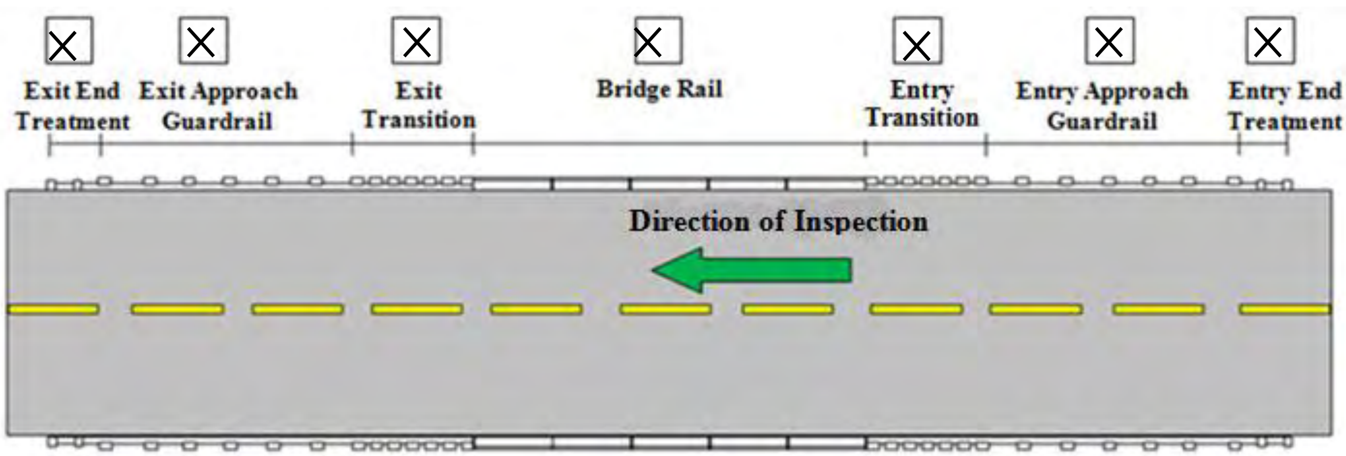


Backslope: L _____ R: _______



Existing Clear Zone:
L=10.3ft R=15ft
Required Clear Zone (See Table 3.1 AASHTO *Roadside Design Guide*)
14-16ft [RDG] 12-14ft [FLH]

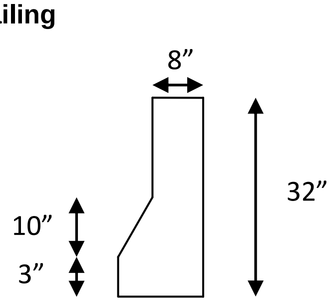
CHECK THE EXISTING TRAFFIC SAFETY FEATURES ON THE BRIDGE BEING INSPECTED
(Fill out the information in the following sections that correspond to the existing safety features)



		EXISTING	DESIGN	COMPLIANCE
Section 6 ENTRY END TREATMENT	Type: MB	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Anchorage	Not present	Functional	☐ YES ☒ NO
	Grading	1V: 35H	1V: 10 H or flatter	☒ YES ☐ NO
Section 7 ENTRY APPROACH GUARDRAIL	Type: W-Beam strong post	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2 Steel blocks	TL-2	☒ YES ☐ NO
	Height	25 inch	27 inch	☐ YES ☒ NO
	Post Spacing	6 ft 3 inch	6 ft 3 inch	☒ YES ☐ NO
	Grading	1V: 30H	1V: 10 H or flatter	☒ YES ☐ NO
	Flare Rate	1V: 7H	Max 1V:7H - 1V: 8H	☒ YES ☐ NO
	Lateral Offset	Varies (Min. 5')	4.6 ft	☒ YES ☐ NO
	Length of Need	76.8 ft	62.5 ft	☒ YES ☐ NO
Section 8 ENTRY TRANSITION	Type: Metal barrier-concrete	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Length	25 ft	18 ft 8 inch	☒ YES ☐ NO
	Height	25 inch	27 inch	☐ YES ☒ NO
	Post Spacing	3 ft 1 inch	1 ft 7 inch – 3ft 1 inch	☐ YES ☒ NO
	Connection	Functional	Functional	☒ YES ☐ NO
Section 9 BRIDGE RAILING	Type: New Jersey	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-4	TL-4	☒ YES ☐ NO
	Height	32 inch	32 inch	☒ YES ☐ NO
	Post Spacing	N/A	N/A	☒ YES ☐ NO
	Lateral Offset	3.6 ft	3.6 ft – 4.6 ft	☒ YES ☐ NO
	Length	68 ft	Min. 27.6 inch	☒ YES ☐ NO

Sketch of Bridge Railing

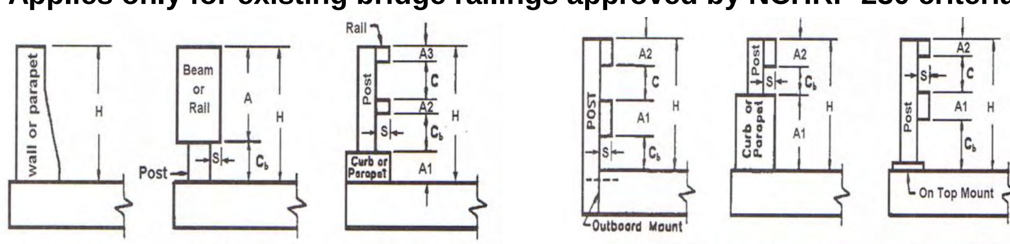
NOT TO SCALE



Check the snagging potential and the post setback criteria of existing bridge rails on section 13.

Section	Type	EXISTING	DESIGN	COMPLIANCE
Section 10 EXIT TRANSITION	Type: Metal barrier-concrete	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Length	25 ft	18 ft 8 inch	☒ YES ☐ NO
	Height	22 inch	27 inch	☐ YES ☒ NO
	Post Spacing	3ft 1 inch	1ft 7 inch – 3 ft 1 inch	☐ YES ☒ NO
	Connection	Functional	Functional	☒ YES ☐ NO
Section 11 EXIT APPROACH GUARDRAIL	Type: W-Beam strong post	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2 (Steel posts)	TL-2	☒ YES ☐ NO
	Height	20 inch	27 inch	☐ YES ☒ NO
	Post Spacing	6 ft 3 inch	6 ft 3 inch	☒ YES ☐ NO
	Grading	1V: 17H	1V: 10 H or flatter	☒ YES ☐ NO
	Flare Rate	1V: 7H	Max 1V:7H – 1V: 8H	☒ YES ☐ NO
	Lateral Offset	Varies Min. 5 ft	4.6 ft	☒ YES ☐ NO
	Length of Need	78 ft	56.4 ft Adjusted value 62.5ft	☒ YES ☐ NO
Section 12 EXIT END TREATMENT	Type: WBeam end terminal	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Anchorage	Not present	Functional	☐ YES ☒ NO
	Grading	1V: 13H	1V: 10 H or flatter	☒ YES ☐ NO

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



CONCRETE PARAPET — CONCRETE RAIL — CONCRETE AND METAL RAIL — METAL OR TIMBER RAIL — CONCRETE AND METAL RAIL — METAL OR TIMBER RAIL

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

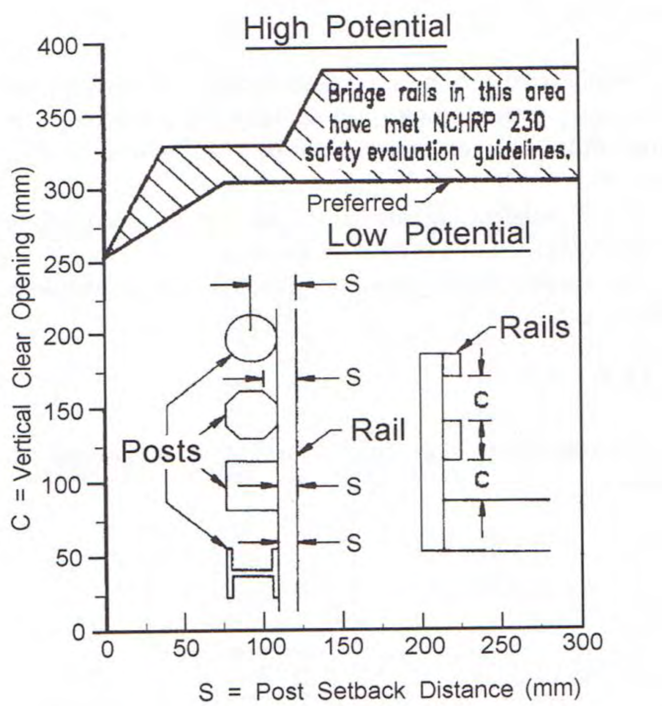


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

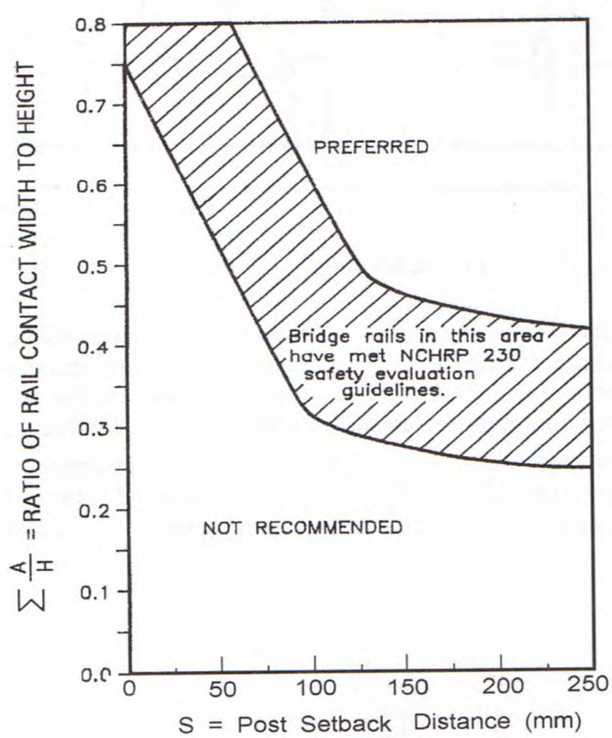


Figure A13.1.1-3 Post Setback Criteria.

Direction of Inspection	* **Only for bridges with one way traffic**
[ ] NB [X] SB [ ] WB [ ] EB	[ ] Left Side [ ] Right Side

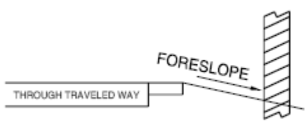
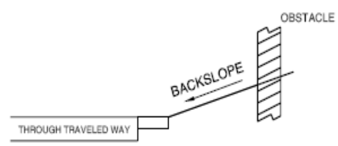
Section 3 BRIDGE ENTRY INFLUENCE ZONE

Length of Influence Zone 360ft	Horizontal Curve [ ] YES [X] NO Radius: ________ Superelevation: ________ Length: ________	Vertical Curve [ ] YES [X] NO Type [ ] Crest [ ] Sag
Intersection [ ] YES [X] NO Type ________________	Visibility of Bridge [X] YES [ ] NO	If NO, indicate the available sight distance ________________

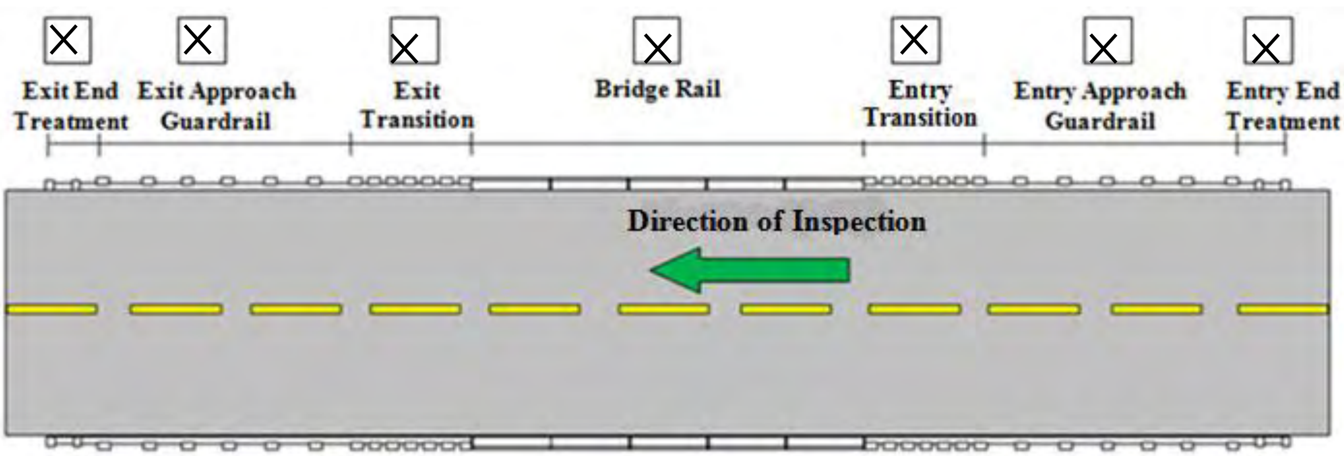
Section 4 BRIDGE EXIT INFLUENCE ZONE

Length of Influence Zone 360ft	Horizontal Curve [ ] YES [X] NO Radius:________ Superelevation:________ Length:________	Vertical Curve [ ] YES [X] NO Type [ ] Crest [ ] Sag
Intersection [ ] YES [X] NO Type ________________	Site Obstructions [ ] YES [X] NO	If YES, describe ________________

Section 5 APPROACH ROADWAY INFORMATION

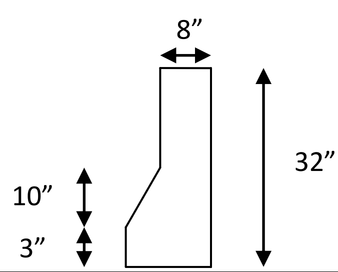
Roadway Width 24'	Shoulder Width L 2.3ft [ ] Not present R 2ft [ ] Not present	Sidewalk Width L ______ [X] Not present R ______ [X] Not present
Roadway Grade -0.3%	Pavement Type Asphalt	Pavement Markings EDGE: L [X] YES [ ] NO R [X] YES [ ] NO CENTER: [X] YES [ ] NO
Foreslope: L1V:12H R1V: 14H 	Backslope: L _____ R: ________ 	Existing Clear Zone: L=22.2ft R=10.4ft Required Clear Zone (See Table 3.1 of AASHTO *Roadside Design Guide*) 14-16ft [RDG] 12-14ft [FLH]

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)



		EXISTING	DESIGN	COMPLIANCE
Section 6 ENTRY END TREATMENT	Type: <u>MB</u>	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Anchorage	Not present	Functional	☐ YES ☒ NO
	Grading	1V:24H	1V:10H or flatter	☒ YES ☐ NO
Section 7 ENTRY APPROACH GUARDRAIL	Type: W-Beam strong post	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2 (Steel Posts)	TL-2 or higher	☒ YES ☐ NO
	Height	24 inch	27 inch	☐ YES ☒ NO
	Post Spacing	6 ft 3 inch	6 ft 3 inch	☒ YES ☐ NO
	Grading	1V:59H	1V:10H or flatter	☒ YES ☐ NO
	Flare Rate	1V: 6H	Max 1V:7H-1V:8H	☒ YES ☐ NO
	Lateral Offset	5 ft	4.6 ft	☒ YES ☐ NO
	Length of Need	76 ft	56.4 ft Adjusted value 62.5ft	☒ YES ☐ NO
Section 8 ENTRY TRANSITION	Type: <u>Metal barrier-concrete</u>	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Length	25 ft	18 ft 8 inch	☒ YES ☐ NO
	Height	24 inch	27 inch	☐ YES ☒ NO
	Post Spacing	3 ft 1 inch	1ft 7 inch – 3 ft 1 inch	☐ YES ☒ NO
	Connection	Functional	Functional	☒ YES ☐ NO
Section 9 BRIDGE RAILING	Type: <u>New Jersey</u>	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-4	TL-4	☒ YES ☐ NO
	Height	32 inch	32 inch	☒ YES ☐ NO
	Post Spacing	N/A	N/A	☒ YES ☐ NO
	Lateral Offset	4 ft	3.6 ft – 4.6 ft	☒ YES ☐ NO
	Length	68 ft	Min. 27.6 ft	☒ YES ☐ NO

Sketch of Bridge Railing

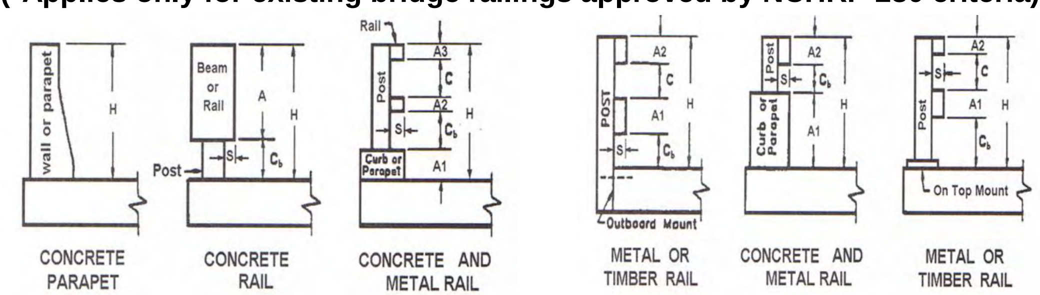


NOT TO SCALE

Check the snagging potential and the post setback criteria of existing bridge rails on section 13.

Section	Type	EXISTING	DESIGN	COMPLIANCE
Section 10 EXIT TRANSITION	Type: Metal barrier-concrete	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Length	25 ft	18 ft 8 inch	☒ YES ☐ NO
	Height	24 inch	27 inch	☐ YES ☒ NO
	Post Spacing	3 ft 1 inch	1ft 7 inch – 3 ft 1 inch	☐ YES ☒ NO
	Connection	Functional	Functional	☒ YES ☐ NO
Section 11 EXIT APPROACH GUARDRAIL	Type: W-Beam	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2 (Steel Posts)	TL-2	☒ YES ☐ NO
	Height	25 inch	27”	☐ YES ☒ NO
	Post Spacing	6 inch 3 ft	6 ft 3 inch	☒ YES ☐ NO
	Grading	1V: 22H	1V:10H or flatter	☒ YES ☐ NO
	Flare Rate	1V:5H	Max 1V:7H-1V:8H	☒ YES ☐ NO
	Lateral Offset	19.5 ft	4.6 ft	☒ YES ☐ NO
	Length of Need	77 ft	52 ft Adjusted value:62.5ft	☒ YES ☐ NO
Section 12 EXIT END TREATMENT	Type: W-beam end terminal	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Anchorage	Not present	Functional	☐ YES ☒ NO
	Grading	1V:12H	1V:10H or flatter	☒ YES ☐ NO

Section 13: 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 =__________

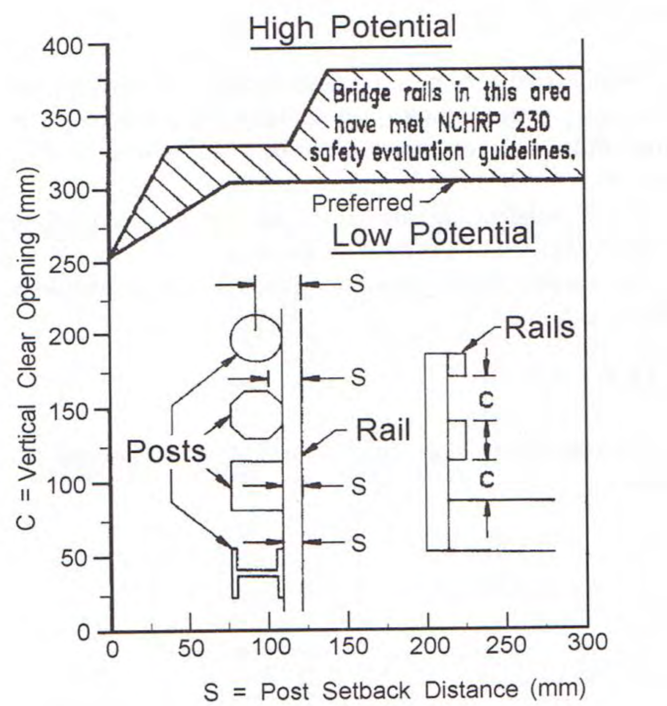


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

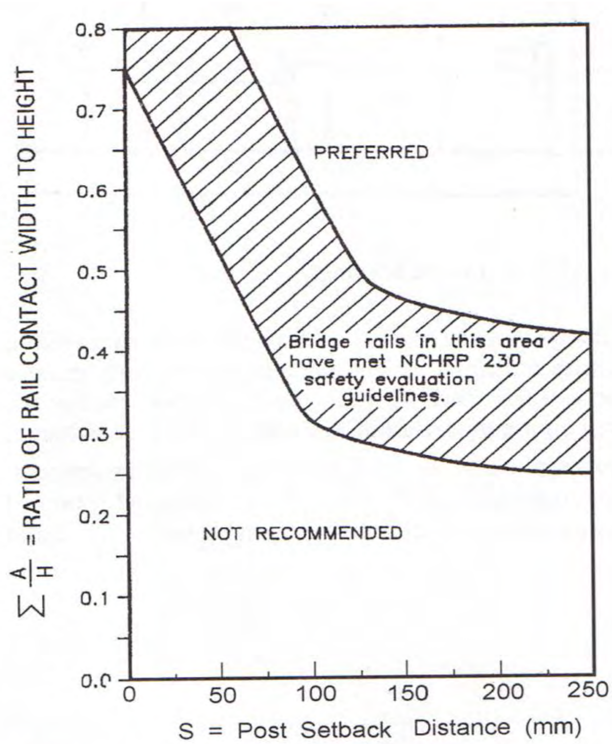


Figure A13.1.1-3 Post Setback Criteria.

Assessment of Traffic Safety Features			
Direction of Inspection ☒ NB ☐ SB ☐ WB ☐ EB		Direction of Inspection ☐ NB ☒ SB ☐ WB ☐ EB	
***Only 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**
Entry End Treatment	**_Average_**	Entry End Treatment	**_Average_**
Entry Approach Guardrail	**_Good_**	Entry Approach Guardrail	**_Good_**
Entry Transition	**_Average_**	Entry Transition	**_Average_**
Bridge Railing	**_Excellent_**	Bridge Railing	**_Excellent_**
Exit Transition	**_Average_**	Exit Transition	**_Average_**
Exit Approach Guardrail	**_Good_**	Exit Approach Guardrail	**_Good_**
Exit End Treatment	**_Average_**	Exit End Treatment	**_Average_**

BRIDGE TRAFFIC SAFETY FEATURES INSPECTION SHEETS

Section 1 SITE IDENTIFICATION	State Puerto Rico	Route No. 125	Municipality / County San Sebastián
	Year Built 1990	Year Reconstructed Not available in PR Bridge Inventory	Inspection Date November 18, 2008
	Road Functional Class Rural Minor Collector	Average Daily Traffic 2300vpd	Year of ADT Not available in PR Bridge Inventory
	Posted Speed (V_P) 35mph	Design Speed (V_D) Not available in PR Bridge Inventory	Highway Type ☐ Divided ☒ Undivided
	From – To (Milepost / Milepoint) ≈ km 16.97 --- km 17.0	Inspector: Elizabeth Negrón E-mail: xxxxx@xxxxxxx.com Phone: (xxx) xxx-xxxx	Direction of Traffic ☐ Highway Traffic not carried ☐ 1 Way Traffic ☒ 2 Way Traffic ☐ One lane bridge two way traffic
Section 2 BRIDGE INFORMATION	NBI Structure # 2231	Bridge Material Prestressed Concrete	Type of Service Highway
	Bridge Length 102.33 ft	Number of Spans 1	Pavement Type Concrete
	Bridge Roadway Width 30.5 ft	Number of Lanes 2	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
	Shoulder Width L 3.6 ft(WB) ☐ Not present R 4.3 ft(WB) ☐ Not present	Sidewalk Width L _______ ☒ Not present R _______ ☒ Not present	

PLAN VIEW OF BRIDGE AND APPROACH ROADWAY CONFIGURATION

Direction of Inspection	* **Only for bridges with One Way Traffic**
☐ NB ☐ SB ☐ WB ☒ EB	☐ Left Side ☐ Right Side

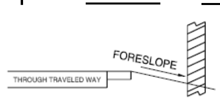
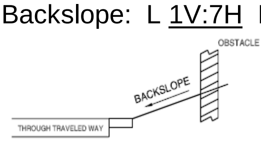
Section 3 BRIDGE ENTRY INFLUENCE ZONE

Length of Influence Zone 360 ft	Horizontal Curve ☐ YES ☒ NO Radius: ________ Superelevation: ________ Length: ________	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☐ YES ☒ NO Type ________________	Visibility of Bridge ☒ YES ☐ NO	If NO, indicate the available sight distance ________________

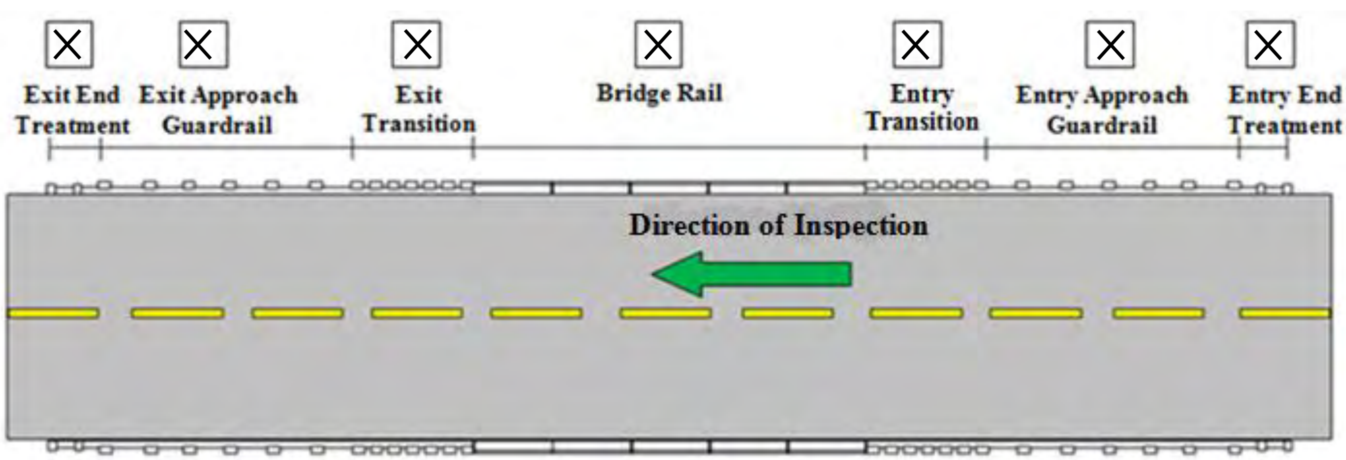
Section 4 BRIDGE EXIT INFLUENCE ZONE

Length of Influence Zone 360 ft	Horizontal Curve ☒ YES ☐ NO Radius:1309.3 ft Superelevation: 6% Length:446.5 ft	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☐ YES ☒ NO Type ________________	Site Obstructions ☒ YES ☐ NO	If YES, describe: Horizontal curve Point of visibility: 270ft from the bridge

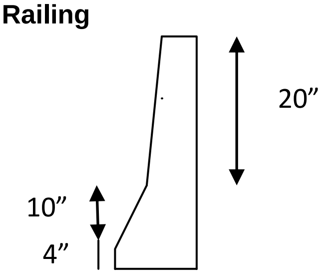
Section 5 APPROACH ROADWAY INFORMATION

Roadway Width 25.4 ft	Shoulder Width L 3.8 ft ☐ Not present R 1.8 ft ☐ Not present	Sidewalk Width L ______ ☒ Not present R ______ ☒ Not present
Roadway Grade +2%	Pavement Type Asphalt	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
Foreslope: L 1V:6H R _____  There is a vee channel located on the left side of the road. The change in slopes coincides with AASHTO recommended values.	Backslope: L 1V:7H R: 1V: 2H  Length 30' Starting at 250ft from the bridge end	Existing Clear Zone: 6 ft Required Clear Zone (See Table 3.1 of AASHTO *Roadside Design Guide*) 12 ft-14 ft

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)

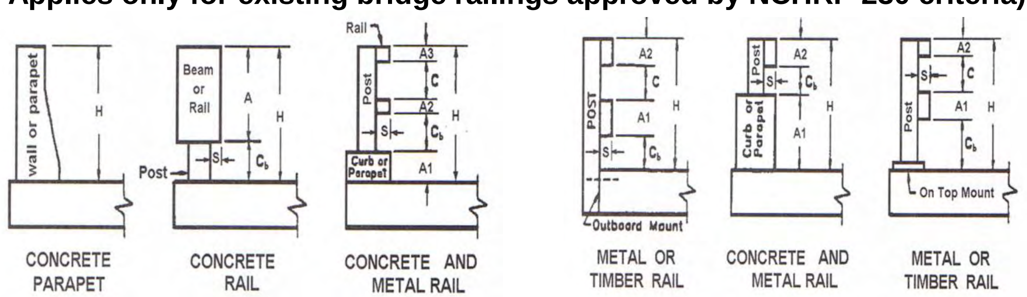


		EXISTING	DESIGN	COMPLIANCE	
Section 6 ENTRY END TREATMENT	Type: MB	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	TL-2	TL-2	☒ YES	☐ NO
	Anchorage	Functional	Functional	☒ YES	☐ NO
	Grading	1V: 7H	1V: 10H or flatter	☐ YES	☒ NO
Section 7 ENTRY APPROACH GUARDRAIL	Type: W-Beam strong post	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	TL-2 (Steel blocks)	TL-2	☒ YES	☐ NO
	Height	26 inch	27 inch	☐ YES	☒ NO
	Post Spacing	6 ft 3 inch	6 ft 3 inch	☒ YES	☐ NO
	Grading	1V: 13H	1V: 10H or flatter	☒ YES	☐ NO
	Flare Rate	NO FLARE	Max. 1V: 8H	☒ YES	☐ NO
	Lateral Offset	4.8 ft	3.6 ft - 4.6 ft	☒ YES	☐ NO
	Length of Need	87.5 ft	131.4 ft Adj. value 137.5ft	☐ YES	☒ NO
Section 8 ENTRY TRANSITION	Type: Metal barrier-concrete	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	TL-2	TL-2	☒ YES	☐ NO
	Length	25 ft	25 ft	☒ YES	☐ NO
	Height	26 inch	27 ft	☐ YES	☒ NO
	Post Spacing	3 ft 1 inch	1ft 7 inch- 3 ft 1 inch	☐ YES	☒ NO
	Connection	Functional	Functional	☒ YES	☐ NO
Section 9 BRIDGE RAILING	Type: New Jersey	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	TL-4	TL-4	☒ YES	☐ NO
	Height	34 inch	32 inch	☒ YES	☐ NO
	Post Spacing	N/A	N/A	☒ YES	☐ NO
	Lateral Offset	3.6 ft	3.6 ft – 4.6 ft	☒ YES	☐ NO
	Length	146.9 ft	> 102.33 ft	☒ YES	☐ NO
	Sketch of Bridge Railing			**Check the snagging potential and the post setback criteria of existing bridge rails on section 13.**	



Section 10 EXIT TRANSITION	Type: Not installed	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	NA	NA	☐ YES ☒ NO
	Length	NA	NA	☐ YES ☒ NO
	Height	NA	NA	☐ YES ☒ NO
	Post Spacing	NA	NA	☐ YES ☒ NO
	Connection	Functional	Functional	☒ YES ☐ NO
Section 11 EXIT APPROACH GUARDRAIL	Type: W-Beam	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Height	26 inch	27 inch	☐ YES ☒ NO
	Post Spacing	6 ft 3 inch	6 ft 3 inch	☒ YES ☐ NO
	Grading	1V: 10H	1V: 10H or flatter	☒ YES ☐ NO
	Flare Rate	NO FLARE	Max. 1V: 8H	☒ YES ☐ NO
	Lateral Offset	6.9 ft	3.6 ft – 4.6 ft	☒ YES ☐ NO
	Length of Need	396.2 ft	58.3 ft Adjusted value: 62.5 ft	☒ YES ☐ NO
Section 12 EXIT END TREATMENT	Type: MB	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Anchorage	Functional	Functional	☒ YES ☐ NO
	Grading	1V: 10H	1V: 10H or flatter	☒ YES ☐ NO

Section 13: 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 =__________

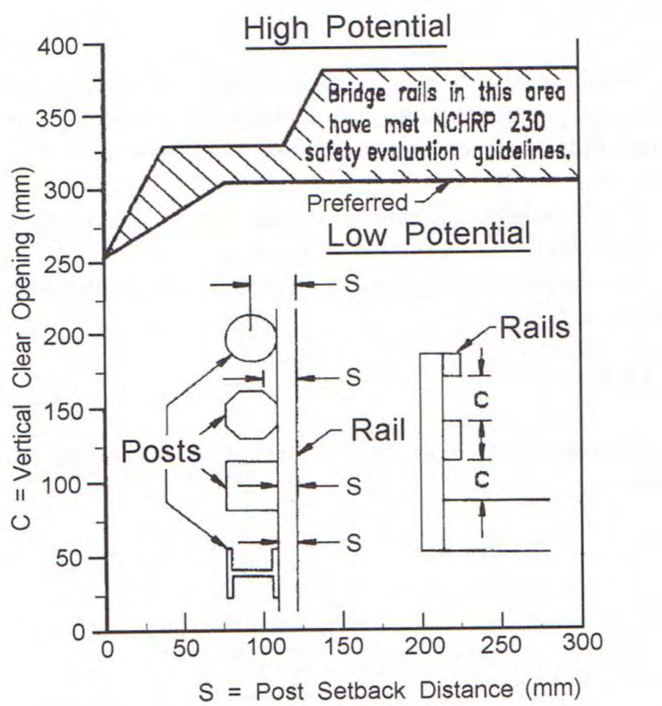


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

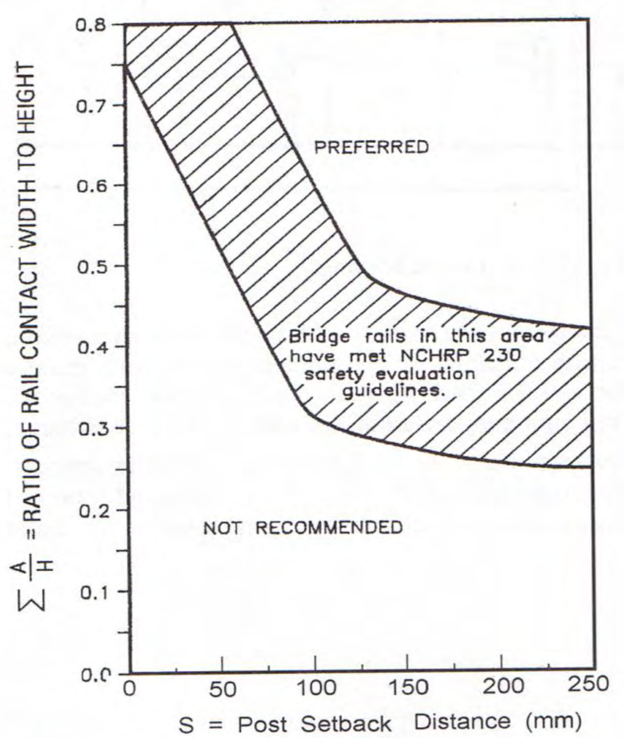
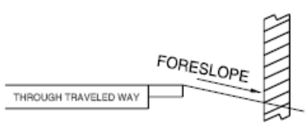
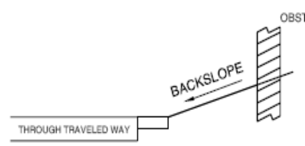


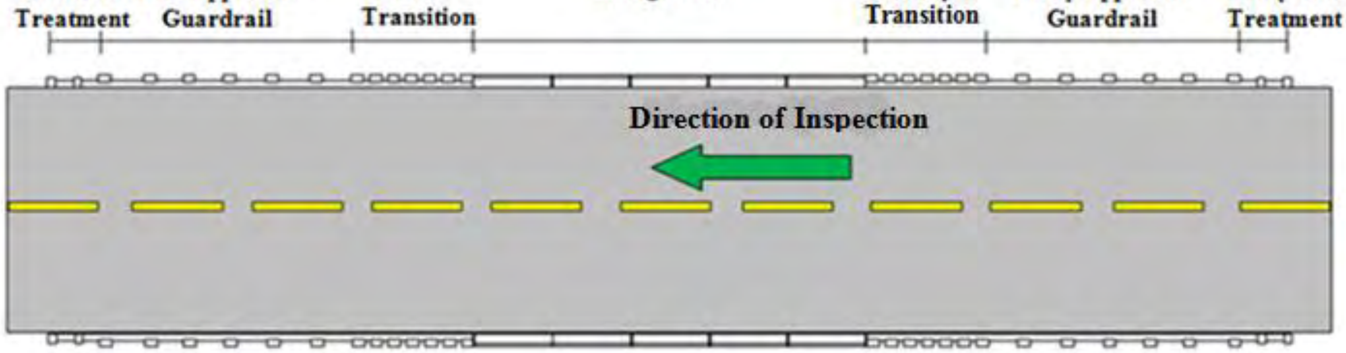
Figure A13.1.1-3 Post Setback Criteria.

Direction of Inspection ☐ NB ☐ SB ☒ WB ☐ EB	* **Only for bridges with One Way Traffic** ☐ Left Side ☐ Right Side

Section 3 BRIDGE ENTRY INFLUENCE ZONE	Length of Influence Zone 360 ft Intersection ☐ YES ☒ NO Type _________________	Horizontal Curve ☒ YES ☐ NO Radius: 1309.3 ft Superelevation: 6% Length: 446.5 ft	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
		Visibility of Bridge ☐ YES ☒ NO	If NO, indicate the available sight distance 270ft
Section 4 BRIDGE EXIT INFLUENCE ZONE	Length of Influence Zone 360ft Intersection ☐ YES ☒ NO Type _________________	Horizontal Curve ☐ YES ☒ NO Radius:_______ Superelevation:_______ Length:________	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
		Site Obstructions ☐ YES ☒ NO	If YES, describe __________________
Section 5 APPROACH ROADWAY INFORMATION	Roadway Width 27.5 ft	Shoulder Width L 2.7 ft ☐ Not present R 2.2 ft ☐ Not present	Sidewalk Width L ______ ☒ Not present R ______ ☒ Not present
	Roadway Grade 2.3%	Pavement Type Asphalt	Pavement Markings EDGE: L ☒ YES ☐ NO; R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
	Foreslope: L 1V:10H R 1V:14H  	Backslope: L N/A__ R: N/A____  	Existing Clear Zone: Guardrail installed Required Clear Zone (See Table 3.1 of AASHTO *Roadside Design Guide*) __12 ft – 14 ft____

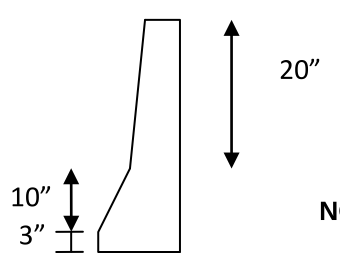
CHECK THE EXISTING TRAFFIC SAFETY FEATURES ON THE BRIDGE BEING INSPECTED
(Fill out the information in the following sections that correspond to the existing safety features)

☒ Exit End Treatment ☒ Exit Approach Guardrail ☒ Exit Transition ☒ Bridge Rail ☒ Entry Transition ☒ Entry Approach Guardrail ☒ Entry End Treatment



		EXISTING	DESIGN	COMPLIANCE
Section 6 ENTRY END TREATMENT	Type: MB	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Anchorage	Damaged	Functional	☐ YES ☒ NO
	Grading	1V: 14H	1V: 10H or flatter	☒ YES ☐ NO
Section 7 ENTRY APPROACH GUARDRAIL	Type: W-Beam strong post	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2 (steel blocks)	TL-2	☒ YES ☐ NO
	Height	24 inch	27 inch	☐ YES ☒ NO
	Post Spacing	6 ft 3 inch	6 ft 3 inch	☒ YES ☐ NO
	Grading	1V: 14H	1V: 10H or flatter	☒ YES ☐ NO
	Flare Rate	1V: 4.5H	Max. 1V: 8H	☒ YES ☐ NO
	Lateral Offset	4.4 ft	3.6 ft – 4.6 ft	☒ YES ☐ NO
	Length of Need	414 ft	222.2 ft Adjusted value: 225ft	☒ YES ☐ NO
Section 8 ENTRY TRANSITION	Type: Metal barrier-concrete	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Length	25 ft	25 ft	☒ YES ☐ NO
	Height	24 inch	27 inch	☐ YES ☒ NO
	Post Spacing	3 ft 1 inch	1 ft 7 inch– 3 ft 1 inch	☐ YES ☒ NO
	Connection	Functional	Functional	☒ YES ☐ NO
Section 9 BRIDGE RAILING	Type: New Jersey	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-4	TL-4	☒ YES ☐ NO
	Height	33 inch	32 inch	☒ YES ☐ NO
	Post Spacing	N/A	N/A	☒ YES ☐ NO
	Lateral Offset	4.3 ft	3.6 ft – 4.6 ft	☒ YES ☐ NO
	Length	146.8 inch	> 102.33 inch	☒ YES ☐ NO

Sketch of Bridge Railing

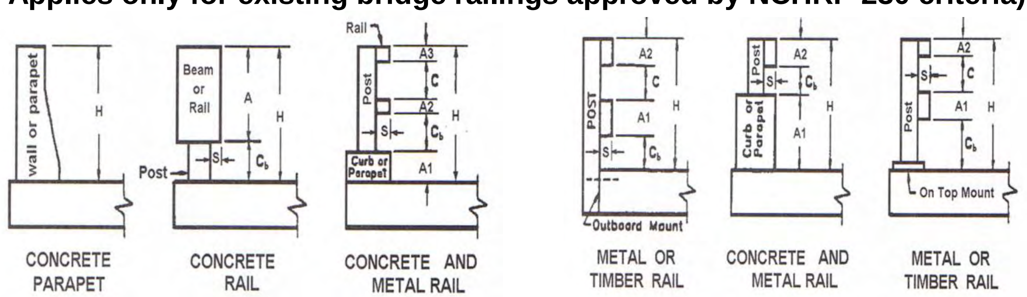


NOT TO SCALE

Check the snagging potential and the post setback criteria of existing bridge rails on section 13.

		EXISTING	DESIGN	COMPLIANCE	
Section 10 EXIT TRANSITION	Type: Not installed	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	NA	NA	☐ YES	☒ NO
	Length	NA	NA	☐ YES	☒ NO
	Height	NA	NA	☐ YES	☒ NO
	Post Spacing	NA	NA	☐ YES	☒ NO
	Connection	Functional	Functional	☒ YES	☐ NO
Section 11 EXIT APPROACH GUARDRAIL	Type: W-Beam strong post	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	TL-2 (steel posts)	TL-2	☒ YES	☐ NO
	Height	28 inch	27 inch	☒ YES	☐ NO
	Post Spacing	6 ft 3 inch	6 ft 3 inch	☒ YES	☐ NO
	Grading	1V: 15H	1V: 10H or flatter	☒ YES	☐ NO
	Flare Rate	NO FLARE	Max. 1V: 8H	☒ YES	☐ NO
	Lateral Offset	6.7 ft	3.6 ft – 4.6 ft	☒ YES	☐ NO
	Length of Need	115.3 ft	54.3 ft Adjusted value 62.5ft	☒ YES	☐ NO
Section 12 EXIT END TREATMENT	Type: W-Beam end treatment	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	TL-2	TL-2	☒ YES	☐ NO
	Anchorage	Functional	Functional	☒ YES	☐ NO
	Grading	1V: 14H	1V: 10H or flatter	☒ YES	☐ NO

Section 13: 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 =__________

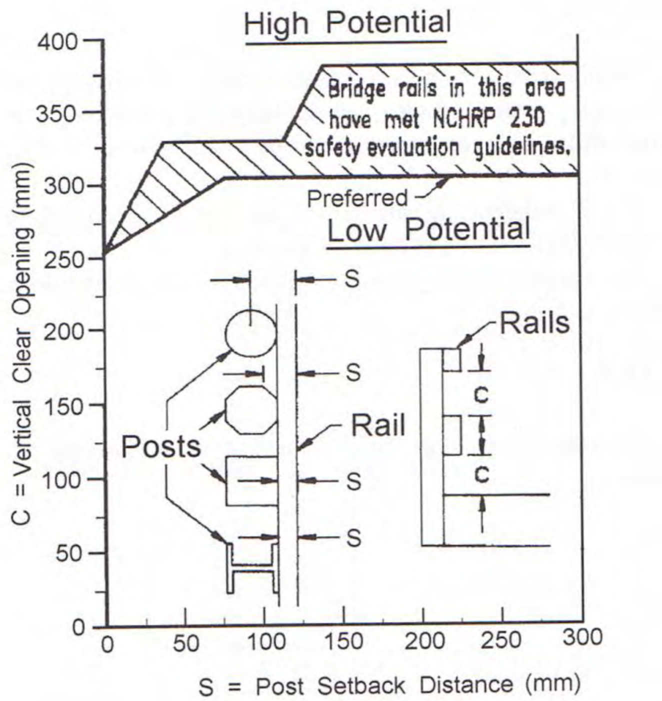


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

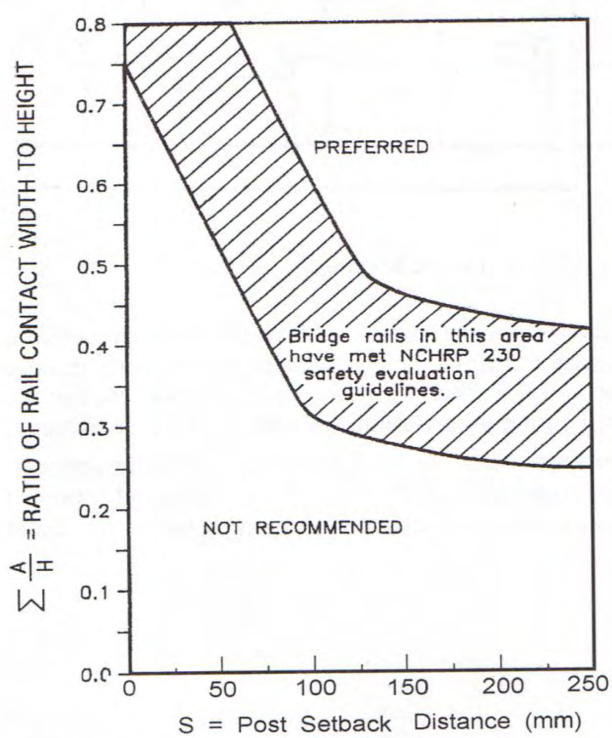


Figure A13.1.1-3 Post Setback Criteria.

Assessment of Traffic Safety Features			
Direction of Inspection ☐ NB ☐ SB ☐ WB ☒ EB		Direction of Inspection ☐ NB ☐ SB ☒ WB ☐ EB	
***Only 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**
Entry End Treatment	**Average**	Entry End Treatment	**Average**
Entry Approach Guardrail	**Good**	Entry Approach Guardrail	**Good**
Entry Transition	**Average**	Entry Transition	**Average**
Bridge Railing	**Excellent**	Bridge Railing	**Excellent**
Exit Transition	**Deficient**	Exit Transition	**Deficient**
Exit Approach Guardrail	**Good**	Exit Approach Guardrail	**Excellent**
Exit End Treatment	**Excellent**	Exit End Treatment	**Excellent**

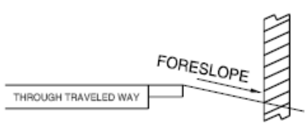
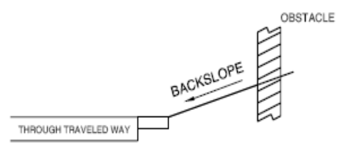
BRIDGE TRAFFIC SAFETY FEATURES INSPECTION SHEETS

Section 1 SITE IDENTIFICATION	State Puerto Rico	Route No. 102	Municipality / County Cabo Rojo
	Year Built 2003	Year Reconstructed	Inspection Date 12-13-2008
	Road Functional Class Rural Major Collector	Average Daily Traffic (ADT) 5900vpd	Year of ADT
	Posted Speed (V_P) 35 mph	Design Speed (V_D)	Highway Type ☐ Divided ☒ Undivided
	From – To (Milepost / Milepoint) km 13.6 --- ______	Inspector: Elizabeth Negrón E-mail: xxxx@xxxxxx.com Phone: (xxx)xxx-xxxx	Direction of Traffic ☐ Highway traffic not carried ☐ 1-way traffic ☒ 2-way traffic ☐ One lane bridge two-way traffic
Section 2 BRIDGE INFORMATION	NBI Structure # 2740	Bridge Material Concrete	Type of Service Highway-pedestrian
	Bridge Length 50.18ft	Number of Spans 1	Pavement Type Concrete
	Bridge Roadway Width 24ft	Number of Lanes 2	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☒ YES ☐ NO
	Shoulder Width L ______ ☒ Not present R ______ ☒ Not present	Sidewalk Width L 4’ ☐ Not present R 4’ ☐ Not present	

PLAN VIEW OF BRIDGE AND APPROACH ROADWAY CONFIGURATION

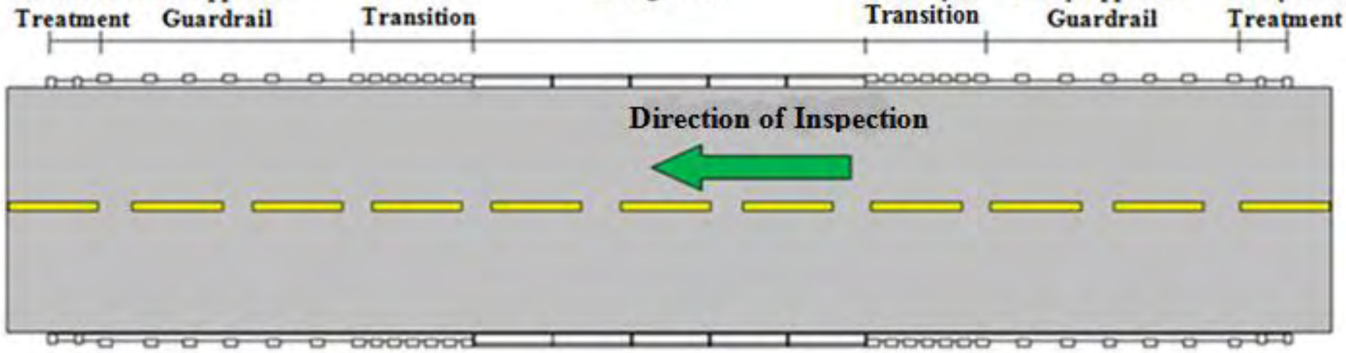
Direction of Inspection ☐ NB ☒ SB ☐ WB ☐ EB

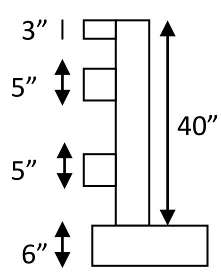
*** Only for bridges with one-way traffic** ☐ Left Side ☐ Right Side

Section			
Section 3 BRIDGE ENTRY INFLUENCE ZONE	Length of Influence Zone 360ft	Horizontal Curve ☐ YES ☒ NO Radius: ________ Superelevation: ________ Length: ________	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
	Intersection ☒ YES ☐ NO Type Local track	Visibility of Bridge ☒ YES ☐ NO	If NO, indicate the available sight distance ________________
Section 4 BRIDGE EXIT INFLUENCE ZONE	Length of Influence Zone 360ft	Horizontal Curve ☒ YES ☐ NO Radius: 1553.41ft Superelevation: 3% Length: 563.11ft	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
	Intersection ☒ YES ☐ NO Type T intersection	Sight Obstructions ☐ YES ☒ NO	If YES, describe ________________
Section 5 APPROACH ROADWAY INFORMATION	Roadway Width 20.4ft	Shoulder Width L ______ ☒ Not present R ______ ☒ Not present	Sidewalk Width L ______ ☒ Not present R ______ ☒ Not present
	Roadway Grade 0.1%	Pavement Type Asphalt	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
	Foreslope:L1V:29H R1V:20H 	Backslope: L _____ R: _______ 	Existing Clear Zone: L=9.8ft R=5.25ft Required Clear Zone (See Table 3.1 AASHTO *Roadside Design Guide*) 12ft-14ft(RDG) 10ft-12ft (FLH)

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)

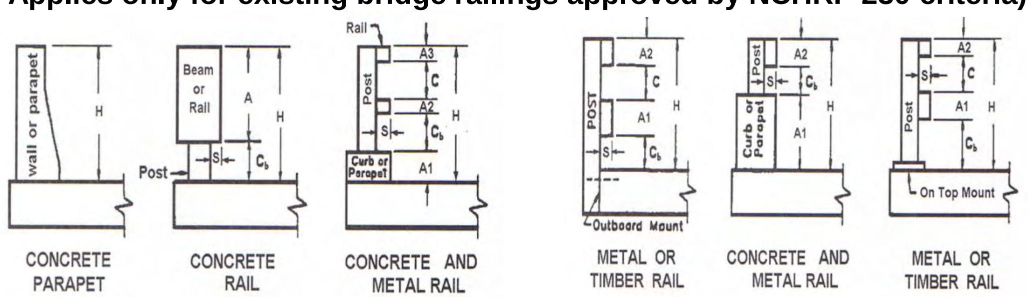
☐ Exit End Treatment | ☐ Exit Approach Guardrail | ☐ Exit Transition | ☒ Bridge Rail | ☐ Entry Transition | ☐ Entry Approach Guardrail | ☐ Entry End Treatment



		EXISTING	DESIGN	COMPLIANCE
Section 6 ENTRY END TREATMENT	Type: ____________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
Section 7 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
Section 8 ENTRY TRANSITION	Type: ____________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO
Section 9 BRIDGE RAILING	Type: 3 Tube Curb Mount	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-4	TL-4	☒ YES ☐ NO
	Height	46 inches	42 inches	☒ YES ☐ NO
	Post Spacing	9.7 ft	Max 10 ft	☒ YES ☐ NO
	Lateral Offset	5 ft	3.6 ft - 4.6 ft	☒ YES ☐ NO
	Length	90.4 ft	Min 50.18 ft	☒ YES ☐ NO
	Sketch of Bridge Railing 		**NOT TO SCALE** 	**Check the snagging potential and the post setback criteria of existing bridge rails on section 13.**

Section 10 EXIT TRANSITION	Type: ___________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO
Section 11 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
Section 12 EXIT END TREATMENT	Type: ____________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO

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



Railing Contact Width $\sum A$=_____ A_1=_____ A_2 = _____ A_3 =______ $\sum A/H$=_____	Vertical Clear Opening C =__________ Post Setback Distance S =__________

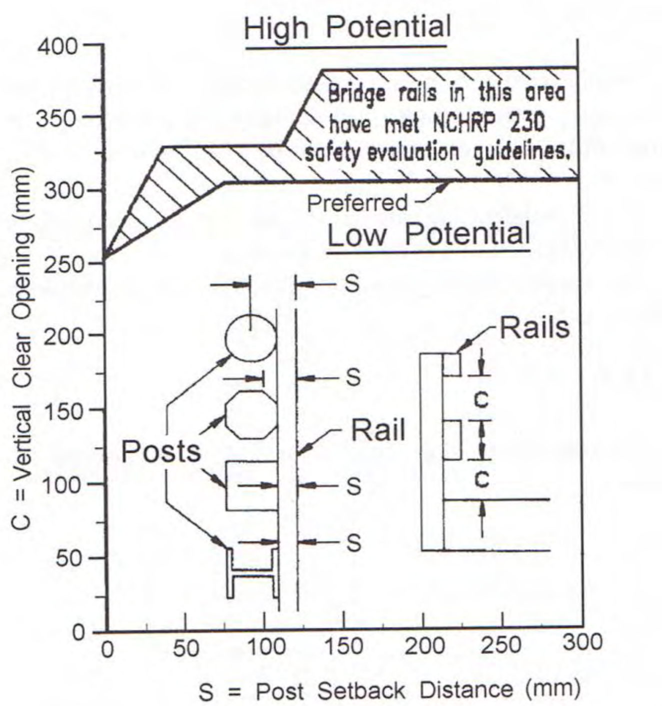


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

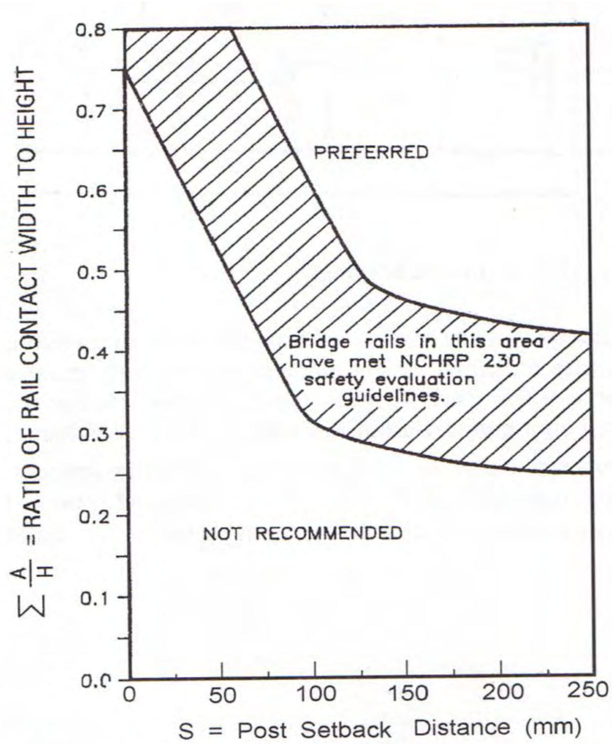


Figure A13.1.1-3 Post Setback Criteria.

Direction of Inspection	* **Only for bridges with one way traffic**
☒ NB ☐ SB ☐ WB ☐ EB	☐ Left Side ☐ Right Side

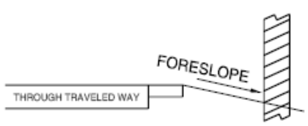
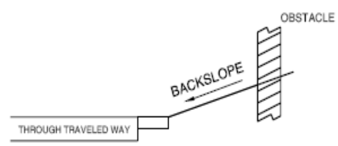
Section 3 BRIDGE ENTRY INFLUENCE ZONE

Length of Influence Zone 360ft	Horizontal Curve ☒ YES ☐ NO Radius: 1553.41ft Superelevation: 3% Length: 446.48ft	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☒ YES ☐ NO Type __T intersection__	Visibility of Bridge ☒ YES ☐ NO	If NO, indicate the available sight distance ________________

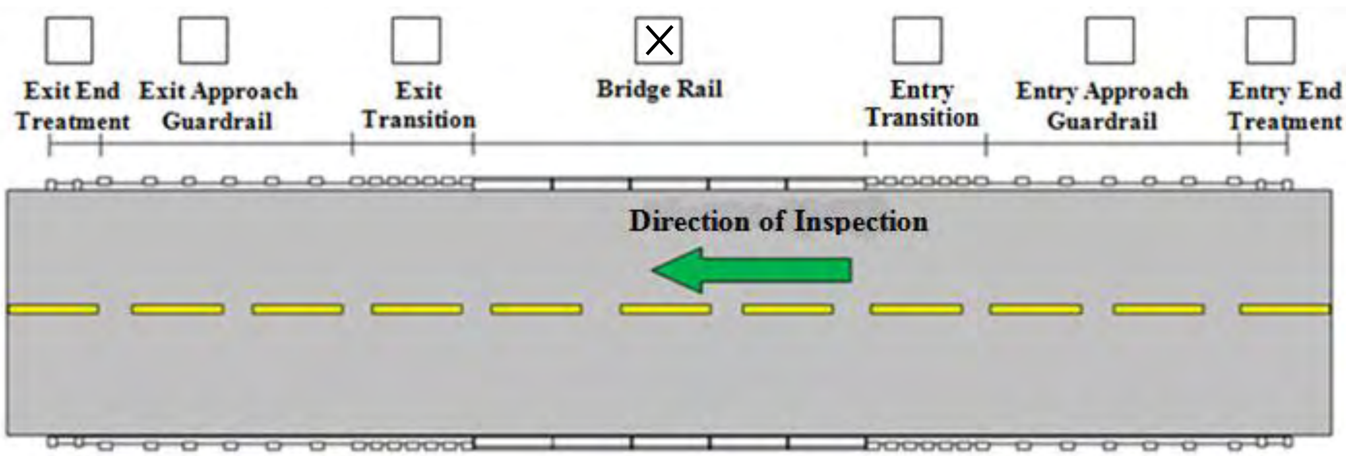
Section 4 BRIDGE EXIT INFLUENCE ZONE

Length of Influence Zone 360ft	Horizontal Curve ☐ YES ☒ NO Radius:_______ Superelevation:_______ Length:________	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☒ YES ☐ NO Type Local track	Site Obstructions ☐ YES ☒ NO	If YES, describe ________________

Section 5 APPROACH ROADWAY INFORMATION

Roadway Width 20.8ft	Shoulder Width L ______ ☒ Not present R ______ ☒ Not present	Sidewalk Width L _4'__ ☐ Not present R ______ ☒ Not present
Roadway Grade 0.7%	Pavement Type Asphalt	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
Foreslope:L1V:43H R1V:77H 	Backslope: L _____ R: _______ 	Existing Clear Zone: L=5.3' R=2.7' Required Clear Zone (See Table 3.1 of AASHTO *Roadside Design Guide*) 12ft-14ft (RDG)

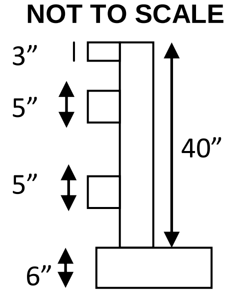
CHECK THE EXISTING TRAFFIC SAFETY FEATURES ON THE BRIDGE BEING INSPECTED
(Fill out the information in the following sections that correspond to the existing safety features)



		EXISTING	DESIGN	COMPLIANCE
Section 6 ENTRY END TREATMENT	Type: ____________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO
Section 7 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
Section 8 ENTRY TRANSITION	Type: ____________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO
Section 9 BRIDGE RAILING	Type: 3Tube Curb Mount	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level	TL-4	TL-4	☒ YES ☐ NO
	Height	46”	42”	☒ YES ☐ NO
	Post Spacing	9.7’	Max 10’	☒ YES ☐ NO
	Lateral Offset	5 ft	3.6 ft - 4.6 ft	☒ YES ☐ NO
	Length	90.4’	Min 50.18’	☒ YES ☐ NO

Sketch of Bridge Railing

NOT TO SCALE



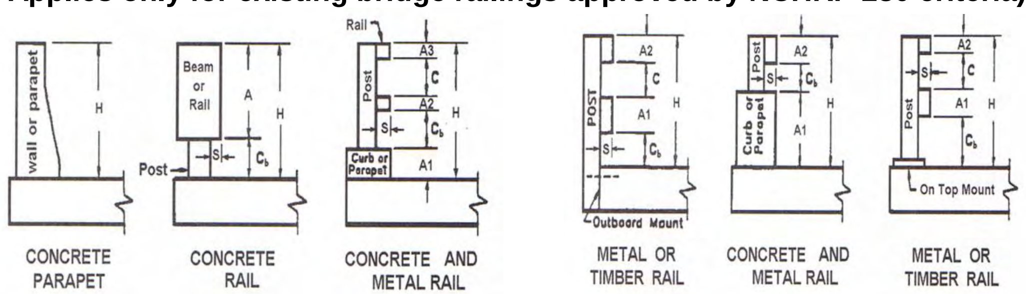
Check the snagging potential and the post setback criteria of existing bridge rails on section 13.

Section 10 EXIT TRANSITION	Type: ___________	EXISTING	DESIGN	COMPLIANCE
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO

Section 11 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

Section 12 EXIT END TREATMENT	Type: ____________	EXISTING	DESIGN	COMPLIANCE
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO

Section 13: 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 =__________

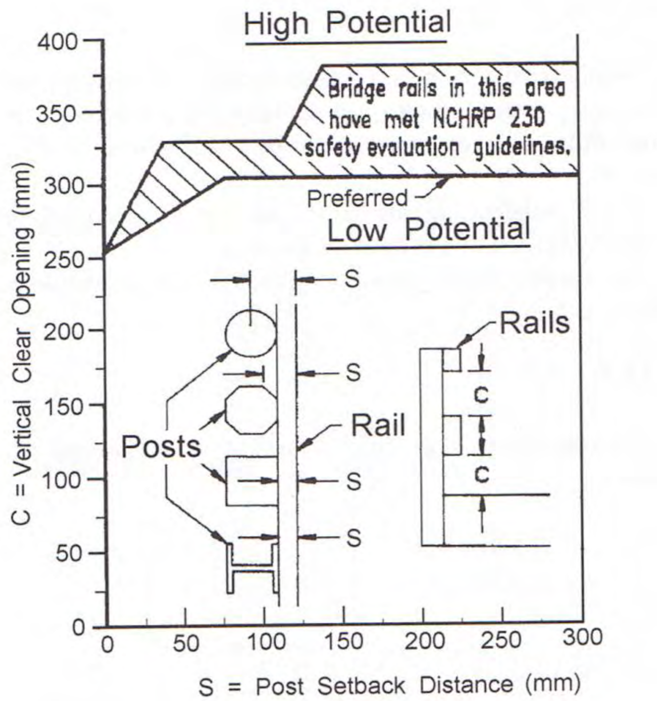


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

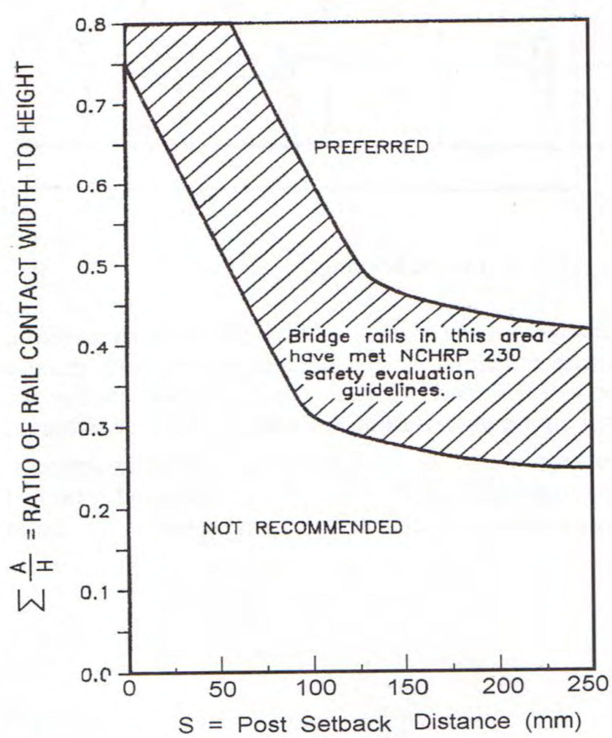


Figure A13.1.1-3 Post Setback Criteria.

Assessment of Traffic Safety Features			
Direction of Inspection ☐ NB ☒ SB ☐ WB ☐ EB		Direction of Inspection ☒ NB ☐ SB ☐ WB ☐ EB	
***Only 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**
Entry End Treatment	**NA**	Entry End Treatment	**NA**
Entry Approach Guardrail	**NA**	Entry Approach Guardrail	**NA**
Entry Transition	**NA**	Entry Transition	**NA**
Bridge Railing	**Excellent**	Bridge Railing	**Excellent**
Exit Transition	**NA**	Exit Transition	**NA**
Exit Approach Guardrail	**NA**	Exit Approach Guardrail	**NA**
Exit End Treatment	**NA**	Exit End Treatment	**NA**

BRIDGE TRAFFIC SAFETY FEATURES INSPECTION SHEETS

Section 1 SITE IDENTIFICATION	State Puerto Rico	Route No. 411	Municipality / County Rincón
	Year Built 1941	Year Reconstructed Not available in PR Bridge Inventory	Inspection Date 11-17-2008
	Road Functional Class Rural Local	Average Daily Traffic (ADT) 12,100 vpd	Year of ADT Not available in PR Bridge Inventory
	Posted Speed (V_P) 35 mph	Design Speed (V_D) Not available in PR Bridge Inventory	Highway Type ☐ Divided ☒ Undivided
	From – To (Milepost / Milepoint) km 0.1 --- ________	Inspector: Elizabeth Negrón E-mail: xxxxx@xxxxxxx.com Phone: (xxx) xxx-xxxx	Direction of Traffic ☐ Highway traffic not carried ☐ 1-way traffic ☒ 2-way traffic ☐ One lane bridge two-way traffic
Section 2 BRIDGE INFORMATION	NBI Structure # 481	Bridge Material Concrete	Type of Service Highway
	Bridge Length 45.92 ft	Number of Spans 4	Pavement Type Asphalt
	Bridge Roadway Width 17 ft	Number of Lanes 2	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
	Shoulder Width L _______ ☒ Not present R _______ ☒ Not present	Sidewalk Width L _______ ☒ Not present R _______ ☒ 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

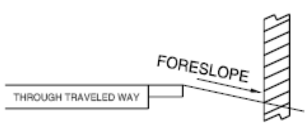
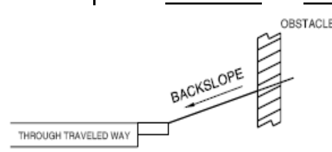
Section 3 BRIDGE ENTRY INFLUENCE ZONE

Length of Influence Zone 360 ft	Horizontal Curve ☐ YES ☒ NO Radius: ________ Superelevation: ________ Length: ________	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☒ YES ☐ NO Type _T-Intersection_____	Visibility of Bridge ☒ YES ☐ NO	If NO, indicate the available sight distance ________________

Section 4 BRIDGE EXIT INFLUENCE ZONE

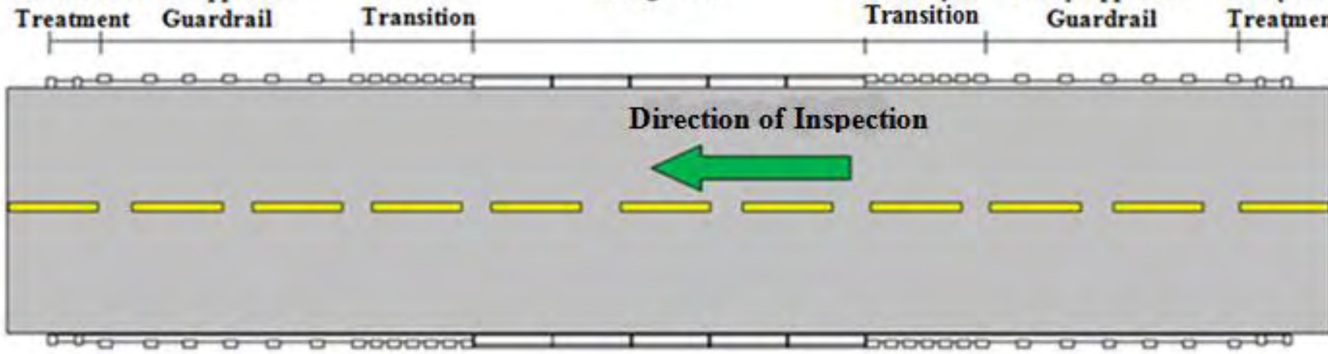
Length of Influence Zone 360 ft	Horizontal Curve ☒ YES ☐ NO Radius:_______ Superelevation:_______ Length:________	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☒ YES ☐ NO Type _T-Intersection___	Sight Obstructions ☐ YES ☒ NO	If YES, describe ________________

Section 5 APPROACH ROADWAY INFORMATION

Roadway Width 17 ft	Shoulder Width L ______ ☒ Not present R ______ ☒ Not present	Sidewalk Width L ______ ☒ Not present R ______ ☒ Not present
Roadway Grade 0.7 %	Pavement Type Asphalt	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
Foreslope: L 1V:5.2H R_____  *On the left roadside there is a Vee channel	Backslope: L 1V:4.5H R: 1V:10H 	Existing Clear Zone: L= 9.13 ft R = 8.65 ft Required Clear Zone (See Table 3.1 AASHTO *Roadside Design Guide*) R=14 ft-16 ft

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)

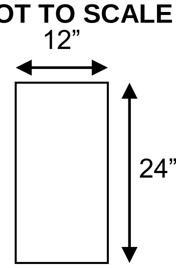
☐ Exit End Treatment ☐ Exit Approach Guardrail ☐ Exit Transition ☒ Bridge Rail ☐ Entry Transition ☐ Entry Approach Guardrail ☒ Entry End Treatment



Section 6 ENTRY END TREATMENT	Type: Sloped concrete ET	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	NA	NA	☐ YES	☒ NO
	Anchorage	Functional	Functional	☒ YES	☐ NO
	Grading	1V:10H	1V:10H or flatter	☒ YES	☐ NO
Section 7 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
Section 8 ENTRY TRANSITION	Type: ____________	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level			☐ YES	☐ NO
	Length			☐ YES	☐ NO
	Height			☐ YES	☐ NO
	Post Spacing			☐ YES	☐ NO
	Connection			☐ YES	☐ NO
Section 9 BRIDGE RAILING	Type: Vertical Concrete Parapet	**EXISTING**	**DESIGN**	**COMPLIANCE**	
	Test Level	TL-4	TL-4	☒ YES	☐ NO
	Height	24 inch	32 inch	☐ YES	☒ NO
	Post Spacing	N/A	N/A	☒ YES	☐ NO
	Lateral Offset	1.3 ft	3.6 ft – 4.6 ft	☐ YES	☒ NO
	Length	83.5 ft	Min. 45.92 ft	☒ YES	☐ NO

Sketch of Bridge Railing

NOT TO SCALE



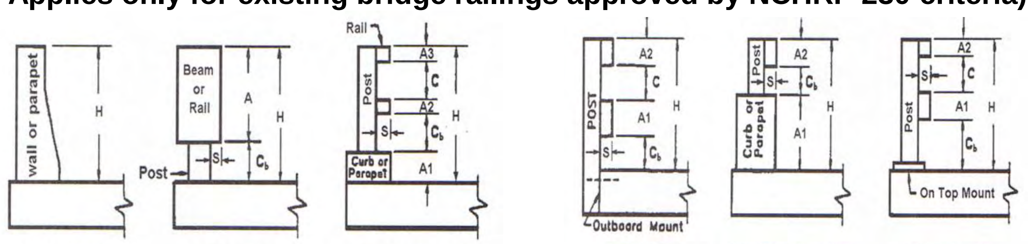
Check the snagging potential and the post setback criteria of existing bridge rails on section 13.

Section 10 EXIT TRANSITION	Type: ___________	EXISTING	DESIGN	COMPLIANCE
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO

Section 11 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

Section 12 EXIT END TREATMENT	Type: ___________	EXISTING	DESIGN	COMPLIANCE
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO

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



CONCRETE PARAPET | CONCRETE RAIL | CONCRETE AND METAL RAIL | METAL OR TIMBER RAIL | CONCRETE AND METAL RAIL | METAL OR TIMBER RAIL

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

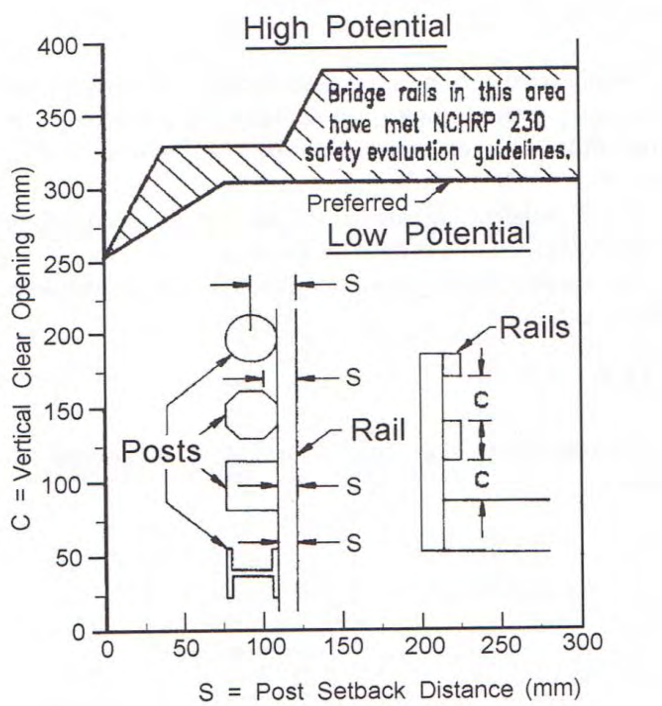


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

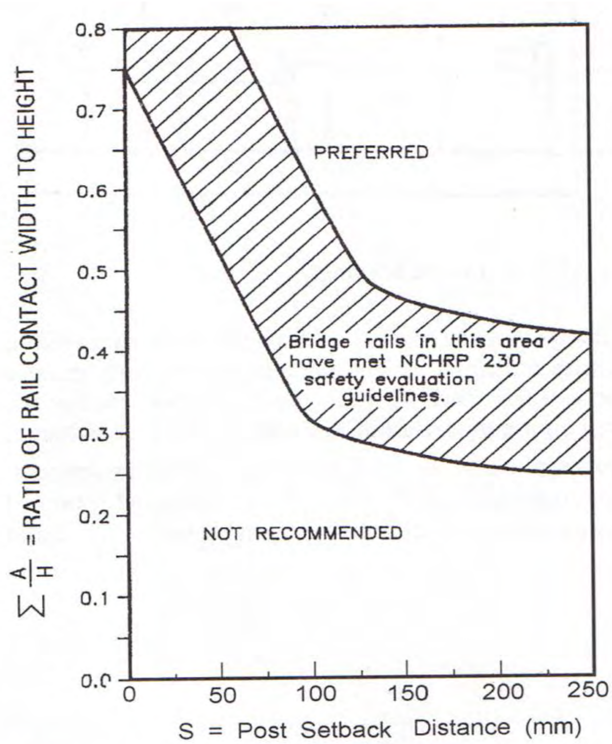


Figure A13.1.1-3 Post Setback Criteria.

Direction of Inspection ☐ NB ☒ SB ☐ WB ☐ EB

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

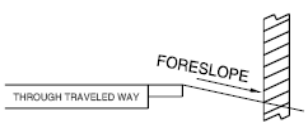
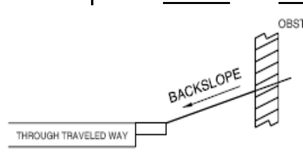
Section 3 BRIDGE ENTRY INFLUENCE ZONE

Length of Influence Zone 360 ft	Horizontal Curve ☒ YES ☐ NO Radius: ________ Superelevation: ________ Length: ________	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☒ YES ☐ NO Type ________________	Visibility of Bridge ☒ YES ☐ NO	If NO, indicate the available sight distance ________________

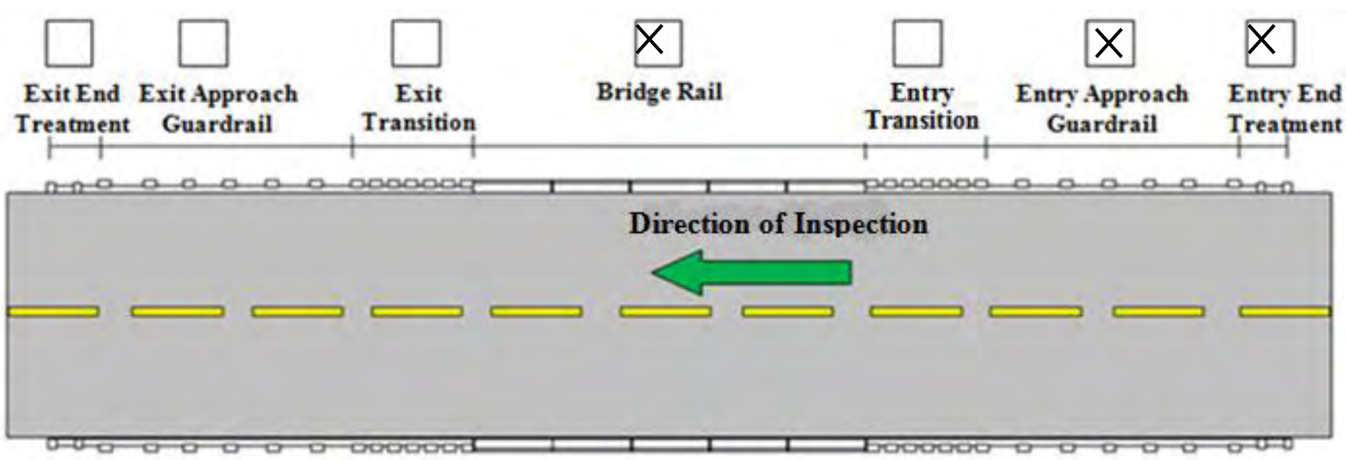
Section 4 BRIDGE EXIT INFLUENCE ZONE

Length of Influence Zone 360 ft	Horizontal Curve ☐ YES ☒ NO Radius:_______ Superelevation:_______ Length:________	Vertical Curve ☐ YES ☒ NO Type ☐ Crest ☐ Sag
Intersection ☒ YES ☐ NO Type ________________	Site Obstructions ☐ YES ☒ NO	If YES, describe ________________

Section 5 APPROACH ROADWAY INFORMATION

Roadway Width 17 ft	Shoulder Width L ______ ☒ Not present R ______ ☒ Not present	Sidewalk Width L ______ ☒ Not present R ______ ☒ Not present
Roadway Grade 1.5 %	Pavement Type Asphalt	Pavement Markings EDGE: L ☒ YES ☐ NO R ☒ YES ☐ NO CENTER: ☐ YES ☒ NO
Foreslope:L 1V:8H R1V:7H  *There's a Vee channel in the left and right side of the road	Backslope: L 1V:6H R: 1V:4H  *The channels cross section are the preferred according to Figure 3.6 RDG	Existing Clear Zone: L=Varies 9.7' -16.2' R=Varies14.2' -16.7' Required Clear Zone (See Table 3.1 of AASHTO *Roadside Design Guide*) 14 ft-16 ft

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)



Section 6 ENTRY END TREATMENT	Type: Sloped concrete ET	EXISTING	DESIGN	COMPLIANCE
	Test Level	NA	NA	☐ YES ☒ NO
	Anchorage	Functional	Functional	☒ YES ☐ NO
	Grading	1V:10H	1V:10H or flatter	☒ YES ☐ NO

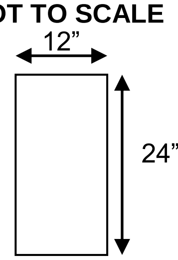
Section 7 ENTRY APPROACH GUARDRAIL	Type: W-Beam weak post	EXISTING	DESIGN	COMPLIANCE
	Test Level	TL-2	TL-2	☒ YES ☐ NO
	Height	24 inch	30.38 inch	☐ YES ☒ NO
	Post Spacing	12.5 ft	12.5 ft	☒ YES ☐ NO
	Grading	1V:6H	1V:10H or flatter	☐ YES ☒ NO
	Flare Rate	NA	NA	☒ YES ☐ NO
	Lateral Offset	10 ft	4.6 ft	☒ YES ☐ NO
	Length of Need	12.5 ft	86.25 ft	☐ YES ☒ NO

Section 8 ENTRY TRANSITION	Type: ___________	EXISTING	DESIGN	COMPLIANCE
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO

Section 9 BRIDGE RAILING	Type: Vertical Concrete Parapet	EXISTING	DESIGN	COMPLIANCE
	Test Level	TL-4	TL-4	☒ YES ☐ NO
	Height	24 inch	32 inch	☐ YES ☒ NO
	Post Spacing	N/A	N/A	☒ YES ☐ NO
	Lateral Offset	1.3 ft	3.6 ft – 4.6 ft	☐ YES ☒ NO
	Length	83.5ft	Min. 45.92 ft	☒ YES ☐ NO

Sketch of Bridge Railing

NOT TO SCALE



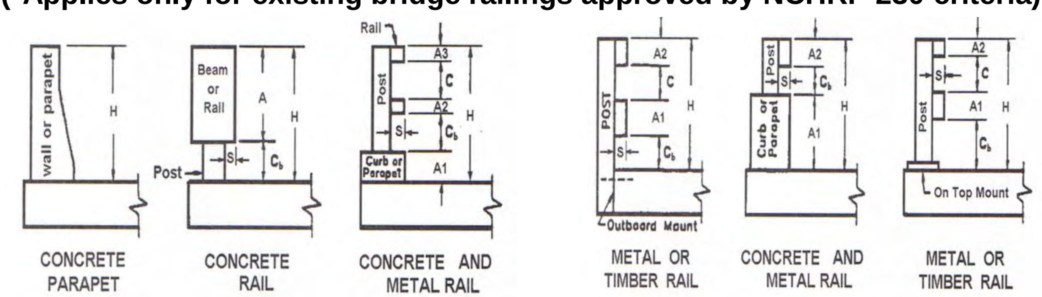
Check the snagging potential and the post setback criteria of existing bridge rails on section 13.

Section 10 EXIT TRANSITION	Type: ___________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Length			☐ YES ☐ NO
	Height			☐ YES ☐ NO
	Post Spacing			☐ YES ☐ NO
	Connection			☐ YES ☐ NO

Section 11 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

Section 12 EXIT END TREATMENT	Type: ___________	**EXISTING**	**DESIGN**	**COMPLIANCE**
	Test Level			☐ YES ☐ NO
	Anchorage			☐ YES ☐ NO
	Grading			☐ YES ☐ NO

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



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

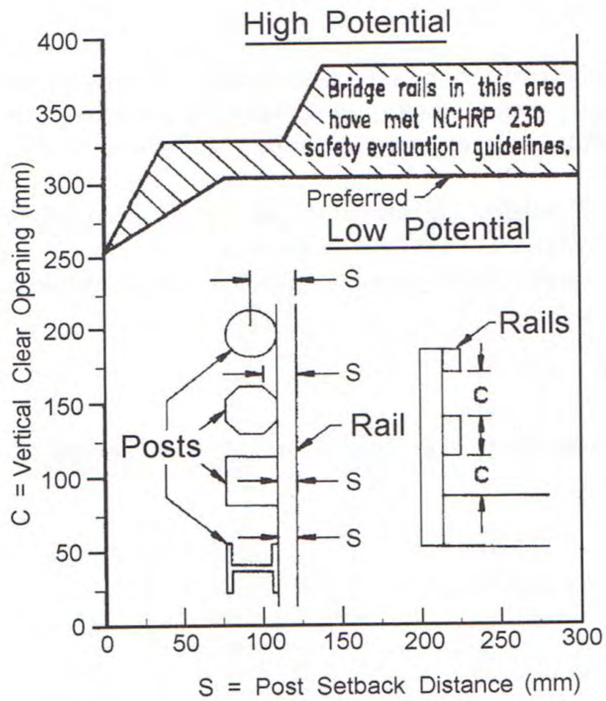


Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

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

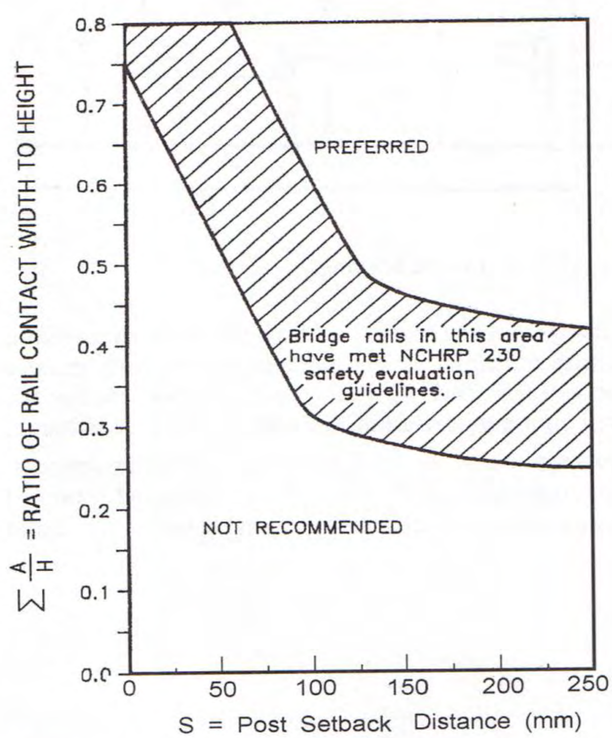


Figure A13.1.1-3 Post Setback Criteria.

Assessment of Traffic Safety Features			
Direction of Inspection ☒ NB ☐ SB ☐ WB ☐ EB		Direction of Inspection ☐ NB ☒ SB ☐ WB ☐ EB	
***Only 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**
Entry End Treatment	**Deficient**	Entry End Treatment	**Deficient**
Entry Approach Guardrail	**NA**	Entry Approach Guardrail	**Deficient**
Entry Transition	**NA**	Entry Transition	**Deficient**
Bridge Railing	**Average**	Bridge Railing	**Average**
Exit Transition	**NA**	Exit Transition	**NA**
Exit Approach Guardrail	**NA**	Exit Approach Guardrail	**NA**
Exit End Treatment	**Deficient**	Exit End Treatment	**Deficient**