Bridge Rail and Approach Railing for Low-Volume Roads In Iowa

BRIDGE ENGINEERING CENTER

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16. Abstract

Bridge rail and approach guardrails provide safety to drivers by shielding more hazardous objects and redirecting vehicles to the roadway. However, guardrail can increase both the initial cost and maintenance cost of a bridge, while adding another object that may be struck by vehicles. Most existing low volume road (LVR) bridges in the state of Iowa are currently indicated to not possess bridge rail meeting "current acceptable standards". The primary objective of the research summarized in this report was to provide the nations bridge and approach rail state of practice and perform a state wide crash analysis on bridge rails and approach guardrails on LVR bridges in Iowa. In support of this objective, the criteria and guidelines used by other bridge owners were investigated, non-standard and innovative bridge and approach guardrails for LVR's were investigated, and descriptive, statistical and economical analyses were performed on a state wide crash analysis.

The state wide crash analysis found the overall number of crashes at/on the more than 17,000+ inventoried and non-inventoried LVR bridges in Iowa was fewer than 350 crashes over an eight year period, representing less than 0.1% of the statewide reportable crashes. In other words, LVR bridge crashes are fairly rare events. The majority of these crashes occurred on bridges with a traffic volume less than 100 vpd and width less than 24 ft. Similarly, the majority of the LVR bridges possess similar characteristics.

Crash rates were highest for bridges with lower traffic volumes, narrower widths, and negative relative bridge widths (relative bridge width is defined as: bridge width minus roadway width). Crash rate did not appear to be effected by bridge length. Statistical analysis confirmed that the frequency of vehicle crashes was higher on bridges with a lower width compared to the roadway width.

The frequency of crashes appeared to not be impacted by weather conditions, but crashes may be over represented at night or in dark conditions. Statistical analysis revealed that crashes that occurred on dark roadways were more likely to result in major injury or fatality. These findings potentially highlight the importance of appropriate delineation and signing.

System wide, benefit-cost (B/C) analyses yielded very low B/C ratios for statewide bridge rail improvements. This finding is consistent with the aforementioned recommendation to address specific sites where safety concerns exist.

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TABLE OF CONTENTS

ACKNOWLEDGMENTS XI
EXECUTIVE SUMMARY XIII
1. GENERAL 1
1.1. Introduction 1
1.2 Research Objectives 1
1.3 Project Scope 1
2. BACKGROUND 3
2.1 Existing IADOT Standards 3
2.2 General Literature Review 5
3. SURVEY RESULTS 14
3.1. Survey Overview 14
3.2. Federal and State Agency Survey Results 14
3.3 Agency Specific Policies 15
3.4. Iowa County Results 16
4. CRASH ANALYSIS METHODOLOGY 19
4.1 Preliminary Bridge and Crash Selection 19
4.2 Crash Refinement 24
5. DESCRIPTIVE ANALYSIS 27
5.1 Overview 27
5.2 Traffic Volume 28
5.3 Bridge Width 28
5.4 Bridge Length 29
5.5 Traffic Safety Features 29
5.6 Road Surface Type 29
5.7 Crash Severity 29
5.8 Crash Location 30
5.9 Lighting Conditions and Time of Day 30
5.10 Weather and Road Surface Conditions 31
5.11 Crash Rate 31
5.12 Multiple Crashes 35
6. STATISTICAL DATA ANALYSIS 37
6.1 Overview 37
6.2 Methodology 37
6.3 Results 40
7. ECONOMIC ANALYSIS 43
7.1 Overview 43
7.2 Improve All Low Volume Bridges with Railing not Meeting "Current Acceptable Standards" 44

7.3 Improve Low Volume Bridges with Railing not Meeting “Current Acceptable Standards” and AADT Less Than 100....45
7.4 Improve Low Volume Bridges with Railing not Meeting “Current Acceptable Standards” and Width Less Than 24 Feet....45
7.5 Improve Low Volume Bridges with Railing not Meeting “Current Acceptable Standards” and Length Less Than 100 Feet....45
7.6 Improve Low Volume Bridges with Railing not Meeting “Current Acceptable Standards” and Negative Relative Bridge Width....46
7.7 Cost of Bridge Rail Yielding a B/C of 0.8....46
7.8 Individual Bridge Analysis....47

8. BRIDGE AND APPROACH RAIL ALTERNATIVES....48

8.1 Terminal Ends....48
8.2 Approach Rails....59
8.3 Bridge Rail....72

9. SUMMARY, CONCLUSION, AND RECOMENDATIONS....84

REFERENCES....86

APPENDIX A: IADOT INSTRUCTIONAL MEMORANDUM 3.213, 3.214, AND 3.215....A-1

APPENDIX B: SURVEY RESPONSES....B-1

APPENDIX C: DESCRIPTIVE ANALYSIS SUMMARY TABLES....C-1

APPENDIX D: BENEFIT-COST SAFETY ANALYSIS WORKSHEETS....D-1

APPENDIX E: STANDARD BRIDGE RAIL AND APPROACH RAIL DRAWINGS FROM VARIOUS STATES....E-1

LIST OF FIGURES

Figure 2.1. Accidents based on relative bridge widths (Turner, 1984)..13
Figure 3.1. Non-Iowa bridge owner responses (24 respondents) 14
Figure 3.2. Iowa county bridge owner responses (31 respondents)...17
Figure 4.1. LVR timber bridge not included in the state inventory...20
Figure 4.2. LVR timber bridge included in the state inventory...20
Figure 4.3. LVR timber bridge, with damaged bridge rail, included in the state inventory..........21
Figure 4.4. LVR concrete bridge not included in the state inventory..21
Figure 4.5. LVR concrete bridge included in the state inventory..22
Figure 4.6. LVR concrete bridge, with timber and metal bridge rail, included in the state inventory 22
Figure 4.7. LVR concrete bridge, with directional approach guardrail, included in the state inventory 23
Figure 4.8. LVR concrete bridge, with continuous guardrail, not included in the state inventory23
Figure 4.9. LVR concrete culvert, with parapets, not included in the state inventory 24
Figure 4.10. Crash located at a LVR bridge not included in the state inventory..........................25
Figure 5.1. Weekday time of crash with time of traffic (traffic information from IADOT Automatic Traffic Recorders 1993-2003, January 2004). 30
Figure 5.2. Weekend time of crash with time of traffic (traffic information from IADOT Automatic Traffic Recorders 1993-2003, January 2004). 31
Figure 5.3. Crash rate for AADT intervals. 32
Figure 5.4. Crash rate for IM Report bridge width intervals. 33
Figure 5.5. Crash rate for IM Report bridge length intervals. 34
Figure 5.6. Crash rate for relative bridge width intervals...35
Figure 8.1. Three-strand cable terminal (AASHTO 2002)..50
Figure 8.2. Wyoming box beam end terminal (AASHTO 2002). 51
Figure 8.3. W-beam guardrail anchored in backslope (AASHTO 2002). 52
Figure 8.4. Eccentric loader terminal (AASHTO 2002)...53
Figure 8.5. Slotted rail terminal (SRT-350) with 1.2 m [4 ft] flare (AASHTO 2002). 54
Figure 8.6. REGENT (AASHTO 2002). 54
Figure 8.7. Vermont low-speed, W-beam guardrail end terminal (AASHTO 2002). 55
Figure 8.8. Flared Energy-Absorbing Terminal (FLEAT) (AASHTO 2002). 56
Figure 8.9. Beam Eating Steel Terminal (BEST) (AASHTO 2002). 56
Figure 8.10. Extruder Terminal (ET-2000) (AASHTO 2002)...57
Figure 8.11. Sequential Kinking Terminal (SKT-350) (AASHTO 2002)...................................58
Figure 8.12. QuadTrend-350 (AASHTO 2002)...58
Figure 8.15. Schematic of SKT-350 (Reid et al. 1998). 59
Figure 8.16. Weak post W-beam barrier (AASHTO 2002)..62
Figure 8.17. Ironwood aesthetic guardrail (AASHTO 2002). 63
Figure 8.18. Weak post box beam barrier (AASHTO 2002)..63
Figure 8.19. Steel post W-beam with wood block-outs (AASHTO 2002)...................................64
Figure 8.20. Wood post W-beam with wood block-outs (AASHTO 2002). 64
Figure 8.21. Wood post thrie-beam barrier (AASHTO 2002)..66
Figure 8.22. Modified thrie-beam guardrail (AASHTO 2002)...66
Figure 8.23. Steel-backed timber guardrail (AASHTO 2002)..67

Figure 8.23. MwGS Design (Reid et al. 2002). 69
Figure 8.24. Comparison of flared guardrail lengths for MwGS (distances in meters) (Faller et al. 2009). 70
Figure 8.25. Demonstration installation of the composite guardrail (Bank et al. 2001)....71
Figure 8.26 Guardrail cross-section and splice connection details (Botting et al. 2006). 72
Figure 8.27 Side-mounted, thrie-beam bridge railing (AASHTO 2002)....73
Figure 8.28. Wyoming two-tube bridge railing (AASHTO 2002). 74
Figure 8.29. Massachusetts S3 steel bridge railing (AASHTO 2002)....75
Figure 8.30. Layout for open concrete bridge rail attached to inverted tee bridge deck system (Faller et al. 2004)....76
Figure 8.31. Finite element model of the aluminum parapet bridge railing (Oldani et al. 2004)..76
Figure 8.32. Steel thrie beam bridge railing successfully crash tested to AASHTO PL-2 (Duwadi et al. 1995). 77
Figure 8.33. Glulam timber bridge railing successfully crash tested to NCHRP Report 350 TL 4 (Duwadi et al. 1995). 77
Figure 8.34. Thrie beam with channel bridge railing (TBD-8000) (Faller et al. 1995)....78
Figure 8.36. (a) Square-shaped curb, (b) trapezoidal-shaped curb, (c) rectangular-shaped curb. (Bunnell et al. 1995). 80
Figure 8.38. (a) Glulam timber bride railing successfully crash tested to NCHRP Report 350 TL-4 (transverse deck); (b) steel thrie-beam bridge railing successfully crash tested to NCHRP Report 350 TL-4 (transverse deck) (Duwadi et al. 1999)....82
Figure 8.39. MDS Bridge Railing (Trinity)....82
Figure 8.40. MDS Bridge Railing Design (Trinity)....83

LIST OF TABLES

Table 2.1. Bridge rail five factor rating system. 4
Table 2.2. Bridge rail upgrades based on point totals....4
Table 2.3. Survey responses of state DOTs....7
Table 2.4. Probability of crash severity versus object struck from logistic regression 8
Table 2.5. Relative Predictor Strength of Key Variables (Turner, 1984)....11
Table 2.6 Probability of Bridge Accident per Million Vehicular Passage (Turner, 1984)....12
Table 5.1. LVR AADT structure crash history and crash rate....32
Table 5.2. LVR structure width crash history and crash rate....33
Table 5.3. LVR structure length crash history and crash rate....34
Table 5.4. LVR relative bridge width and crash rate....35
Table 5.5. Inventoried bridges with multiple crashes and crash severity. 36
Table 6.1. Test of proportion result summary....41
Table 6.2 Negative Binomial Regression Model for Frequency of Crashes on Low-volume Bridges. 41
Table 6.3. Multinomial logit model for vehicle crash injury severity on low volume bridges in Iowa....42
Table 7.1. Cost of a crash by severity. 43
Table 7.2. Crash Reduction factors used for analysis. 44
Table 7.3. Summary of B/C analysis for improving all bridges with bridge rail not up to "standard". 45
Table 7.4. Summary of B/C analysis for improving bridges with bridge rail not up to "standard" and AADT<100. 45
Table 7.5. Summary of B/C analysis for improving bridges with bridge rail not up to "standard" and bridge width < 24 ft....45
Table 7.6. Summary of B/C analysis for improving bridges with bridge rail not up to "standard" and bridge length < 100 ft....46
Table 7.7. Summary of B/C analysis for improving bridges with bridge rail not up to "standard" and bridge relative width < 0 ft....46
Table 7.8. Summary of B/C analysis for improving bridges with bridge rail not up to "standard" and bridge relative width >= 0 ft. 46
Table 7.9. B/C analysis individual generic bridge with a fatal crash. 47
Table 8.1. Crashworthy end treatments (AASHTO 2002). 49
Table 8.2 Roadside barriers and their approved test levels (AASHTO 2002)....61
Table 8.3. NCHRP Report 350 TL of Blocked-Out W-beam (Strong Post) Designs. 65
Table 8.4. NCHRP Report 350 TL of Blocked-Out Thrie-Beam Designs. 65
Table B.1. Survey Responses....B-2
Table C.1. AADT frequency data for LVR inventoried bridge population. C-2
Table C.2. AADT frequency for LVR bridge related crashes. C-3
Table C.3. Bridge width frequency data for LVR inventoried bridge population. C-6
Table C.4. Bridge width frequency for LVR bridge crashes. C-7
Table C.5. Bridge length frequency data for LVR inventoried bridge population. C-10
Table C.6. Bridge Length frequency for LVR bridge crashes. C-11
Table C.7. Object struck crash frequency with respect to bridge safety features. C-14

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EXECUTIVE SUMMARY

Bridge rail and approach guardrails provide safety to drivers by shielding more hazardous objects and redirecting vehicles to the roadway. However, guardrail can increase both the initial cost and maintenance cost of a bridge, while adding another object that may be struck by vehicles. Most existing low volume road (LVR) bridges in the state of Iowa are currently indicated to not possess bridge rail meeting "current acceptable standards". The primary objective of the research summarized in this report was to provide the nations bridge and approach rail state of practice and perform a state wide crash analysis on bridge rails and approach guardrails on LVR bridges in Iowa. In support of this objective, the criteria and guidelines used by other bridge owners were investigated, non-standard and innovative bridge and approach guardrails for LVR's were investigated, and descriptive, statistical and economical analyses were performed on a state wide crash analysis.

The state wide crash analysis found the overall number of crashes at/on the more than 17,000 inventoried LVR bridges and unknown number of non-inventoried LVR bridges in Iowa was fewer than 350 crashes over an eight year period, representing less than 0.1% of the statewide reportable crashes. In other words, LVR bridge crashes are fairly rare events. The majority of these crashes occurred on bridges with a traffic volume less than 100 vpd and width less than 24 ft. Similarly, the majority of the LVR bridges possess similar characteristics.

Crash rates were highest for bridges with lower traffic volumes, narrower widths, and negative relative bridge widths (relative bridge width is defined as: bridge width minus roadway width). Crash rate did not appear to be effected by bridge length. Statistical analysis confirmed that the frequency of vehicle crashes was higher on bridges with a lower width compared to the roadway width.

The frequency of crashes appeared to not be impacted by weather conditions, but crashes may be over represented at night or in dark conditions. Statistical analysis revealed that crashes that occurred on dark roadways were more likely to result in major injury or fatality. These findings potentially highlight the importance of appropriate delineation and signing.

System wide, benefit-cost (B/C) analyses yielded very low B/C ratios for statewide bridge rail improvements. This finding is consistent with the aforementioned recommendation to address specific sites where safety concerns exist.

Given the findings of the descriptive and statistical analyses, possible areas of the existing IADOT IM 2.213 that could be changed or added during any future revisions include traffic volume ranges, relative bridge width and crash frequency/severity.

1. GENERAL

1.1. Introduction

Bridge and approach guardrails have the important task of withstanding impact forces associated with vehicular crashes while at the same time smoothly redirecting vehicles to the travel way without causing these vehicles to stop abruptly, snag, rollover, or vault over the guardrail. The installation of guardrail systems (Gates, 2005) add costs to the bridge, and may cause additional safety and maintenances problems that may outweigh the benefits when used in some situations. Currently, the Federal Highway Administration (FHWA) requires bridge and approach guardrails on all National Highway System roadways and federally funded bridges. However, the use (and type) of rail systems on non-national highway systems, such as low-volume roads (LVR), is left to the discretion of the state or county. These structures (LVR bridges) are the emphasis of this research. Specifically, application of guardrail policy by various agencies, potential safety impacts including benefit and cost, and current state of practice for guard rail systems were investigated.

1.2 Research Objectives

The primary objective of the research summarized in this report was to describe the state of the practice regarding the nation's bridge rails and approach guardrails and to perform a statewide crash analysis involving bridge rails and approach guardrails on Iowa's low-volume road (LVR) bridges by:

- Determining the criteria and guidelines used by other states for bridge and approach guardrail implementation on low and very low-volume roads.
- Performing a system-wide crash analysis on LVR bridges in Iowa
- Performing benefit-cost analyses for use of bridge and approach guardrails based on traffic levels and road classifications.
- Investigating the use of non-standard and innovative bridge and approach guardrails for low-volume roads.

1.3 Project Scope

In order to satisfy the research objectives, the project scope include the following tasks:

1. **A literature review** was conducted to investigate if similar studies had been conducted and to more fully understand bridge and approach rail usage.

2. **A survey of state and county agencies** was completed to obtain input on how other agencies determine bridge rail and bridge approach rail usage criteria for low-volume roads.

3. **System-wide crash analysis** for low-volume road bridges in Iowa was performed. The IADOT crash and geographic information management systems (GIMS) databases were utilized to quantify crash related metrics.

4. **Statistical analyses** were performed to identify relationships between crash metrics such as rail usage, rail condition, roadway geometry, bridge geometry.

5. **Railing alternatives** that are economical and aesthetically pleasing were investigated.

2. BACKGROUND

2.1 Existing IADOT Standards

The IADOT has Instruction Memorandums (IM) (IADOT, 2009) for Iowa public agencies that provide guidance on administrative works, project development, and systems classification. Included in the series of IM is IM No. 3.213 that provides guidelines for determining the need for traffic barriers on low-volume roadway bridges and culverts. In addition, IM No. 3.215, which provides information on clear zone widths, and IM No. 3.216, which presents the benefit-cost ratio method for determining the feasibility of an improvement, are also available and can be helpful in determining the feasibility of installing approach guardrails. Instruction Memorandum No. 3.213 was the primary focus of the work presented herein. IM No. 3.213 is summarized below. The original IM documents for IM No. 3.213, 3.215, and 3.216 can be found in Appendix A. All IADOT IM's can be found at:
http://www.iowadot.gov/local_systems/publications/im/imtoc.pdf.

Instruction Memorandum No. 3.213 defines a traffic barrier as a device used to shield a roadside obstacle that is located within the minimum clear zone width and in the right-of-way. A roadside obstacle is further classified as either a non-traversable object (e.g., large culvert) or a fixed object (e.g., unprotected end of bridge rail). The fixed objects were the focus here since unprotected bridge ends are fixed objects. The IM first suggests the removal or relocation of the object outside the clear zone whenever possible. However a traffic barrier may be necessary if removal or relocation is not possible and a benefit by severity reduction is found.

An approach guardrail should to be installed in the following situations:

1. "All four bridge corners on newly constructed bridges on the Farm-to-Market systems, except bridges located within an established speed zone of 35 mph or less."
2. "On the approach bridge corners (right side) on new federally funded bridges constructed on the area service system, except bridges within 35 mph or less speed zone. Consideration should be given to shielding the opposite corner if it is located on the outside edge of a curve. The FHWA will participate in guardrail at all four corners if desired by the county."
3. "All four bridge corners on existing bridges within the termini of a 3R project on the Farm-to-Market System. Existing w-beam installations that are flared and anchored at both ends may be used as constructed without upgrading to current standards."
4. "Culverts with spans greater than six feet (circular pipe culverts greater than 72" in diameter) if it is impractical to extend beyond the clear zone and grates are not utilized."

The following exceptions apply when approach guardrail is not needed on a bridge:

1. "Current ADT at structure is less than 200 vehicles per day"
2. "The structure is 24 ft wide or greater"
3. "The structure is on tangent alignment"

4. “The benefit-cost ratio is less than 0.80”

Bridge rails should always be designed in accordance with the latest available standards on newly constructed bridges. For existing bridges being rehabilitated using federal-aid money the bridge rail should be reviewed for possible retrofitting.

Included in the IM is a Bridge Rail Rating System matrix that can be used to determine if a bridge rail should be upgraded and to what extent it should be upgraded. The matrix includes five factors: crashes, ADT, width, length, and type of bridge rail. The sum of the points from the five factors is the total bridge score which can be used to determine if the bridge needs upgrading; the higher the score the more upgrade needed. Table 2.1 shows the Bridge Rail Rating System and points associated with each factor. Table 2.2 shows the types of recommended upgrades which are based on the point totals for the bridge.

Table 2.1. Bridge rail five factor rating system.

Points	**0**	**5**	**10**	**15**	**20**
Factors			**Description**		
Crashes (in last 5 years)	None	1 PDO	1 PI	1 F or 2 PDO’s or 1 PI and 1 PDO	2 or more F’s/PI’s or 3 or more PDO’s
ADT (current year)	< 200	200-299	300-399	400-750	>750
Bridge Width (feet)	≥ 30	28	24	22	≤ 20
Bridge Length (feet)	< 50	50-99	100-149	150-200	>200
Bridge Rail (type)	Aluminum Rail (1967 standard)	Steel Box Rail (1964 standard)	Formed Steel Beam Rail (1951 and 1957 standards)	Steel Rail (1941 standard Concrete Rail 1928 standard)	Angel Handrail (1928 standard)

Abbreviations: PDO = Property Damage Only crash
PI = Personal Injury crash
F = Fatality crash

Table 2.2. Bridge rail upgrades based on point totals

Point total	**Upgrade Description**
Under 25 points	No upgrading at this time
25 – 50 points	Delineation according to standard RE-48A
51 – 75 points	Block out with thrie beam to curb edge (if existing approach guardrail is W-beam, W beam may be used)
Over 75 points	Retrofit

2.2 General Literature Review

2.2.1 National Level

Modern highway design concepts (AASHTO 2002B) essentially began in the 1940's. Concerted focus on roadside safety design, however, didn't start until the 1970's. Today many of the roads that were built prior to 1970 have reached their useful life span and are being reconstructed which allows the opportunity for updating their safety features. Some of these safety features include bridge railing and approach railing. Bridge railing differs from roadside railing in that it is rigidly connected to the bridge and when struck it has very little deflection capability (i.e., flexibility). The Roadside Design Guide notes that railing designed to full AASHTO standards may not be necessary nor desirable for low-speed or low-volume roads. The design guide suggests that engineers refer to the AASHTO LRFD (AASHTO, 2006) design manual for guidance in determining the merits of using bridge railing. AASHTO LRFD explains that the "owner shall develop the warrants for the bridge site"; this leaves the designer of a low-volume bridge with very little guidance on if/when guardrail and/or approach railing is needed. The Roadside Design Guide does, however, provide options for reducing crash hazards caused by roadside obstacles. The following are cited techniques for reducing crashes and crash severity in order of preference.

1. Remove the obstacle.
2. Redesign the obstacle so it can be safely traversed.
3. Relocate the obstacle to a point where it is less likely to be struck.
4. Reduce impact severity by using an appropriate breakaway device.
5. Shield the obstacle with a longitudinal traffic barrier designed for redirection or use a crash cushion.
6. Delineate the obstacle if the above alternatives are not appropriate.

The inherent nature of bridges and bridge railing reduces the feasibility of options one, two, and three. However options four, five, and six offer ways to reduce crash numbers and severity when crashing into a bridge end.

AASHTO (2001A) has an additional manual, "Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT<400vpd)" that addresses very low-volume road geometric considerations that are typically different from those applied to higher volume roads. The design guide stresses that geometric changes generally need only be completed when a documentable, site-specific safety problem exists and can be corrected by road side improvements. When safety problems do not exist, roadside improvements generally do not provide substantial safety benefits. By providing safety improvements only to roads that have a history of safety problems, expenditures can be focused at known problematic locations helping to ensure the most impact.

The geometric design guide does not contain specific information on bridge and approach guardrail, but instead emphasizes roadway cross-sections, bridge widths, alignment, and sight distance characteristics. The guide indicates that bridge widths for newly constructed bridges on new roadways should be equal to the width of the traveled way plus 2 ft. If the roadway is paved, the bridge width is recommended to be equal to the roadway width. For one and two lane roads with an ADT less than 100 vpd one lane bridges can be provided. A minimum bridge width of 15 ft, but not wider than 16ft assures drivers will not try to use them as two lanes. When existing bridges are being replaced, and there is no evidence of site-specific safety problems, the new bridge width can be the same as the existing width. Site-specific safety indicators include a documented crash history, skid marks, damage to bridge rail or approach rail, and concerns raised by law enforcement officials.

2.2.1.1Crash Reduction Factors

The FHWA has published a Desktop Reference for Crash Reduction Factors (CRFs) which is used, along with engineering judgment, to estimate the impact various countermeasures might have on crashes. The Desktop Reference contains 12 tables of CRFs. Among other data, the tables contain the crash type, crash severity, daily traffic volume, and CRFs. The table containing bridge countermeasures contains the CRFs for installing guardrail (at bridge), upgrading bridge railing, widening a bridge, etc.

The CRFs for upgrading of installing guardrail (at bridge) ranges from 11 to 90. For the case in which the CRF was 11, the crash type is all and the crash severity is all. For the case in which the CRF was 90, the crash type is all and the crash severity is fatal.

The CRFs of upgrading bridge railing ranges from 5 to 92. For the case in which the CRF was 5, the crash type is all and the crash severity is all. Two cases existed in which the CRF was 92, in both cases the crash type was all, one case had a crash severity of fatal and one had a crash severity of injury.

2.2.2 State Level

2.2.2.1 Kansas

Past research conducted by Russell et al. (1998) developed guidelines for using guardrails on LVR in Kansas. The work consisted of reviewing state-of-the-art roadside safety practices, interviewing local roads personnel, studying local roadside scenarios, particularly culverts and embankments, and developing guidelines for LVR roadside safety and barrier rails.

The research completed by Russell et al. utilized the computer program ROADSIDE. ROADSIDE was used to calculate present worth and annualized cost at a particular location needing safety improvements. The program was also used to compare the costs of various improvements. Several criteria were adjusted to allow the ROADSIDE program to analyze guardrails in a LVR situation. Traffic volume was set to between 100 vehicles per day (vpd) to 400 vpd including a growth factor of 1% per year. The ROADSIDE results varied depending on the types of culverts and embankments. For straight wing culverts, a guardrail was not economically justifiable if the culvert's lateral offset was two or more meters from the nearest driving lane. However, and for example, with speeds of 56 mph, an ADT of 300 or greater, and a culvert end height of 7.9 ft the guardrail was shown to be economically justifiable. If the culvert's lateral offset from the nearest driving lane was larger than the three meters under all scenarios on flared wing culverts then guardrails were not economically justifiable. In culvert pipe/headwall systems a guardrail was not economically justifiable with an ADT of 100. In general, most scenarios showed that structures with ADT of 400 vehicles or less were not economically justifiable to have bridge approach guardrails installed. The results should be used with judgment after considering other, non-economic factors. Pham and Ragland (2005) also noted that crash prediction models might differ for each jurisdiction and data set, and no single model is capable of serving all road types, ramps, or intersections. Consequently it was noted that the task of developing safety performance functions requires detailed assessments and can be very time consuming.

2.2.2.2 Minnesota

Gates et al. (2005) conducted a study on Minnesota LVR bridge approach railing. The objective was to determine the ADT at which the benefit-to-cost ratio suggests that installing bridge-approach guardrail is cost-effective (i.e., B/C > 1.0) for county, state-aid highway bridges in Minnesota.

As part of Gates work, a survey of state DOTs was conducted to determine the state-of-the-practice for bridge approach guardrail installation on low volume highways. Table 2.3 displays the number of states using a particular factor to determine when the installation of guardrail is needed on low volume highways. Many of the states included exceptions with their responses including such thing as: (1) historic bridges, (2) minimum operating speed and ADT, (3) bridge width, (4) benefit-cost ratio, (5) urban areas, and (6) bridge crash history, etc.

Table 2.3. Survey responses of state DOTs

Determining Factor for Approach Rail Use	Number of Responses
All state-aid bridges protected	26
ADT threshold	2
Speed threshold	3
ADT and speed threshold	3
Decision made on case-by-case basis	1
No response	15

The Gates et al. study began with a sample of 398 bridges, mostly rural county state-aid highway bridges from 10 counties in Minnesota. Of the 398 bridges, there were 155 with approach guardrail and 243 without approach guardrail. The crashes near the sample bridges were filtered to include all single-vehicle fixed-object or run-off-the-road crashes within 200 ft of the bridge and occurring between 1988 and 2002. This filter left 263 crashes with 156 being at bridges with approach guardrail and 107 being at bridges without approach guardrail.

In order to determine whether or not the crash involved approach guardrail, or would likely have had it existed, the following information was reviewed from the police reports of the 263 filtered crashes: (1) initial object struck in crash, (2) physical local of crash with respect to bridge, and (3) verification of presence or absence of approach guardrail. A crash was included in further analyses if (1) the crash occurred on the approach or departure side or (2) the crash involved collision with a bridge component, road-side fixed object, or other roadside collision very near bridge. Thus, all crashes occurring on the bridge were not included in the subsequently completed analyses. This second filter left a sample of 96 bridges, 47 with approach guardrail and 49 without approach guardrail.

The statistical analyses performed on the data included (1) logistic regression used to determine if crash severity was affected by various roadway, bridge, and crash characteristics and (2) a two-way Pearson chi-square test to determine if guardrail presence had an impact on both crash type and severity.

Table 2.4 shows the findings of the logistic regression analysis. According to the analysis, collisions with the roadside or bridge rail end are approximately 2.5 times more likely to result in fatalities or incapacitating injury (A-injuries) versus collisions with approach guardrail. Also, guardrail crashes are nearly twice as likely to result in no injuries versus roadside or bridge rail crashes.

Table 2.4. Probability of crash severity versus object struck from logistic regression

	Probability of a Given Crash Severity Based on the Object Struck		
Severity (based on KABCO scale)	**Roadside**	**Bridge Rail**	**Guardrail**
Property damage only	0.337	0.299	0.586
B-injuries/C-injuries	0.451	0.458	0.326
Fatalities/A-injuries	0.213	0.243	0.088

According to two-way Pearson chi-square analysis that was performed, when the crash severity was associated with the object stuck, zero of the 33 crashes with approach guardrail resulted in fatalities or A-injuries, while roughly one-quarter of the 63 roadside and bridge rail crashes resulted in fatalities or A-injuries. Like the logistic regression analysis, the chi-square test showed that crashes with the approach guardrail were much more likely to result in no injury versus roadside or bridge rail crashes. It appears that the crash severity is significantly affected by the type of object struck in the collision.

The chi-square analysis of object struck vs. guardrail presence showed that the presence of a guardrail did have an effect on the type of objects struck. In crashes at bridges without approach guardrail about 70 percent of the crashes were collisions with the bridge rail. Of the crashes at bridges with approach guardrail about 6 percent were collisions with the bridge rail.

A third chi-square analysis - crash severity vs. guardrail presence - was completed. The chi-square analysis confirmed that crashes at bridges with approach guardrail were significantly less severe than crashes at bridges without approach guardrail. The percentage of fatality/A-injury crashes at bridges without approach guardrail was 4.5 greater than the percentage of fatality/A-injury crashes at bridges with approach guardrails.

Analysis of the approach-side versus departure-side crashes was completed. The analysis showed that the location of the crash, either approach or departure side, was not affected by the presence of the guardrail. The approach side guardrail was effective in 69% of the cases and the departure side guardrail was effective 35% of the time. Although the departure guardrail was less effective further analysis suggests substantial reductions in crash severity will occur if departure-side guardrail is installed in addition to approach-side guardrail.

In order to determine the cost-effectiveness of bridge approach guardrail Gates et al. performed a benefit-cost analysis. A 30-year life-cycle cost for bridge approach guardrail was estimated and halved to match the 15 year length of the crash analysis period. The benefit for installing approach guardrail is the reduction in severity and subsequent cost of crashes near the bridge. The cost of each of the KABCO (i.e. K=fatal crash, A=incapacitating injury, B=non-incapacitating injury, C=possible injury) severity levels was estimated for use as benefits. Prior to performing the benefit-cost calculations, the sample of bridges without approach guardrail was separated into categories based on the ADT. The benefit-cost analysis was performed on the sample of bridge without approach guardrail. Equation 1 was used to compute the benefit-cost ratio. The benefit-cost ratio became greater than 1.0 at an ADT threshold of 400.

$$\frac{Benefit}{Cost} = \frac{Cost\ of\ Crashes\ Based\ on\ Reported\ Severities}{Cost\ of\ Crashes\ Assuming\ Guardrail\ Installed + Guardrail\ Install\ and\ Maintenance\ Cost} \quad (1)$$

Gates et al. recommended that Mn/DOT use guardrails at bridges with an ADT of greater than or equal to 400 vpd, and that those with an ADT between 150 and 400 vpd be reviewed individually. It was also noted that bridges located on horizontal curves and bridges with a bridge deck width less than the approach roadway may warrant guardrail even with an ADT between 150 and 400 vpd. It was further stated that guardrail is probably not cost-effective on bridges with an ADT of less than 150 vpd. Also, when guardrail is installed, it is recommended to be installed on all four corners of the bridge.

2.2.2.3 Missouri

The Missouri Highway and Transportation Department (Dare, 1992) also concluded that roads with ADT of 400 vehicles per day and a 60 mph speed limit and 2 ft lateral guardrail offset do not have large enough traffic volumes to warrant approach guardrails. The same study also provided higher ADT threshold values for 40 mph and 50 mph speeds and lateral offsets of 8 ft and 10 ft.

2.2.2.4 Iowa

A similar study in the state of Iowa (Schwall, 1989), looked at the cost-effectiveness of approach guardrails on primary system roads. Schwall’s study found that in order to obtain a benefit-cost ratio of 1.0, a traffic volume of at least 1400 vehicles per day with a guardrail offset of 2 ft is needed. The study also found that the benefit-cost increase with increased traffic volume would decrease with an increase in the guardrail offset. In general, all previously presented research was limited to only the approach railing for bridges, and did not focus on bridge and approach railing on low-volume roads, specifically in Iowa.

2.2.2.5 Texas

Turner (1984) conducted a study to predict bridge accidents at bridges. Rural, two-lane, two-way bridge accidents were the focus of the study which included a data set containing 1,000,000 accidents, 29,000 bridges, and 100,000 roadway segments. The investigation was narrowed to a statistically consistent sample of 2,849 accidents that occurred at/on 2,087 structures over a four year period. Manual, correlation, and regression analyses were used to form relationships between accidents and predictor variables. The research led to emphasis on three key variables: (1) Bridge relative width (bridge width minus road width); (2) average daily traffic (ADT); and (3) approach roadway width. Using these factors as independent variables, regression curves helped predict accidents as well as a probability table. Combining the rates with ADT values for particular structures produced the expected accidents per year. Statistical devices were used to measure the effectiveness of the study and produced values that represented very strong trends, indicating that the probability table was a good means for predicting bridge accidents.

The Turner project was completed with the intent of identifying hazardous structures, evaluating potential safety treatments, and setting priorities for improvements. Identification of an accident prediction technique was the primary focus of the project in which a simple and direct way to measure a structure’s likelihood of being the site of an accident was the objective. Based on historical data, the predicted trend was that bridges constructed narrower than their approach pavement become increasingly more dangerous as the difference in relative width increased. Previous studies evaluated with Turner’s conclusions found that 70% of all bridge accidents occurred on bridges 20% narrower that the approach and 60% of all accidents had a point of impact occurring on the approach bridge end on the vehicle’s side of the road (typically the right side). One previous study found that approach pavement transition, narrow bridge width, roadway curvature to the left, and adjacent intersection bridge geometry characteristics seemed to exist at bridges with notorious accident records. These multiple historical studies show that widespread concerns exist for the narrow bridge accident problem.

Three specific types of data were gathered and prepared for a thorough examination of the narrow bridge issue. The examined structures were restricted to two-lane, two-way traffic carrying structures on rural roads. The collected data included (1) Accident data were gathered to characterize the most hazardous structures and the collisions occurring at those locations, (2) Bridge data were acquired to establish the geometric details of dangerous structures, and (3) Approach roadway data were needed to isolate the impacts of the bridge from the roadway. Limiting the data to these conditions helped to eliminate as many extraneous variables as possible. The four year period studied resulted in a data sample of 4,095 incidents. After developing the set of guidelines for the desired study population (rural, two-lane, two-way bridges) all bridge collisions not within the criteria were removed from the data set. This stage purified the data to a consistent sample of 2,849 crashes that occurred on 2,087 structures over the four year period.

Searching for a simple, direct way to evaluate the degree of hazard for any structure was accomplished via a manual review of the plotted/tabulated data, correlation and regression studies, and the designation of key variables and selection of the final predictor model. Fourteen of the 25 variables showed a strong relationship with accident rate during the correlation analysis (note that five of the fourteen were the square of another variable.) Using the Coefficient of Multiple Determination, R^2 (a measure of the prediction accuracy), it was found that 8 of the 25 variables were significantly related to accident rate. Turner ranked the variables in ascending order of importance based on individual ratings and their subjective judgment to form the Table 2.5.

Table 2.5. Relative Predictor Strength of Key Variables (Turner, 1984)

Variable	Tabulation and Plotting	Correlation	Regression	Study Rank
Relative Width	Very good	Very strong	Strong	1
Average Daily Traffic	Good	Very strong	Strong	2
Approach Width	Good	Very strong	Strong	3
Road Class	Uncertain	Strong	Strong	4
Relative width	-	Very strong	Poor	5

The variables ADT, relative width, and approach width were chosen as key variables for developing a probability table capable of predicting collisions. The crash probabilities were expressed as the number of occurrences per million vehicles in order to be directly related to ADT. Approach roadway width and bridge relative width were used to organize a results table (see Table 2.6). Accordingly, the 7,245 structures were assigned to appropriate cells in the table. As expected, the majority of the structures were located on roads in the 18-26 ft range. The accident probabilities fit the expected pattern well. Generally, the structures become safer as one moves from the upper left corner of the table to the bottom right. Cells containing irregular values of accident rate were found to be the result of either a small number of bridges or a low number of vehicular passages. Since these data contained smaller sample sizes they produced misleading results and were “smoothed” using data from more reliable cells. After further investigation, approach roadway width was dropped from the analysis because it was found to be non-significant.

Table 2.6 Probability of Bridge Accident per Million Vehicular Passage (Turner, 1984)

Bridge Relative Width (ft)	Approach Roadway Width (ft)							
	16.0 - 18.0	18.1 – 20.0	20.1 – 22.0	22.1 – 24.0	24.1 – 26.0	26.1 – 28.0	28.1 – 30.0	Over 30.0
Over 6.0 narrower	1.200	0.767	0.436	0.135	0.060	0.030	0.200	0.163
4.1 – 6.0 narrower	1.200	1.171	0.757	0.686	0.604	0.533	0.472	0.150
2.1 – 4.0 narrower	1.194	0.476	0.490	0.503	0.500	0.400	0.300	0.140
0.1 – 2.0 narrower	0.611	0.649	0.553	0.695	0.479	0.500	0.400	0.130
0.0 – 2.0 wider	0.344	0.496	0.330	0.529	0.319	0.497	0.677	0.120
2.1 – 4.0 wider	0.641	0.319	0.319	0.308	0.477	0.448	0.420	0.105
4.1 – 6.0 wider	0.217	0.200	0.193	0.256	0.224	0.176	0.128	0.080
6.1 – 8.0 wider	0.254	0.170	0.234	0.061	0.162	0.113	0.064	0.056
8.1 – 10.0 wider	0.165	0.000	0.170	0.145	0.333	0.331	0.200	0.120
10.1 – 14.1 wider	0.140	0.123	0.120	0.083	0.148	0.171	0.068	0.176
Over 14.0	0.113	0.110	0.066	0.090	0.098	0.102	0.299	0.248

Initially, a simple regression was used based solely on relative width producing an R^2 value of 0.62 indicating a fair fit to the data. Weighted regression analysis was then performed to overcome this weakness by weighting each data point based on the number of vehicular passages during the study period. Therefore, data points with more traffic were given a higher level of importance to reduce the impacts of the scattered data in the low relative width portion of the table. The weighted equation resulted in a strong R^2 value of 0.74 and is listed as:

$$A = 0.5085 - 0.0522RW - 0.0053\ RW^2 - 0.001\ RW^3 \qquad (1)$$

Where A = the accident rate per million vehicular passages and RW = the relative width in feet

The final equation used consisted of a second weighted analysis that was performed for all structures except those with extremely narrow relative widths. This equation was an excellent predictor of the data as noted by its high R^2 value of 0.81. This equation was:

$$A = 0.4949 - 0.0612\ RW + 0.0022\ RW^2 \qquad (2)$$

Figure 2.1 shows a comparison of the final two regression equations. Equation 2 represents an accident rate pattern that better fits the expected situation. The effort of finding a simple and direct way to predict bridge accidents was successful for several reasons. One, a large data set was screened and reduced to a desired and pertinent collection of bridge collision data for rural, two-lane, two-way traffic structures. Second, the use of manual, correlation, and regression techniques revealed that bridge relative width, average daily traffic volume, and approach roadway width were the most important variables in predicting accidents. Third, a probability table that includes combinations of approach roadway width and bridge relative width outputting expected collision rates was found to be the best way to predict crashes at various sites. Using the rates from this table multiplied by average traffic volume one is able to yield the number of crashes expected at any particular structure. Lastly, weighted regression analysis proved that the table does a great job predicting accidents in the normal range of bridge widths as confirmed with a high measure of prediction accuracy (R^2 = 0.81.)

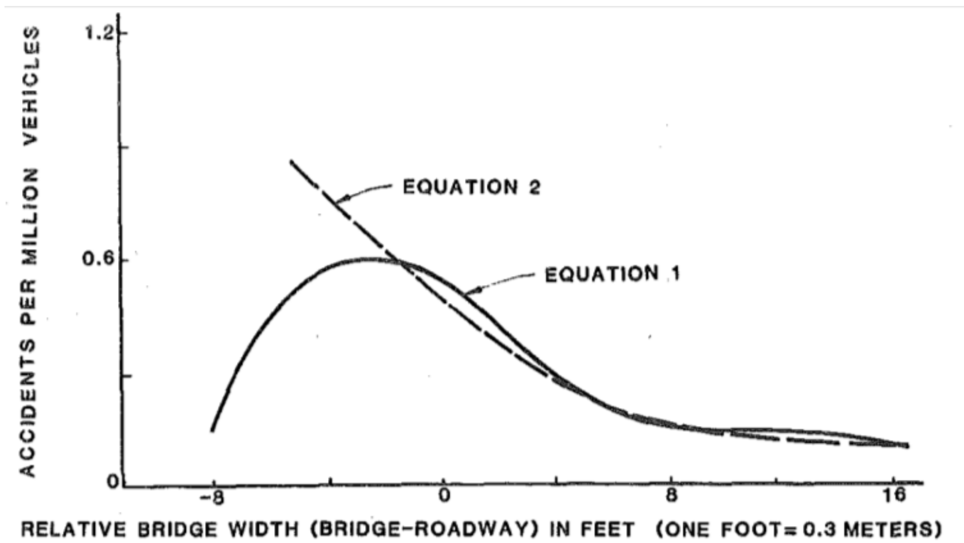


Figure 2.1. Accidents based on relative bridge widths (Turner, 1984)

3. SURVEY RESULTS

3.1. Survey Overview

As mentioned previously IM 3.213 provides guidance for determining if guardrail and bridge rails are needed. To collect similar information about the guidelines or policies of organizations, an eight question survey was sent to federal, state, and local bridge owners across that nation. The survey was divided into three basic categories; the first related to the basis for placement of traffic barriers on low-volume road bridges, the second related to the types of protective treatments being used for guardrail and bridge rail systems, and the third related to determining if the criteria for barrier placement had been modified in the past 10 years and the effects of the changes. The survey can be found in Appendix B along with the complete respondent answers.

3.2. Federal and State Agency Survey Results

In total, 27 non-Iowa bridge owners responded to the survey; 1 of the respondents was a federal agency, 22 were state transportation departments, 3 were local county agencies, and 1 was a Canadian providence agency. Figure 3.1 summarizes the response of the 24 non-local bridge owners to the three basic questions. It should be noted that some of the responding agencies (e.g., State DOTs) indicated that they do not have roads with ADTs of 400vpd or less.

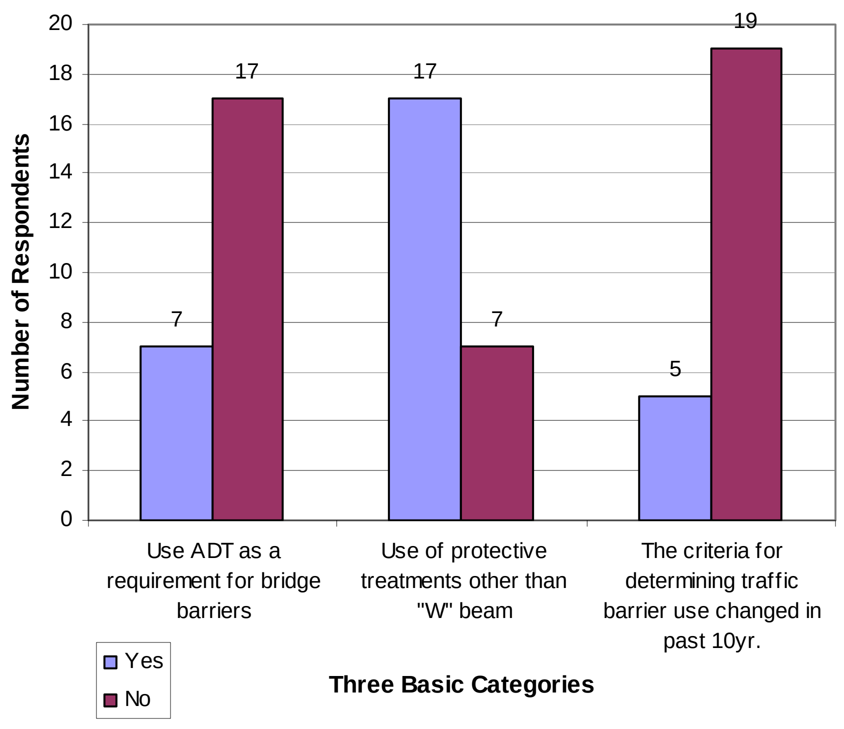


Figure 3.1. Non-Iowa bridge owner responses (24 respondents)

In general, the respondents that did use ADT as a criterion for guard rail usage also used other criteria for establishing the use or guardrail type. Many owners indicate that they include speed limit and geometry as criteria. The states using ADT did not necessarily use it as a limit for determining when a guardrail was needed but as a factor for determining the minimum performance requirements for the guardrail. An ADT of 400 vpd was the most commonly cited threshold.

As seen from Figure 3.1, 17 of the 24 respondents used protective treatment types other than “W” beams. A commonly cited alternative rail type was the thrie beam. However, tube rails, concrete barriers, and timber were also listed as alternatives to standard “W” beams. No state specifically stated the use of cable railing as an alternate to “W” beams.

From the responses, it appears that very few states have changed their criteria for determining traffic barrier use on low-volume roads in the last 10 years. The agencies that have changed their criteria based the use of protective treatment on ADT and other speed or geometric factors. For example, Minnesota DOT changed their criteria in 2008 based on the Minnesota Local Road Research Board Study conducted in 2005. The old criteria stated that guardrail is required where the speed limit is higher than 40 mph and the ADT exceeds 749 vpd or the bridge clear width is less than the sum of lane and shoulder widths. The new 2008 criteria lowers the ADT threshold to 400vpd. None of the positively responding agencies indicated that they had information on the impacts of the criteria change.

Several agencies provided standard drawings for bridge and/or approach rails. Appendix E illustrates the various state bridge and approach rail standard drawings. In addition, some state agencies provided information pertaining to bridge and approach rail policy. The policy information is summarized below.

3.3 Agency Specific Policies

3.3.1 US Forest Service

The US Forest Service has a policy, FSH 7709.56b, section 7, that states that the primary criterion for bridge railing system selection is safety. Details of bridge rail function are listed within the policy; however, no road criteria (i.e., road width, ADT, geometry, etc.) are given with which the benefit-cost of the system could be evaluated. The strength and geometry of the railing system is to be based on AASHTO “Standard Specifications for Highway Bridges”.
All new road bridges are required to have approach rails if the bridge has bridge railing, and the approach rail is to conform to the AASHTO Roadside Design Guide.

3.3.2 Illinois DOT

The Illinois DOT requires an approaching roadside barrier or terminal section for all bridge rail ends nearest the flow of traffic. Exceptions to this policy are made for the following situations:

1. Bridges are located on low speed (less than 25mph) curbed roads
2. Bridges with ADT less than 150, the bridge width is the approach roadway width, and the bridge has tangent alignment.

3. The township or district bridge has a larger width than the roadway and the bridge is on tangent alignment.

However, these exceptions do not apply if the design speed exceeds the design speed shown in the Illinois DOT Bureau of Local Roads and Streets Geometric Design Tables. With respect to bridge rail ends on the departure end of two-way roadways, the need for shielding the bridge end is determined by whether the bridge is in the clear zone.

3.3.3 North Carolina DOT

The North Carolina DOT guardrail and bridge rail policies can be found in the Sub Regional Tier Design Guidelines for Bridge Projects. These guidelines require transition guardrails on all four corners of an undivided two-way, two-lane bridge. The minimum length of guardrail required is dependent upon the design speed of the bridge. In the case of very low volume local roads, the North Carolina DOT allows the use of the Guidelines for Geometric Design for Very Low-Volume Local Roads (ADT<400) (AASHTO 2001A) in lieu of the Sub Regional Tier Design Guidelines for Bridge Projects.

3.3.4 North Dakota DOT

The North Dakota DOT requires bridge rail ends be treated with W-beam guardrails and the bridge rail be crash tested to NCHRP Report 350 standards. The type of W-beam guardrail to be used is dependent upon the bridge rail type. The guardrail shall be flared unless the geometry does not allow a flare. The required flare rate and length are dependent upon the design speed. The North Dakota DOT uses four W-beam guardrail end treatments with varying site location and guardrail installation configuration requirements. The four end treatments are the ET-2000, the Flared Energy Absorbing Terminal, the Sequential Kinking Terminal, and the Slotted Rail Terminal.

3.4. Iowa County Results

In addition to the national survey, Iowa's 99 counties were also solicited for their input on protective bridge treatments. Thirty one counties responded to the survey. The responses to the three general categories are summarized in Figure 3.2.

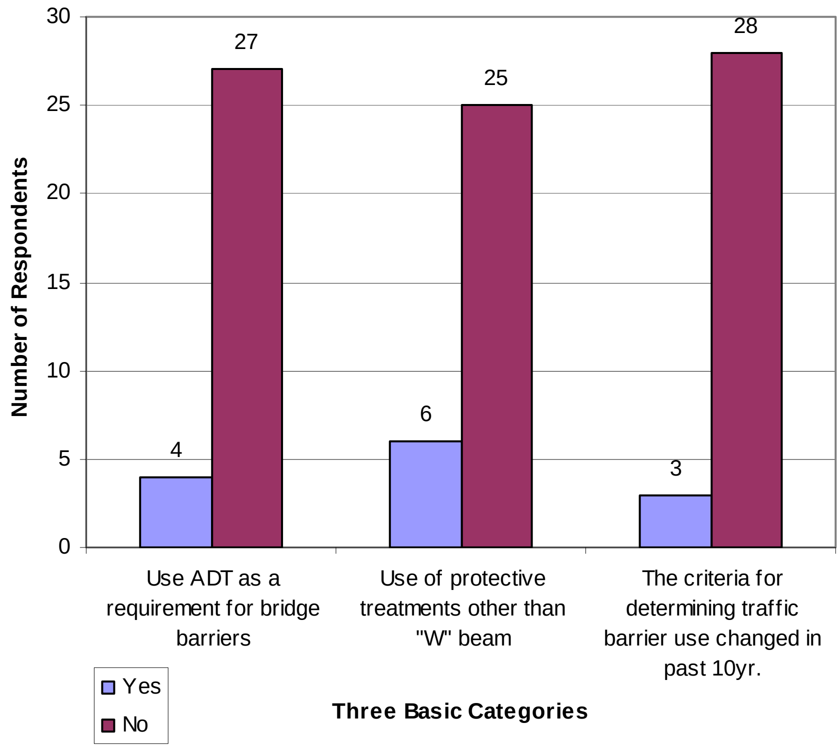


Figure 3.2. Iowa county bridge owner responses (31 respondents)

Very few counties were found to use ADT as a requirement for bridge protection. One county indicated that they use an ADT of 100 vpd for traffic barriers, however, it was indicated that this is not a written policy. Another county responded that it has a three level written policy for determining if traffic barriers should be installed on locally funded bridges. No traffic barriers are needed if the ADT is 50 vpd or less, and the bridge width is 24 ft or greater. The approach ends of a bridge needs traffic barriers if the ADT is 51 to 99 vpd, and the bridge width is 24 ft or more. Traffic barriers on all four bridge ends need to be installed when the ADT is 100 vpd or greater, and the bridge width is 24 ft or wider.

The majority of Iowa County respondents indicated that they did not have specific ADT criteria stated other criteria that were generally included in IM 3.213. Other criteria not stated in the IM 3.213, that are being used by Iowa counties, include project funding, crash history, and road surface type. Some counties stated all new or rehabilitated bridges are constructed with guardrail independent of the criteria previously mentioned.

The general majority of the county respondents indicated that they use a “W” or thrie beam for their bridge protective treatments. Two counties stated in addition to “W” or thrie beams, they used cable rail. One county stated extra signage and delineators have also been used to provide end of bridge delineation.

The three counties that have changed their criteria for determining the use of protective treatments have either changed to using The IADOT IM 3.213 or changed the type of barrier they have been using. One county stated the cost of guardrails went up when they changed their policy to using only “W” beams.

4. CRASH ANALYSIS METHODOLOGY

4.1 Preliminary Bridge and Crash Selection

To evaluate the possible safety impacts of bridge rail and guardrail on low volume road (LVR) structures in the state of Iowa, statewide analyses of LVR bridge crashes was conducted. Primary data sources for these analyses included the Iowa DOT's Geographic Information Management System (GIMS) roadway and structures databases and the 2001 to 2008 crash database. These databases include all public roadways (~113,000 miles), structures with a minimum length of 20 feet (~26,500), and reportable crashes on public roadways (injury or minimum property damage of $1,000; eight year average of 59,000 crashes annually) within Iowa. Given the eight year analysis period, the 2001 to 2008 GIMS databases were compared to assess potential temporal differences, particularly with respect to the extent of the LVR network and number of corresponding structures. Since limited temporal differences were observed, the 2003 GIMS snapshot, a central year in the analysis period, was ultimately selected for use in analysis.

The GIMS roadway database was first utilized to identify all LVRs in the state. LVRs were defined using the following criteria:

- annual average daily traffic (AADT) less than or equal to 400 vehicles per day,
- high speed, i.e. speed limit greater than or equal to 45 mph, and
- road classification (municipal and secondary only)

Based on these criteria, approximately 78,900 miles of LVRs were identified, representing approximately 70% of the public roadways in the state.

With the LVRs established, the bridges located on these roadways were identified. Of the nearly 26,500 bridges in the structures database, approximately 17,230 (65%) were located on LVRs. As alluded to previously, not all structures in the state are contained in the structures database; specifically, only structures with a minimum length of 20 feet are included. Since many LVR structures are less than 20 feet in length, the GIMS database underestimates the number of LVR bridges where crashes may occur. Based on bridge inventories obtained from two counties, the GIMs database excluded 5% and 20% from the total number of bridges. Therefore, in an attempt to capture all crashes of possible interest, including those not located at an inventoried bridge, crashes located within 50 meters of either an inventoried bridge or stream/ river proximate to a LVR were selected. The spatial proximity of 50 meters was employed to address changes (improvements) in the spatial accuracies of the roadway, structures and crash databases through the analysis period.

Figures 4.1 to 4.9 present various representative LVR bridges, bridge rail and approach guardrail applications found in the state. Figures 4.1 and 4.2 demonstrate why the crash identification process was expanded beyond the statewide bridge inventory to include structures under 20 ft in length. Both bridges are timber with timber bridge rail, and no approach guardrail; however, the bridge in Figure 4.1 is not included in the state inventory due to its length. Figure 4.3 presents a similar timber bridge with a damaged bridge rail.

Figure 4.1. LVR timber bridge not included in the state inventory

Figure 4.2. LVR timber bridge included in the state inventory

Figure 4.3. LVR timber bridge, with damaged bridge rail, included in the state inventory

Figures 4.4 through 4.8 are example concrete LVR bridges, some with different types of bridge rail and approach guardrail applications. Similar to the timber bridges in Figures 4.1 and 4.2, the bridges in Figures 4.4 and 4.5 appear nearly identical but only Figure 4.5 is included in the state inventory.

Figure 4.4. LVR concrete bridge not included in the state inventory

Figure 4.5. LVR concrete bridge included in the state inventory

Figure 4.6. LVR concrete bridge, with timber and metal bridge rail, included in the state inventory

Figure 4.7. LVR concrete bridge, with directional approach guardrail, included in the state inventory

Figure 4.8. LVR concrete bridge, with continuous guardrail, not included in the state inventory

Figure 4.9 represents a commonly found concrete culvert with concrete parapets. While this culvert would not be classified as a bridge, regardless of its length, the parapets likely pose a hazard similar to the bridges presented in Figures 4.4 and 4.5.

Figure 4.9. LVR concrete culvert, with parapets, not included in the state inventory

4.2 Crash Refinement

The preliminary crashes of interest were then refined by selecting only those involving a rollover, roadway departure, collision with a guardrail, or collision with a bridge or bridge rail. The majority of the crashes eliminated from consideration were either located at an intersection, were multi-vehicle head-on collisions, or were collisions with an animal. Through detailed visual inspection, crashes located on a high volume roadway at/near a LVR overpass were also excluded from consideration. Additionally, upon advisement from the project technical advisory committee, all roadway departure crashes not involving a collision with a bridge-related component were excluded from consideration. These crashes were excluded because the primary purpose of approach guardrail on LVR bridges in Iowa is to shield the bridge end and not to protect motorists from other secondary hazards, such as a ditch, ravine, or waterway.
The locations of the 397 remaining crashes were then visually reviewed within GIS, supplementing the roadway, structures and crash data with aerial imagery. Aerial imagery was used to verify the presence of a bridge at the crash site. This was particularly important for crashes selected based on their spatial proximity to a LVR and stream/river (i.e., sites where a bridge did not exist in the structures database). Figure 4.10 presents a crash that occurred at a bridge not included in the state inventory. The figure also presents the location of an inventoried bridge with no crash history. It is also important to note that crashes are geocoded based on the available GIS data sets (of various spatial accuracies), and not aerial imagery. This explains the differences in the actual and GIS-represented stream alignment.

Figure 4.10. Crash located at a LVR bridge not included in the state inventory

Crash narratives and diagrams were also reviewed to validate the accuracy of the attribute data contained in the crash database (particularly a collision with approach guardrail, bridge rail or other bridge-related component) and eliminate any crashes that may not be applicable. Based on the crash narratives and diagrams, the crash data were supplemented with the following fixed object collision categories and collision locations:

- Approach rail between terminal end and bridge
- Approach rail at the terminal end
- Approach rail unclear
- Bridge rail
- Bridge terminal end
- Bridge unclear
- Not applicable

The following subcategories were also populated to classify the order in which the fixed object was struck. The primary objective of this classification was to determine whether the fixed object collision was preceded by a collision with another vehicle (i.e., if the object was directly or indirectly impacted).

- Primary collision with approach rail or bridge rail
- Secondary collision with approach rail or bridge rail
- Not applicable

Upon final validation, a total of 341 crashes with LVR bridges were identified over the eight year analysis period. These 341 crashes occurred at 268 inventoried bridges. Of the 268 bridges two of them had three crashes, ten of them had two crashes, and 256 of them had one crash. Fifty nine of the crashes occurred on non-inventoried bridges.

5. DESCRIPTIVE ANALYSIS

5.1 Overview

Descriptive analysis techniques and graphical representations were used to summarize and interpret the various characteristics of the 17,230 inventoried LVR bridges and the 341 crashes that occurred at these LVR bridges during the analysis period. The IADOT IM traffic volume (AADT), bridge width and bridge length categories were used, in part, as guidelines during data assimilation. Bridge and crash data were also summarized based on traffic safety feature standards, road surface type, crash severity, object struck, sequence (order) of collision, light conditions, weather conditions, driving surface conditions, and relative bridge width. Brief descriptions of each of the characteristics follow:

- AADT: The average annual daily traffic (vehicles per day) traversing the bridge. In some cases, if no data were provided, an estimate was utilized.
- Bridge Width: The most restrictive (minimum) distance between curbs or rails on the structure. The primary width increments were based on ranges presented in the IM report.
- Bridge Length: The overall length of the roadway supported on the structure from back faces of the backwalls, measured along the centerline.
- Traffic Safety: Indicates whether the bridge rail, transitions, approach rail and approach ends are coded as meeting “current acceptable standards”, as designated by the inspections conducted in accordance with *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation’s Bridges* (FHWA 1995), or if the aforementioned safety features are required. Note that the research team has relied upon the accuracy of these assessments that have, obviously, been made by others.
- Road Surface Type: The roadway surface material approaching the bridge. This surface is often different from that of the bridge itself.
- Crash Severity: The severity of the crash based on the worst injury suffered by any person involved in the crash (e.g., fatal, major injury, minor injury, or possible injury). If no injuries occurred in the crash, the severity is classified as property damage only.
- Object Struck: The bridge feature, and the corresponding location on this feature, struck by a vehicle (e.g., bridge rail or approach guardrail end or between ends).
- Order of Strike: Indicates whether a bridge rail or guardrail strike was the primary collision (i.e., first object struck) or the secondary collision (e.g., collision with another vehicle, followed by bridge rail collision).
- Light Conditions: The natural lighting conditions at the time of the crash, and if dark, whether the location was artificially lit.
- Weather Conditions: The weather conditions at the time of the crash (e.g., foggy, mist, snow, etc.).

- Driving Surface Conditions: The roadway surface conditions at the time of the crash.
- Relative Bridge Width: The difference between the bridge and approach roadway width (i.e., bridge width minus roadway width). A negative value indicates that the bridge is narrower than the roadway.

Crash rate was also computed for various bridge characteristics. Crash rate takes into consideration the exposure of vehicles to individual bridge characteristics. For example, the number of bridges possessing a certain feature, and the number of vehicles exposed to this feature, may not be proportional (e.g., each bridge possesses a different AADT). Given the relatively short length of the majority of bridges, the linear extent of each bridge was ignored in the crash rate calculations. Bridge AADT was treated as daily entering vehicles (DEV). The equation used for calculating crash rate (CR) per million entering vehicles is as follows:

$$CR = \frac{\#Crashes * 1000000}{DEV * \frac{365 days}{year} * \#Years} \tag{5.1}$$

Appendix C contains a series of summary tables based on the IADOT Instructional Memorandum (IM) factors of AADT, bridge width, and bridge length. Pertinent details from these tables are presented in the following sections.

5.2 Traffic Volume

The traffic volume for the majority of bridges, 57% (9,792), is less than 50 vehicles per day (vpd). Another 25% (4,337) of bridges have a traffic volume from 50 to 99 vpd. Moreover, the vast majority of the low volume bridges, 92% (15,839), fall within the first IM category (i.e., less than 200 vpd).

Regarding crash experience, approximately 77% (263) of the crashes occurred on bridges with a traffic volume less than 100 vpd. Under the IADOT IM No. 3.213 these bridges do not receive points in the bridge rail rating system and are listed as bridges that may not qualify as needing guardrail according to the design exceptions.

5.3 Bridge Width

Approximately 60% (10,178) of all low volume bridges have a width less than 24 feet, representing two of the five IM bridge width categories. The width of half (4,748) of the bridges with a traffic volume less than 50 vpd is 20 feet or less. In general, bridges with higher traffic volumes (100 vpd or more) are wider (28 feet or greater).

Nearly 75% (205) of crashes occurred on bridges with known widths less than 25 feet (270). Additionally, over 30% (84) of crashes occurred on bridges with known widths less than 20 feet. Over 40% (42) of the crashes that occurred on roads with less than 50 vpd (99) were on/at bridges with widths of 20 feet or less.

5.4 Bridge Length

Over 50% (9,004) of the low volume bridges fall within the first (of five) IM length category (1 to 49 feet). Nearly half, 45% (158), of crashes occur on bridges with a length less than 49 ft, assuming that crashes at non-inventoried bridges also fall within this category.

5.5 Traffic Safety Features

The vast majority, 71% (12,312), of low volume bridges are indicated to not have bridge rail that meets "current acceptable standards" during their most recent inspection. This percentage increases to 78% (7,615) for bridges with less than 50 vpd (9,792).

Over half, 55% (53), of the crashes that occurred on roads with less than 50 vpd (99) were at/on bridges where the bridge rail was indicated to not meet "current acceptable standards".

Approximately 77% (13,342) of low volume bridges did not have transitions that were indicated to meet "current acceptable standards", with a similar number of bridges not having approach rails and approach ends indicated to meet "current acceptable standards". The percentages of crashes associated with these traffic safety features are 77% (216), 74% (209), and 77% (218), respectively.

In general, roads with higher traffic volumes were more likely to have features that were identified as meeting traffic safety "current acceptable standards". Upon review of the crash narratives, it was found that the bridge rail was indicated as not meeting "current acceptable standards" in over half, 54% (75), of the crashes known to strike the bridge rail (140). The bridge rail was indicated as not meeting "current acceptable standards" in 66% (45) of the crashes where the location of the bridge crash was unclear (68).

Guardrail was indicated to meet "current acceptable standards" in 41% (14) of the guardrail crashes (34). Guardrail was indicated as not meeting "current acceptable standards" in nearly half, 48% (16), of crashes where the location of impact with guardrail was unclear (33).

5.6 Road Surface Type

The approach roadway surface at 84% (14,507) of low volume bridges is gravel. This percentage increased to 90% (8,788) and 97% (4,200) for bridges with less than 50 vpd (9,729) and 50 to 99 vpd (4,337), respectively.

Over three-quarters, 76% (258), of crashes occurred on bridges where the surface of the adjacent roadway is gravel. The percentages of crashes occurring on gravel roads are 94% (93) and 96% (97) for bridges with less than 50 vpd (99) and 50 to 99 vpd (101), respectively.

5.7 Crash Severity

Half of the crashes (172) at/on low volume bridges were property damage only; 10% (31) were fatal and major injury crashes. The remaining crashes involved minor or possible injuries.

5.8 Crash Location

The bridge rail was struck in 41% (140) of the low volume bridge crashes. The bridge end was struck in 16% (54) of the crashes, and approach guardrail was struck in 24% (79) of the crashes. The location of the collision was unclear in approximately 20% (68) of all crashes. The bridge (or guardrail) was the first (primary) object struck in 96% (329) of all crashes.

5.9 Lighting Conditions and Time of Day

Nearly half, 47% (161), of the crashes occurred at dark (unlit) bridges, while 45% (153) of crashes occurred in day light. Figure 5.1 and Figure 5.2 present a comparison of the distributions of rural secondary road traffic volumes (source: IADOT Automatic Traffic Recorders 1993-2003, January 2004) and low volume road bridge crashes by time of day and weekday or weekend, respectively. During weekdays, similar distribution patterns exist between 6:00 a.m. and 5:00 p.m., with the morning commute period being the most similar. However, the percentage of crashes is consistently higher from 7:00 p.m. to 6:00 a.m. In fact, the greatest, single hour percentage of crashes occurred during the 11:00 p.m. hour. This may suggest that there is an over representation of night time crashes.

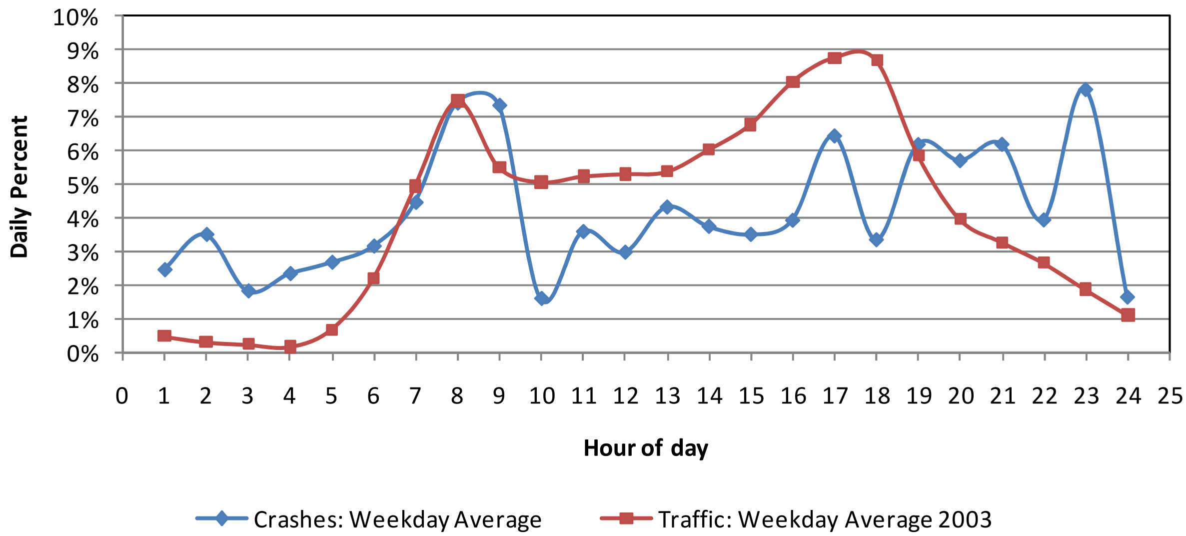


Figure 5.1. Weekday time of crash with time of traffic (traffic information from IADOT Automatic Traffic Recorders 1993-2003, January 2004).

Figure 5.2 indicates that a much larger percentage of crashes occur during the early morning and late night hours on the weekend, compared to the during week traffic volume. The proportion of crashes appears nearly inversely proportionally to traffic volumes. During the higher traffic periods (e.g., midday to afternoon) the crash percentage is the lowest. As with the weekday analysis, there appears to be an over representation of night time crashes but much more pronounced during the weekend.

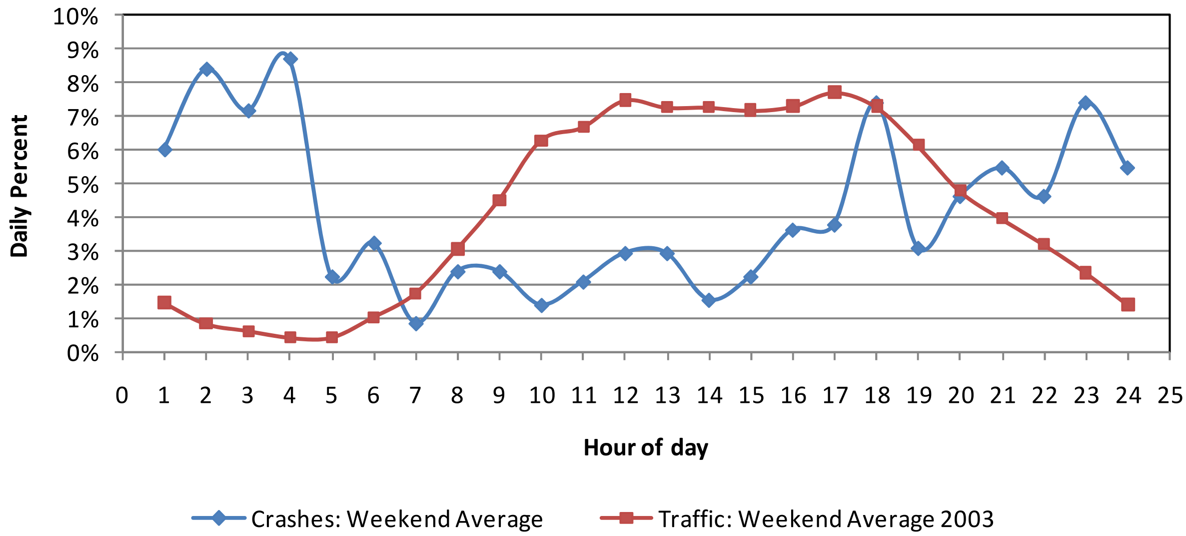


Figure 5.2. Weekend time of crash with time of traffic (traffic information from IADOT Automatic Traffic Recorders 1993-2003, January 2004).

5.10 Weather and Road Surface Conditions

Approximately 80% (265) of low volume bridge crashes occurred under normal weather conditions. Nearly half, 46% (158), of crashes occurred on a dry surface, with nearly another 30% (95) reported as occurring on a gravel surface, which is reported in the same category as surface conditions related to weather.

5.11 Crash Rate

To take exposure into consideration, crash rate was computed for the IM categories of AADT, bridge width, and bridge length. Tables 5.1 to 5.3 present crash rates for various AADT, bridge width, and bridge length ranges. In addition to the IM categories, crash rate was also calculated for relative bridge width (Table 5.4). Bridges with inventory information left blank or defaulted to zero are presented as not listed in the tables.

When evaluating crash rate by traffic volume (shown in Table 5.1), crash rate decreased as bridge traffic volume increased. In other words, bridges with lower traffic volumes possessed higher crash rates. This becomes more evident when graphed, as seen in Figure 5.3. Both the crash frequency and crash rate are higher for bridges with lower traffic volumes (i.e., less than 100 vpd).

Table 5.1. LVR AADT structure crash history and crash rate.

AADT	All Inventoried LVR Bridges				# of Crashes (%)		Crash Rate per MEV
	# of Bridges (%)		DEV (%)				
Not Listed	11	(0%)	0	(0%)	1	(0%)	N/A
1 to 49	9,792	(57%)	250,960	(22%)	99	(29%)	0.14
50 to 99	4,337	(25%)	282,017	(24%)	101	(30%)	0.12
100 to 149	1,190	(7%)	136,208	(12%)	40	(12%)	0.10
150 to 199	520	(3%)	86,376	(7%)	23	(7%)	0.09
200 to 400	1,380	(8%)	403,837	(35%)	77	(23%)	0.07
Grand Total	**17,230**	**(100%)**	**1,159,398**	**(100%)**	**341**	**(100%)**	0.10

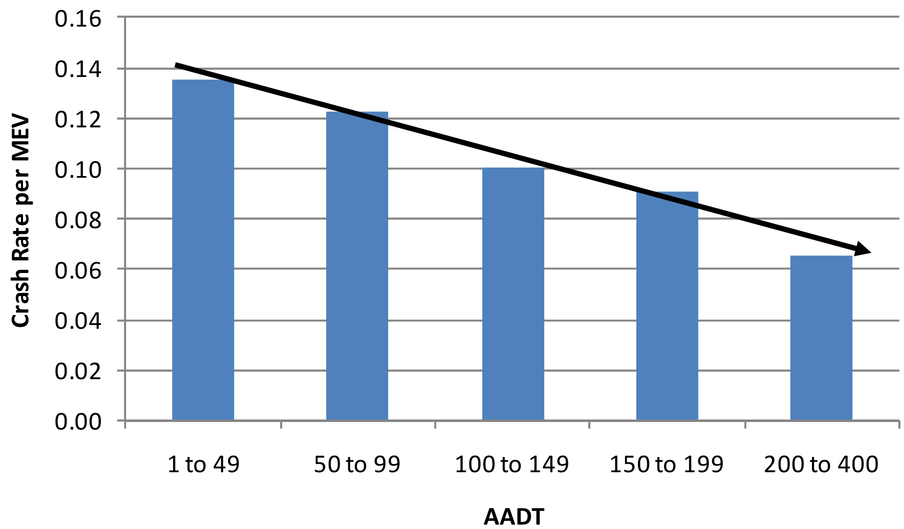


Figure 5.3. Crash rate for AADT intervals.

The crash rate by bridge width, tabulated in Table 5.2 and graphed in Figure 5.4, decreased with an increase in bridge width. However, as the bridge width exceeds approximately 24 ft, the crash rate appears to become relatively constant. This observation is supported by the crash frequency analysis, where the majority of crashes occurred on bridges with known widths less than 25 feet.

Table 5.2. LVR structure width crash history and crash rate.

Bridge Width,ft (IM Report)	All Inventoried LVR Bridges # of Bridges (%)		DEV (%)		# of Crashes (%)		Crash Rate per MEV
Non-Inventoried	-	(-)	-	(-)	59	(17%)	N/A
Not Listed	1,807	(10%)	170,910	(15%)	12	(4%)	0.02
1 to 20	6,846	(40%)	306,664	(26%)	124	(36%)	0.14
20.1 to 23.9	3,332	(19%)	189,502	(16%)	49	(14%)	0.09
24 to 27.9	2,840	(16%)	201,382	(17%)	44	(13%)	0.07
28 to 29.9	1,204	(7%)	143,280	(12%)	27	(8%)	0.06
30 or greater	1,201	(7%)	147,660	(13%)	26	(8%)	0.06
Grand Total	**17,230**	**(100%)**	**1,159,398**	**(100%)**	**341**	**(100%)**	**0.10**

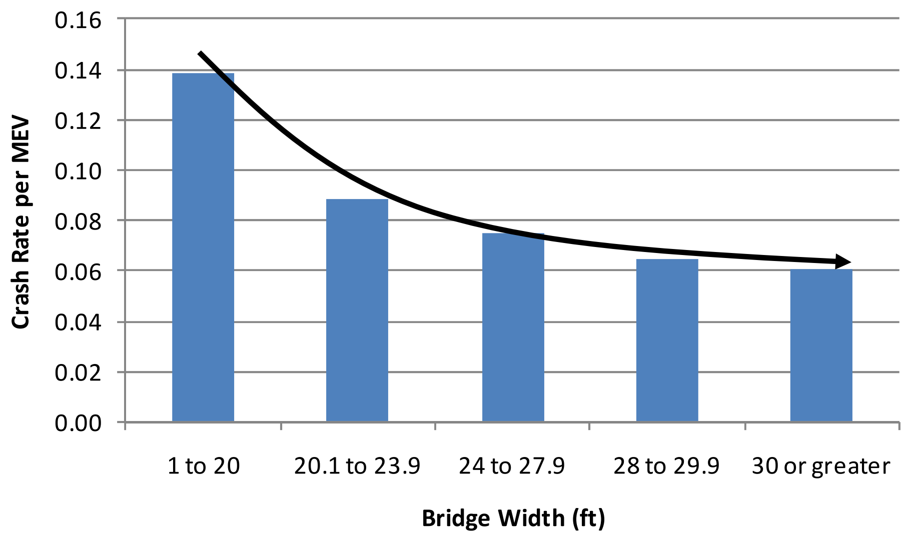


Figure 5.4. Crash rate for IM Report bridge width intervals.

The crash rate for different bridge lengths was found to be consistent regardless of bridge length, Table 5.3 and Figure 5.5. Since daily entering vehicles (DEV) was used to compute crash rate instead of vehicle-miles of travel (VMT), one may have assumed that the rate would be higher for longer structures, because more opportunity exists to strike the bridge rail. However, this was not the case, validating use of DEV in the benefit-cost analysis presented subsequently.

Table 5.3. LVR structure length crash history and crash rate.

Bridge Length,ft (IM Report)	All Inventoried LVR Bridges # of Bridges (%)		DEV (%)		# of Crashes (%)		Crash Rate per MEV
Non-Inventoried	-	(-)	-	(-)	59	(17%)	N/A
1 to 49	9,004	(52%)	532,576	(46%)	96	(28%)	0.06
50 to 99	4,102	(24%)	241,185	(21%)	80	(23%)	0.11
100 to 149	2,343	(14%)	189,050	(16%)	51	(15%)	0.09
150 to 199	918	(5%)	91,625	(8%)	23	(7%)	0.09
200 or greater	863	(5%)	104,962	(9%)	32	(9%)	0.10
Grand Total	**17,230**	**(100%)**	**1,159,398**	**(100%)**	**341**	**(100%)**	**0.10**

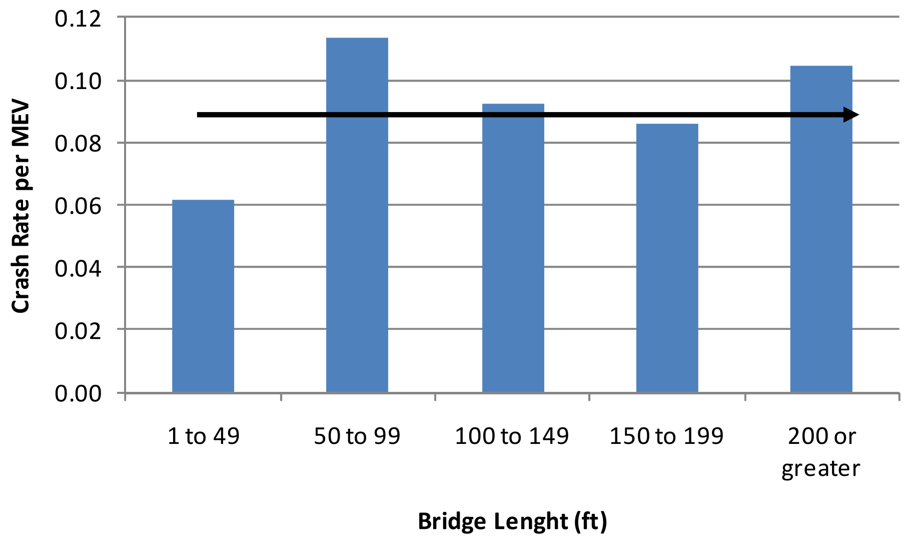


Figure 5.5. Crash rate for IM Report bridge length intervals.

The crash rate for the relative bridge width categories decreased with decreasing negative relative bridge width. Additionally, crash rate appeared to level off once the relative bridge width became positive, as shown in Figure 5.6. In other words, the crash rate was higher for bridges narrower than the approaching roadway width.

Table 5.4. LVR relative bridge width and crash rate.

Relative Bridge Width,ft	All Inventoried LVR Bridges				# of Crashes (%)		Crash Rate per MEV
	# of Bridges (%)		DEV (%)				
Non-Inventoried	-	(-)	-	(-)	59	(17%)	N/A
Not Listed	1807	(10%)	170910	(15%)	12	(4%)	0.02
9 or narrower	452	(3%)	25852	(2%)	13	(4%)	0.17
7-8 narrower	1028	(6%)	50520	(4%)	23	(7%)	0.16
5-6 narrower	1890	(11%)	88477	(8%)	33	(10%)	0.13
3-4 narrower	2600	(15%)	118412	(10%)	39	(11%)	0.11
1-2 narrower	2563	(15%)	136080	(12%)	46	(13%)	0.12
0 (same width)	1525	(9%)	91902	(8%)	25	(7%)	0.09
1-2 wider	1942	(11%)	124095	(11%)	25	(7%)	0.07
3-4 wider	1309	(8%)	83695	(7%)	19	(6%)	0.08
5-6 wider	1030	(6%)	117135	(10%)	19	(6%)	0.06
7-8 wider	726	(4%)	105260	(9%)	19	(6%)	0.06
9 or wider	358	(2%)	47060	(4%)	9	(3%)	0.07
Grand Total	**17,230**	**(100%)**	**1,159,398**	**(100%)**	**341**	**(100%)**	**0.10**

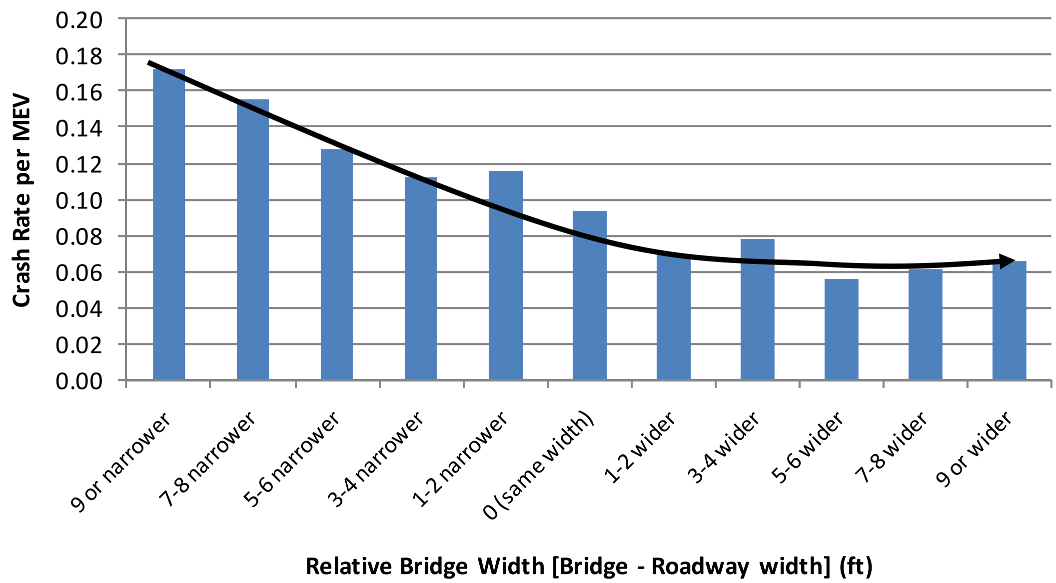


Figure 5.6. Crash rate for relative bridge width intervals.

5.12 Multiple Crashes

Table 5.5 shows the 12 inventoried bridges that have multiple crashes and the crash severity for each of the crashes. Twenty six of the 341 crashes occurred at bridges with more than one crash. Therefore, approximately 4% (14) of the crashes occurred at bridges with more than one crash. Over 50% (14) of crashes that occurred on bridges with multiple crashes were property damage only and approximately 40% were minor injury or possible/unknown injury crashes.

Table 5.5. Inventoried bridges with multiple crashes and crash severity.

Bridge Identification	Crash Severity					Total Crashes
	Fatal	Major Injury	Minor Injury	Possible/ Unknown	Property Damage Only	
A	1		1			2
B			1	1	1	3
C			1		1	2
D					2	2
E			1		1	2
F			1		2	3
G			1		1	2
H			1		1	2
I			1		1	2
J					2	2
K			1		1	2
L				1	1	2
Total	1	0	9	2	14	26

6. STATISTICAL DATA ANALYSIS

6.1 Overview

Two statistical methods were employed to analyze the 341 crashes that occurred at low volume bridges during the analysis period. These methods included test of proportions and probability modeling. The following sections provide the methodological background of these methods and summaries of the results.

6.2 Methodology

6.2.1 Test of Proportions

Statistical testing of the difference between two proportions was performed to determine whether specific crash characteristics increased for specific bridge characteristics. To accomplish this, several discrete pairs of bridge characteristics were established (e.g., width less than 24 feet vs. width greater than 24 feet), and the proportions of various crash characteristics (e.g., severity) within these pairs computed. The differences between these pairs of proportions were statistically tested for significance using the z-statistic for a standard Normal random variable. The z-statistic was applicable because the frequency of crashes for the tested characteristics in each sample were greater than five, and the two population proportions being compared were independent (Moore et al, 2003). Statistically significant differences within the samples suggest an increase of a specific crash characteristic for the corresponding bridge characteristic.

To begin, the null hypothesis was defined as “the two population proportions are equal, or are not different”, given by:

$$H_0: p_1 = p_2. \tag{6.1}$$

Therefore, the alternate hypothesis was defined as “the two population proportions are not equal, or are different”, i.e.:

$$H_1: p_1 \neq p_2 \tag{6.2}$$

where p_1 represents the first proportion being tested and p_2 represents the second proportion.

A 95% level of confidence (significance level of 0.05) was selected, and the difference between the sample proportions computed:

$$|p_1 - p_2| \tag{6.3}$$

Then, the weighted average of the two sample proportions was computed:

$$p = \frac{n_1 p_1 + n_2 p_2}{n_1 + n_2} \tag{6.4}$$

where n_1 and n_2 are the respective number of observations sampled from the two populations. The estimated standard error of the difference between proportions was calculated as:

$$s_{p_1\text{-}p_2} = \sqrt{\frac{p(1\text{-}p)}{n_1} + \frac{p(1\text{-}p)}{n_2}} \quad (6.5)$$

The z-statistic was computed by the general formula:

$$z = \frac{|p_1 - p_2|}{s_{p_1 - p_2}} \quad (6.6)$$

The probability of obtaining a difference between the population proportions as large as, or larger than, the difference observed in the experiment, i.e. probability value or p-value, was determined within Microsoft Excel (Lane, 2009). The basic formula can be expressed as:

=IF(z-stat<0,2*NORMDIST(z-stat,0,1,1),2*(1-NORMDIST(z-stat,0,1,1))) (6.7)

where "z-stat" represents the address of the cell containing the z-statistic value (Barreto and Howland, 2008).

Lastly, the probability value was compared to the significance level of 0.05. If the probability value was less than or equal to the significance level, the difference tested was significant, and the null hypothesis was rejected. The tests were also conducted using a 90% level of confidence, which would yield less significant results.

6.2.2 Crash Frequency

The frequency of vehicle crashes is properly modeled using count data models, the most popular of which are Poisson and negative binomial regression models. One requirement of the Poisson distribution is that the mean of the count process equals its variance. When the variance is significantly larger than the mean, the data are said to be over dispersed, and can be properly modeled using a negative binomial model (Washington, et al., 2003).

6.2.2.1 Poisson Regression

For a non-negative integer variable, Y, with observed frequencies, $y_i, i = 1, \ldots, N$, the probability of y_i (in this case, guardrail injuries) at i is given by:

$$P(y_i) = \frac{EXP(-\lambda_i)\lambda_i^{y_i}}{y_i!} \quad (6.8)$$

where λ_i is the Poisson parameter for i, which is equal to the expected frequency low volume bridge crashes at i, $E[y_i]$.

The log-linear model form used in this paper to predict the expected number of low volume bridge crashes:

$$\ln\lambda_i = \beta_i \cdot x_i \qquad (6.9)$$

where x_i is a vector of explanatory variables, and β_i is a vector of estimable parameters by maximum likelihood estimation techniques.

6.2.2.2 Negative Binomial Regression

The negative binomial regression model is an extension of the Poisson regression model which allows the variance of the process to differ from the mean. One way that the model arises is as a modification of the Poisson model in which λ_i is specified so that:

$$\ln\lambda_i = \beta_i \cdot x_i + \varepsilon_i \qquad (6.10)$$

where $EXP(\varepsilon_i)$ follows a gamma distribution with mean 1.0 and variance α^2. This model has an additional parameter, α, which is often referred to as the over dispersion parameter, such that:

$$VAR[y_i] = E[y_i] \cdot [1 + \alpha \cdot E[y_i]] \qquad (6.11)$$

6.2.3 Injury Severity

The objective is to model vehicle crash injury severity on low-volume bridges in Iowa. Consideration was given to three possible discrete outcomes when a vehicle is involved in a crash: no injury (property damage only), possible/unknown or minor injury, and major injury or fatality.

Recent literature (summarized in Savolainen and Mannering, 2007) indicates that both ordered (ordered logit and probit) and unordered (multinomial logit and nested logit) probability models have been used for modeling crash injury severity data. However, ordered models place a restriction on variable effect which, in the current case, would not allow for the possibility of a variable simultaneously decreasing the probability of no injury and major injury (alternatively increasing only the probability of minor injury). Because this is an unnecessary and potentially erroneous restriction, an unordered discrete outcome model was adopted (see Washington et. al. 2003, for a further explanation of this point).

For crash injury severity outcomes, the multinomial logit model defines a function that determines injury severity as,

$$W_{in} = \boldsymbol{\beta}_i \mathbf{X}_{in} + \varepsilon_{in} \qquad (6.12)$$

where W_{in} is the function that determines the probability of discrete injury severity outcome i for crash n, $\mathbf{X}_{in}$ is a vector of measurable characteristics (roadway and crash characteristics) that determine the injury severity for crash n, $\boldsymbol{\beta}_i$ is a vector of estimable coefficients, and ε_{in} is an error term accounting for unobserved effects influencing the injury severity outcome i for crash n.

It can be shown that if ε_{in} are assumed to be extreme value distributed (see McFadden, 1981), then a standard multinomial logit model results,

$$P_n(i) = \frac{EXP\left[\boldsymbol{\beta}_i \mathbf{X}_{in}\right]}{\sum_{\forall I} EXP\left[\boldsymbol{\beta}_I \mathbf{X}_{In}\right]} \qquad (6.13)$$

where $P_n(i)$ is the probability that crash n will result in an injury outcome i and I is the set of possible crash injury severity outcomes.

6.3 Results

6.3.1 Test of Proportions

A summary of the test of proportions results is presented in Table 6.1. The crash characteristics of severity, lighting conditions, and/or object struck were tested with respect to discrete pairs of bridge traffic volume (AADT), width, length, and relative width. In general, very few statistically significant differences in proportions were observed.

Of the proportions tested, the difference of possible/unknown injury crashes was statistically significant at a 95% level of confidence for bridges less than 24 feet wide. The difference of possible/unknown injury crashes was also statistically significant at a 95 % level of confidence for bridges with a negative relative width. The difference for guardrail crashes on bridges wider than 23.9 feet was statistically significant as well. However, this result may not be entirely valid, because not all bridges possess guardrail.

Decreasing the confidence level to 90%, the difference of major injury crashes was statistically significant for bridges with a relative width zero or less. Also, the difference of bridge end crashes was statistically significant for bridges less than 24 feet wide.

Bridge length and traffic volume did not yield in any statistical significance differences when tested with various crash characteristics.

Table 6.1. Test of proportion result summary.

Bridge Characteristic	Category		Crash Characteristics			
	Group 1	Group 2	Crash Severity	Light Conditions	Object Struck - Excluding Guardrail*	Object Struck - Including Guardrail *
AADT	1-99 VPD	100-400 VPD	None	N/T	N/T	N/T
AADT	1-49 VPD	50-400 VPD	None	N/T	N/T	N/T
Bridge Width	1-23.9'	24-30'	Possible/Unknown Injury Crashes. Greater for 1-23.9’. (α = 0.05, 95% level of confidence)	None	None	Guardrail Crashes. Greater for 24-30’. (α = 0.05, 95% level of confidence) Bridge End Crashes. Greater for 1-23.9’. (α = 0.10, 90% level of confidence)
Bridge Length	1-49'	> 49'	None	None	None	None
Relative Bridge Width	<= 0'	> 0'	Major Injury Crashes. Greater for <=0'. (α = 0.10, 90% level of confidence)	N/T	N/T	N/T
Relative Bridge Width	< 0'	>= 0'	Possible/Unknown Injury Crashes. Greater for < 0'. (α = 0.05, 95% level of confidence)	N/T	N/T	N/T

* Test may not be applicable because of exposure, e.g. not all bridges have guardrail.

N/T : Comparison not tested

6.3.2 Crash Frequency

The estimation results from the low volume bridge crash frequency analysis are presented in Table 6.2. The frequency of vehicle crashes was more likely to be higher on low-volume bridges that had lower width compared to the roadway, and lower on low-volume bridges that had higher width compared to the roadway.

Table 6.2 Negative Binomial Regression Model for Frequency of Crashes on Low-volume Bridges.

Variable	Estimated Coefficient	*t*-Statistic
Constant	1.963	5.93
Relative bridge width (bridge minus roadway width)	–0.116	–2.81
Dispersion parameter α	2.511	3.67
Number of observations	52	
Log-likelihood at zero	–297.60	
Log- likelihood at convergence	–114.12	
McFadden Pseudo *R*-squared	0.617	

6.3.3 Injury Severity

The estimation results for the multinomial logit model for low volume bridge vehicle crash severity are presented in Table 6.3. For crash-specific variables, findings show that crashes that occurred on roadways, which were not lighted (i.e., dark), were more likely to result in a major injury or fatality. Crashes that occurred under partly cloudy or cloudy conditions were less likely to result in a major injury or fatality (or alternatively more likely to result in no injury or minor injury).

Turning to roadway-specific variables, it was found that crashes that occurred on bridges of higher length and crashes that occurred on wider roads were less likely to result in a minor injury (or alternatively more likely to result in no injury or major injury). On the other hand, the outcome of crashes that occurred on bridges of higher traffic volume was more likely to be a minor injury. Last, crashes on gravel roads were more likely to result in minor injury.

Table 6.3. Multinomial logit model for vehicle crash injury severity on low volume bridges in Iowa.

Variable	Estimated Coefficient	*t*-Statistic
Constant [N]	-2.034	-4.83
Constant [I]	-0.206	-0.07
Crash-Specific Variables		
Light conditions—Dark, roadway not lighted [F]	0.959	2.04
Weather conditions—Partly cloudy or cloudy [F]	-1.146	-2.45
Roadway-Specific Variables		
Bridge length [I]	-0.011	-1.79
Traffic volume of road (intervals of 50 ft) [I]	0.007	2
Roadway width [I]	-0.195	-1.62
Roadway surface type—Gravel [I]	3.395	2.56
Number of observations	341	
Mc-Fadden R-squared	0.08	

Variables are defined for outcomes: [N] no injury, [I] minor injury, [F] major injury or fatality

7. ECONOMIC ANALYSIS

7.1 Overview

On a statewide basis (not for an individual bridge), benefit-cost economic analyses were performed to compare the relative safety benefit of improving bridge rails to meet "current acceptable standards" and the cost of doing so. The objective of these analyses was to determine whether statewide improvement of bridges possessing certain characteristics could be warranted. Several scenarios, evaluating bridges with various traffic volumes, widths, lengths, and relative widths were evaluated.

Life cycle cost for standard bridge rail was estimated through consultation with IADOT staff and county engineers. The approximate, total present worth of bridge rail was estimated to be $194/ft of bridge. The following assumptions were used to estimate the present worth and life cycle cost of bridge rail:

- The life of a bridge rail is approximately 30 years.
- There is no useful salvage at the end of the bridge rail life.
- The railing cost of $90/ft of bridge length includes:
  - SL-1 system with a thrie-beam on both sides of the bridge.
  - Bridge rail end treatment.
  - Labor.
- The maintenance cost of $6/ft of bridge per year includes:
  - Replacement of a thrie-beam section every five years.
- The interest rate is assumed at 4% annual discount rate.

The cost of a crash is primarily based on the number and severity of injuries suffered in the crash. The monetary value assigned to a given injury severity is defined by the FHWA and shown in Table 7.1. Total crash cost includes all persons killed/injured in the crash as well as the resulting property damage. For property damage only crashes a police estimate or a value of $2,700 is used for the crash cost. For the purposes of this study $2,700 was used for all property damage only crashes.

Table 7.1. Cost of a crash by severity.

Severity	Cost
Fatality	$3,500,000
Major Injury	$240,000
Minor Injury	$48,000
Possible Injury	$25,000
Property Damage	$2,700, or Police Estimate

Benefit is obtained by using the crash cost in conjunction with crash reduction factors (CRF) to determine the equivalent monetary value of the societal cost from crashes that could be reduced in number or severity by updating the bridge rail. The CRF values were obtained from the Desktop Reference for Crash Reduction Factors published by the FHWA in September 2007. Table 7.2 shows the CRF used for various situations.

Table 7.2. Crash Reduction factors used for analysis.

Type of Treatment	Severity	CRF
Upgrade Bridge Railing	All (high)	20%
	All (low)	5%
	Fatal	92%

To investigate the economic benefits of improving the bridge rail to "current acceptable standards", only the bridges with rails not meeting "current acceptable standards", as designated by the inspections conducted in accordance with Inventory and Appraisal of the Nation's Bridges (FHWA 1995), were used for comparison. However, due to the relatively few crashes experiences, all crashes at/on such bridges were included in the analyses. These crashes may include those where the bridge rail itself was not necessarily struck. By including all crashes, as well as crashes associated with non-inventoried bridges (assuming their rails also do not meet "current acceptable standards"), yielded a more liberal benefit estimate (and, therefore, a conservative B/C analysis).

Typically, when performing a benefit-cost analysis for a site, the IADOT treats the first fatality as a major injury. This approach is employed to address the random nature of fatal crashes, which can inflate the crash cost for a specific site. However, since system wide analyses were conducted for this project, the actual number of fatalities was used to compute crash cost. In the final scenario, the benefit-cost ratio for a single (but not specific) bridge was performed with the first fatality treated as a major injury.

As with the crash rate calculations, daily entering vehicles (DEV) was utilized in the benefit-cost analyses; this approach is analogues to intersection or spot analysis. The standard IADOT Office of Traffic and Safety Traffic Safety Improvement Program Benefit/Cost Excel worksheet was utilized for the various scenarios. The worksheets for each scenario are presented in Appendix D.

7.2 Improve All Low Volume Bridges with Railing not Meeting "Current Acceptable Standards"

Of the 17,230 inventoried low volume road bridges, 12,312 (828,880 feet of bridge) were reported as having a bridge rail that does not meet "current acceptable standards". The crashes associated with these bridges resulted in five fatalities, 20 major injuries, 55 minor injuries, 57 possible injuries, and 87 property damage only crashes. Table 7.3 provides the benefit-cost ratio for each CRF mentioned previously. Given the very low benefit-cost ratios for each CRF, only the higher two CRF values were used in the additional scenarios, which may yield somewhat more liberal results.

Table 7.3. Summary of B/C analysis for improving all bridges with bridge rail not up to "standard".

Crash Type	CRF	Benefit	Cost	B/C
All	5	$2,874,790	$160,441,400	0.02
All	20	$11,499,159	$160,441,400	0.07
Fatal	92	$34,800,217	$160,441,400	0.22

7.3 Improve Low Volume Bridges with Railing not Meeting "Current Acceptable Standards" and AADT Less Than 100

Because the crash rate was highest for low volume bridges with traffic volumes less than 100 vpd (Figure 5.3), benefit-cost analysis was performed for the 10,542 inventoried bridges satisfying these conditions. Four fatalities occurred on these bridges, 15 major injuries, 31 minor injuries, 36 possible injuries, and 59 property damage only crashes. Table 7.4 provides a summary of the results of this scenario.

Table 7.4. Summary of B/C analysis for improving bridges with bridge rail not up to "standard" and AADT<100.

Crash Type	CRF	Benefit	Cost	B/C
All	20	$8,709,694	$128,434,070	0.07
Fatal	92	$27,840,173	$99,012,436	0.28

7.4 Improve Low Volume Bridges with Railing not Meeting "Current Acceptable Standards" and Width Less Than 24 Feet

Bridges with a width less than 24 ft were found to have a higher crash rate than similar bridges with larger widths (Figure 5.4). A total of 9,230 (572,193 feet) of inventoried bridges exist on low volume roads that have rails that do not meet "current acceptable standards" and a width less than 24 ft. There were four fatalities, 17 major injuries, 36 minor injuries, 48 possible injuries, and 62 property damage only crashes at these locations. Table 7.5 provides a summary of the summary benefit cost for scenario 3.

Table 7.5. Summary of B/C analysis for improving bridges with bridge rail not up to "standard" and bridge width < 24 ft.

Crash Type	CRF	Benefit	Cost	B/C
All	20	$9,154,143	$110,863,652	0.08
Fatal	92	$27,840,173	$110,863,652	0.25

7.5 Improve Low Volume Bridges with Railing not Meeting "Current Acceptable Standards" and Length Less Than 100 Feet

Although no definite relationship was observed between bridge length and crash rate (Figure 5.5), in keeping with the IM, benefit-cost was analyzed for bridges with a length less than 100 ft.

There were a total of 9,796 (437,784 ft) inventoried bridges satisfying these conditions without rail meeting “current acceptable standards”. Bridges with zero recorded length were assumed to have a length of less than 100 ft. These bridges had 4 fatalities, 20 major injuries, 52 minor injuries, 46 possible injuries, and 93 property damage only crashes. Table 7.6 provides summary results for this scenario.

Table 7.6. Summary of B/C analysis for improving bridges with bridge rail not up to “standard” and bridge length < 100 ft.

Crash Type	CRF	Benefit	Cost	B/C
All	20	$9,811,975	$78,753,976	0.12
Fatal	92	$27,840,173	$78,753,976	0.35

7.6 Improve Low Volume Bridges with Railing not Meeting “Current Acceptable Standards” and Negative Relative Bridge Width

As seen in Figure 5.6. crash rate increased as the relative bridge width decreased from zero; therefore, the benefit-cost for bridges with a negative relative width less was investigated. There were 7,422 (483,641 ft) inventoried bridges with relative widths less than zero. These bridges had 3 fatalities, 13 major injuries, 29 minor injuries, 42 possible injuries, and 57 property damage only crashes. Table 7.7 provides summary results for this scenario.

Table 7.7. Summary of B/C analysis for improving bridges with bridge rail not up to “standard” and bridge relative width < 0 ft.

Crash Type	CRF	Benefit	Cost	B/C
All	20	$7,010,147	$93,706,507	0.07
Fatal	92	$20,880,130	$93,706,507	0.22

For comparison the benefit-cost for bridges with relative bridges width greater than or equal to zero were investigated. There were 4,421 (332,114 ft) inventoried bridges with 2 fatalities, 7 major injuries, 24 minor injuries, 15 possible injuries, and 30 property damage only crashes. As seen in Table 7.8 the benefit-cost were the same as bridges with relative bridge widths less than zero.

Table 7.8. Summary of B/C analysis for improving bridges with bridge rail not up to “standard” and bridge relative width >= 0 ft.

Crash Type	CRF	Benefit	Cost	B/C
All	20	$4,447,511	$64,347,818	0.07
Fatal	92	$13,920,087	$64,347,818	0.22

7.7 Cost of Bridge Rail Yielding a B/C of 0.8

As seen by Table 7.3 to 7.8, the benefit-cost ratio was very low for all scenarios; therefore, to obtain a higher benefit-cost ratio, a variable that could be modified was the cost of the bridge rail

system. If the bridge rail system cost decreased enough a higher B/C can be obtained.
The first scenario, addressing all low volume bridges with rail not meeting "current acceptable standards", was reinvestigated. The cost of bridge rail was decreased until the B/C = 0.80 (which is recommended by the IM). To increase the benefit-cost ratio from 0.07, with a $90/foot rail to 0.80, the bridge rail would need to have an initial cost of $8.1/foot of bridge length and an annual maintenance cost of $0.54/foot of bridge. In other words, the bridge rail cost must be reduced by 91% for the benefit-cost ratio to have the B/C specified in the current IM.

7.8 Individual Bridge Analysis

The previously summarized benefit-cost analyses were conducted on a system wide basis. Although the objective of this project was to perform system wide analysis, the impact of a fatal crash at a single, typical low volume bridge was also investigated. The typical bridge was based on the most common bridge sizes from the descriptive analysis (i.e., a length of 75 feet and AADT of 50) to have the most applicability. The bridge was assumed to have a 30 year life and a single fatal crash occurring within the 30 years. As stated previously, the fatal crash was be treated as a major injury as to not inflate the crash cost due to the random nature of fatalities. The benefit cost for the bridge was 8.76, as seen in Table 7.9.

Table 7.9. B/C analysis individual generic bridge with a fatal crash.

Crash Type	CRF	Benefit	Cost	B/C
Fatal	92	$127,269	$14,531	8.76

It should be noted, however, that this does not suggest that every bridge with a fatal crash should be updated. Moreover, only 4% of the crashes involved a fatality, and only 0.07% of the low volume bridges experienced a fatal crash. The aforementioned analysis and the percentage of bridges with multiple crashes, as presented in section 5.12, does suggest that treatments (e.g. improvement to bridge rail) may be cost effective if one could predict the locations where fatal crashes would occur. In general, each bridge, and its crash history, should be evaluated independently.

8. BRIDGE AND APPROACH RAIL ALTERNATIVES

The dynamics of a crash are complex, and therefore full-scale testing is the most effective means of ensuring barrier performance. However, the results of these crash tests can only be compared/useful if the tests and the test procedures are standardized. National Cooperative Highway Research Program Report No. 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features* (NCHRP Report 350) established six test levels (TLs) for the evaluation of longitudinal barrier systems. Test level 1, 2, and 3 will be the focus herein since they are suited for LVR. Level 4, 5, and 6 pertain primarily to high volume roads and larger tractor-trailer type vehicle traffic. The following are evaluated to determine the TL: 1) occupant risk, 2) structural integrity of the barrier, and 3) post-impact behavior of the vehicle. The vehicle mass, speed and impact angle vary with each TL.

In addition to the NCHRP testing, AASHTO has established subjective factors for determining a barrier's Performance Level (PLs). The barrier performance level considers the percentage of heavy vehicles in the traffic stream, adverse geometrics, and consequences associated with penetration of a barrier. A barrier PL can range from 1 to 3. LVR bridges should be evaluated for AASHTO Performance Level individually, due to the subjectivity of the evaluation factors.

8.1 Terminal Ends

The FHWA (1998) states that approach guardrails should be ended appropriately to reduce the risk of the following: 1) abruptly stopping a vehicle, 2) causing instability and over-turning a vehicle, 3) directing the car into traffic, and 4) penetration of the guardrail into the vehicle compartment. An approach guardrail can be ended safely in two main ways. One option for ending a guardrail is to flare the guardrail away from the roadway at an appropriate flare rate. In this case the guardrail should end far enough away from the travel lane that it is unlikely to be hit by a vehicle in a crash. The second option is to install a crash worthy terminal.

8.1.1. Widely Used Terminal Ends

This section gives a variety of standard end treatments for roadside barriers as found in the AASHTO *Roadside Design Guide.* Table 8.1 lists the end treatments, their test level, and their size. A barrier terminating within the clear zone or located in an area where it is likely to be struck by an errant motorist requires a crashworthy end treatment. End treatments should have the same redirectional capabilities of a standard roadside barrier. End treatments should also be capable of preventing rollover and spearing of the impacting vehicle at head-on angles as well as angled impacts. The terrain in the area behind an end treatment should be relatively traversable.

Table 8.1. Crashworthy end treatments (AASHTO 2002).

System	NCHRP Report 350 Test Level	System Width	System Length
Three-Strand Cable	TL-3	1.2 m [4.0 ft] Flare	N/A
Wyoming Box Beam End Terminal (WYBET-350)	TL-3	0.6 m [2 ft]	15.2 m [50 ft]
Barrier Anchored in Backslope	TL-3	N/A	N/A
Eccentric Loader Terminal (ELT)	TL-3	0.5 m [1.6 ft] plus 1.2 m [4 ft] Flare	11.4 m [37.5 ft]
Slotted Rail Terminal (SRT-350)	TL-3	0.5 m [1.6 ft] plus 1.2 m [4 ft] Flare or 0.5 m [1.6 ft] plus 0.9 m [3 ft] Flare	11.4 m [37.5 ft]
REGENT	TL-3	0.5 m [1.6 ft] plus 1.3 m [4.3 ft] Flare	11.4 m [37.5 ft]
Vermont Low-Speed, W-Beam Guardrail End Terminal	TL-2	1.5 m [4.9 ft]	3.4 m [11.15 ft]
Flared Energy-Absorbing Terminal (FLEAT)	TL-2	0.5 m [1.6 ft] plus 0.51 - 0.81 m [1.7 - 2.7 ft] Flare	7.62 m [25 ft]
	TL-3	0.5 m [1.6 ft] plus 0.76 - 1.2 m [2.5 - 4 ft] Flare	11.4 m [37.5 ft]
Beam-Eating Steel Terminal (BEST)	TL-3	0.5 m [1.6 ft]	11.4 m [37.5 ft] or 15.2 m [50 ft]
Extruder Terminal (ET-2000)	TL-3	0.5 m [1.6 ft]	11.4 m [37.5 ft] or 15.2 m [50 ft]
Sequential Kinking Terminal (SKT-350)	TL-3	0.5 m [1.6 ft]	15.2 m [50 ft]
QuadTrend-350	TL-3	0.46 m [1.5 ft]	6.1 m [20 ft]
NEAT	TL-2	0.57 m [1.9 ft]	2.957 m [9.7 ft]
Slope Concrete End Treatment	N/A	0.6 m [2 ft]	6 - 12 m [20 - 40 ft]

8.1.1.1 Three-Strand Cable Terminal

Three-strand cable terminals are specific to the three-strand cable barrier they accompany. Figure 8.1 shows an example of a three-strand cable terminal which has been successfully tested, by the FHWA, to NCHRP Report 350 TL-3.

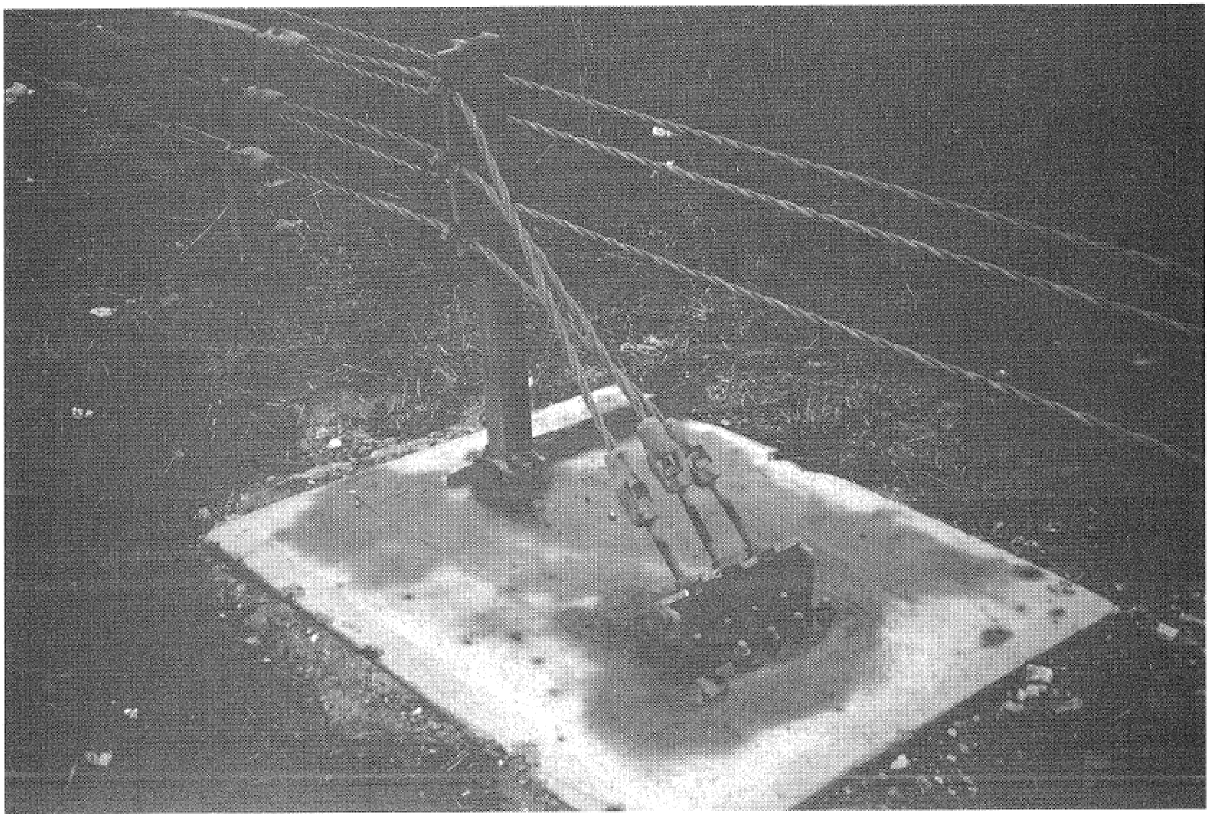


Figure 8.1. Three-strand cable terminal (AASHTO 2002).

8.1.1.2 Wyoming Box Beam End Terminal (WYBET-350)

The Wyoming Box Beam End Terminal (WYBET-350) is shown in Figure 8.2. The dissipation of kinetic energy in a WYBET-350 system comes from crushing a tube system within a telescoping nosepiece. The WYBET-350 has been successfully tested to NCHRP Report 350 TL-3.

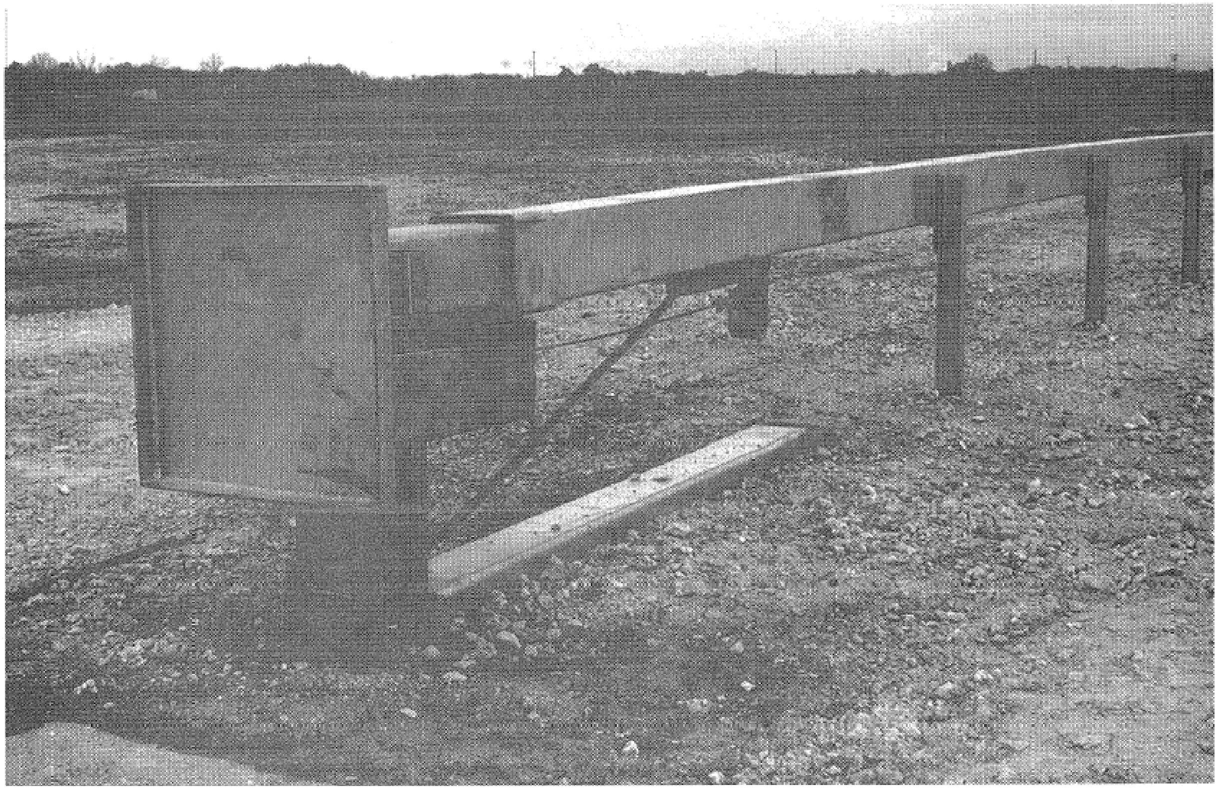


Figure 8.2. Wyoming box beam end terminal (AASHTO 2002).

8.1.1.3 Barrier Anchored in Backslope

In certain situations it is possible to terminate a guardrail in the backslope. This type of design can be applied to various types of guardrail systems including, but not limited to the following: 1) W-beam systems, 2) thrie-beam systems, 3) Ironwood guardrails systems, and 4) steel-backed wood guardrail systems. Figure 8.3 is an example of a W-beam guardrail system terminated in the backslope which has been successfully tested to NCHRP Report 350 TL-3.

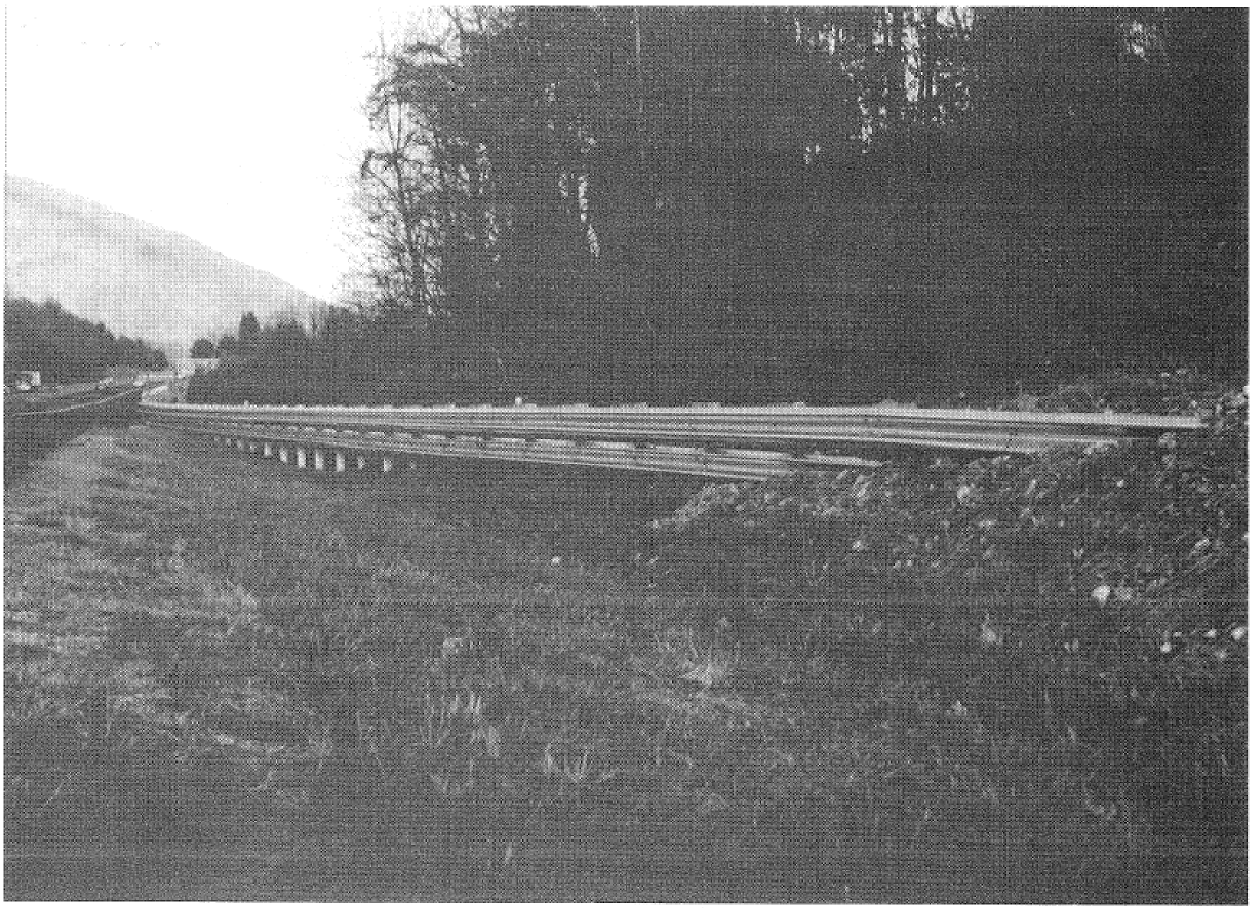


Figure 8.3. W-beam guardrail anchored in backslope (AASHTO 2002).

8.1.1.4 Eccentric Loader Terminal (ELT)

The Eccentric Loader Terminal (ELT), shown in Figure 8.4, consists of a fabricated steel lever nose enclosed inside a section of corrugate steel pipe and break away posts. The ELT system is also dependent on a curved flare for proper impact performance. The ELT has been successfully test to NCHRP Report 350 TL-3.

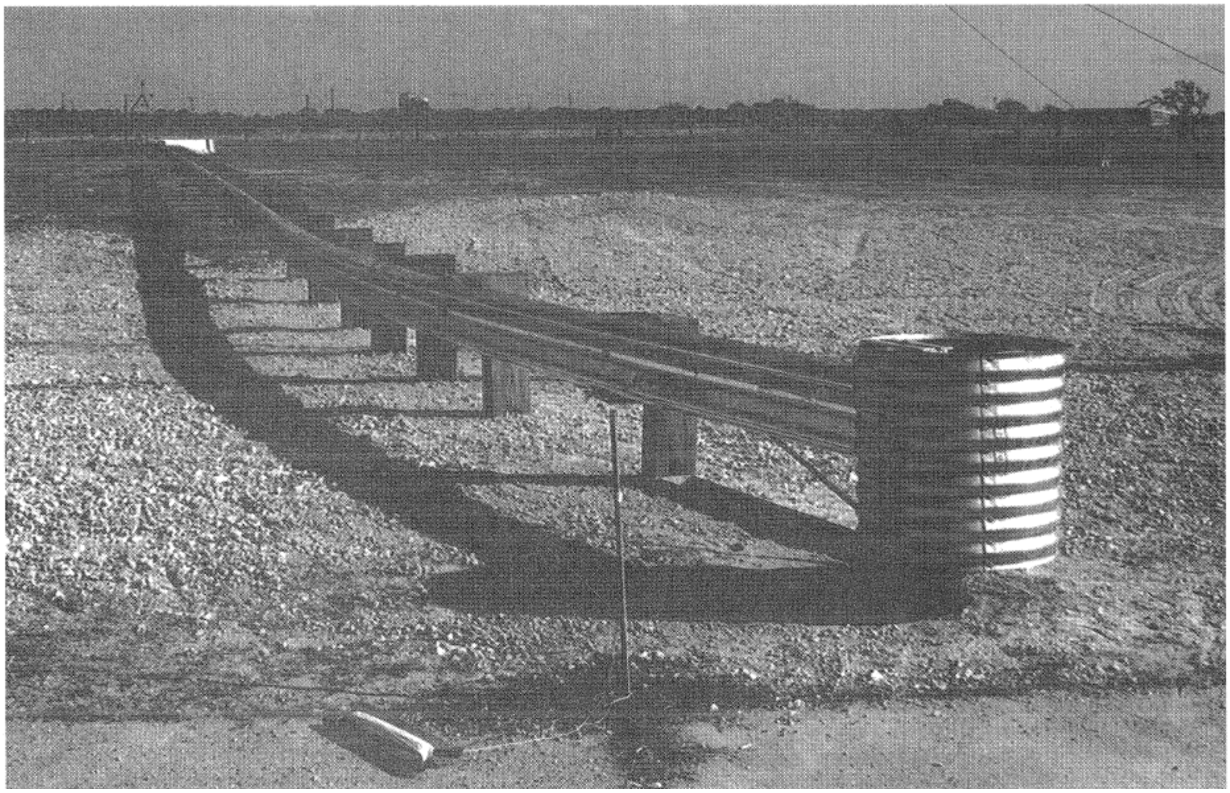


Figure 8.4. Eccentric loader terminal (AASHTO 2002).

8.1.1.5 Slotted Rail Terminal (SRT-350)

The SRT-350 is a proprietary, flared, non-energy-absorbing terminal with two versions, both successfully test to NCHRP Report 350 TL-3. One version of the SRT-350 can be seen in Figure 8.5. The SRT-350 is made up of curved W-beam with reduced buckling strength. The buckling strength is reduced with longitudinal slots cut in specific locations. The SRT-350 system is designed to break away when impacted and therefore requires a sufficient traversable area behind the guardrail end.

8.1.1.6 REGENT Terminal

The REGENT is a proprietary, flared, energy-absorbing terminal which has be successfully tested to NCHRP Report 350 TL-3. The REGENT design consists of a slider head assembly, a strut assembly, modified W-beam rail panels, and unique weakened wood posts. A sufficient traversable area behind this terminal is required. Figure 8.6 shows a REGENT Terminal.

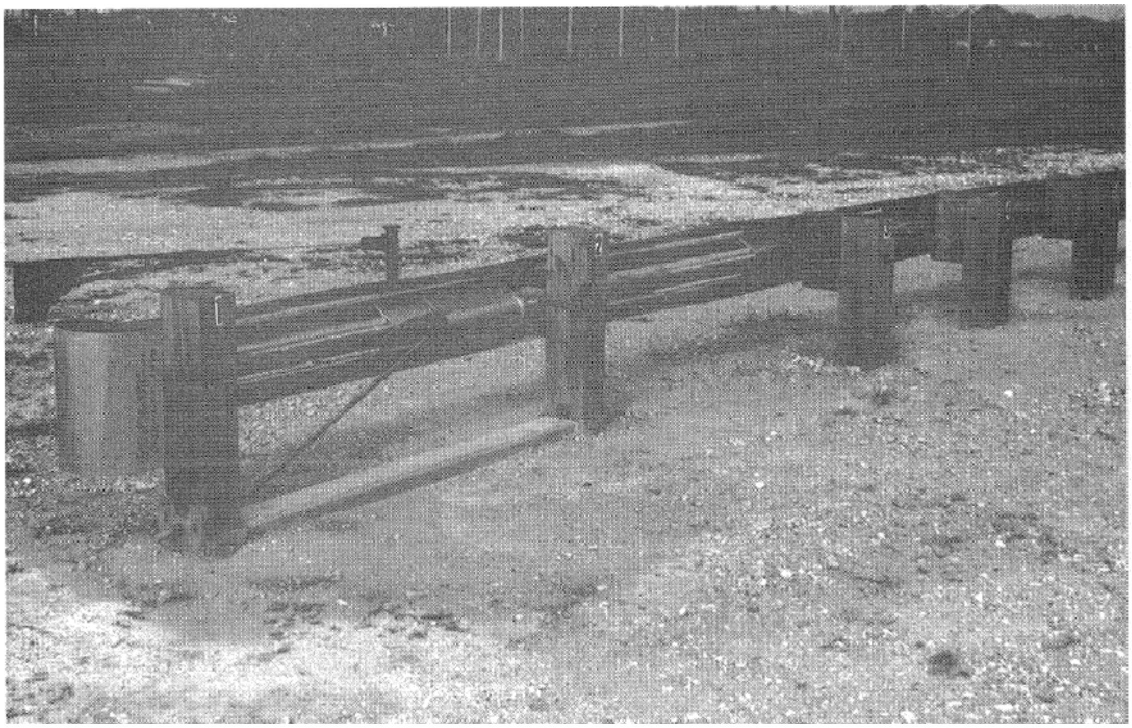


Figure 8.5. Slotted rail terminal (SRT-350) with 1.2 m [4 ft] flare (AASHTO 2002).

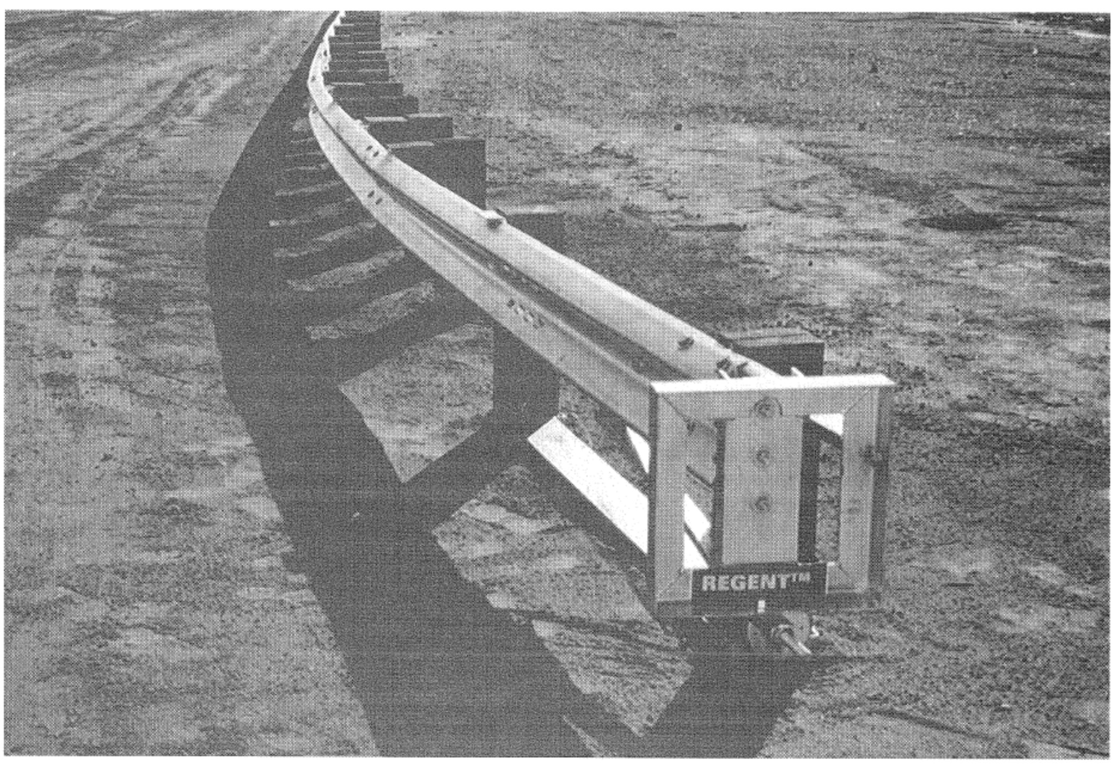


Figure 8.6. REGENT (AASHTO 2002).

8.1.1.7 Vermont Low-Speed, W-Beam Guardrail End Terminal

The Vermont Low-Speed, W-Beam Guardrail End Terminal has been successfully tested to NCHRP Report 350 TL-2 and is appropriate for use on roadways where anticipated impact speeds do not exceed 45 mph. Figure 8.7 shows a Vermont Low-Speed, W-Beam Guardrail End Terminal.

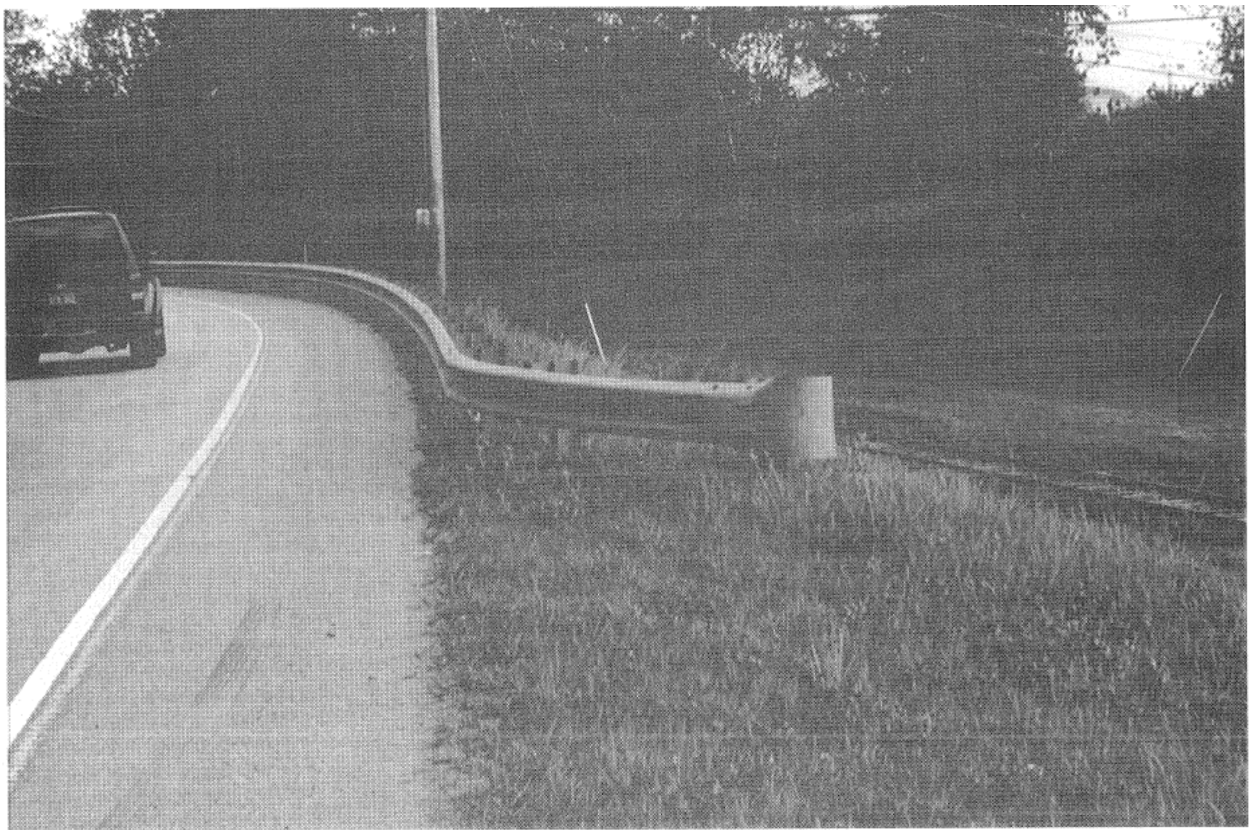


Figure 8.7. Vermont low-speed, W-beam guardrail end terminal (AASHTO 2002).

8.1.1.8 Flared Energy-Absorbing Terminal (FLEAT)

Figure 8.8 shows the FLEAT, a proprietary energy-absorbing terminal. The FLEAT is made up of an impact head mounted at the end of a modified W-beam rail element. Two designs of the FLEAT have been successfully tested to NCHRP Report 350 criteria, one meeting TL-2 and one meeting TL-3. A traversable area behind the terminal is critical.

8.1.1.9 Beam-Eating Steel Terminal (BEST)

Shown in Figure 8.9 is a proprietary energy-absorbing end treatment, the BEST. The BEST has been successfully tested to NCHRP Report 350 TL-3. The BEST consists of an impact head installed on the end of a wood post W-beam guardrail system.

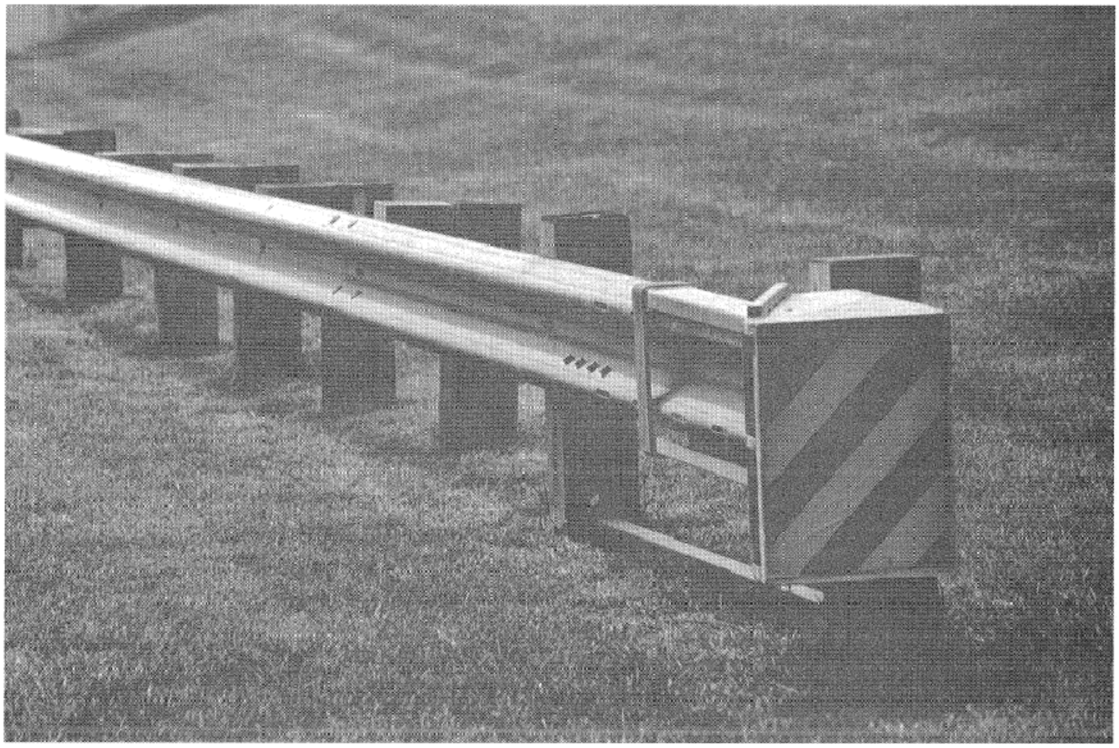


Figure 8.8. Flared Energy-Absorbing Terminal (FLEAT) (AASHTO 2002).

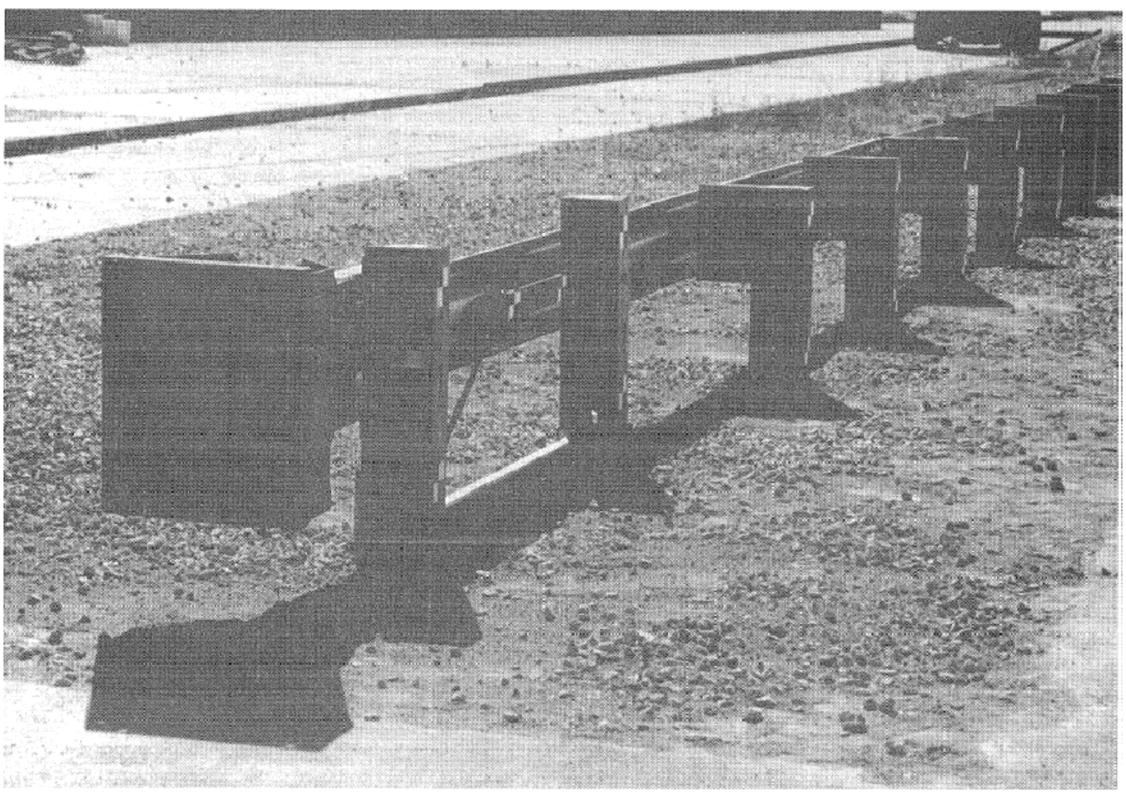


Figure 8.9. Beam Eating Steel Terminal (BEST) (AASHTO 2002).

8.1.1.10 Extruder Terminal (ET-2000)

A proprietary energy-absorbing end treatment consisting of an extruder head installed over the end of a W-beam guardrail element, called the ET-2000, is shown in Figure 8.10. The ET-2000 has been successfully tested to NCHRP Report 350 TL-3. The ET-2000 has acceptable designs with and without breakaway posts.

Figure 8.10. Extruder Terminal (ET-2000) (AASHTO 2002).

8.1.1.11 Sequential Kinking Terminal (SKT-350)

The SKT-350, a proprietary energy-absorbing end treatment, is made up of an impact head installed over the end of a modified W-beam guardrail element. Figure 8.11 shows the SKT-350 which has been successfully tested to NCHRP Report 350 TL-3. The SKT-350 has acceptable designs with steel breakaway posts and with timber posts.

8.1.1.12 QuadTrend-350

Shown in Figure 8.12 is the QuadTrend-350, a proprietary, unidirectional end treatment. The QuadTrend-350 has been tested for direct attachment to vertical concrete barriers or vertical concrete bridge parapets without transition guardrail sections. A concrete pad is required with use of the QuadTrend-350 terminal which has been successfully tested to NCHRP Report 350 TL-3.

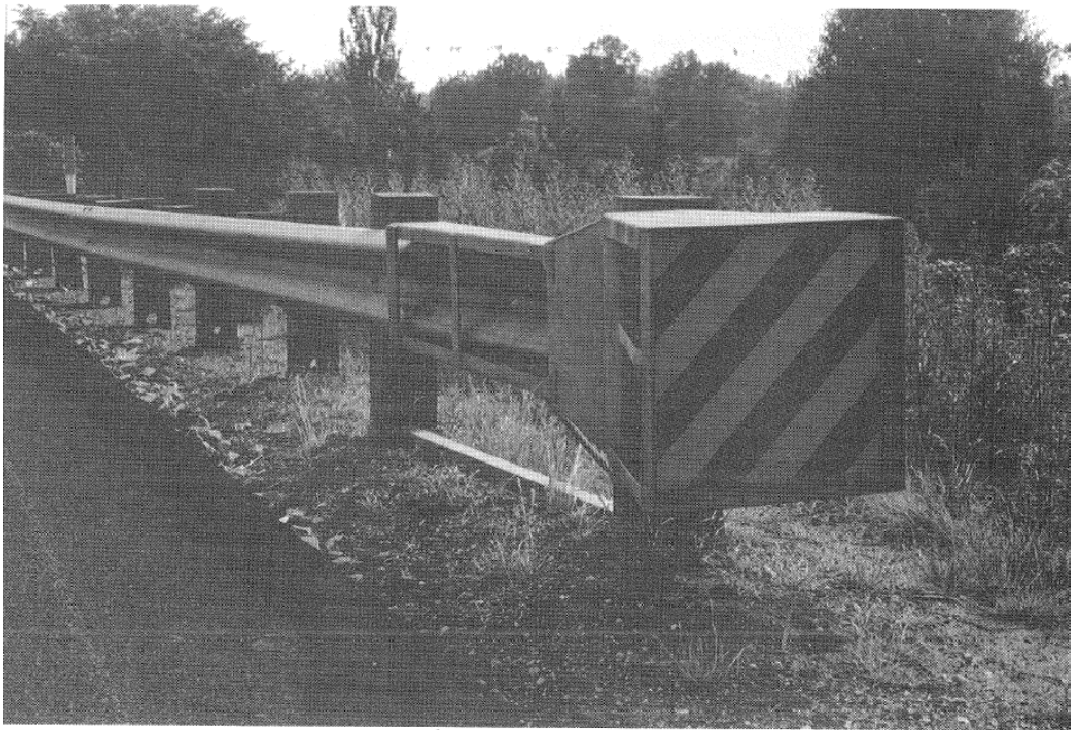


Figure 8.11. Sequential Kinking Terminal (SKT-350) (AASHTO 2002).

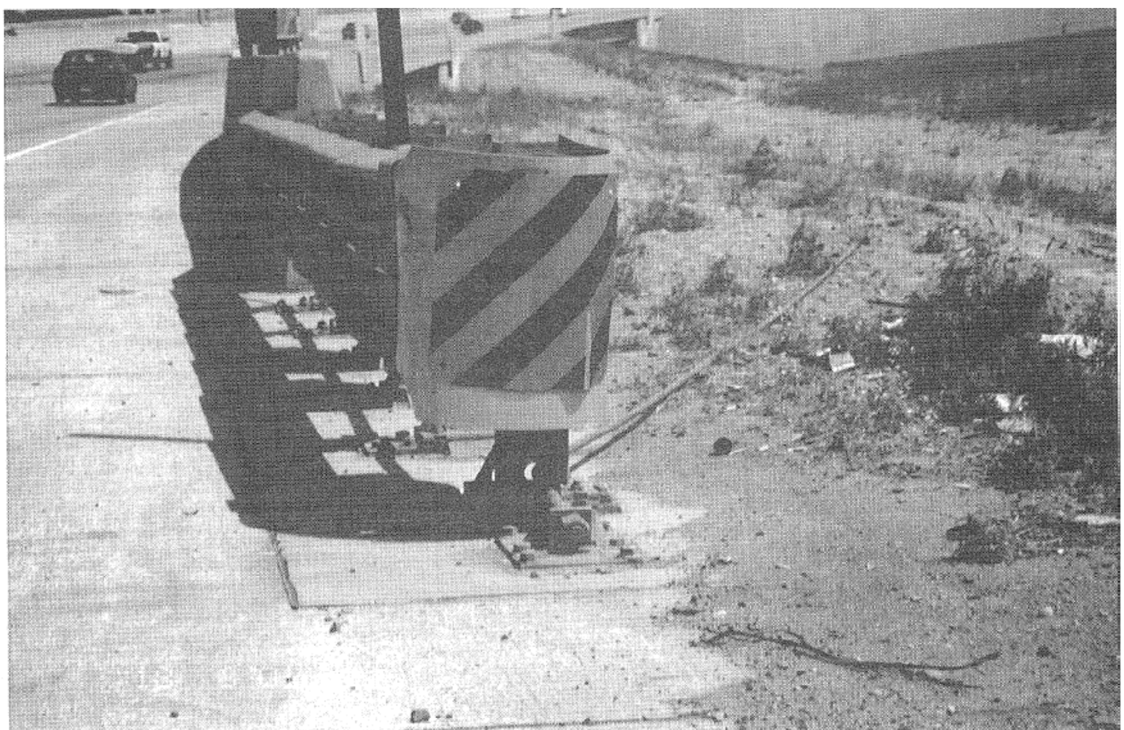


Figure 8.12. QuadTrend-350 (AASHTO 2002).

8.1.2. Innovation and Research on Terminal Ends

Guardrail terminal ends (Reid et al. 1998) may be needed to prevent guardrails from causing harm to vehicle occupants. The SKT-350, designed using computer simulation and verified with the use of bogie and full-scale crash tests, is an energy absorbing guardrail terminal end. A schematic of the system is shown in Figure 8.15. The SKT-350 is approved by the FHWA as meeting all NCHRP Report 350 recommendations.

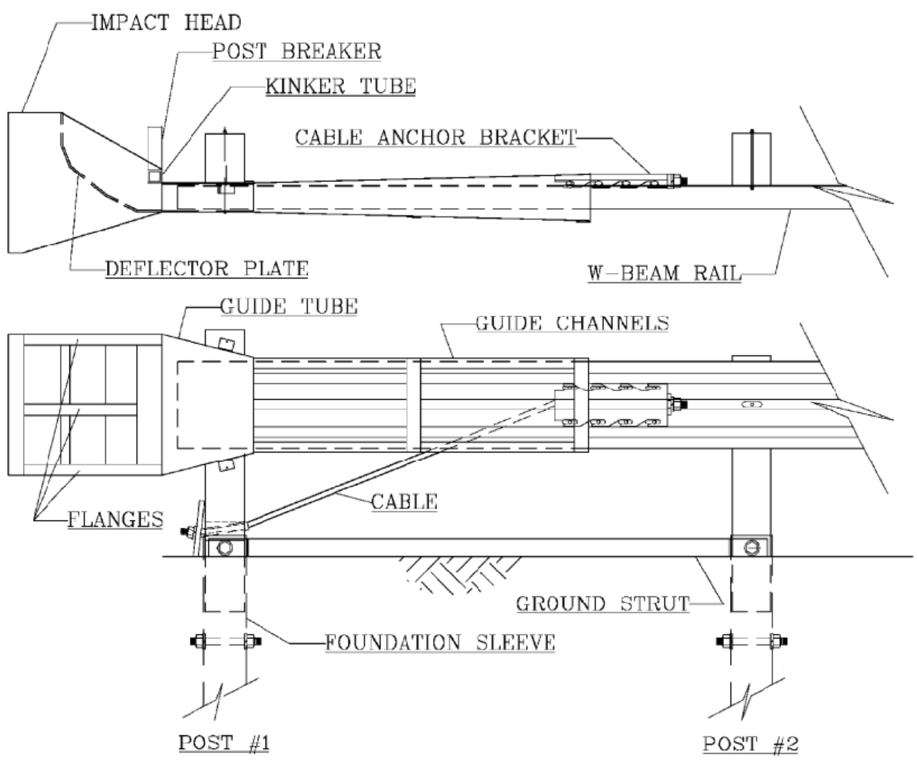


Figure 8.15. Schematic of SKT-350 (Reid et al. 1998).

8.2 Approach Rails

The FHWA (1998) requires that an approach guardrail must be both structurally and functionally adequate. To be considered structurally adequate, the approach guardrail system must include: 1) an adequate connection to the bridge rail, 2) a crash-worthy transition section between the approach guardrail and the bridge rail, and 3) a crash worthy end terminal. To be considered functionally adequate an approach guardrail should smoothly redirect an errant vehicle without snagging, abruptly decelerating, overturning, or penetrating the vehicle compartment.

Approach guardrail must be long enough and in the correct position to shield a vehicle from entering into any of the hazardous areas at a bridge approach. The length and placement of approach guardrail is unique to each bridge and depends upon the types of potential hazards present, bridge approach grading, and other roadside features. Rigid objects protruding more than 4 in. cause a potential hazard capable of abruptly stopping a vehicle, snagging the underside of a vehicle, or initiating vaulting of a vehicle and therefore a guardrail is required for such an object. When the area directly behind the bridge rail presents more of a hazard than other sections of the roadway, a guardrail is essential. To be effective, an approach guardrail must be of sufficient length so as to prevent a vehicle from going around it and into a hazardous area.

In order to prevent pocketing or deflection capable of abruptly stopping a vehicle, approach guardrail should run parallel to the road or be flared away at a rate of 1:15 or flatter and be sufficiently stiffened in the transition. The semi-flexible design of a guardrail must be transitioned (stiffened) to a rigid system before it is connected to the bridge rail to lower the risk of the following: 1) directing a vehicle into the end of the bridge rail (causing excessive deceleration), 2) causing the guardrail to form a pocket which can redirect a vehicle into opposing traffic or bridge rail on the other side, and 3) causing failure of the guardrail system which can direct a vehicle into or behind the bridge rail.

The following is a discussion of existing guardrail systems, new materials being used in guardrail systems, and guardrail terminal ends that, if applicable, can be used for bridge approach rails.

8.2.1. Widely Used Guardrails Rails

A variety of standard sections of roadside barriers can be found in the AASHTO *Roadside Design Guide.* Table 8.2 lists the barriers and their approved test levels.

Table 8.2 Roadside barriers and their approved test levels (AASHTO 2002).

Barrier System (with AASHTO-AGC-ARTBA designation)	Test Level
Flexible Systems	
• 3-Strand cable (Weak Post) (SGR01a & b)	TL-3
• W-Beam (Weak Post (SGR02)	TL-2
• Modified W-Beam (Weak Post) (SGR02)	TL-3
• Ironwood Aesthetic Barrier	TL-3
Semi-Rigid Systems	
• Box Beam (Weak Post) (SGR03)	TL-3
• Blocked-out W-Beam (Strong Post)	
- Steel or Wood Post with Wood or Plastic Block (SGR04a & b)	TL-3
- Steel Post with Steel Block (SGR04a)	TL-2
• Blocked-out Thrie Beam (Strong Post)	
- Wood or Steel Post with Wood or Plastic Block (SGR09a & c)	TL-3
• Modified Thrie Beam (Strong Post) (SGR09b)	TL-4
• Merritt Parkway Aesthetic Guardrail	TL-3
• Steel-Backed Timber Guardrail	TL-3
Rigid Systems (Concrete & Masonry)	
• New Jersey Concrete Safety Shape	
- 810 mm [32 in.] tall (SGM11a)	TL-4
- 1070 mm [42 in.] tall (SGM11b)	TL-5
• F-Shape Barrier	
- 810 mm [32 in.] (SGM10a)	TL-4
- 1070 mm [42 in.] (SGM10b)	TL-5
• Vertical Concrete Barrier	
- 810 mm [32 in.]	TL-4
- 1070 mm [42 in.]	TL-5
• Single Slope Barrier	
- 810 mm [32 in.]	TL-4
- 1070 mm [42 in.]	TL-5
• Ontario Tall Wall Median Barrier (SGM12)	TL-5
• Stone Masonry Wall/Precast Masonry Wall	TL-3

8.2.1.1Three Strand Cable

Many variations of three strand cable barrier have been successfully crash tested for use as a guardrail; however, the barrier has not been tested or standardized for use as approach rail or bridge rail. The required clear area behind the barrier, large barrier deflections caused by impact, and the length of barrier needed to safely redirect errant vehicles are the major disadvantage of being able to use cable barriers for bridges.

8.2.1.2 W-Beam (Weak Post)

Unlike the cable system, the weak post W-beam guardrail system shown in Figure 8.16 is still functional after minor impacts. However, the weak post W-beam is prone to vehicle override when installed at incorrect heights and also because of approach terrain. The original design of the weak-post W-beam system was successfully tested to NCHRP Report 350 TL-2 but with a slightly modified design, TL-3 was achieved.

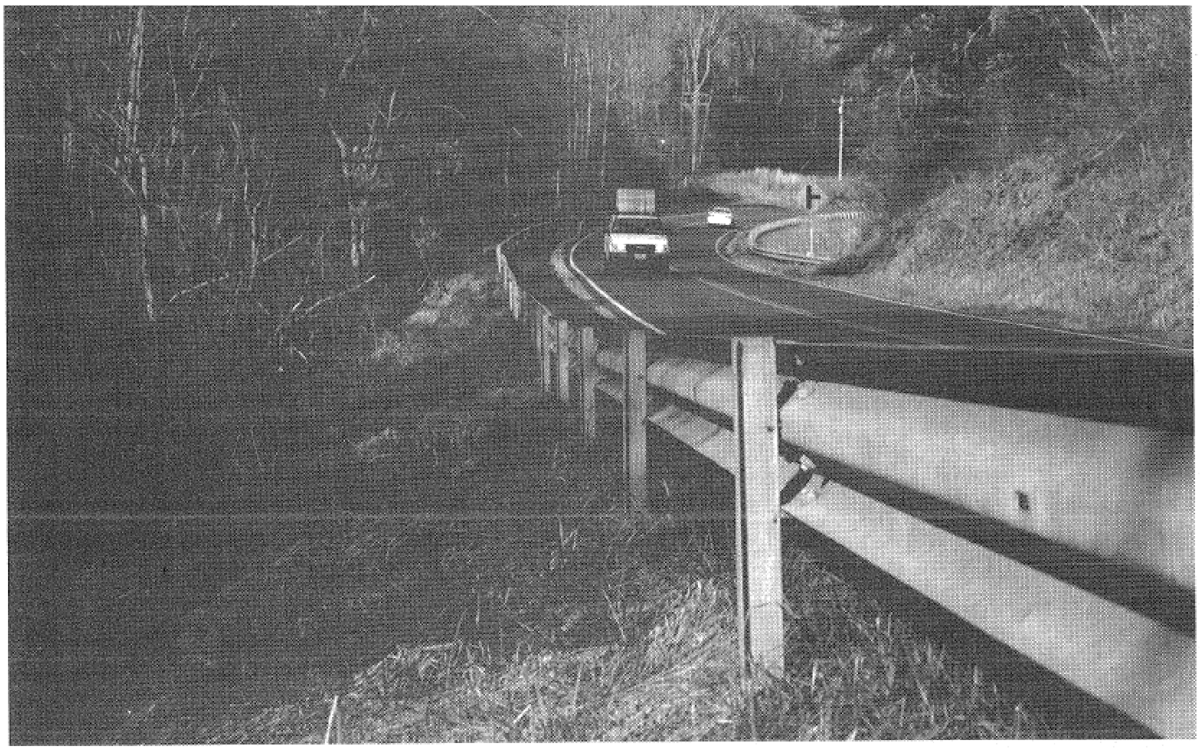


Figure 8.16. Weak post W-beam barrier (AASHTO 2002).

8.2.1.3 Ironwood Aesthetic Guardrail

The ironwood aesthetic guardrail, shown in Figure 8.17, is also a weak post design. One major disadvantage of this system is the lack of crashworthy terminal designs. However, it is acceptable to anchor or flare the barrier. The ironwood aesthetic guardrail system is a proprietary design which has been successfully tested to NCHRP Report 350 TL-3.

8.2.1.4 Box Beam (Weak Post)

Another weak post system is the box beam guardrail shown in Figure 8.18. Like the weak post W-beam system, the box beam system is sensitive to mounting height and terrain irregularities. The weak-post box beam design has been successfully tested to NCHRP Report 350 TL-3.

Figure 8.17. Ironwood aesthetic guardrail (AASHTO 2002).

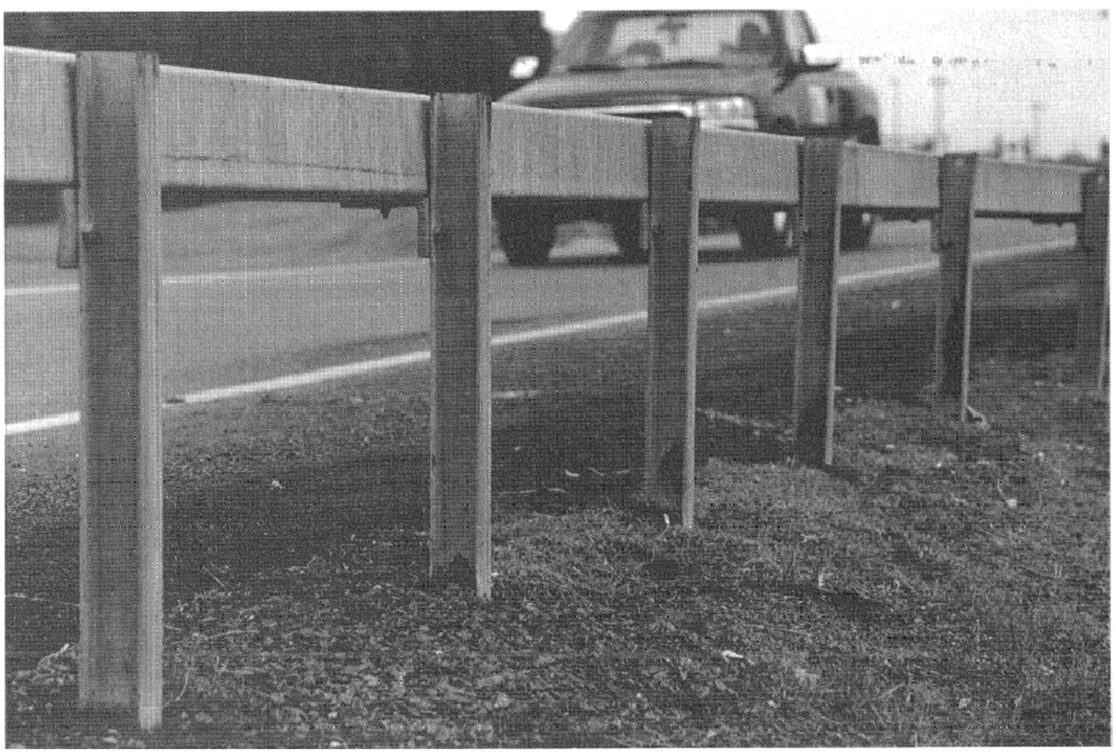


Figure 8.18. Weak post box beam barrier (AASHTO 2002).

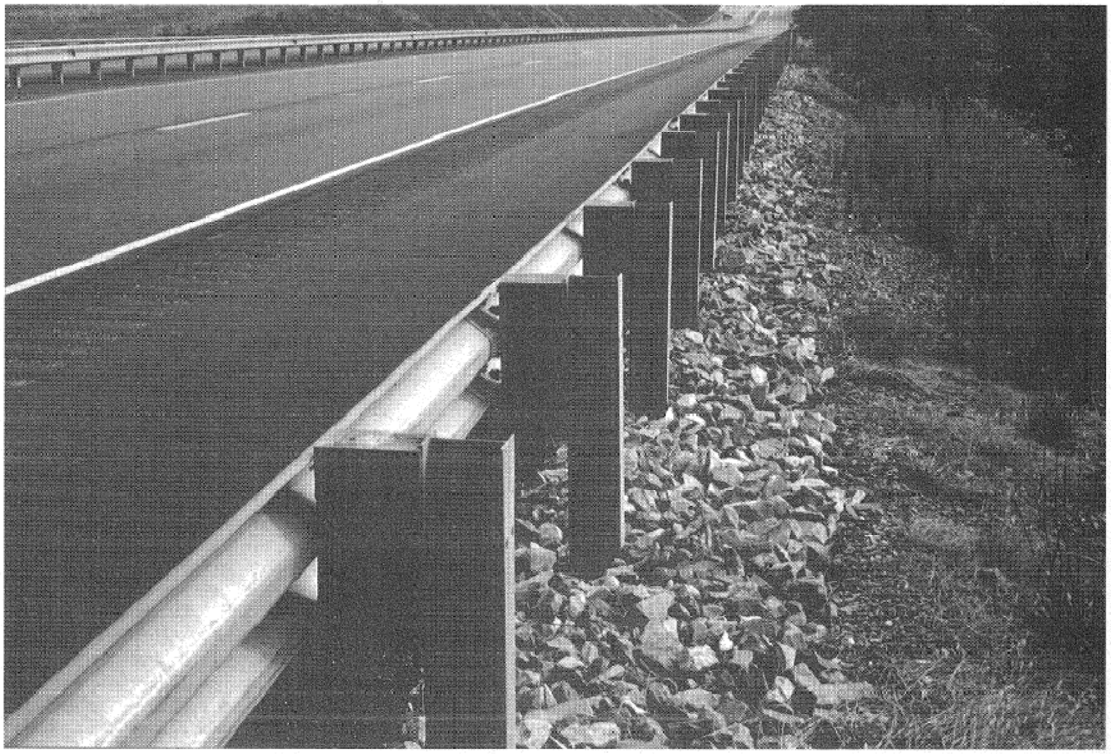


Figure 8.19. Steel post W-beam with wood block-outs (AASHTO 2002).

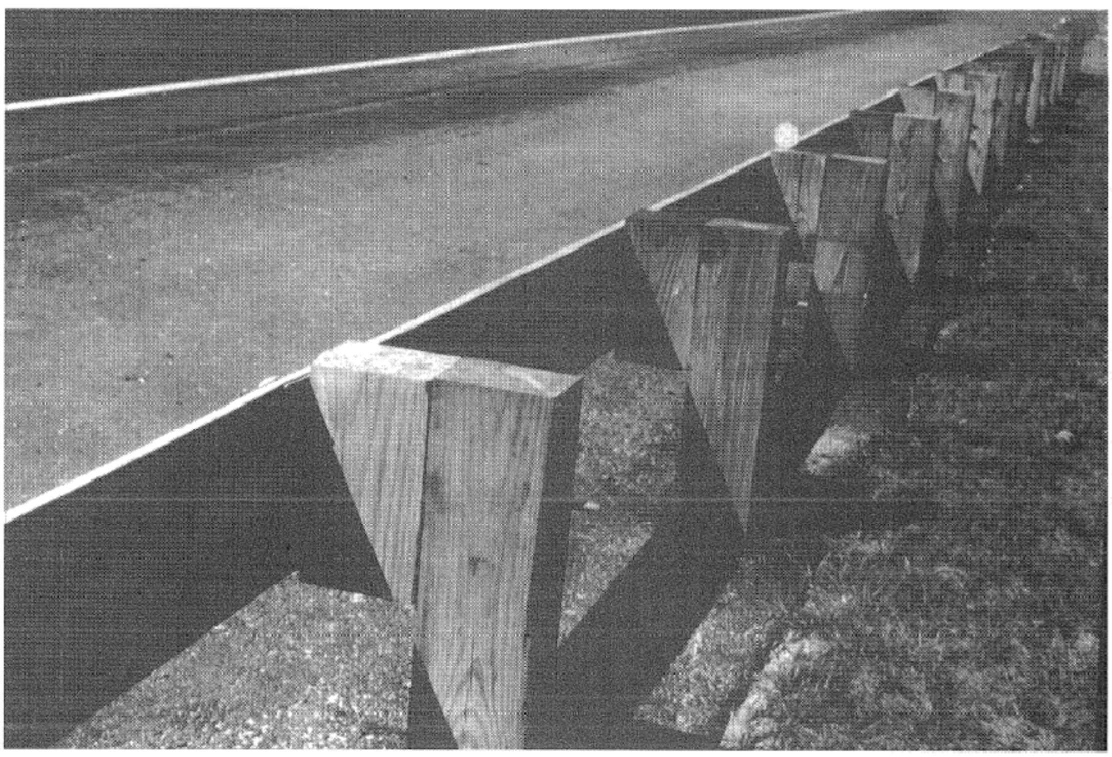


Figure 8.20. Wood post W-beam with wood block-outs (AASHTO 2002).

8.2.1.5 Blocked-Out W-Beam (Strong Post)

The most common guardrail system in use today is the strong post W-beam. Figure 8.19 displays the installation using steel posts and Figure 8.20 displays the installation with wood posts. The use of spacer blocks helps to minimize wheel snagging on the posts and reduce the likelihood of vehicles overriding the rail. The strong post W-beam system has several acceptable designs in use today. The strong post W-beam system has the ability to remain effective after moderate to low speed impacts. Table 8.3 lists the NCHRP Report 350 TL associated with three different designs of the strong-post blocked-out W-beam system.

Table 8.3. NCHRP Report 350 TL of Blocked-Out W-beam (Strong Post) Designs.

Design Elements	Test Level
Wood post with wood block	TL-3
Steel post with routed wood block	TL-3
Steel post with steel block	TL-2

8.2.1.6 Blocked-Out Thrie-Beams

Three blocked-out thrie-beam guardrail systems have been tested under NCHRP Report 350: 1) the wood strong post blocked-out thrie-beam, shown in Figure 8.21, 2) the steel strong post blocked-out thrie-beam, and 3) the modified thrie-beam, shown in Figure 8.22. Thrie-beam systems are stiffer than W-beam systems due to an additional corrugation in the cross-section. This added stiffness makes the system less prone to damage during impacts of low- to moderate-speed. The larger beam allows the rail to be mounted higher, increasing the system’s ability to contain larger vehicles. The modified thrie-beam guardrail system includes the following modifications: 1) a notched steel block-out, 2) omitting rectangular post bolt washers, and 3) increasing the top of rail height.

Installation and maintenance is generally easier for thrie-beam systems as opposed to W-beam/rubrail systems (which has a higher effective height than traditional W-beam system). Also, all three of these thrie-beam systems may remain partially functional after even moderate to severe impacts and do not usually require immediate repair. The NCHRP Report 350 TL associated with three different designs of the strong-post blocked-out thrie-beam system are listed in table 8.4.

Table 8.4. NCHRP Report 350 TL of Blocked-Out Thrie-Beam Designs.

Design	Test Level
Wood post with wood block	TL-3
Steel post with wood block	TL-3
Modified for heavy vehicles	TL-4

Figure 8.21. Wood post thrie-beam barrier (AASHTO 2002).

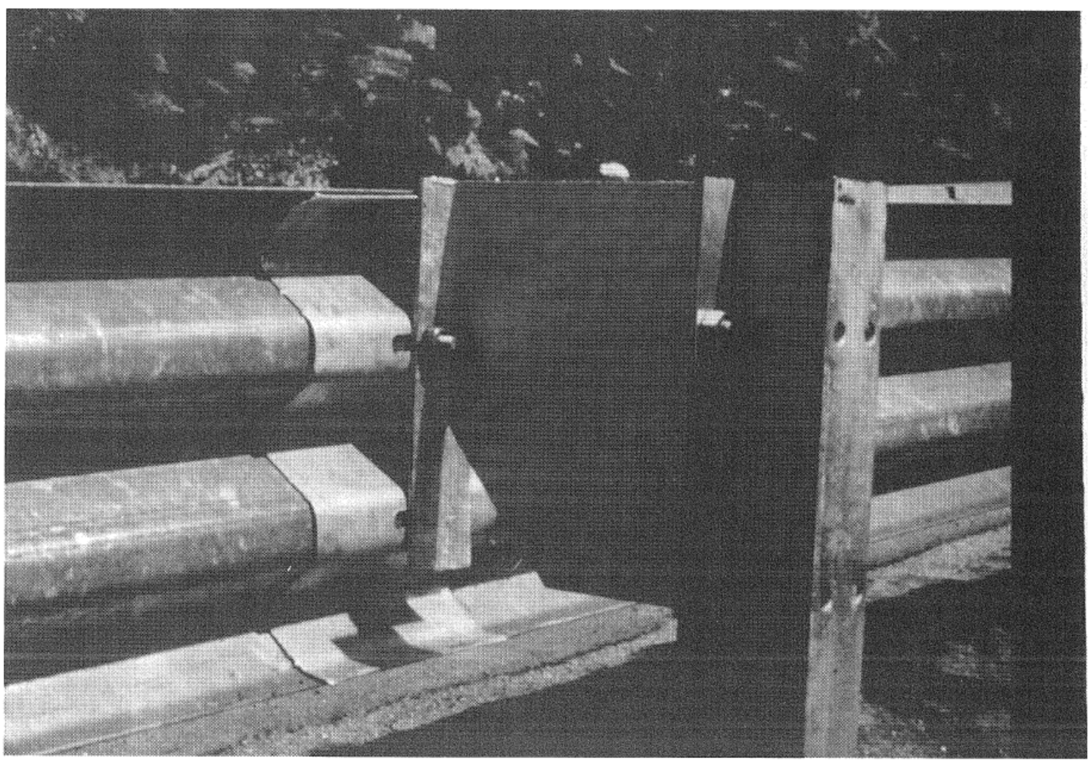


Figure 8.22. Modified thrie-beam guardrail (AASHTO 2002).

8.2.1.7 Steel-Backed Timber Guardrail

The steel-backed timber guardrail system, shown in Figure 8.23, is a semi-rigid barrier. The system was developed as an aesthetic alternative to conventional guardrail systems. The Merritt Parkway Aesthetic Guardrail, developed by the Connecticut Department of Transportation is a version of a steel-backed timber guardrail. The steel-backed timber guardrail system has been successfully tested to NCHRP Report 350 TL-3.

Figure 8.23. Steel-backed timber guardrail (AASHTO 2002).

8.2.2. Innovation and Research on Guardrails Rails

Hiranmayee et al. (2000) conducted a finite element and full scale crash test comparison of the G4(1W) and the G4(2W) guardrail systems. The guardrail systems differ in the size and stiffness of the wood post which support a w-beam. The G4(1W) model has a 50mm wider post than the G4(2W) model and provides 12.5 percent more stiffness.

The results of the testing found that wheel snagging was a significant issue in both simulations. Moderate damage occurred to both types of barriers with the maximum total deflection of the G4(1W) system being approximately 4 percent less than the G4(2W) system.

The G4(1W) guardrail system has not been crash test in accordance with NCHRP Report 350, however, due to similar performances of the finite element simulations of both guardrail systems it is believed the G4(1W) system would satisfy the NCHRP Report 350 requirements.

Another existing guardrail system, the strong-post W-beam is a widely used guardrail system designed in the 1960s. In an attempt to better accommodate vehicles of the time. Reid et al. (2002) has suggested design changes to the strong-post W-beam guardrail that would improve its performance for high center-of-gravity vehicles while maintaining performance for small vehicles and to allow more tolerance for low mounting heights. The design changes included the following:

1) raising the standard rail height to 25 in.
2) moving rail splices to midspan between posts, and
3) increasing blockout size of post bolt slots.

Reid et al. (2002) called the improved strong-post W-beam system the Midwest guardrail system (MwGS), and is shown in Figure 8.23. The MwGS performed adequately in full-scale crash testing with NCHRP Report 350 test criteria. The new guardrail system should have only modestly higher implementation costs than the strong-post W-beam guardrail system.

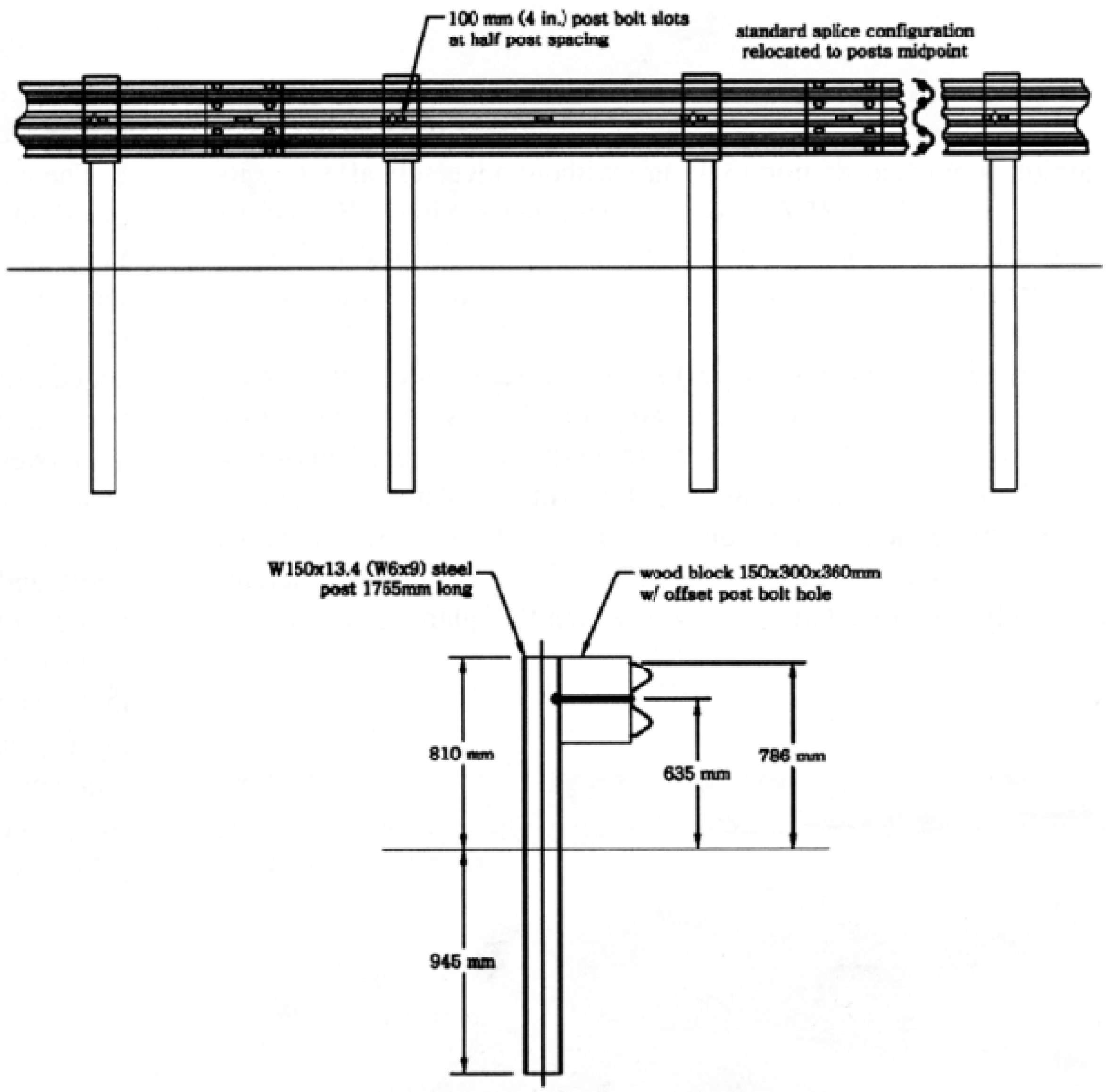


Figure 8.23. MwGS Design (Reid et al. 2002).

Faller et al. (2009) found changing the orientation of the MwGS can reduce its cost. The full-scale crash testing of MwGS installed at various flare rates passed all NCHRP Report 350 safety performance requirements. Increasing the flare rate resulted in advantages such as significantly reducing guardrail lengths and associated costs. An example of the reduction in guardrail length is illustrated in Figure 8.24. The recommendation of Faller et al. is to increase the flare rate of MwGS installations whenever roadside or median slopes are relatively flat (i.e.10:1 or flatter).

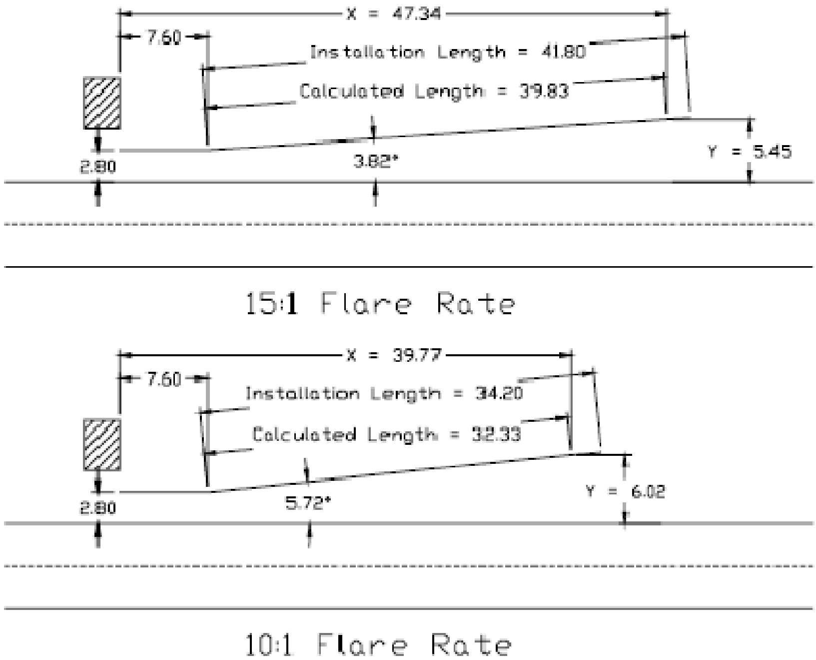


Figure 8.24. Comparison of flared guardrail lengths for MwGS (distances in meters) (Faller et al. 2009).

Alternative materials (Bank et al. 2001) are another way to decrease the cost of a guardrail system. Ongoing research of composite material highway guardrail shows that E-glass/thermosetting polymer composite material guardrails, shown in Figure 8.25, are a potential replacement for steel W-beam guardrails. Laboratory testing showed these composite prototype guardrails have the potential to remain intact under full-scale impacts similar to those tested in NCHRP Report 350. The structural capacity of these guardrails is similar to that of steel W-beam guardrails. According to Bank et al., these composite guardrail have not been crash tested and are under further evaluation.

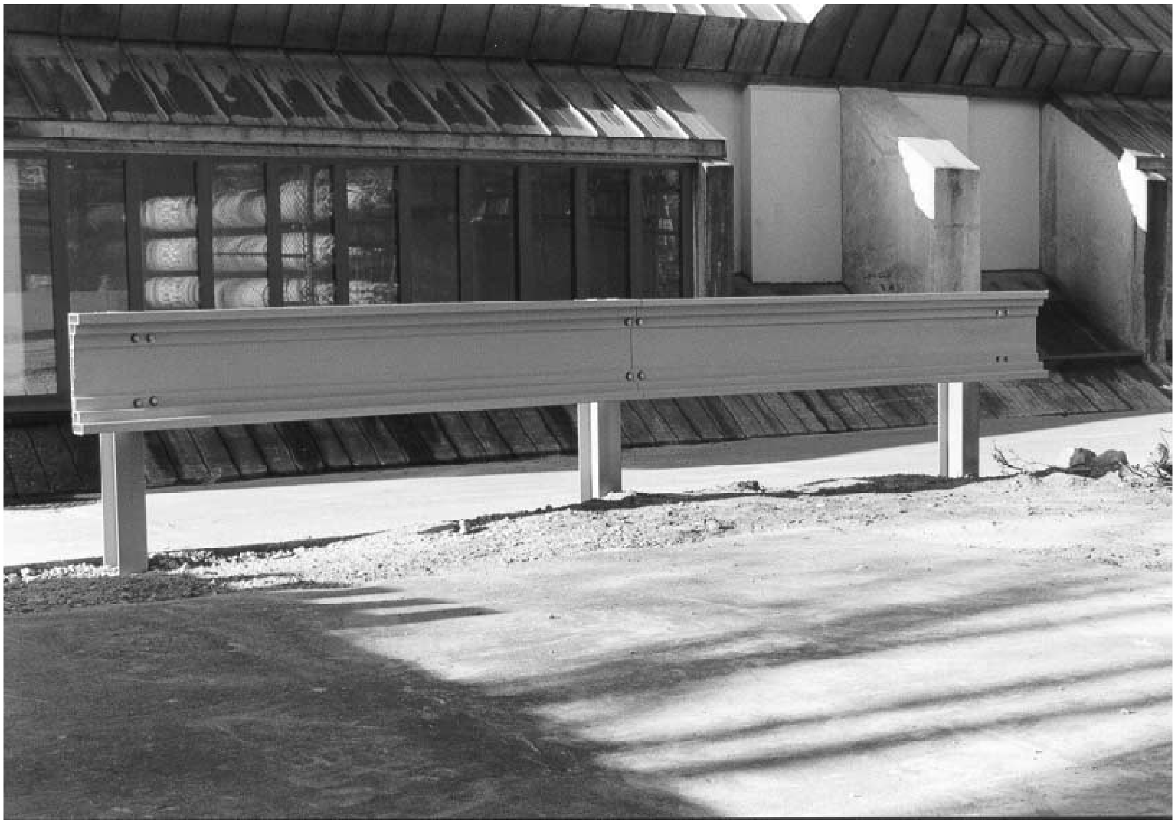
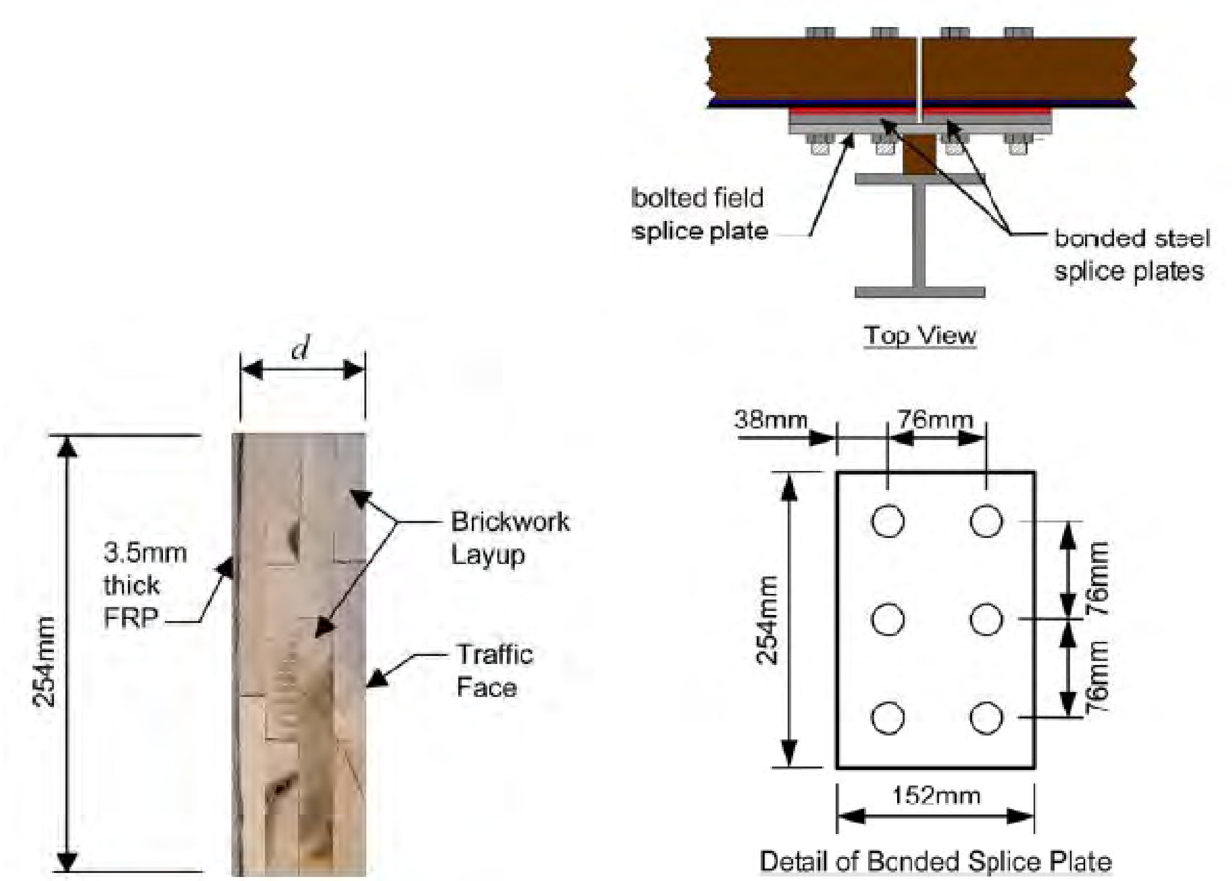


Figure 8.25. Demonstration installation of the composite guardrail (Bank et al. 2001).

The use of glulam (Botting et al. 2006) members compositely connected to fiber-reinforced polymer (FRP) materials can create a lightweight, cost-effective, easy-to-install timber guardrail. The structural performance of the composite system has been tested for flexure and tension by using a hydraulic actuator and three-point bending. Though, this guardrail system was not crash tested, there is high potential for passing the NCHRP TL-3 crash test based upon the completed laboratory test. A unique bonded tension splice was developed and tested for strength and delamination resistance. The splice performed well when tested. Figure 8.26 shows a cross-section of the guardrail and details of the splice connection. Prior to highway use, this guardrail system must undergo proper crash testing and more rigorous testing to establish its long term durability.



a. FRP-glulam guardrail cross-section **b. Splice connection**

Figure 8.26 Guardrail cross-section and splice connection details (Botting et al. 2006).

8.3 Bridge Rail

The FHWA (1998) requires that a bridge rail must be both structurally and functionally adequate. To be considered structurally adequate, the bridge rail system must be capable of withstanding the impact of a vehicle and redirecting the impacting vehicle. To be considered functionally adequate bridge rails must be crash worthy.

According the FHWA, consideration should be given to replacement of substandard bridge rails as part of any future bridge rehabilitation, reconstruction or replacement project. Adding a continuous section of standard guardrail in front of and attached to the existing bridge rail is the most common manner of upgrading substandard bridge rail. This method of upgrade can be very cost effective.

8.3.1. Widely Used Bridge Rails

8.3.1.1 Side-Mounted, Thrie-Beam Bridge Railing

The side-mounted, thrie-beam bridge railing, a non-rigid bridge railing, is shown in Figure 8.27. The bridge rail system has not been crash tested to NCHRP Report 350 criteria, but is considered equivalent to a TL-2 design. The side-mounted, thrie-beam system is advantageous because of its relative simplicity and low cost.

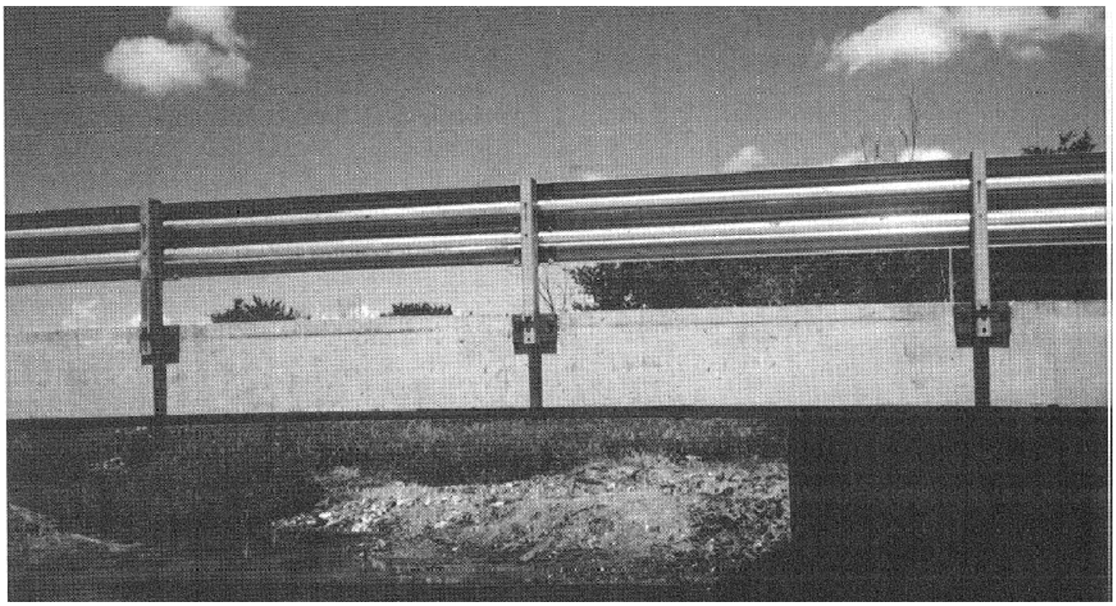


Figure 8.27 Side-mounted, thrie-beam bridge railing (AASHTO 2002).

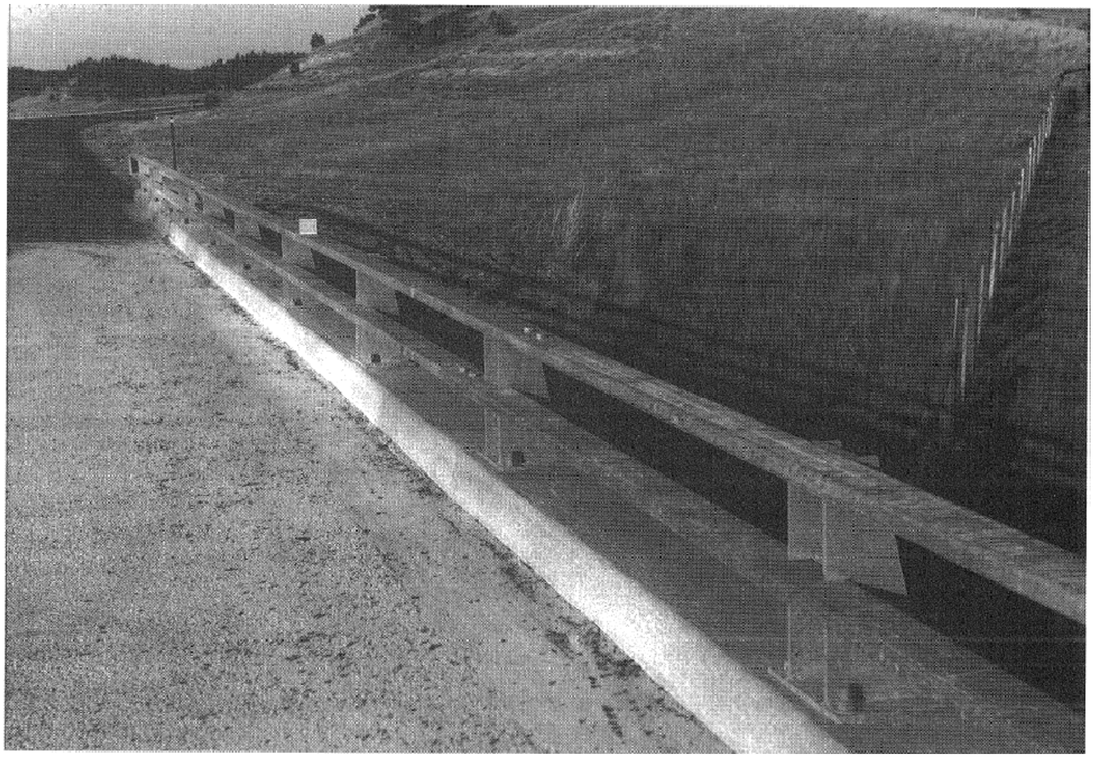


Figure 8.28. Wyoming two-tube bridge railing (AASHTO 2002).

8.3.1.2 Wyoming Two-Tube Bridge Railing

The Wyoming Two-Tube Bridge Railing is shown in Figure 8.28. The design shown in Figure 8.28 has been successfully tested to NCHRP Report 350 TL-3 and a similar design with larger elements was successfully tested to TL-4.

The S3 Steel Bridge Railing is a system which can be mounting flush on the outside of a sidewalk, as shown in Figure 8.29, or directly on an 8 in. curb. This bridge rail system provides an aesthetic look and satisfies all AASTHO pedestrian rail geometrics.

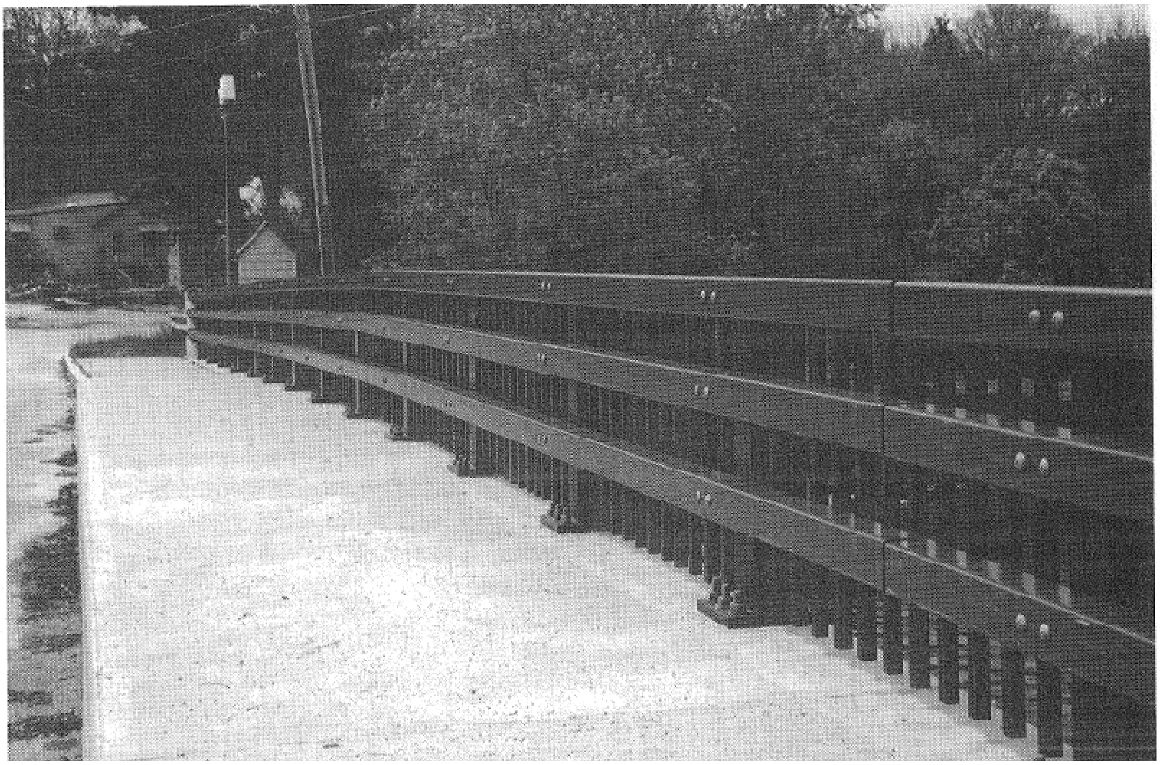


Figure 8.29. Massachusetts S3 steel bridge railing (AASHTO 2002).

8.3.2. Innovation and Research on Bridge Rails

The Texas T-6 bridge rail system (Abu-Odeh et al. 2003), a breakaway rail system designed for use on culvert headwalls and thin bridge decks, is widely used in Texas. In a full-scale crash test the T-6 bridge rail system failed to meet NCHRP Report 350 criteria for TL-3 because the vehicle rolled on its side. Results of the crash test indicated the T-6 rail system was not tall enough to prevent rollover. Modification of the system by replacing the tubular W-beam with a tubular thrie beam was proposed and analyzed using finite element analysis (FEA) techniques. Results of the FEA efforts indicated that the T-6 rail system with the tubular thrie beam would pass NCHRP Report 350 criteria for TL-3.

Nebraska's open concrete bridge rail (Faller et al. 2004) was attached to an inverted tee bridge deck system and was full-scale crash tested according to NCHRP Report 350 TL-4 criteria. Figure 8.30 shows the open concrete bridge rail system. The bridge performance under full-scale crash testing was considered acceptable with only minor cracking to the bridge deck and railing.

Figure 8.30. Layout for open concrete bridge rail attached to inverted tee bridge deck system (Faller et al. 2004).

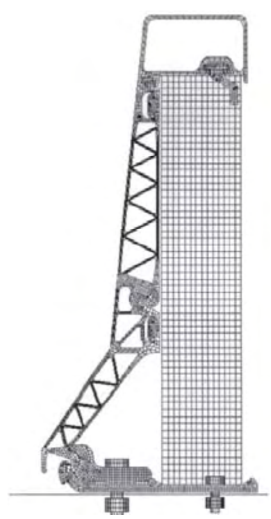


Figure 8.31. Finite element model of the aluminum parapet bridge railing (Oldani et al. 2004).

Oldani et al. (2004) compared the strength of the F-shape parapet, shown in Figure 8.31, and the F-shape aluminum median barrier bridge railing with the strength of previously crash tested F-shape barriers. The likely performance of the aluminum F-shape barrier was assessed in nonlinear dynamic finite element simulations for the NCRHP Report 350 TL-3. The test barrier deformations, material stress and other structural performance parameters were found to be acceptable and even showed the barrier has considerable reserve capacity. Therefore, it is inferred that crash tests with aluminum bridge parapet railings are very likely to result in acceptable performance in test level three and four conditions. Rigid F-shape barriers are considered to satisfy TL-3, because the aluminum parapet railing can be considered a rigid F-shape barrier.

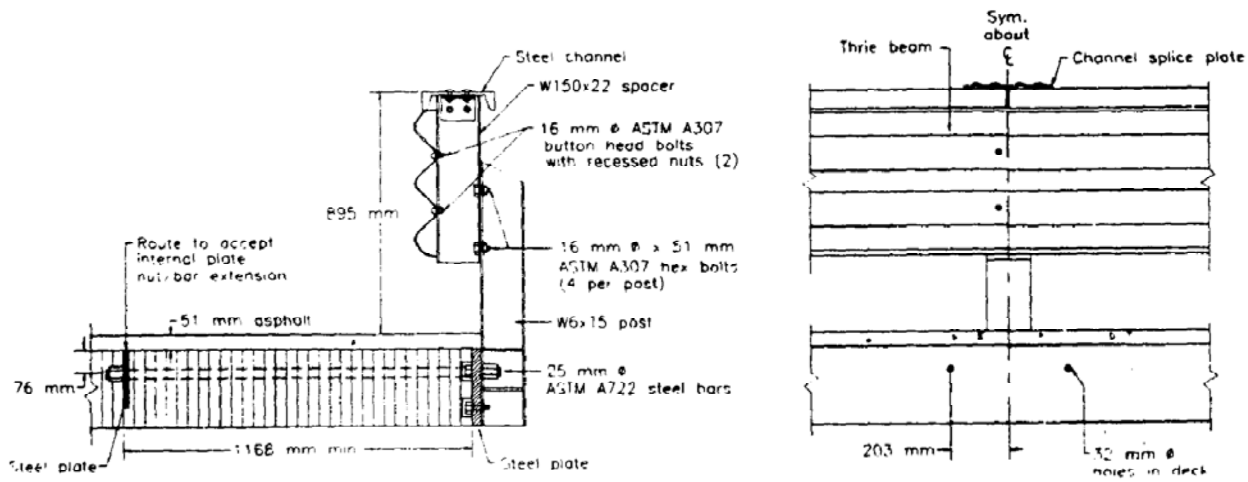


Figure 8.32. Steel thrie beam bridge railing successfully crash tested to AASHTO PL-2 (Duwadi et al. 1995).

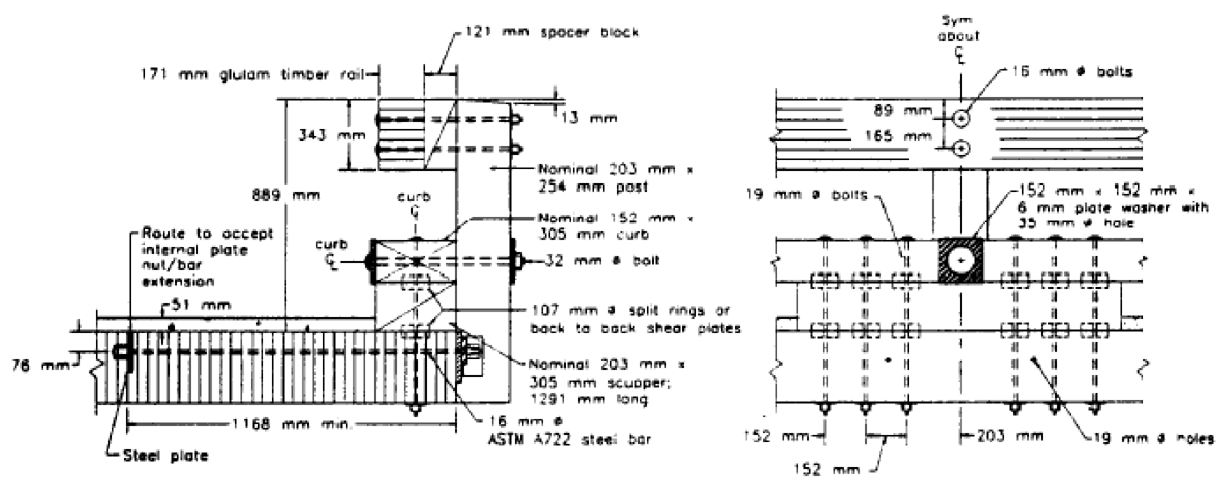


Figure 8.33. Glulam timber bridge railing successfully crash tested to NCHRP Report 350 TL 4 (Duwadi et al. 1995).

Duwadi et al. (1995) discusses five bridge railing systems which were successfully developed and tested for longitudinal wood decks. Three of these railings were tested at AASHTO PL-1, one was tested at PL-2, and one was tested at NCHRP Report 350 TL-4. Each railing was tested on a glulam timber deck and is adaptable to both spike-laminated and stress-laminated decks. Shown in Figures 8.32 and 8.33 are schematics of two of the bridge railing systems. No damage to the test bridge was evident from any of the vehicle impact tests. For the railing systems with glulam timber rails, the railing remained intact and serviceable after the tests, and replacement of the railing was not considered necessary. For the steel thrie beam rails, permanent deformation occurred in the rail and post in the vicinity of the impact location, necessitating replacement in sections.

The performance (Faller et al. 1995) of the TBC-8000 bridge rail system, shown in Figure 8.34, and the GC-8000 bridge rail system, shown in Figure 8.35, were evaluated on AASTHO PL-2 criteria and are both acceptable. Both bridge rail systems are recommended for use on longitudinal timber bridges. The TBC-8000 is an economical, low construction cost bridge railing for longitudinal timber bridges

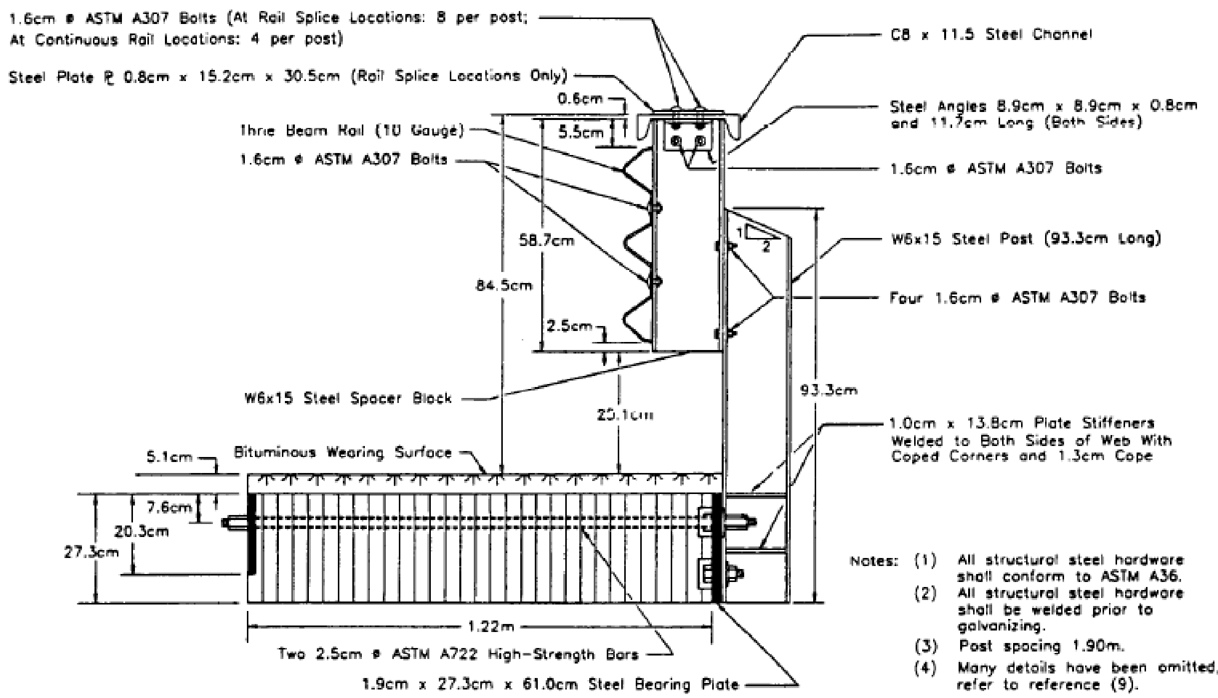


Figure 8.34. Thrie beam with channel bridge railing (TBD-8000) (Faller et al. 1995).

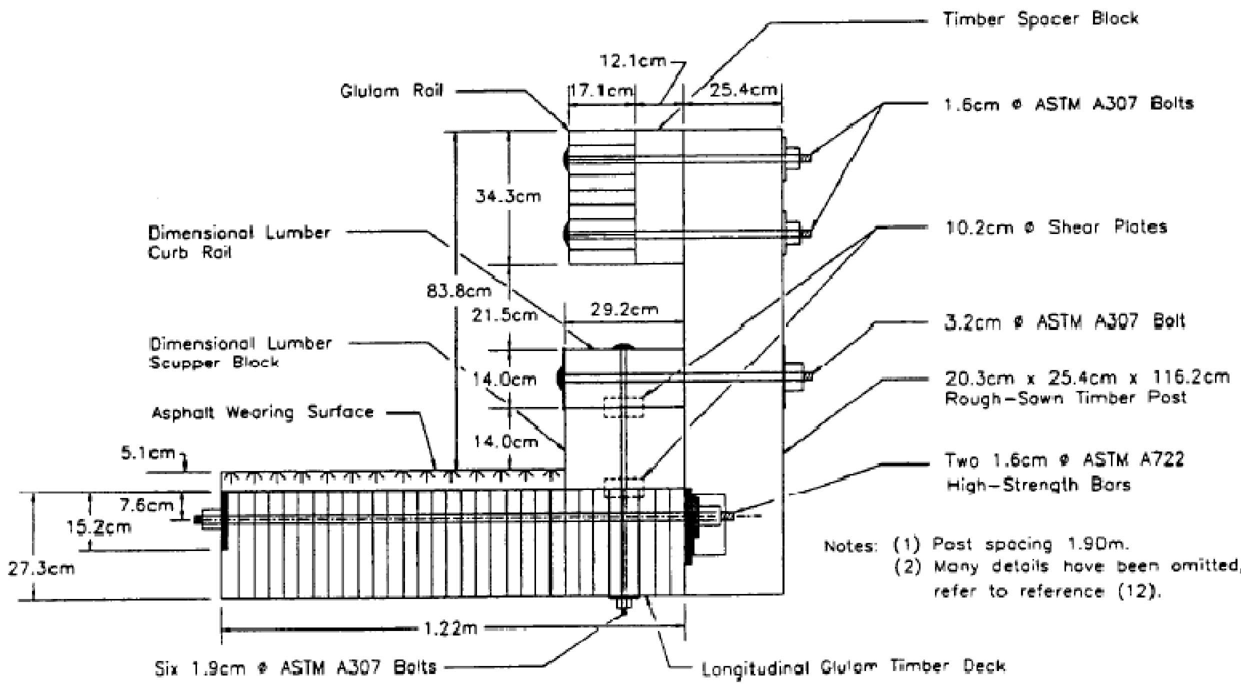
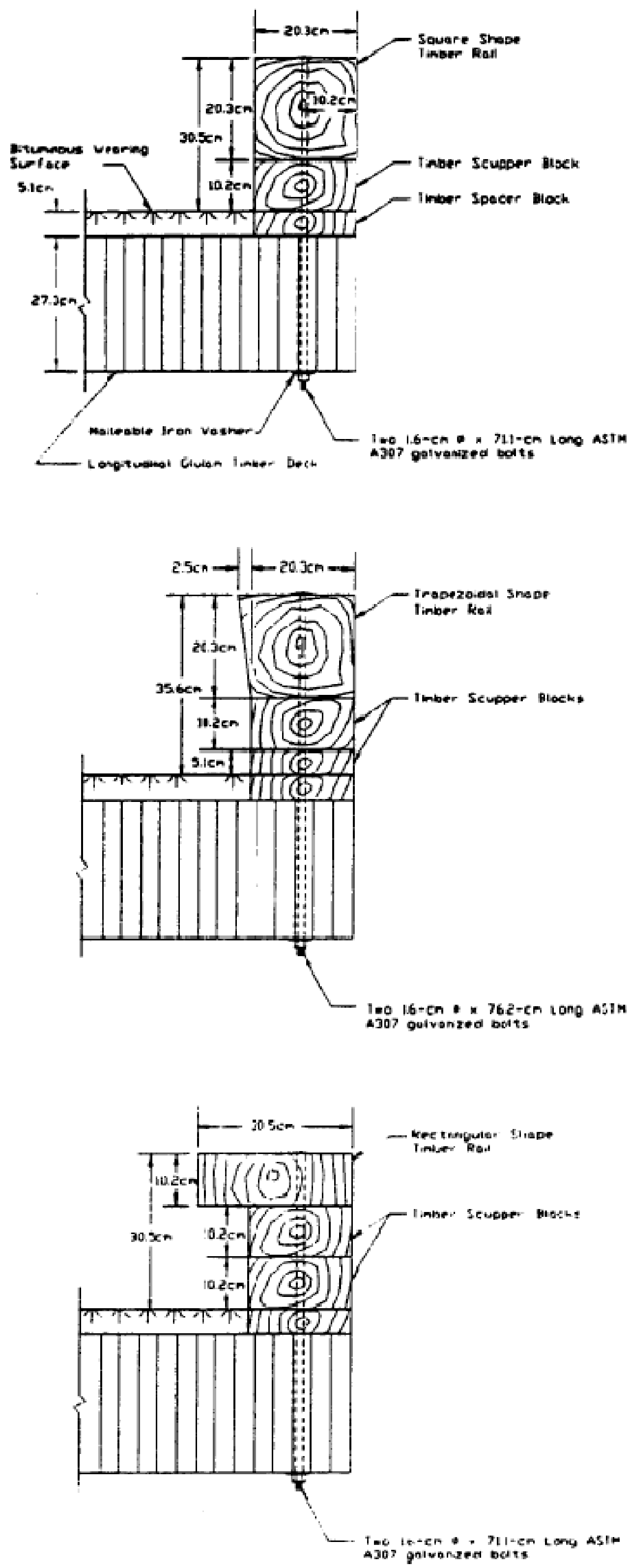


Figure 8.35. Thrie beam with channel bridge railing (TBD-8000) (Faller et al. 1995).

The following two bridge rail systems were developed for U.S. Forest Service utility and service loads, for roads with very low traffic volumes, and for roads with operating speeds of 15 to 20 mph. The two low-cost bridge railing systems: 1) a curb-type timber railing system and 2) a flexible railing system were developed for use on longitudinal timber bridge decks with low traffic volumes and speeds. Both railing systems include low material costs, low construction labor costs, and minimal repair costs. Both railing systems could easily be adapted to various timber bridge deck types.

The curb-type railing was tested using NCHRP Report 350 TL-1 conditions. A ¾-ton pickup truck operating at a speed of 15 mph and an angle of attack of 15 degrees were used for the testing. In full-scale crash testing a 12 in. high square-shaped bridge rail showed successful performance. Findings from a developmental testing program gave reason to believe that a 14 in. high trapezoidal and a 12 in. high rectangular shaped bridge rail would behave similarly to the square-shaped rail, though full-scale testing was not performed on these shapes. All three curb-type railing shapes are shown in Figure 8.36.



(a)

(b)

(c)

Figure 8.36. (a) Square-shaped curb, (b) trapezoidal-shaped curb, (c) rectangular-shaped curb. (Bunnell et al. 1995).

The flexible railing system, consisting of steel W-beam supported by breakaway timber posts, was successfully tested to NCHRP Report 350 TL-1 conditions (Bunnell et al. 1995). The flexible railing system is illustrated in Figure 8.37.

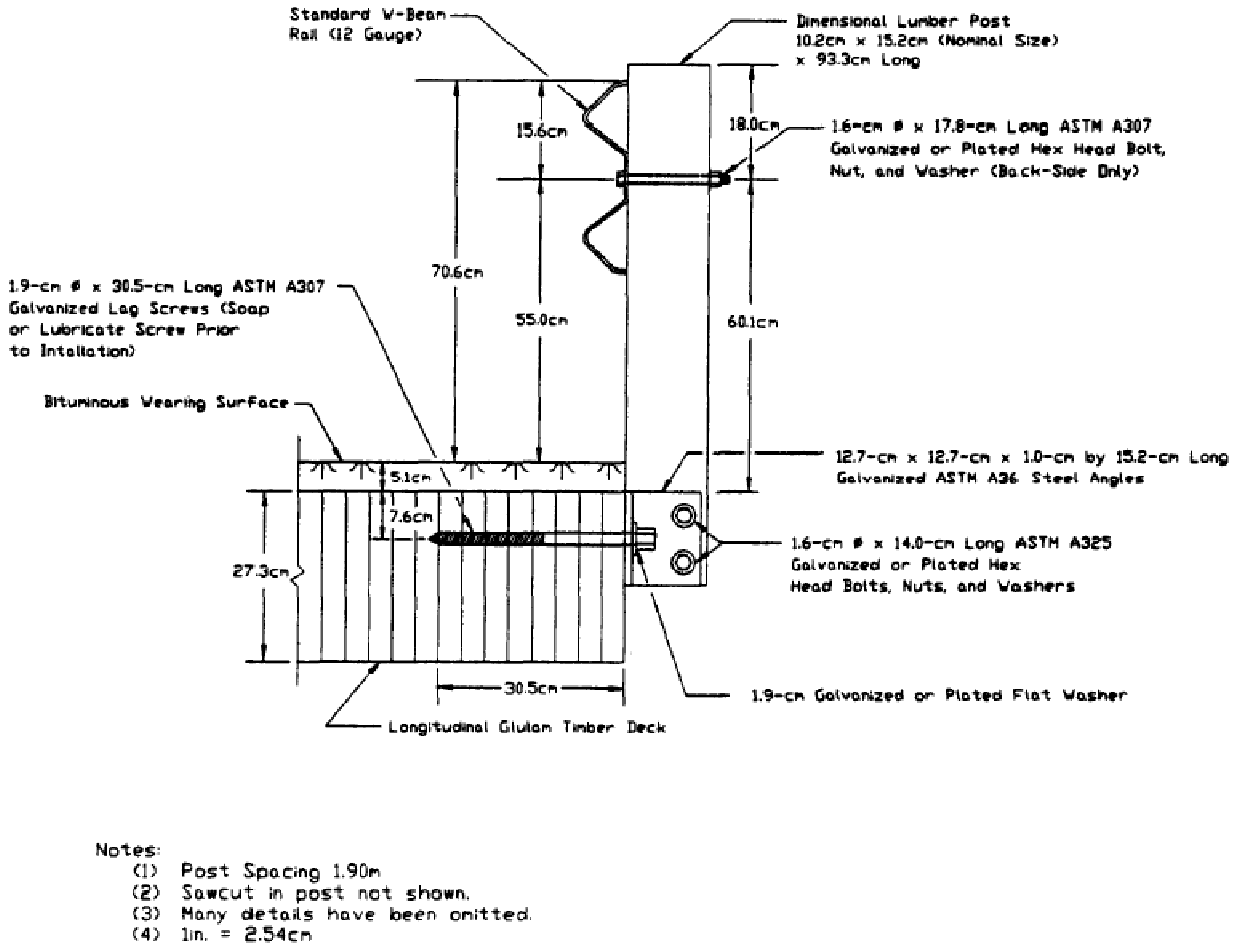


Figure 8.37. Modified breakaway bridge railing (Bunnell et al. 1995).

Two bridge railing systems (Duwadi et al. 1999)., for use on transverse wood bridge decks of thickness no greater than 5.1 in., were developed and tested to according to NCHRP Report 350 TL-4 criteria. One railing system was a glulam timber railing and the other was a steel thrie-beam railing, shown in Figure 8.38. Significant damage was not evident to the test bridge superstructure after the crash tests. Replacement of the glulam railing was deemed unnecessary. The steel thrie-beam railing incurred permanent deformation in the rail and post which necessitated replacement of specific portions near the impact location

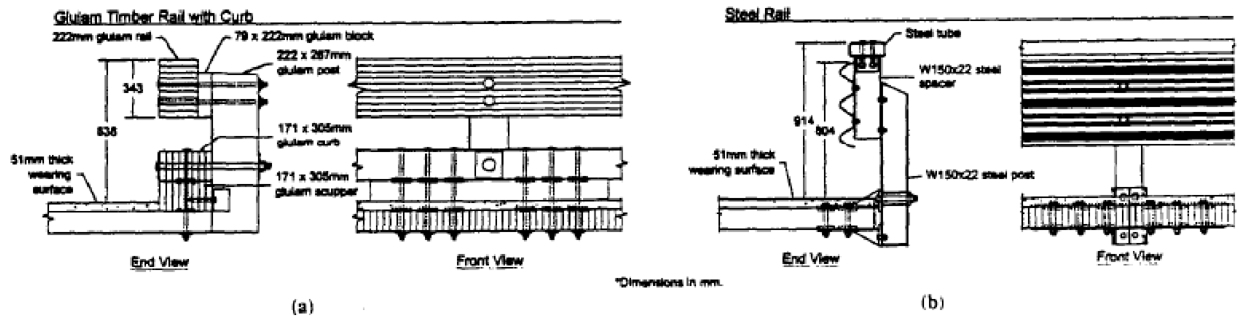
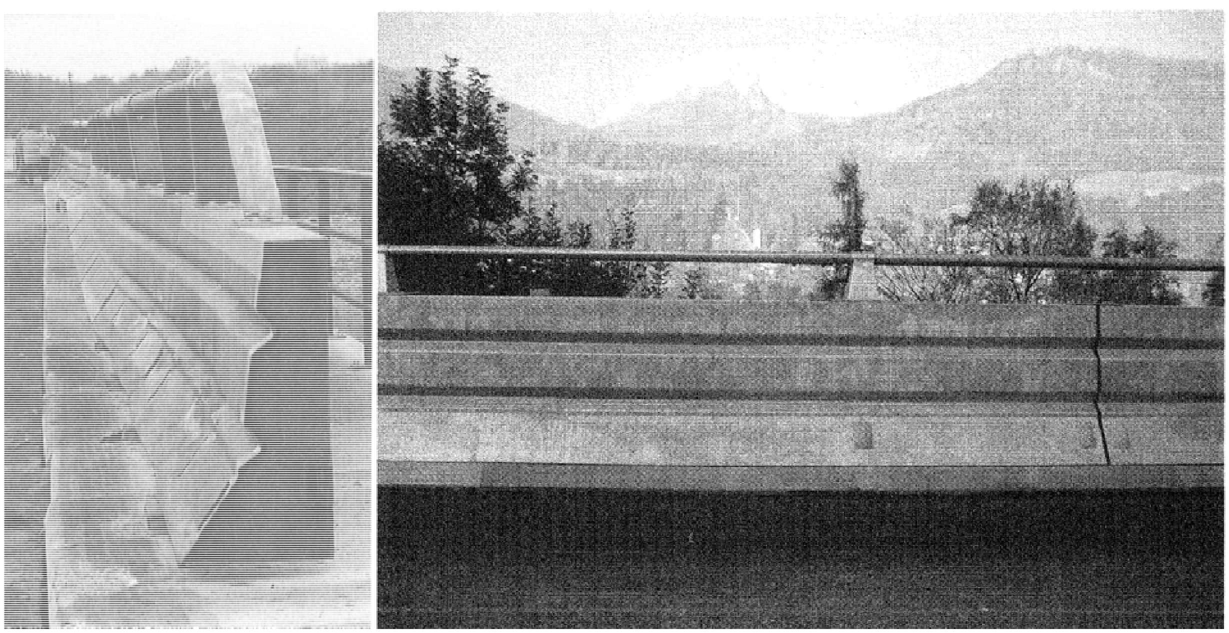


Figure 8.38. (a) Glulam timber bride railing successfully crash tested to NCHRP Report 350 TL-4 (transverse deck); (b) steel thrie-beam bridge railing successfully crash tested to NCHRP Report 350 TL-4 (transverse deck) (Duwadi et al. 1999).

The MDS Bridge Railing, shown in Figures 8.39a and b, is a proprietary design. The unique sliding base plate used in this design is intended to dissipate energy from an impact and also minimize the forces transferred to the bridge deck (FHWA. 2008). There are two designs of the system, the MDS-4 and MDS-5; both are all steel safety-shape barriers. The MDS-4 and MDS-5 are suitable for NCHRP Report 350 TL-4 and TL-5 conditions, respectfully. Both versions have an optional noise barrier which does not contribute to the safety performance of the railing. Figure 8.40 shows a schematic of the design.



a. MDS after impact **b. MDS Bridge Railing installation**

Figure 8.39. MDS Bridge Railing (Trinity).

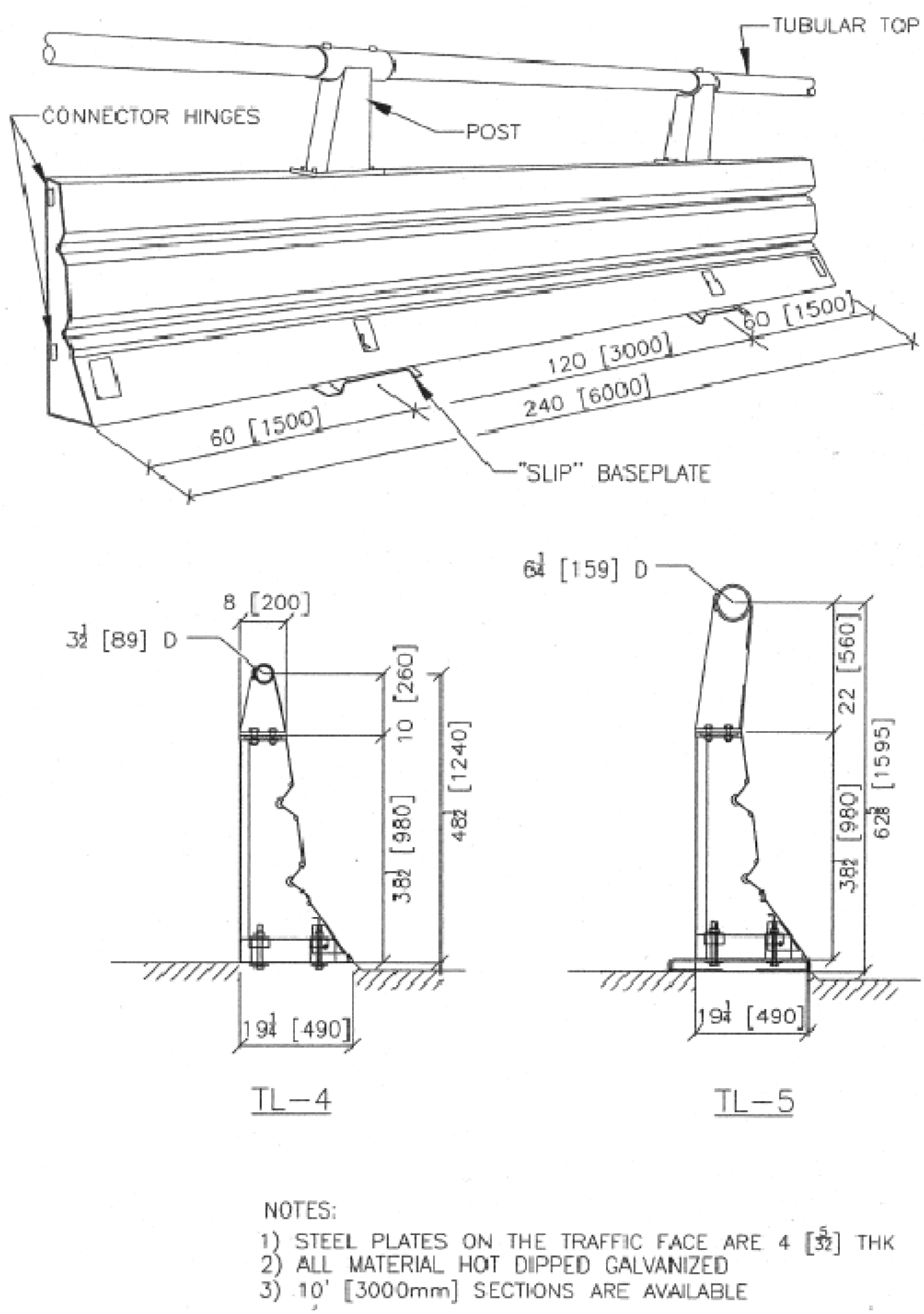


Figure 8.40. MDS Bridge Railing Design (Trinity).

9. SUMMARY, CONCLUSION, AND RECOMENDATIONS

Bridge rail and approach guardrails provide safety to drivers by shielding more hazardous objects and redirecting vehicles to the roadway. However, guardrail can increase both the initial cost and maintenance cost of a bridge, while adding another object that may be struck by vehicles. Most existing low volume road (LVR) bridges are currently indicated to not possess bridge rail meeting “current acceptable standards”. The primary objective of the research summarized in this report was to provide the nations state of practice and perform a state wide crash analysis on bridge rails and approach guardrails on LVR bridges in Iowa. In support of this objective, the criteria and guidelines used by other bridge owners were investigated, non-standard and innovative bridge and approach guardrails for LVR’s were investigated, and descriptive, statistical and economical analyses were performed.

Guidelines for Geometric Design of Very Low-Volume Local Roads (ADT<400vpd) recommends that safety improvements should only be initiated when a safety problem exists at a site. Additionally, the *Geometric Design Guide* states that a one lane bridge can be used for roads with a traffic volume less than 100 vehicles per day.

According to the Federal Highway Administration (FHWA), adding a continuous section of standard guardrail in front of, and attached to, the existing bridge is the most economical manner of upgrading a substandard bridge rail. The retrofitted bridge rails should be assessed to ensure structural and functional adequacy. To accomplish this, approach railing and terminals should be chosen in accordance with NCHRP report 350 Test Level (TL) 1, 2, or 3. The AASHTO Performance Level (PL) of the railing should also be evaluated.

The overall number of crashes at/on the more than 17,000 inventoried LVR bridges and unknown number of non-inventoried LVR bridges in Iowa was fewer than 350 crashes over an eight year period, representing less than 0.1% of the statewide reportable crashes. In other words, LVR bridge crashes are fairly rare events. The majority of these crashes occurred on bridges with a traffic volume less than 100 vpd and width less than 24 ft. Similarly, the majority of the LVR bridges possess similar characteristics.

Crash rates were highest for bridges with lower traffic volumes, narrower widths and negative relative bridge widths. Crash rate did not appear to be effected by bridge length. Statistical analysis confirmed that the frequency of vehicle crashes was higher on bridges with a lower width compared to the roadway width.

The frequency of crashes appeared to not be impacted by weather conditions, but crashes may be over represented at night or in dark conditions. Statistical analysis revealed that crashes that occurred on dark roadways were more likely to result in major injury or fatality. These findings potentially highlight the importance of appropriate delineation and signing.

System wide, benefit-cost analyses yielded very low B/C ratios for statewide bridge rail improvements. This finding is consistent with the aforementioned recommendation to address specific sites where safety concerns exist.

Given the findings of the descriptive and statistical analyses, possible areas of the existing IADOT IM that could be changed or added during any future revisions include traffic volume ranges, relative bridge width and crash frequency/severity.

Future research entailing crash history regarding bridge delineation and signing are recommended in order to better understand their potential benefits on low volume road bridges in Iowa.

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APPENDIX A: IADOT INSTRUCTIONAL MEMORANDUM 3.213, 3.214, AND 3.215

Form 740001WD
4-96

Iowa Department of Transportation

INSTRUCTIONAL MEMORANDUMS
To County Engineers

To	Date
County Engineers	November 2001
From	IM No.
Office of Local Systems	3.213
Subject	
Traffic Barriers (Guardrail and Bridge Rail)	

The purpose of this I.M. is to provide guidelines for determining the need for traffic barriers at roadway bridges and culverts. A traffic barrier is a device used to shield a roadside obstacle that is located on the right-of-way within an established minimum width clear zone (see I.M. 3.215 for clear zone instruction).

Roadside obstacles are classified as non-traversable objects (such as large culverts) and as fixed objects (such as unprotected ends of bridge rails). These roadside obstacles should first be reviewed for possible removal or relocation outside the Clear Zone. If this is not practical, then a traffic barrier may be necessary. A traffic barrier itself poses some risk to an errant motorist and should be installed only if it is clear that the barrier reduces the severity of potential crashes.

GUARDRAIL (Approach Guardrail):

In general, guardrail should be installed at:

1. All four bridge corners on newly constructed bridges on the Farm-to-Market system, except bridges located within an established speed zone of 35 mph or less.

2. On the approach bridge corners (right side) on new federally funded bridges constructed on the area service system, except bridges within a 35 mph or less speed zone. Consideration should be given to shielding the opposite corner if it is located on the outside edge of a curve. The FHWA will participate in guardrail at all four corners if desired by the county.

3. All four bridge corners on existing bridges within the termini of a 3R project on the Farm-to-Market System. Existing w-beam installations that are flared and anchored at both ends may be used as constructed without upgrading to current standards.

4. Culverts with spans greater than six feet (circular pipe culverts greater than 72" in diameter), if it is impractical to extend beyond the clear zone and grates are not utilized.

Design exceptions (see I.M. 3.218 for design exception instructions) to not utilize guardrail at bridges or culverts will be considered if the following conditions exist:

1. Current ADT at structure is less than 200 vehicles per day.

2. Structure width is 24' or greater.

3. Structure is on tangent alignment.

4. Benefit/cost Ratio is less than 0.80.

Other obstructions, within the right-of-way and clear zone, should be reviewed for removal, relocation, installation of a traffic barrier or the "do nothing" option based on a cost-effectiveness approach.

BRIDGE RAILS (Barrier Rail):

Bridge rails on newly constructed bridges should be constructed to the latest available standards (includes SL-1 type rail on structures with less than 1000 vpd). On bridge rehabilitation projects involving federal-aid, any substandard bridge rail should be reviewed for retrofitting.

Bridge rails which are both structurally deficient and functionally obsolete should be reviewed for upgrading as part of the 3R projects. Included with this I.M. is a "Bridge Rail Rating System" developed to assist in determining if a bridge rail should be upgraded with the 3R project and to what extent it should be upgraded. Any bridge which is programmed in the near future for replacement or rehabilitation may not require upgrading as part of the 3R project.

The rating system assigns points to five factors (Crashes, ADT, Width, Length and Type of bridge rail); the sum of these factors will indicate the degree or amount of upgrading required, if any. The crash factor involves crashes (property damage only, personal injury and fatality) in the last five years (Access ALAS). The types of bridge rail are from various county bridge standards. If the existing rail is not an old standard, then determine which type it is similar to and assign the corresponding points.

Consideration should be given to extending the guardrail through the bridge on short bridges or bridges which have no end posts. This may be less costly than attaching the guardrail as per standard RE-27B or constructing an end post.

BRIDGE RAIL RATING SYSTEM

5 FACTOR SYSTEM

POINTS	**0**	**5**	**10**	**15**	**20**
Crashes (in the last 5 years)	None	1 PDO	1 PI	1 F or 2 PDO's or 1 PI and 1 PDO	2 or more F's/PI's or 3 or more PDO's
ADT (current year)	< 200	200 - 299	300 - 399	400 - 750	> 750
Bridge Width (feet)	≥ 30	28	24	22	≤ 20
Bridge Length (feet)	< 50	50 - 99	100 - 149	150 - 200	> 200
Bridge Rail (type)	Aluminum Rail (1967 Standard)	Steel Box Rail (1964 Standard)	Formed Steel Beam Rail (1951 and 1957 Standards)	Steel Rail (1941 Standard) Concrete Rail (1928 Standard)	Angle Handrail (1928 Standard)

Abbreviations:
PDO = Property Damage Only crash
PI = Personal Injury crash
F = Fatality crash

UPGRADING NEEDED

under 25 Points	No Upgrading at this time
25 - 50 Points	Delineation according to Standard RE-48A
51 - 75 Points	Block out with Thrie Beam to curb edge (If existing approach guardrail is W-Beam, W-Beam may be used)
Over 75 Points	Retrofit

Form 740001WD
4-96

Iowa Department of Transportation

INSTRUCTIONAL MEMORANDUMS

To County Engineers

To	Date
County Engineers	February 2002
From	IM No.
Office of Local Systems	3.215
Subject	
Clear Zone	

Clear Zone is the roadside border area within the highway right-of-way, starting at the edge of the traveled way, available for the recovery of errant vehicles. The width of the clear zone is influenced by traffic volume, speed and embankment slopes. Clear Zone is desirable because recovery of high speed vehicles outside of the traveled way is more likely to occur when clear zones meet the minimum values shown in the following tables and defined by the AASHTO "Roadside Design Guide."

On new and major reconstruction projects, clear zone distances vary. For rural collectors less than 40 mph and less than 750 ADT and all rural local roads, a minimum clear zone width of 10 feet should be provided. On rural collector roads with design speeds of 55 mph, a clear zone distance according to the Clear Zone table (see page 2) should be used. This table is derived from the AASHTO "Roadside Design Guide." Projects with design speeds different than 55 mph should use Table 3.1 in the AASHTO "Roadside Design Guide" (see page 3).

Any obstructions within the clear zone of the project that might severely damage an out-of-control vehicle and cause serious injuries should be reviewed (corrected) in the following priority order:

1. Removal.
2. Relocation outside the clear zone or to the right of way line.
3. Redesign the obstacle to make it traversable.
4. Installation of a traffic barrier if the barrier is less hazardous than the obstruction.
5. Do nothing (after considering the safety aspects, environmental effects and cost-effectiveness) and delineate the obstacle.

Bridges and large culverts within the clear zone should be reviewed according to I.M. 3.213.

CLEAR ZONE (feet) for 55 mph Design Speed
For New or Completely Reconstructed Collector Roads
On the Farm to Market and Federal Aid System

Foreslope	Design Traffic (ADT)			
	Under 750	750-1500	1500-6000	Over 6000
3:1 to 4:1 *	12-14 beyond the toe of slope	16-18 beyond the toe of slope	20-22 beyond the toe of slope	22-24 beyond the toe of slope
4:1 to 5:1 **	14-18	20-24	24-30	26-32
6:1 or flatter **	12-14	16-18	20-22	22-24

* The distance beyond the toe of the foreslope may be reduced by the width of the shoulder. The distance between the edge of the traveled way and the beginning of the foreslope is considered to be part of the clear zone. Foreslopes that are 3:1 to 4:1 are considered to be non-recoverable parallel slopes and do not count toward the clear zone measurement. Example: if a road has 1000 design year ADT and a 6' shoulder, then the clear zone would be 10 feet to 12 feet beyond the toe of the foreslope

Fixed objects should not be present in the vicinity of the toe of 3:1 foreslopes unless they are at the right-of-way line. Recovery of errant vehicles may be expected to occur beyond the toe of the slope. Determination of the width of the recovery area at the toe of a 3:1 slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs and crash histories.

** Clear Zone distance measured from edge of driving lane.

TABLE 3.1 Clear Zone Distances (In feet from edge of driving lane)
Source: AASHTO Roadside Design Guide, 1988

Design Speed (mph)	Design Traffic (ADT)	FILL SLOPES			CUT SLOPES		
		6:1 or flatter	5:1 to 4:1	3:1	3:1	4:1 to 5:1	6:1 or flatter
≤ 40	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	Under 750	10-12	12-14	**	8-10	8-10	10-12
	750-1500	12-14	16-20	**	10-12	12-14	14-16
	1500-6000	16-18	20-26	**	12-14	14-16	16-18
	Over 6000	18-20	24-28	**	14-16	18-20	20-22
55	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	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	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 accidents, or such occurrences are indicated by accident history, the designer may provide clear zone distances greater than 30 feet as indicated. Clear zones may be limited to 30 feet 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 3:1 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 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 accident histories. Also, the distance between the edge of the travel lane and the beginning of the 3:1 slope should influence the recovery area provided at the toe of the slope. While the application may be limited by several factors, the fill slope parameters which may enter into determining a maximum desirable recovery area are illustrated in figure 3.2 of the "Roadside Design Guide".

Form 740001WD
4-96

Iowa Department of Transportation

INSTRUCTIONAL MEMORANDUMS

To County Engineers

To	Date
County Engineers	October 2001
From	IM No.
Office of Local Systems	3.216
Subject	
Economic Analysis (Benefit-to-Cost-Ratio)	

The purpose of this I.M. is to provide a mechanism to help determine the feasibility of an improvement or analyze various alternatives or countermeasures. Various methods (Cost-Effectiveness, Benefit/Cost Ratio, Rate-of-Return, Time of Return and Net Annual Benefit) are available to determine the economic feasibility of an improvement. This I.M. will present only one method, Benefit-to-Cost Ratio, for your consideration.

The Benefit/Cost Ratio is the ratio of the expected benefits, (accrued from a crash/severity reduction based on an improvement), to the costs of the improvement (construction, right of way, engineering, etc.). Included are two forms, which may be utilized to determine the Benefit/Cost Ratio for a particular improvement that is being considered. One form will obtain the Benefit-to-Cost Ratio as it relates to the project length (Rural Roadway Section). The other form is for spot locations, such as intersections, bridges, or curves within the project limits. The only difference in the forms is that the roadway section is based on 100 million vehicle miles (HMVM) of travel whereas the spot location is based on million entering vehicles (MEV).

The information required to fill out the forms is as follows:

1. CRASH DATA: This information can be obtained through Access ALAS Computer Software that is available through Iowa Department of Transportation (Iowa DOT) Office of Traffic and Safety. For most county roads, with no major improvements within the time frame, the data should go back five years. ALAS data should be requested for whole years (no partial years) only. The crash data on the Access ALAS printout should be transferred to the appropriate blanks on the form, keeping in mind that the number of fatalities or injuries may not be the same number of these types of crashes (two injury crashes could involve five injuries). The actual property damage of all crashes should be totaled and entered in the appropriate blank. Use the value of $2,500 per crash, if no damage is recorded. All crashes within the project termini or at the spot location should be included, regardless of type. The crash severity reduction percentage is based on all crashes.

2. IMPROVEMENT BEING CONSIDERED: The improvement described and the cost estimate should only be for the work for which the Benefit/Cost Ratio is being determined.

Example: If, as part of a resurfacing project, the county is considering widening the shoulders and flattening the foreslopes, the description should be similar to: Widen shoulders from 2' to 6' and flatten slopes from 2:1 to 3:1. The cost estimate might include:

Class 10 Excavation, including borrow
Culvert Extensions
Surfacing or Finishing the Shoulders
Seeding and Fertilizing
Right of Way (if necessary),including any damages to fences, buildings, etc.
Additional Engineering or Surveying
Driveway Culverts (remove and relay or replace)

3. SERVICE LIFE AND CRASH/SEVERITY REDUCTION FACTORS: Tables are included listing estimated values for these items for both roadway sections and spot locations. Crash/Severity reduction factors are usually provided for a single countermeasure. However, where multiple countermeasures are being proposed, the crash/severity reduction factor will be a combination of the individual crash/severity reduction factors. Since it is not feasible to reduce crashes by more than 100 percent, the following formula is used to develop an overall crash/severity reduction factor for multiple improvements at a location or along a route.

$AR_M = AR_1 + (1\text{-}AR_1)\ AR_2\ + (1\text{-}AR_1)(1\text{-}AR_2)\ AR3 + \ldots + (1\text{-}AR_1)(1\text{-}AR_{i\text{-}1})\ AR_i$ where:

AR_M = overall crash/severity reduction factor for multiple improvements.

AR_i = crash/severity reduction factor for specific improvement or countermeasure.

i = number of improvements.

Example

An example of the use of the multiple improvement formula is shown for three improvements at a single location with individual crash/severity reduction factors of:

$AR_1 = 0.45$
$AR_2 = 0.30$
$AR_3 = 0.15$

The overall crash/severity reduction factor is:
$AR_M = AR_1 + (1\text{-}AR_1)\ AR_2 + (1\text{-}AR_1)\ (1\text{-}AR_2)\ AR_3$

$= 0.450 + (1\text{-}0.45)(0.30) + (1\text{-}0.45)(1\text{-}0.30)(0.15)$
$= 0.450 + 0.165 + 0.058$
$= 0.673 = 0.67$

Most studies indicate that an improvement with a Benefit/Cost Ratio over 1.0 is considered beneficial and under 1.0 is not. However, when considering that estimated values are being utilized, a more in-depth review is in order for ratios from 0.80 to 1.20, inclusive. This review might include items listed on the Review Sheet (Page #4), in this I.M., as:

1. The crash rate determined in the forms should be reviewed against the statewide average for all secondary roads. The five year average rate per 100 million vehicle miles in 1995 - 1999 was 237.

2. Type of crashes should be reviewed against the type of improvement. If the majority of the crashes within the project termini occurred at intersections, then flattening foreslopes may not have much of an effect.

3. The severity of the crashes should be reviewed with respect to location. If most of the crashes along the route were Property Damage Only (PDO's) and one location had a number of injury or fatality crashes then a review of that particular "spot" location may be in order.

4. The cost of the improvement being considered should be compared with the project cost without the improvement. If a proposed resurfacing project is estimated to cost \$200,000 and the estimated cost to widen shoulders or flatten foreslopes is \$500,000, it may be desirable to program the improvement at some future time. If the project is estimated at \$750,000 and the improvement at \$50,000, it may be wise to include the improvement.

5. The environmental or social effects of the improvement should always be considered. These might include: farmland being taken out of production; relocation of families; adverse effect on wetlands or parks; and disturbance of historical or archaeological areas. The Context-Sensitive Design process may be appropriate.

6. In some cases, other alternatives are available that may result in a similar benefit, or lower cost partial improvements may be used to mitigate the existing condition, if a total improvement is not cost effective or feasible. If the reconstruction of a horizontal curve requires taking a farmstead or relocating a bridge, and is not economically feasible, installing chevrons and advisory speed plates may be used to mitigate the situation.

These forms can be utilized as a tool in deciding whether an improvement is economically feasible. The completed Benefit/Cost Ratio sheet(s) should be attached, with copies of the ALAS printout, to the justification letter outlining the reasons for the county's request for any design exceptions. The Benefit/Cost Ratio should not be your only basis; other reasons that were considered in the decision-making process should be detailed in the county's justification letter. See I.M. 3.218.

BENEFIT/COST RATIO REVIEW SHEET

1. **B/C Ratio under 0.80:** Improvement probably not cost-effective at this time.

2. **B/C Ratio = 0.80 to 1.20:** Improvement may be cost effective, should also consider:

   1. Crash rate compared to statewide average.
   2. Type of crashes vs. type of improvement.
   3. Severity of Crashes.
   4. Cost of improvement vs. project cost without improvement.
   5. Environment and social effects of improvement.
   6. Other alternatives to the improvement (i.e. signing, pavement markings, etc.).

3. **B/C Ratio over 1.20:** Improvement is probably cost effective and should be accomplished as part of project or the work programmed in the near future.

Note: The following B/C determination sheets are available in Microsoft Excel 2000® spreadsheet format. These spreadsheets are available from the Iowa DOT Office of Traffic and Safety (515-239-1557) and are also located on the Office of Local Systems web site at: http://www.dot.state.ia.us/local_systems/publications/publications.htm.

BENEFIT/COST DETERMINATION
(Rural Roadway Section)

COUNTY ______________

Project No. ______________________________ Date __________________________

Location ________________________________ Prepared by __________________________

Length (miles) ___________________________ Current ADT __________________________

CRASH DATA: From __________ to __________, Total # __________ Years
(date) (date)

# Fatal Crashes	__________	# Fatalities	__________	x $1,000,000	= $__________
# Injury Crashes	__________	# Major Injuries	__________	x $150,000	= $__________
		# Minor Injuries	__________	x $10,000	= $__________
		# Possible Injuries	__________	x $2,500	= $__________
#PDO Crashes	__________		Actual Prop. Dam. (Total)		= $__________

(Use $2,500/Crash if no actual $ property loss is shown)

(1) Total # Crash __________ **(2)** Total Loss = $__________

(3) Cost/Crash = (2)/(1) =Total Loss/Total # Crash = $__________/crash

(4) Crash Rate $= \frac{\text{Total \# Crash} \times 100{,}000{,}000}{\text{ADT} \times \text{Length} \times \text{years} \times 365}$ = ______________ Crash/HMVM

DESIGN EXCEPTION BEING CONSIDERED:

Description of Improvement:
(not project description)

(5) Estimated Cost Imp. $ __________ (Thousand)

(5A) Estimated Service Life (E.S.L.) __________ years

(5B) Estimated Overall Crash/Severity Reduction Factor ____________ percent

(See #3, Page 2)

B/C ANALYSIS:

(6) Estimated Traffic Volume =
ADT x $\frac{1 + (1.02)^{(5A)}}{2}$ x 5A x Length x 0.00000365 = ____________ HMVM

(7) Total Crash Loss = (3) x (4) x (6)
Cost/ Crash x Crash Rate x Est. Traf. Vol. = ____________ (Thousand)

(8) Total Crash Benefit = (7) x (5B) =
Tot. Crash Loss x Est. % Crash Reduction = ____________________ (Thousand)

Benefit/Cost Ratio = $\frac{(8)}{(5)}$ = $\frac{\text{Tot. Crash Benefit}}{\text{Est. Cost Imp.}}$ = ________________________

IMPROVEMENTS FOR RURAL ROADWAY SECTIONS

	Estimated Service Life (Years)	Estimated Crash/ Severity Reduction Factor (%)
Add Lane(s)	20	05
Widen Pavement	20	22
Widen Shoulder	20	08
Widen Pavement/Shoulder	20	28
Flatten Foreslopes	20	08
Widen Shoulder/Flatten Foreslopes	20	15
Friction Improvement:		
Overlay	10	27
P. C. Grooving	10	14
Signing	6	05
Edgeline Markings	2	04
Horizontal Realignment	20	25
Vertical Realignment	20	30
Horizontal/Vertical Realignment/ Correct Superelevation	20	45
Roadway Lighting	15	06
Relocate Driveways	20	05
Flatten Entrance Slopes	20	05
Right of Way	100	--

BENEFIT/COST DETERMINATION
(Spot Location)

COUNTY ______________

Project No. ________________________ Date ____________________

Location ________________________ Prepared by ____________________

Length (miles) ____________________ Current ADT ____________________

<u>CRASH DATA</u>: From ________ to ________, Total # ________ Years
(date) (date)

# Fatal Crashes	________	# Fatalities	________	x \$1,000,000	= \$________
# Injury Crashes	________	# Major Injuries	________	x \$150,000	= \$________
		# Minor Injuries	________	x \$10,000	= \$________
		# Possible Injuries	________	x \$2,500	= \$________
#PDO Crashes	________			Actual Prop. Dam. (Total)	= \$________

(Use \$2,500/Crash if no actual \$ property loss is shown)

(1) Total # Crash ________ **(2)** Total Loss = \$________

(3) Cost/Crash = (2)/(1) =Total Loss/Total # Crash = \$________/crash

(4) Crash Rate = $\frac{\text{Total \# Crash x 1,000,000}}{\text{ADT x years x 365}}$ = ______________Crash/MEV

<u>DESIGN EXCEPTION BEING CONSIDERED:</u>
Description of Improvement:
(not project description)
(5) Estimated Cost Imp. \$__________(Thousand)
(5A) Estimated Service Life (E.S.L.) ____________ years
(5B) Estimated Overall Crash/Severity Reduction Factor ____________ percent
(See #3, page 2)

<u>B/C ANALYSIS:</u>

(6) Estimated Traffic Volume = ADT x $\frac{1+(1.02)^{(5A)}}{2}$ x (5A) x 0.000365 = ____________ MEV

(7) Total Crash Loss = (3) x (4) x (6)
Cost/ Crash x Crash Rate x Est. Traf. Vol. = ____________ (Thousand)

(8) Total Crash Benefit = (7) x (5B) =
Tot. Crash Loss x Est. % Crash Reduction = ____________ (Thousand)

Benefit/Cost Ratio = $\frac{(8)}{(5)}$ = $\frac{\text{Tot. Crash Benefit}}{\text{Est. Cost Imp.}}$ = ____________________

IMPROVEMENTS FOR SPOT LOCATIONS

	Estimated Service Life (Years)	Estimated Crash/ Severity Reduction Factor (%)
Intersections:		
Channelize/Add Turning Lanes	15	25
Improve Sight Distance	15	35
Upgrade Signs/Markings	6/2	36
Illuminate (not destination lighting)	15	20
Add Accel/Decel lane	20	25
Rumble Strips (Applies only to crashes involving stop condition)	5 A.C. 10 P.C.	44 44
Reconstruct Approach Angle	20	35
Add Beacons	10	25
Curves:		
Vertical Realignment	20	57
Horizontal Realignment	20	38
Horizontal/Vertical Realignment/ Correct Superelevation	20	73
Pavement Markings/Delineate	2/6	15
Bridges:		
Widen	20	48
Guardrail	15	24
Impact Attenuator	10	35
Replace	50	50
Eliminate	50	75

IMPROVEMENTS FOR SPOT LOCATIONS (continued)

	Estimated Service Life (Years)	Estimated Crash/ Severity Reduction Factor (%)
Culverts:		
Lengthen	20	48
Guardrail or Grate	15	24
Remove Headwall & Delineate	20	35
Railroad Crossing:		
Signalize	10	50
Upgrade Warning Devices	10	27
Illuminate	15	62
Replace with Grade Separation	50	39
Eliminate	50	75
High Fills:		
Guardrail	10	16
Delineate	6	10
Flatten Foreslopes	20	25

APPENDIX B: SURVEY RESPONSES

Table B.1. Survey Responses.

Name	Agency	1. Does your agency use average daily traffic (ADT) to determine if traffic barriers (i.e., guardrail) are required for bridges located on low-volume roads?	2. If yes, what are the specific ADT criteria for requiring traffic barrier placement and why was this specific ADT value chosen as the threshold?	3. If no, what is the basis for placement of traffic barriers on low-volume road bridges?	4. Does your agency recommend or use protective treatments other than "W" beam type guardrail systems for low-volume road bridges?	5. If yes, what are they, why were these alternate traffic barrier systems chosen for use and have they been effective?	6. Have the criteria for determining traffic barrier use on low-volume roads been modified in the past 10 years?	7. If yes, have any safety, cost, or other effects been seen due to the change in criteria?	8. May we receive a copy of the currently policy/ guardrail for traffic barriers on low-volume bridges and current design standards for the bridge approach guardrail?
Federal Bridge Owners									
John Kattell	US Forest Service	No	No Response	The Forest Service has a variety of roads from single lane native surface to two-lane paved with the vast majority under 400 ADT. We use criteria with respect to the character and nature of the road, design speeds, and sight distances to help us qualify the hazards and protections needed.	Yes	We use tube rail systems, Thrie-beam, concrete barrier and for many of our low level roads we use a "curb only" system. They have been effective.	No	No Response	Yes, Send me an e-mail address and I will get our policy to you. We are very interested in this work and applications to the roads on National Forest Lands. My e-mail is jkattell@fs.fed.us.
State Bridge Owners									
Jean Nehme	Arizona DOT; Bridge Group	No	No Response	AASHTO Guidelines	No	No Response	No	No Response	ADOT does not have a specific policy addressing traffic barriers on low-volume bridges.
Randy Hiatt	Caltrans	No	No Response	AASHTO LRFD Bridge Specifications	No	No Response	No	AASHTO LRFD Bridge Specifications in effect in 1998. More aesthetic bridge rails are available at higher costs	Yes, The current design standard for bridge approach guardrail on CA state highways is contained in 2006 State Standard Plan A77J4 - link is attached: http://www.dot.ca.gov/hq/esc/oe/project_plans/highway_plans/stdplans_US-customary-units_06/viewable_pdf/rspa77j4.pdf
Mark Leonard	Colorado DOT; Staff Bridge	No	No Response	If rail does not meet AASHTO Standard Specs, replace/upgrade rail when any project in the area takes place, funds permitting. If the rail is removed for any reason (bridge widening or replacement) replace it with one of CDOT's current FHWA approved crash tested bridge rails.	Yes	CDOT's W-beam is a TL-3 system and is not necessarily less expensive than CDOT's TL-4 systems. Where the TL-4 systems are not significantly different in costs, and are otherwise compatible with the bridge, they are used.	No	No Response	Yes, Bridge Design Manual Subsection 2.1 (not up to date): http://www.dot.state.co.us/Bridge/DesignManual/dm_s02.pdf Bridge rail standard drawings, B-606 series: http://www.dot.state.co.us/Bridge/Worksheets/Worksheets.htm
Barry Benton	Delaware DOT; Bridge Design	No	No Response	Design Speed and clear zone	Yes	We use timber rails for aesthetic reasons if requested by the community	No	No Response	No
Jiten Soneji	Delaware DOT; Bridge	No	No Response	Posted Speed/Design Speed, Functional Class, Accident History, Crash tested barriers	Yes	Timber Rails	No	No Response	No Response
Charles Boyd	Florida DOT; Structures Design Office	No	No Response	NCHRP Report 350 Test Level 4 compliant traffic railings are required for all FDOT owned bridges regardless of design speed or traffic counts	Yes	A flared and tapered F shape transition is used for approaches on roadways with curb and gutter cross sections and with design speeds of 45 mph and less	No	No Response	Yes, FDOT Design Standards are available at the following website: http://www.dot.state.fl.us/rddesign/rd/rtds/08/2008Standards.shtm Look for the 400 series standards, all bridge and roadway traffic railings and approaches are there. Also, bridge traffic railing policy can be found in Section 6.7 of the FDOT Structures Design Guidelines Volume 1 at this website: http://www.dot.state.fl.us/structures/StructuresManual/CurrentRelease/StructuresManual.htm
Paul Liles	Georgia DOT, Bridge Engineer	No	No Response	We use jersey shape traffic barrier on all our rural bridges	We use guardrail on the approaches and a jersey shaped barrier on the bridge	The system we use has been effective	No	No Response	Yes
Paul Santo	Hawaii DOT, Highways	No	No Response	We have no basis. In the first place, we don't have any roads in our jurisdiction with ADT less than 400. We generally use the same criteria regardless of ADT.	Yes	We have no special barriers for low-volume roads/bridges. We use all the options that we have for all bridges regardless of ADT	No	No Response	No, We have no policy/guideline for traffic barriers on low-volume bridges.
Kevin Burke	Illinois DOT; Highways Bureau of local roads and streets	Yes	400	AASHTO Definition of low volume road	No	No Response	No	No Response	Yes, http://www.dot.il.gov/blr/manuals/Chapter%2035.pdf http://www.dot.il.gov/blr/manuals/Chapter%2036.pdf

Table B.1. Survey Responses (cont.).

Name	Agency	1. Does your agency use average daily traffic (ADT) to determine if traffic barriers (i.e., guardrail) are required for bridges located on low-volume roads?	2. If yes, what are the specific ADT criteria for requiring traffic barrier placement and why was this specific ADT value chosen as the threshold?	3. If no, what is the basis for placement of traffic barriers on low-volume road bridges?	4. Does your agency recommend or use protective treatments other than "W" beam type guardrail systems for low-volume road bridges?	5. If yes, what are they, why were these alternate traffic barrier systems chosen for use and have they been effective?	6. Have the criteria for determining traffic barrier use on low-volume roads been modified in the past 10 years?	7. If yes, have any safety, cost, or other effects been seen due to the change in criteria?	8. May we receive a copy of the currently policy/ guardrail for traffic barriers on low-volume bridges and current design standards for the bridge approach guardrail?
Kurt Brauner	Louisiana DOT; Bridge Design	No	No Response	We try and use guard rail or some other type of barrier system on all bridges, regardless of the ADT.	Yes	Typically we recommend guard rail but in certain urban situations, we allow the use of a turned down concrete barrier so as to tie into the roadway curb.	No	No Response	Yes, Contact me via e-mail and I can send you a copy of our standards for off-system (low volume) roads. Again, we use guard rail on all bridges regardless of ADT, therefore we have no written policy for low-volume roads.
Dave Conkel	MnDOT; Bridge Office, State Aid Bridge Unit	Yes	Guardrail is required to be installed at all local bridges where the design speed exceeds 40 mph, and either the existing ADT exceeds 400, or the bridge clear width is less than the sum of the lane and shoulder widths. The costs associated with the more severe crashes (guardrail reduces severity (and subsequent costs) appears to be pushing up the benefit cost ratio in favor of using guardrail at lower traffic volumes.	No response	Yes	Steel tubular box beam guardrail and posts. We believe the box beam guardrail will provide less maintenance and a smaller distance to shielded object. We're still in the implementation phase on the local system, however we know they have been successfully used on the New York local bridge system. They're more expensive than the "W" beam type.	Yes	Criteria, From: Guardrail is required to be installed at all local bridges where the design speed exceeds 40 mph, and either the existing ADT exceeds 749, or the bridge clear width is less than the sum of the lane and shoulder widths. To: Guardrail is required to be installed at all local bridges where the design speed exceeds 40 mph, and either the existing ADT exceeds 400, or the bridge clear width is less than the sum of the lane and shoulder widths. Change in criteria was based on research of the "safety and cost-effectiveness of bridge approach guardrail for county state aid bridges in Minnesota. The research was conducted through the Minnesota Local Road Research Board (LRRB). The new criterion was just recently adopted in the State-Aid Operation Rules Chapter 8820 in February 2008. It's anticipated that the data on safety, cost, effectiveness and etc…will be comparable to other states with similar criteria. We would recommend the LRRB research report 2005-39 on the safety and cost-	Yes
Suresh Patel	MoDOT	Yes	If operating speed is < 60 MPH, AADT is 400 or less per day and bridge does not end in area of poor geometry then barrier not provided.	No Response	No	No Response	Yes	I don't know	Yes, http://epg.modot.org/index.php?title=Category:606_Guardrail_and_Guard_Cable
David Scott	New Hampshire DOT; Bureau of Bridge Design	No	N/A	Location of hazards	Yes	We do recommend the use of "W" beam type guardrail systems for low-volume road bridges, especially the T101 Texas rail, but we also recommend aluminum rail on low speed roads, which are typically low volume roads. Aluminum rail is sometimes preferred due to its low maintenance requirements.	No	N/A	Yes, Please contact to obtain a copy of our current Bridge Design Manual. Rail details may be found at http://www.nh.gov/dot/bureaus/bridgedesign/BridgeDesignStandards.htm; http://www.nh.gov/dot/org/projectdevelopment/bridgedesign/documents.htm
Ray Trujillo	New Mexico DOT Bridge Bureau	Yes	If the 20-year projected ADT is less than 400 vehicles per day, the railing shall meet as a minimum the requirement for Performance Level One (PL-1) or other bridge railing as defined in AASHTO Guide Specs for Bridge Railing. The policy is 15 years old, so I am not sure why 400 vpd was chosen, maybe because our state is mostly rural and most of our bridges fall into this category?	No response	Yes	Have used moveable concrete barrier railing (K-rail)which has been effective. This has been used when our District offices have excess concrete K-rail.	No	No Response	Yes, I can either mail you a hard copy or scan our policy into a pdf file and e-mail it. My e-mail is listed above.
Arthur Yannotti	New York State DOT, Office of Structures	Yes	Traffic barrier is always used, but for low volume local roads two simpler barrier system are allowed. The criteria are less than 500 ADT for one system and less than 1500 ADT for the other	No response	Yes	We use Thrie beam and box beam systems as well. They are less expensive than the standard railings used on state highways. They have been effective	Yes	Low volume railing standards were issued for the first time in 2001	yes, They are available on the NYSDOT website. The direct link is below: https://www.nysdot.gov/portal/page/portal/main/business-center/engineering/cadd-info/drawings/bridge-detail-sheets-usc/rl-rail-for-low-volume-bridges-usc

Table B.1. Survey Responses (cont.).

Name	Agency	1. Does your agency use average daily traffic (ADT) to determine if traffic barriers (i.e., guardrail) are required for bridges located on low-volume roads?	2. If yes, what are the specific ADT criteria for requiring traffic barrier placement and why was this specific ADT value chosen as the threshold?	3. If no, what is the basis for placement of traffic barriers on low-volume road bridges?	4. Does your agency recommend or use protective treatments other than "W" beam type guardrail systems for low-volume road bridges?	5. If yes, what are they, why were these alternate traffic barrier systems chosen for use and have they been effective?	6. Have the criteria for determining traffic barrier use on low-volume roads been modified in the past 10 years?	7. If yes, have any safety, cost, or other effects been seen due to the change in criteria?	8. May we receive a copy of the currently policy/ guardrail for traffic barriers on low-volume bridges and current design standards for the bridge approach guardrail?
Guichuru Muchane	North Carolina DOT	No	Note: Traffic Barriers are used on all Bridges	Type of traffic barrier used is based on posted speed limit of the facility	No	No Response	No	No Response	Yes, http://www.ncdot.org/doh/preconstruct/highway/roadway/policymemos/Design/SubregionalTierDesign.pdf
Bryon Fuchs	NDDOT; Local	No	No Response	All new bridges receive "W" beam type guardrail for low volume roads.	No	No Response	No	No Response	Yes, http://www.dot.nd.gov/manuals/design/designmanual/designmanual.htm
Barry Bowers	South Carolina DOT; Preconstruction	No	No Response	SCDOT typically uses a 32-inch concrete barrier parapet on all bridges that do not include sidewalks.	Yes	A thrie beam guardrail bridge connector is used at the ends of the concrete barrier parapet.	No	No Response	Yes, See Section 17.6.1 of the SCDOT Bridge Design Manual (http://www.scdot.org/doing/bridge/pdfs/BD_manual/Files/Chapter_17.pdf) and Section 805 of the SCDOT Standard Drawings (http://www.scdot.org/doing/pdfs/stddrawings/new_2008/sd08-09_800_incidental_construction.pdf)
Edward Wasserman	Tennessee DOT; Structures	No	No Response	We use traffic barriers on all bridges regardless of traffic count	Yes	We use open concrete rails, equivalent to the Kansas corral or solid parapet, depending on overtopping conditions. On bos or slab bridges we use a guardrail conforming to the Texas T101	Yes	Not Quantified	Yes, http://www.tdot.state.tn.us/Chief_Engineer/engr_library/design/StdDrwgEng_PDFs/SGR22_031308.pdf
John Holt	Texas DOT; Bridge Division	No	No Response	If the bridge is built by the state, regardless of traffic volume, a traffic barrier that is compliant with NCHRP Report 350 is used	Yes	Single Sided Crash Cushions have been employed where not enough length was available to place the usual guardrail terminal, such as a bridge end in close proximity to a driveway. Details can be found online at: ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/cserve/standard/roadway/sscc03a.pdf	No	No Response	Yes, TxDOT policy on bridge rails can be found in the TxDOT Bridge Railing Manual, available online at: http://gsd-ultraseek/txdotmanuals/rlg/index.htm TxDOT standard drawings for approach guardrail can be found online at: http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/standard/rdwylse.htm
Bryant Lowery	Virginia DOT; Location and Design	Yes	ADT is only one of several items we review. We typically handle low volume (ADT approx. 400 per AASHTO) bridges on a case by case basis.	No response	No	No Response	No	No Response	No Response
Ryan Collins	Washington; Bridge and Structures Office	No	No Response	We use a test level 4 (TL-4) minimum design standard for all bridges regardless of volume. We do occasionally use less for retrofits where the bridge does not have the strength to support a TL-4 system such as a timber deck or thin slab. Low speeds and accident history have also been used to justify a change in retrofit requirements, but not volume.	Yes	Our first choice is to place concrete barrier on new construction and thrie beam on retrofits. We do use W-beam on highway applications which include culverts and spans less than 20 feet.	No	No Response	Yes, Our policies do not address low volumes relative to bridge barrier. Design guidance can be found in our WSDOT Design Manual, chapter 710 and WSDOT Standard Plans in section C. The WSDOT Bridge Design Manual chapter 10 gives recommendations on guardrail and barrier placement. http://www.wsdot.wa.gov/Design/Standards http://www.wsdot.wa.gov/Design/Policy/Chapters.htm http://www.wsdot.wa.gov/Publications/Manuals/M23-50.htm
Gregg Fredrick	Wyoming DOT; Bridge program	No	No Response	Bridges on low volume roadways utilize Wyoming's TL3 steel tube open bridge railing	Yes	W beam and box beam approach railing are both considered on a case by case basis	No	No Response	Yes, Our typical bridge railing details can be found at http://www.dot.state.wy.us/Default.jsp?sCode=hombh
Canadian Providence Bridge Owners									
Raymond Yu	Alberta Transportation; Technical Standards Branch	Yes	Use CSA-S6-06 code Performance Level requirements based on multi factors including highway type, speed, ADT, % truck, grade, curve, height	No response	Yes	Deck mounted thrie beam (no curb or 75 mm curb where drainage control required). This is a Performance Level 1 (TL2) barrier modified from a crash tested system.	Yes	Change driven by CSA S6 Canadian Bridge Design Code published in 2000. Previous experience in W-beam bridge rail with curb in collisions not good.	Yes, http://www.transportation.alberta.ca/Content/doctype30/production/S1652-00-rev3.pdf
Non-Iowa Counties Bridge Owners									
Michael Clark	St Clair County Road Commission	Yes	We use the AASHTO roadside design guidelines for calculations of clear zones and barrier need	No response	No	No Response	No	No Response	Yes, AASHTO roadside design guide from the Feds

Table B.1. Survey Responses (cont.).

Name	Agency	1. Does your agency use average daily traffic (ADT) to determine if traffic barriers (i.e., guardrail) are required for bridges located on low-volume roads?	2. If yes, what are the specific ADT criteria for requiring traffic barrier placement and why was this specific ADT value chosen as the threshold?	3. If no, what is the basis for placement of traffic barriers on low-volume road bridges?	4. Does your agency recommend or use protective treatments other than "W" beam type guardrail systems for low-volume road bridges?	5. If yes, what are they, why were these alternate traffic barrier systems chosen for use and have they been effective?	6. Have the criteria for determining traffic barrier use on low-volume roads been modified in the past 10 years?	7. If yes, have any safety, cost, or other effects been seen due to the change in criteria?	8. May we receive a copy of the currently policy/ guardrail for traffic barriers on low-volume bridges and current design standards for the bridge approach guardrail?
Wayne Schoonover	Ionia County Road Commission; Michigan	No	No Response	Safety transition to rigid bridge railing system.	No	No Response	No	No Response	Yes, Michigan Department of Transportation's Road Design Manual found on-line at MDOT's website
Eugene Calvert	Collier County; Florida	No	No Response	Deign Standards & Crash history	No	No Response	No	No Response	No, We do not have a written policy /guideline for low-volume bridges. Current design standard is Florida Department of Transportation (FDOT) standard
Iowa Counties Bridge Owners									
Brian Keierleber	Buchanan County Iowa, Secondary Roads	No	No Response	Funding, we use 4 corner rails when federal funds are available, and place rails on the bridge only when local funds are used after documenting no crash history.	No	No Response	no	No Response	Yes, Send fax number.
Ron Haden	Calhoun County Iowa, Secondary Roads	Yes	50vpd or less and bridge width 24' or more -no barrier 51-99vpd and bridge width 24' or more -barriers on approach corners only over 100 vpd and bridge width of 24'or more - barriers on all 4 corners		No	No Response	No	No Response	Yes, request and I can email or fax
David Paulson	Carroll County Iowa, Secondary Roads	No	No Response	Guardrail is only placed on federally funded bridge replacement projects	No	No Response	No	No Response	No Response
Robert Fangmann	Cedar County Iowa, Secondary Roads	No	No Response	We place guardrail in accordance to clear zone requirements as outlined in County Engineers Instructional Memorandum 3.215	No	No Response	No	No Response	no
Mary Kelly	Cerro Gordo County Iowa	No	No Response	We generally use guardrail on hard surface roads	Yes	Cable rail but that would be for protecting obstructions, i.e. drainage ways within the clear zone.	No	No Response	No written policy
David Shanahan	Cherokee County Iowa, Secondary Roads	No	No Response	Width of bridges, & sight distances, although we place railing on nearly all of our bridges	No	No Response	no	No Response	Being new here I do not know if in fact they do have a policy other than trying to put railing on all new bridges
Tom Anderson	Clark County Iowa	No	No Response	Has t be BRS/BROS, etc. project	No	No Response	No	No Response	No written policy
Paul Assman	Crawford County Secondary Roads	No	No Response	County Engineer IM 3.213	No	No Response	No	No Response	Yes, IM 3.213 requires the use of guardrail at all four corners of new bridges constructed on the Farm-to-Market system. We generally do not use guardrail on Non FM roads as the ADT is less than 100 vpd and in many cases request a design exception on FM roads with granular surfaces to eliminate the guardrail. The guardrail create some challenges with surface water erosion on granular surfaced roads. We have some very good examples of guardrail usage on low volume roads and the associated issues. It is also important to note that we have not had any bridge impact accidents in the county that anyone can remember (38 year employees). I would be in favor of revising the criteria thru application of an updated "risk based" approach

Table B.1. Survey Responses (cont.).

Name	Agency	1. Does your agency use average daily traffic (ADT) to determine if traffic barriers (i.e., guardrail) are required for bridges located on low-volume roads?	2. If yes, what are the specific ADT criteria for requiring traffic barrier placement and why was this specific ADT value chosen as the threshold?	3. If no, what is the basis for placement of traffic barriers on low-volume road bridges?	4. Does your agency recommend or use protective treatments other than "W" beam type guardrail systems for low-volume road bridges?	5. If yes, what are they, why were these alternate traffic barrier systems chosen for use and have they been effective?	6. Have the criteria for determining traffic barrier use on low-volume roads been modified in the past 10 years?	7. If yes, have any safety, cost, or other effects been seen due to the change in criteria?	8. May we receive a copy of the currently policy/ guardrail for traffic barriers on low-volume bridges and current design standards for the bridge approach guardrail?
Jim George	Dallas County Iowa, Road Department	No	No Response	Generally, I.M. 3.213 although practically speaking, we put barrier on all four corners	No	No Response	No	No Response	I.M. 3.213
Keith Hinds	Decatur County Iowa	No	No Response	Accident History	No	No Response	No	No Response	We do not have a written policy at this time
Dan Ecker	Dickinson County Iowa, Secondary Roads	Yes	As per IADOT design guides and aides	No response	Yes	Thire beam, cable rail	Yes	As per IADOT	Yes, refer to IADOT memorandum to county engineers
Roger Patocka	Emmet County Iowa, County Engineer	Yes	No Specific ADT	No response	Yes	Signage, delineators	No	No Response	No local specific current policy/guidelines for traffic barriers other than those required/recommended by standards exist.
JD King	Fayette County Iowa, Road Department	No	No Response	Pave roadway vs. granular surfaced roadway	No	We use corner guardrail only on the approach side, not the opposing lane side. 2 of 4 corners for granular. Paved = 4 corners	No	No Response	No written policy at FCRD, just standard practice
Daniel Davis	Fremont County Iowa, Secondary Roads	No	No Response	We probably look more at run off the road crash criteria	No	No Response	No	No Response	No
Tom Stoner	Harrison County Iowa, County Roads	No	No Response	Accident data/ available funds	No	No Response	No	No Response	N/A
Mike McClain	Jones County Iowa, Secondary Roads	No	No Response	For new bridges, we always place approach guardrail at all four corners	No	No Response	No	No Response	We utilize the current road standards for the IADOT of these installations
Christy Van Buskirk	Keokuk County Iowa, Highway Department	No	No Response	Traffic barriers upgraded when bridge is rehabilitated or replaced	No	Alternate traffic barriers are considered based on ADT, functional classification, and design criteria based on funding source	No	No Response	Do not have a written policy
Doug Miller	Kossuth County Iowa, Engineers Office	No	No Response	On paved routes, we install guardrail on all corners of the bridge. On gravel roads we install guardrail on approach sides only	No	No Response	No	No Response	No, it is not written, see question #4
Ernest Steffensmeier	Lee County Iowa, Secondary Roads	No	No Response	Lee County uses I.M. 3.213 (guardrail and bridge rail) for all bridges in the county (local or farm-to-market) when reconstruction or resurfacing of roadways are done. All new bridges no matter what the traffic volume has approach guardrail on all four corners.	No	No Response	No	No Response	Lee County has no written policy on this since we use the I.M. 3.213
Steve Gannon	Linn County Iowa, Secondary Roads	No	N/A	We place traffic barriers on all bridges	Yes	Thrie beam is used as well. We use concrete barriers of several types	No	N/A	Yes, We place traffic barriers as we build new bridges. we place guardrail at each corner. We use the current DOT standard for new bridges built with F-M or Federal funding. We extend w-beam with local projects
Jeff Williams	Lyon County Iowa, Secondary Roads	No	No Response	Federal aid route or FM route--constructed with federal aid dollars	No	No Response	No	No Response	No written policy
Jay Davis	Marion County Iowa, Secondary Roads	No	No Response	Some type of barrier is placed on all bridges, barrier may not meet standards on some projects	Yes	Sometimes we use thrie beam, in past channel iron sections have been used	Yes	we have always had a rail installed on all bridges, recently we have tried to make them stronger and safer	we have no official policy. typically we will install thrie beam across the bridge on 6 inch wide flange beams for posts. At the bridge ends we transition to W beam and place a curved section of W beam. beyond the wing wall. An end section is used for the end. The W beam is installed on 6" wood posts

Table B.1. Survey Responses (cont.).

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Royce Fichtner	Marshall County Iowa	No	No Response	Guardrail is installed on all new construction bridges	No	No Response	No	No Response	Policy is stated in the answer question number 4
Thomas Snyder	Osceola County Iowa, Secondary Roads	No	No Response	Paved road vs. non-paved road	No	No Response	No	No Response	No, We do not have a written policy /guideline for low-volume bridges. Current design standard is Florida Department of Transportation (FDOT) standard
Kurt Bailey	Polk County Public Works, Iowa	No	No Response	Accident History	Yes	DOT Standards are used for liability purposes	No	No Response	No, have not developed a policy
Doug Coulson	Ringgold County Iowa, Secondary Roads	No	No Response	Do not place expect new bridges on farm to market	No	No Response	No	No Response	No written policy
Steve Akes	Union County Iowa, County Engineers office	No	No Response	Only when performing road improvements such as grading or paving	No	No Response	No	No Response	Do not have a written policy
Brain Moore	Wapello County Iowa, Secondary Roads	No	No Response	All new contracted bridges have IDOT standard guardrail and approach rail. Accident history is considered for replacement or upgrade of guardrail of existing bridges	No	No Response	No	No Response	We currently do not have a written policy. For design we use IDOT standards and recommendations in the County IM's
David Patterson	Washington County Iowa, Secondary Roads	No	No Response	clear zone recommendations	no	No Response	no	No Response	No, don't have a policy
Lee Bjerke	Winneshiek County Iowa, Secondary Roads	Yes	<100 ADT	No response	No	No Response	Yes	Costs have risen when we changed to solely w-beam railings	No. There is no written policy
Mark Nahra	Woodbury County Iowa, Secondary Roads	No	No Response	No response	no	No Response	no	No Response	Yes, We utilize IDOT local agency guidelines and design standards for determining need for guardrail. Personally, I put it up on all new bridges built, unless I build the bridge roadway wider than the lane width plus clear zone (box culvert replacements).

APPENDIX C: DESCRIPTIVE ANALYSIS SUMMARY TABLES

Table C.1. AADT frequency data for LVR inventoried bridge population.

	Criteria	AADT: Unknown	(%)	1 to 49	(%)	50 to 99	(%)	100 to 149	(%)	150 to 199	(%)	200 to 400	(%)	Total	(%)	Known Info
Bridges	# of inventoried bridges	11	(100%)	9792	(100%)	4337	(100%)	1190	(100%)	520	(100%)	1380	(100%)	17230	(100%)	15423
AADT (IM Report)	Unknown	11	(100%)		(0%)		(0%)		(0%)		(0%)		(0%)	11	(0%)	
	1 to 199		(0%)	9792	(100%)	4337	(100%)	1190	(100%)	520	(100%)		(0%)	15839	(92%)	
	200 to 299		(0%)		(0%)		(0%)		(0%)		(0%)	1380	(100%)	1380	(8%)	
	300 to 400		(0%)		(0%)		(0%)		(0%)		(0%)	37	(3%)	37	(0%)	
Bridge Width, ft (IM Report)	Unknown	1	(9%)	795	(8%)	483	(11%)	169	(14%)	79	(15%)	280	(20%)	1807	(10%)	(-)
	1 to 20	9	(82%)	4748	(48%)	1482	(34%)	333	(28%)	126	(24%)	148	(11%)	6846	(40%)	(44%)
	20.1 to 23.9		(0%)	1993	(20%)	892	(21%)	220	(18%)	85	(16%)	142	(10%)	3332	(19%)	(22%)
	24 to 27.9		(0%)	1462	(15%)	857	(20%)	206	(17%)	82	(16%)	233	(17%)	2840	(16%)	(18%)
	28 to 29.9		(0%)	412	(4%)	315	(7%)	117	(10%)	67	(13%)	293	(21%)	1204	(7%)	(8%)
	30 or greater	1	(9%)	382	(4%)	308	(7%)	145	(12%)	81	(16%)	284	(21%)	1201	(7%)	(8%)
Bridge Length, ft (IM Report)	1 to 49	6	(55%)	5525	(56%)	2178	(50%)	545	(46%)	214	(41%)	536	(39%)	9004	(52%)	
	50 to 99	3	(27%)	2567	(26%)	943	(22%)	261	(22%)	93	(18%)	235	(17%)	4102	(24%)	
	100 to 149	1	(9%)	1144	(12%)	654	(15%)	177	(15%)	93	(18%)	274	(20%)	2343	(14%)	
	150 to 199	1	(9%)	349	(4%)	271	(6%)	90	(8%)	54	(10%)	153	(11%)	918	(5%)	
	200 or greater		(0%)	207	(2%)	291	(7%)	117	(10%)	66	(13%)	182	(13%)	863	(5%)	
Traffic Safety	Unknown		(0%)		(0%)		(0%)		(0%)		(0%)		(0%)		(0%)	
	Bridgerail not to standard	10	(91%)	7615	(78%)	2927	(67%)	769	(65%)	302	(58%)	689	(50%)	12312	(71%)	
	Bridgerail meets standards	1	(9%)	1627	(17%)	1087	(25%)	316	(27%)	166	(32%)	508	(37%)	3705	(22%)	
	Bridgerail not required		(0%)	550	(6%)	323	(7%)	105	(9%)	52	(10%)	183	(13%)	1213	(7%)	
	Unknown		(0%)		(0%)		(0%)	1	(0%)		(0%)		(0%)	1	(0%)	
	Transitions not to standard	10	(91%)	8243	(84%)	3259	(75%)	835	(70%)	317	(61%)	678	(49%)	13342	(77%)	
	Transitions meet standards	1	(9%)	888	(9%)	715	(16%)	248	(21%)	147	(28%)	519	(38%)	2518	(15%)	
	Transitions not required		(0%)	661	(7%)	363	(8%)	106	(9%)	56	(11%)	183	(13%)	1369	(8%)	
	Unknown		(0%)		(0%)		(0%)	1	(0%)		(0%)		(0%)	1	(0%)	
	Approach rail not to standard	10	(91%)	8186	(84%)	3270	(75%)	820	(69%)	305	(59%)	596	(43%)	13187	(77%)	
	Approach rail meets standards	1	(9%)	950	(10%)	706	(16%)	263	(22%)	161	(31%)	604	(44%)	2685	(16%)	
	Approach rail not required		(0%)	656	(7%)	361	(8%)	106	(9%)	54	(10%)	180	(13%)	1357	(8%)	
	Unknown		(0%)	1	(0%)		(0%)	1	(0%)		(0%)		(0%)	2	(0%)	
	Approach ends not to standard	10	(91%)	8239	(84%)	3351	(77%)	856	(72%)	326	(63%)	699	(51%)	13481	(78%)	
	Approach ends meet standard	1	(9%)	898	(9%)	632	(15%)	228	(19%)	141	(27%)	500	(36%)	2400	(14%)	
	Approach ends not required		(0%)	654	(7%)	354	(8%)	105	(9%)	53	(10%)	181	(13%)	1347	(8%)	
Road Surface Type	Soil surface	7	(64%)	972	(10%)	31	(1%)	1	(0%)	3	(1%)	1	(0%)	1015	(6%)	
	Gravel surface	3	(27%)	8788	(90%)	4200	(97%)	1001	(84%)	297	(57%)	218	(16%)	14507	(84%)	
	Bituminous		(0%)	14	(0%)	34	(1%)	55	(5%)	42	(8%)	109	(8%)	254	(1%)	
	Asphalt	1	(9%)	9	(0%)	50	(1%)	93	(8%)	106	(20%)	671	(49%)	930	(5%)	
	Concrete		(0%)	9	(0%)	22	(1%)	40	(3%)	72	(14%)	381	(28%)	524	(3%)	

Table C.2. AADT frequency for LVR bridge related crashes.

		AADT														
	Criteria	Unknown*	1 to 49 (%)		50 to 99(%)		100 to 149 (%)		150 to 199 (%)		200 to 400 (%)		Total (%)		Known Info	
Crashes	# of bridge related crashes	1	99	(100%)	101	(100%)	40	(100%)	23	(100%)	77	(100%)	341	(100%)	282	270
AADT (IM Report)	Unknown	1		(0%)		(0%)		(0%)		(0%)		(0%)	1	(0%)		
	1 to 199		99	(100%)	101	(100%)	40	(100%)	23	(100%)		(0%)	263	(77%)		
	200 to 299			(0%)		(0%)		(0%)		(0%)	40	(52%)	40	(12%)		
	300 to 400			(0%)		(0%)		(0%)		(0%)	37	(48%)	37	(11%)		
Bridge Width, ft (IM Report)	Unkown		28	(28%)	19	(19%)	7	(18%)	6	(26%)	11	(14%)	71	(21%)		
	1 to 20	1	42	(42%)	46	(46%)	16	(40%)	7	(30%)	12	(16%)	124	(36%)		(46%)
	20.1 to 23.9		11	(11%)	15	(15%)	8	(20%)	3	(13%)	12	(16%)	49	(14%)		(18%)
	24 to 27.9		8	(8%)	15	(15%)	5	(13%)	3	(13%)	13	(17%)	44	(13%)		(16%)
	28 to 29.9		5	(5%)	2	(2%)		(0%)	2	(9%)	18	(23%)	27	(8%)		(10%)
	30 or greater		5	(5%)	4	(4%)	4	(10%)	2	(9%)	11	(14%)	26	(8%)		(10%)
Bridge Length, ft (IM Report)	Unknown		26	(26%)	15	(15%)	5	(13%)	6	(26%)	7	(9%)	59	(17%)		
	1 to 49		32	(32%)	34	(34%)	11	(28%)	5	(22%)	14	(18%)	96	(28%)	(34%)	
	50 to 99	1	25	(25%)	24	(24%)	12	(30%)	4	(17%)	14	(18%)	80	(23%)	(28%)	
	100 to 149		7	(7%)	13	(13%)	4	(10%)	4	(17%)	23	(30%)	51	(15%)	(18%)	
	150 to 199		7	(7%)	4	(4%)	5	(13%)	1	(4%)	6	(8%)	23	(7%)	(8%)	
	200 or greater		2	(2%)	11	(11%)	3	(8%)	3	(13%)	13	(17%)	32	(9%)	(11%)	
Traffic Safety	Unknown		26	(26%)	15	(15%)	5	(13%)	6	(26%)	7	(9%)	59	(17%)		
	Bridgerail not up to standard	1	53	(54%)	64	(63%)	24	(60%)	10	(43%)	35	(45%)	187	(55%)	(66%)	
	Bridgerail meets standards		18	(18%)	20	(20%)	11	(28%)	7	(30%)	31	(40%)	87	(26%)	(31%)	
	Bridgerail not required		2	(2%)	2	(2%)		(0%)		(0%)	4	(5%)	8	(2%)	(3%)	
	Unknown		26	(26%)	15	(15%)	5	(13%)	6	(26%)	7	(9%)	59	(17%)		
	Transitions not up to standard	1	61	(62%)	74	(73%)	32	(80%)	10	(43%)	38	(49%)	216	(63%)	(77%)	
	Transitions meet standards		8	(8%)	9	(9%)	3	(8%)	7	(30%)	28	(36%)	55	(16%)	(20%)	
	Transitions not required		4	(4%)	3	(3%)		(0%)		(0%)	4	(5%)	11	(3%)	(4%)	
	Unknown		26	(26%)	15	(15%)	5	(13%)	6	(26%)	7	(9%)	59	(17%)		
	Approach rail not up to standard	1	61	(62%)	74	(73%)	32	(80%)	8	(35%)	33	(43%)	209	(61%)	(74%)	
	Approach rail meets standards		8	(8%)	9	(9%)	3	(8%)	9	(39%)	35	(45%)	64	(19%)	(23%)	
	Approach rail not required		4	(4%)	3	(3%)		(0%)		(0%)	2	(3%)	9	(3%)	(3%)	
	Unknown		26	(26%)	15	(15%)	5	(13%)	6	(26%)	7	(9%)	59	(17%)		
	Approach ends not up to standard	1	61	(62%)	76	(75%)	32	(80%)	8	(35%)	40	(52%)	218	(64%)	(77%)	
	Approach ends meet standard		8	(8%)	7	(7%)	3	(8%)	9	(39%)	28	(36%)	55	(16%)	(20%)	
	Approach ends not required		4	(4%)	3	(3%)		(0%)		(0%)	2	(3%)	9	(3%)	(3%)	
Road Surface Type	Soil Surface		5	(5%)		(0%)		(0%)		(0%)		(0%)	5	(1%)		
	Gravel Surface	1	93	(94%)	97	(96%)	36	(90%)	16	(70%)	15	(19%)	258	(76%)		
	Bituminous		1	(1%)	2	(2%)	3	(8%)	2	(9%)	9	(12%)	17	(5%)		
	Asphalt			(0%)	1	(1%)	1	(3%)	4	(17%)	38	(49%)	44	(13%)		
	Concrete			(0%)	1	(1%)		(0%)	1	(4%)	15	(19%)	17	(5%)		

*Percentage of crashes are very close to zero or zero

Table C.2. AADT frequency for LVR bridge crashes (cont.).

		AADT													
	Criteria	Unknown*	1 to 49 (%)		50 to 99(%)		100 to 149 (%)		150 to 199 (%)		200 to 400 (%)		Total (%)	
Crash Severity	Fatal Crash		5	(5%)	2	(2%)		(0%)		(0%)	5	(6%)	12	(4%)
	Major Injury		3	(3%)	9	(9%)	4	(10%)		(0%)	3	(4%)	19	(6%)
	Minor Injury		23	(23%)	24	(24%)	12	(30%)	4	(17%)	18	(23%)	81	(24%)
	Possible or unknown		16	(16%)	13	(13%)	6	(15%)	8	(35%)	14	(18%)	57	(17%)
	Property Damage only	1	52	(53%)	53	(52%)	18	(45%)	11	(48%)	37	(48%)	172	(50%)
Object Struck	Guardrail (b/n terminal & bridge)		7	(7%)	6	(6%)	2	(5%)	4	(17%)	15	(19%)	34	(10%)
	Guardrail (terminal)		4	(4%)	1	(1%)	1	(3%)	1	(4%)	5	(6%)	12	(4%)
	Guardrail (unclear)		10	(10%)	10	(10%)	1	(3%)	2	(9%)	10	(13%)	33	(10%)
	Bridge rail	1	41	(41%)	43	(43%)	15	(38%)	7	(30%)	33	(43%)	140	(41%)
	Bridge end		13	(13%)	16	(16%)	11	(28%)	5	(22%)	9	(12%)	54	(16%)
	Bridge Unclear		24	(24%)	25	(25%)	10	(25%)	4	(17%)	5	(6%)	68	(20%)
Order of Strike	Primary Strike	1	94	(95%)	99	(98%)	38	(95%)	23	(100%)	74	(96%)	329	(96%)
	Secondary Strike		5	(5%)	2	(2%)	2	(5%)		(0%)	3	(4%)	12	(4%)
Light Conditions	# of crashes in Day Light		42	(42%)	45	(45%)	21	(53%)	10	(43%)	35	(45%)	153	(45%)
	# of crashes Dusk		5	(5%)	5	(5%)	1	(3%)		(0%)	1	(1%)	12	(4%)
	# of crashes Dawn		2	(2%)		(0%)	1	(3%)		(0%)	3	(4%)	6	(2%)
	# of crashes Dark Roadway Lit		2	(2%)	1	(1%)		(0%)		(0%)		(0%)	3	(1%)
	# of crashes Dark Roadway not Lit	1	46	(46%)	47	(47%)	17	(43%)	13	(57%)	37	(48%)	161	(47%)
	# of crashes Dark unkown lighting		1	(1%)		(0%)		(0%)		(0%)		(0%)	1	(0%)
	Unknown		1	(1%)	1	(1%)		(0%)		(0%)		(0%)	2	(1%)
	Not Reported			(0%)	2	(2%)		(0%)		(0%)	1	(1%)	3	(1%)

*Percentage of crashes are very close to zero or zero

Table C.2. AADT frequency for LVR bridge crashes (cont.).

	Criteria	AADT Unknown*	1 to 49	(%)	50 to 99	(%)	100 to 149	(%)	150 to 199	(%)	200 to 400	(%)	Total	(%)
Weather Condition #1	# of crashes on Clear day		41	(41%)	56	(55%)	27	(68%)	11	(48%)	40	(52%)	175	(51%)
	# of crashes on partly cloudy day		22	(22%)	14	(14%)	7	(18%)	2	(9%)	12	(16%)	57	(17%)
	# of crashes on a cloudy day	1	10	(10%)	10	(10%)	3	(8%)	3	(13%)	6	(8%)	33	(10%)
	# of crashes on a Foggy day		4	(4%)	1	(1%)		(0%)		(0%)		(0%)	5	(1%)
	# of crashes on Misty day		3	(3%)		(0%)		(0%)		(0%)	2	(3%)	5	(1%)
	# of crashes on Rainy day		2	(2%)	3	(3%)		(0%)		(0%)	4	(5%)	9	(3%)
	# of crashes with Sleet/hail		2	(2%)	2	(2%)		(0%)	1	(4%)	2	(3%)	7	(2%)
	# of crashes on snowy day		2	(2%)	5	(5%)	1	(3%)	4	(17%)	5	(6%)	17	(5%)
	# of crashes on Severe Winds		2	(2%)	2	(2%)		(0%)		(0%)	2	(3%)	6	(2%)
	# of crashes w/ Blowing Soil/Snow			(0%)		(0%)	1	(3%)		(0%)		(0%)	1	(0%)
	# of crashes condition not reported		3	(3%)	3	(3%)		(0%)	1	(4%)	1	(1%)	8	(2%)
	Other			(0%)		(0%)	1	(3%)		(0%)		(0%)	1	(0%)
	# of crashes unknown		8	(8%)	5	(5%)		(0%)	1	(4%)	3	(4%)	17	(5%)
Driving Surface Conditions	# of crashes on dry surface	1	43	(43%)	41	(41%)	18	(45%)	8	(35%)	47	(61%)	158	(46%)
	# of crashes on wet surface		5	(5%)	2	(2%)		(0%)	1	(4%)	4	(5%)	12	(4%)
	# of crashes on icy surface		4	(4%)	11	(11%)	6	(15%)	2	(9%)	7	(9%)	30	(9%)
	# of crashes on snowy surface		6	(6%)	8	(8%)	2	(5%)	4	(17%)	4	(5%)	24	(7%)
	# of crashes on slushy surface		1	(1%)	1	(1%)	1	(3%)	1	(4%)	4	(5%)	8	(2%)
	# of crashes on dirt/oil/gravel		38	(38%)	33	(33%)	12	(30%)	6	(26%)	6	(8%)	95	(28%)
	other			(0%)		(0%)	1	(3%)		(0%)	2	(3%)	3	(1%)
	Unknown		1	(1%)	1	(1%)		(0%)		(0%)	1	(1%)	3	(1%)
	Not Reported		1	(1%)	4	(4%)		(0%)	1	(4%)	2	(3%)	8	(2%)

*Percentage of crashes are very close to zero or zero

Table C.4. Bridge width frequency for LVR bridge crashes.

		Bridge Width, ft (IM Report)															
	Criteria	Unknown		1 to 20 (%)		20.1 to 23.9 (%)		24 to 27.9 (%)		28 to 29.9 (%)		30 or greater (%)		Total (%)		Known Info	
Crashes	# of bridge related crashes	71	(100%)	124	(100%)	49	(100%)	44	(100%)	27	(100%)	26	(100%)	341	(100%)	282	270
AADT	Unknown		(0%)	1	(1%)		(0%)		(0%)		(0%)		(0%)	1	(0%)		
	1 to 49	28	(39%)	42	(34%)	11	(22%)	8	(18%)	5	(19%)	5	(19%)	99	(29%)		
	50 to 99	19	(27%)	46	(37%)	15	(31%)	15	(34%)	2	(7%)	4	(15%)	101	(30%)		
	100 to 149	7	(10%)	16	(13%)	8	(16%)	5	(11%)		(0%)	4	(15%)	40	(12%)		
	150 to 199	6	(8%)	7	(6%)	3	(6%)	3	(7%)	2	(7%)	2	(8%)	23	(7%)		
	200 to 400	11	(15%)	12	(10%)	12	(24%)	13	(30%)	18	(67%)	11	(42%)	77	(23%)		
Bridge Width, ft	Inknown	71	(100%)		(0%)		(0%)		(0%)		(0%)		(0%)	71	(21%)		
	1 to 9.9		(0%)		(0%)		(0%)		(0%)		(0%)		(0%)	0	(0%)		(0%)
	10 to 14.9		(0%)	6	(5%)		(0%)		(0%)		(0%)		(0%)	6	(2%)		(2%)
	15 to 19.9		(0%)	83	(67%)		(0%)		(0%)		(0%)		(0%)	83	(24%)		(31%)
	20 to 24.9		(0%)	35	(28%)	49	(100%)	32	(73%)		(0%)		(0%)	116	(34%)		(43%)
	25 to 30		(0%)		(0%)		(0%)	12	(27%)	27	(100%)		(0%)	39	(11%)		(14%)
	30 to 34.9		(0%)		(0%)		(0%)		(0%)		(0%)	23	(88%)	23	(7%)		(9%)
	35 or greater		(0%)		(0%)		(0%)		(0%)		(0%)	3	(12%)	3	(1%)		(1%)
Bridge Length, ft (IM Report)	Unknown	59	(83%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	1 to 49	12	(17%)	45	(36%)	20	(41%)	14	(32%)	3	(11%)	2	(8%)	96	(28%)	(34%)	
	50 to 99		(0%)	45	(36%)	9	(18%)	11	(25%)	10	(37%)	5	(19%)	80	(23%)	(28%)	
	100 to 149		(0%)	13	(10%)	12	(24%)	9	(20%)	12	(44%)	5	(19%)	51	(15%)	(18%)	
	150 to 199		(0%)	9	(7%)	6	(12%)	4	(9%)		(0%)	4	(15%)	23	(7%)	(8%)	
	200 or greater		(0%)	12	(10%)	2	(4%)	6	(14%)	2	(7%)	10	(38%)	32	(9%)	(11%)	
Traffic Safety	Unknown	59	(83%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Bridgerail not up to standard	2	(3%)	99	(80%)	34	(69%)	29	(66%)	15	(56%)	8	(31%)	187	(55%)	(66%)	
	Bridgerail meets standards	3	(4%)	25	(20%)	15	(31%)	15	(34%)	12	(44%)	17	(65%)	87	(26%)	(31%)	
	Bridgerail not required	7	(10%)		(0%)		(0%)		(0%)		(0%)	1	(4%)	8	(2%)	(3%)	
	Unknown	59	(83%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Transitions not up to standard	4	(6%)	112	(90%)	36	(73%)	33	(75%)	18	(67%)	13	(50%)	216	(63%)	(77%)	
	Transitions meet standards	1	(1%)	9	(7%)	13	(27%)	11	(25%)	9	(33%)	12	(46%)	55	(16%)	(20%)	
	Transitions not required	7	(10%)	3	(2%)		(0%)		(0%)		(0%)	1	(4%)	11	(3%)	(4%)	
	Unknown	59	(83%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Approach rail not up to standard	4	(6%)	116	(94%)	38	(78%)	28	(64%)	14	(52%)	9	(35%)	209	(61%)	(74%)	
	Approach rail meets standards	3	(4%)	5	(4%)	11	(22%)	16	(36%)	13	(48%)	16	(62%)	64	(19%)	(23%)	
	Approach rail not required	5	(7%)	3	(2%)		(0%)		(0%)		(0%)	1	(4%)	9	(3%)	(3%)	
	Unknown	59	(83%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Approach ends not up to standard	4	(6%)	116	(94%)	38	(78%)	31	(70%)	16	(59%)	13	(50%)	218	(64%)	(77%)	
	Approach ends meet standard	3	(4%)	5	(4%)	11	(22%)	13	(30%)	11	(41%)	12	(46%)	55	(16%)	(20%)	
	Approach ends not required	5	(7%)	3	(2%)		(0%)		(0%)		(0%)	1	(4%)	9	(3%)	(3%)	
Road Surface Type	Soil Surface	3	(4%)	1	(1%)		(0%)		(0%)		(0%)	1	(4%)	5	(1%)		
	Gravel Surface	57	(80%)	112	(90%)	39	(80%)	30	(68%)	7	(26%)	13	(50%)	258	(76%)		
	Bituminous	3	(4%)	8	(6%)	1	(2%)	1	(2%)	1	(4%)	3	(12%)	17	(5%)		
	Asphalt	7	(10%)	2	(2%)	8	(16%)	9	(20%)	15	(56%)	3	(12%)	44	(13%)		
	Concrete	1	(1%)	1	(1%)	1	(2%)	4	(9%)	4	(15%)	6	(23%)	17	(5%)		

Table C.4. Bridge width frequency for LVR bridge crashes (cont.).

		Bridge Width, ft (IM Report)													
	Criteria	Unknown		1 to 20 (%)		20.1 to 23.9 (%)		24 to 27.9 (%)		28 to 29.9 (%)		30 or greater (%)		Total (%)	
Weather Condition #1	# of crashes on Clear day	37	(52%)	58	(47%)	29	(59%)	22	(50%)	14	(52%)	15	(58%)	175	(51%)
	# of crashes on partly cloudy day	11	(15%)	24	(19%)	4	(8%)	7	(16%)	6	(22%)	5		57	(17%)
	# of crashes on a cloudy day	6	(8%)	15	(12%)	4	(8%)	4	(9%)	4	(15%)			33	(10%)
	# of crashes on a Foggy day		(0%)	3	(2%)	1	(2%)		(0%)		(0%)	1		5	(1%)
	# of crashes on Misty day	1	(1%)	1	(1%)		(0%)	2	(5%)		(0%)	1		5	(1%)
	# of crashes on Rainy day	1	(1%)	5	(4%)	2	(4%)	1	(2%)		(0%)			9	(3%)
	# of crashes with Sleet/hail	2	(3%)	1	(1%)	1	(2%)	1	(2%)	1	(4%)	1		7	(2%)
	# of crashes on snowy day	5	(7%)	4	(3%)	2	(4%)	2	(5%)	2	(7%)	2		17	(5%)
	# of crashes on Severe Winds	1	(1%)	2	(2%)	1	(2%)	1	(2%)		(0%)	1		6	(2%)
	# of crashes w/ Blowing Soil/Snow		(0%)	1	(1%)		(0%)		(0%)		(0%)			1	(0%)
	# of crashes condition not reported	2	(3%)	2	(2%)	2	(4%)	2	(5%)		(0%)			8	(2%)
	Other		(0%)	1	(1%)		(0%)		(0%)		(0%)			1	(0%)
	# of crashes unknown	5	(7%)	7	(6%)	3	(6%)	2	(5%)		(0%)			17	(5%)
Driving Surface Conditions	# of crashes on dry surface	33	(46%)	54	(44%)	27	(55%)	20	(45%)	14	(52%)	10		158	(46%)
	# of crashes on wet surface	1	(1%)	4	(3%)	3	(6%)	2	(5%)		(0%)	2		12	(4%)
	# of crashes on icy surface	3	(4%)	13	(10%)	1	(2%)	5	(11%)	4	(15%)	4		30	(9%)
	# of crashes on snowy surface	7	(10%)	5	(4%)	4	(8%)	3	(7%)	2	(7%)	3		24	(7%)
	# of crashes on slushy surface	2	(3%)	2	(2%)		(0%)	2	(5%)	1	(4%)	1		8	(2%)
	# of crashes on dirt/oil/gravel	22	(31%)	45	(36%)	12	(24%)	6	(14%)	4	(15%)	6		95	(28%)
	other		(0%)		(0%)	1	(2%)	1	(2%)	1	(4%)			3	(1%)
	Unknown	1	(1%)		(0%)		(0%)	1	(2%)	1	(4%)			3	(1%)
	Not Reported	2	(3%)	1	(1%)	1	(2%)	4	(9%)		(0%)			8	(2%)

Table C.6. Bridge Length frequency for LVR bridge crashes.

		Bridge Length, ft (IM Report)															
	Criteria	Unknown (%)		1 to 49 (%)		50 to 99 (%)		100 to 149 (%)		150 to 199 (%)		200 or more (%)		Total (%)		Known Info	
Crashes	# fo bridge related crashes	59	(100%)	96	(100%)	80	(100%)	51	(100%)	23	(100%)	32	(100%)	341	(100%)	282	270
AADT	Unknown		(0%)		(0%)	1	(1%)		(0%)		(0%)		(0%)	1	(0%)		
	1 to 49	26	(44%)	32	(33%)	25	(31%)	7	(14%)	7	(30%)	2	(6%)	99	(29%)		
	50 to 99	15	(25%)	34	(35%)	24	(30%)	13	(25%)	4	(17%)	11	(34%)	101	(30%)		
	100 to 149	5	(8%)	11	(11%)	12	(15%)	4	(8%)	5	(22%)	3	(9%)	40	(12%)		
	150 to 199	6	(10%)	5	(5%)	4	(5%)	4	(8%)	1	(4%)	3	(9%)	23	(7%)		
	200 to 400	7	(12%)	14	(15%)	14	(18%)	23	(45%)	6	(26%)	13	(41%)	77	(23%)		
Bridge Width, ft (IM Report)	Unknown	59	(100%)	12	(13%)		(0%)		(0%)		(0%)		(0%)	71	(21%)		
	1 to 20		(0%)	45	(47%)	45	(56%)	13	(25%)	9	(39%)	12	(38%)	124	(36%)		(46%)
	20.1 to 23.9		(0%)	20	(21%)	9	(11%)	12	(24%)	6	(26%)	2	(6%)	49	(14%)		(18%)
	24 to 27.9		(0%)	14	(15%)	11	(14%)	9	(18%)	4	(17%)	6	(19%)	44	(13%)		(16%)
	28 to 29.9		(0%)	3	(3%)	10	(13%)	12	(24%)		(0%)	2	(6%)	27	(8%)		(10%)
	30 or greater		(0%)	2	(2%)	5	(6%)	5	(10%)	4	(17%)	10	(31%)	26	(8%)		(10%)
Bridge Length, ft (IM Report)	Unknown	59	(100%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	1 to 49		(0%)	96	(100%)		(0%)		(0%)		(0%)		(0%)	96	(28%)	(34%)	
	50 to 99		(0%)		(0%)	80	(100%)		(0%)		(0%)		(0%)	80	(23%)	(28%)	
	100 to 149		(0%)		(0%)		(0%)	51	(100%)		(0%)		(0%)	51	(15%)	(18%)	
	150 to 199		(0%)		(0%)		(0%)		(0%)	23	(100%)		(0%)	223	(65%)	(79%)	
	200 or greater		(0%)		(0%)		(0%)		(0%)		(0%)	32	(100%)	32	(9%)	(11%)	
Traffic Safety	Unknown	59	(100%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Bridgerail not up to standard		(0%)	71	(74%)	56	(70%)	26	(51%)	17	(74%)	17	(53%)	187	(55%)	(66%)	
	Bridgerail meets standards		(0%)	18	(19%)	23	(29%)	25	(49%)	6	(26%)	15	(47%)	87	(26%)	(31%)	
	Bridgerail not required		(0%)	7	(7%)	1	(1%)		(0%)		(0%)		(0%)	8	(2%)	(3%)	
	Unknown	59	(100%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Transitions not up to standard		(0%)	77	(80%)	69	(86%)	29	(57%)	17	(74%)	24	(75%)	216	(63%)	(77%)	
	Transitions meet standards		(0%)	11	(11%)	9	(11%)	22	(43%)	5	(22%)	8	(25%)	55	(16%)	(20%)	
	Transitions not required		(0%)	8	(8%)	2	(3%)		(0%)	1	(4%)		(0%)	11	(3%)	(4%)	
	Unknown	59	(100%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Approach rail not up to standard		(0%)	76	(79%)	67	(84%)	28	(55%)	18	(78%)	20	(63%)	209	(61%)	(74%)	
	Approach rail meets standards		(0%)	14	(15%)	11	(14%)	23	(45%)	4	(17%)	12	(38%)	64	(19%)	(23%)	
	Approach rail not required		(0%)	6	(6%)	2	(3%)		(0%)	1	(4%)		(0%)	9	(3%)	(3%)	
	Unknown	59	(100%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Approach ends not up to standard		(0%)	78	(81%)	68	(85%)	31	(61%)	18	(78%)	23	(72%)	218	(64%)	(77%)	
	Approach ends meet standard		(0%)	12	(13%)	10	(13%)	20	(39%)	4	(17%)	9	(28%)	55	(16%)	(20%)	
	Approach ends not required		(0%)	6	(6%)	2	(3%)		(0%)	1	(4%)		(0%)	9	(3%)	(3%)	
Road Surface Type	Soil Surface	3	(5%)	1	(1%)	1	(1%)		(0%)		(0%)		(0%)	5	(1%)		
	Gravel Surface	49	(83%)	79	(82%)	60	(75%)	28	(55%)	20	(87%)	22	(69%)	258	(76%)		
	Bituminous	3	(5%)		(0%)	8	(10%)	5	(10%)		(0%)	1	(3%)	17	(5%)		
	Asphalt	3	(5%)	14	(15%)	9	(11%)	14	(27%)	1	(4%)	3	(9%)	44	(13%)		
	Concrete	1	(2%)	2	(2%)	2	(3%)	4	(8%)	2	(9%)	6	(19%)	17	(5%)		

Table C.2. AADT frequency for LVR bridge crashes (cont.).

		AADT													
	Criteria	Unknown*	1 to 49	(%)	50 to 99	(%)	100 to 149	(%)	150 to 199	(%)	200 to 400	(%)	Total	(%)
Weather Condition #1	# of crashes on Clear day		41	(41%)	56	(55%)	27	(68%)	11	(48%)	40	(52%)	175	(51%)
	# of crashes on partly cloudy day		22	(22%)	14	(14%)	7	(18%)	2	(9%)	12	(16%)	57	(17%)
	# of crashes on a cloudy day	1	10	(10%)	10	(10%)	3	(8%)	3	(13%)	6	(8%)	33	(10%)
	# of crashes on a Foggy day		4	(4%)	1	(1%)		(0%)		(0%)		(0%)	5	(1%)
	# of crashes on Misty day		3	(3%)		(0%)		(0%)		(0%)	2	(3%)	5	(1%)
	# of crashes on Rainy day		2	(2%)	3	(3%)		(0%)		(0%)	4	(5%)	9	(3%)
	# of crashes with Sleet/hail		2	(2%)	2	(2%)		(0%)	1	(4%)	2	(3%)	7	(2%)
	# of crashes on snowy day		2	(2%)	5	(5%)	1	(3%)	4	(17%)	5	(6%)	17	(5%)
	# of crashes on Severe Winds		2	(2%)	2	(2%)		(0%)		(0%)	2	(3%)	6	(2%)
	# of crashes w/ Blowing Soil/Snow			(0%)		(0%)	1	(3%)		(0%)		(0%)	1	(0%)
	# of crashes condition not reported		3	(3%)	3	(3%)		(0%)	1	(4%)	1	(1%)	8	(2%)
	Other			(0%)		(0%)	1	(3%)		(0%)		(0%)	1	(0%)
	# of crashes unknown		8	(8%)	5	(5%)		(0%)	1	(4%)	3	(4%)	17	(5%)
Driving Surface Conditions	# of crashes on dry surface	1	43	(43%)	41	(41%)	18	(45%)	8	(35%)	47	(61%)	158	(46%)
	# of crashes on wet surface		5	(5%)	2	(2%)		(0%)	1	(4%)	4	(5%)	12	(4%)
	# of crashes on icy surface		4	(4%)	11	(11%)	6	(15%)	2	(9%)	7	(9%)	30	(9%)
	# of crashes on snowy surface		6	(6%)	8	(8%)	2	(5%)	4	(17%)	4	(5%)	24	(7%)
	# of crashes on slushy surface		1	(1%)	1	(1%)	1	(3%)	1	(4%)	4	(5%)	8	(2%)
	# of crashes on dirt/oil/gravel		38	(38%)	33	(33%)	12	(30%)	6	(26%)	6	(8%)	95	(28%)
	other			(0%)		(0%)	1	(3%)		(0%)	2	(3%)	3	(1%)
	Unknown		1	(1%)	1	(1%)		(0%)		(0%)	1	(1%)	3	(1%)
	Not Reported		1	(1%)	4	(4%)		(0%)	1	(4%)	2	(3%)	8	(2%)

*Percentage of crashes are very close to zero or zero

Table C.3. Bridge width frequency data for LVR inventoried bridge population.

Bridges	Criteria	Unknown	(%)	1 to 20	(%)	20.1 to 23.9	(%)	24 to 27.9	(%)	28 to 29.9	(%)	30 or greater	(%)	Total	(%)	Known Info
		Bridge Width, ft (IM Report)														
Bridges	# of inventoried bridges	1,807	(100%)	6,846	(100%)	3,332	(100%)	2,840	(100%)	1,204	(100%)	1,201	(100%)	17230	(100%)	15423
AADT	Unknown	1	(0%)	9	(0%)		(0%)		(0%)		(0%)	1	(0%)	11	(0%)	
	1 to 49	795	(44%)	4748	(69%)	1993	(60%)	1462	(51%)	412	(34%)	382	(32%)	9792	(57%)	
	50 to 99	483	(27%)	1482	(22%)	892	(27%)	857	(30%)	315	(26%)	308	(26%)	4337	(25%)	
	100 to 149	169	(9%)	333	(5%)	220	(7%)	206	(7%)	117	(10%)	145	(12%)	1190	(7%)	
	150 to 199	79	(4%)	126	(2%)	85	(3%)	82	(3%)	67	(6%)	81	(7%)	520	(3%)	
	200 to 400	280	(15%)	148	(2%)	142	(4%)	233	(8%)	293	(24%)	284	(24%)	1380	(8%)	
Bridge Width, ft	Unknown	1807	(100%)		(0%)		(0%)		(0%)		(0%)		(0%)	1807	(10%)	(-)
	1 to 9.9		(0%)	1	(0%)		(0%)		(0%)		(0%)		(0%)	1	(0%)	(0%)
	10 to 14.9		(0%)	183	(3%)		(0%)		(0%)		(0%)		(0%)	183	(1%)	(1%)
	15 to 19.9		(0%)	4749	(69%)		(0%)		(0%)		(0%)		(0%)	4749	(28%)	(31%)
	20 to 24.9		(0%)	1913	(28%)	3332	(100%)	2034	(72%)		(0%)		(0%)	7279	(42%)	(47%)
	25 to 30		(0%)		(0%)		(0%)	806	(28%)	1204	(100%)		(0%)	2010	(12%)	(13%)
	30 to 34.9		(0%)		(0%)		(0%)		(0%)		(0%)	1145	(95%)	1145	(7%)	(7%)
	35 or greater		(0%)		(0%)		(0%)		(0%)		(0%)	56	(5%)	56	(0%)	(0%)
Bridge Length, ft (IM Report)	1 to 49	1748	(97%)	3652	(53%)	1841	(55%)	1209	(43%)	308	(26%)	246	(20%)	9004	(52%)	
	50 to 99	55	(3%)	1984	(29%)	806	(24%)	628	(22%)	333	(28%)	296	(25%)	4102	(24%)	
	100 to 149	2	(0%)	692	(10%)	397	(12%)	612	(22%)	320	(27%)	320	(27%)	2343	(14%)	
	150 to 199	2	(0%)	325	(5%)	147	(4%)	211	(7%)	105	(9%)	128	(11%)	918	(5%)	
	200 or greater		(0%)	193	(3%)	141	(4%)	180	(6%)	138	(11%)	211	(18%)	863	(5%)	
Traffic Safety	Unknown		(0%)		(0%)		(0%)		(0%)		(0%)		(0%)		(0%)	
	Bridgerail not to standard	469	(26%)	6137	(90%)	2624	(79%)	1799	(63%)	755	(63%)	528	(44%)	12312	(71%)	
	Bridgerail meets standards	151	(8%)	705	(10%)	707	(21%)	1034	(36%)	447	(37%)	661	(55%)	3705	(22%)	
	Bridgerail not required	1187	(66%)	4	(0%)	1	(0%)	7	(0%)	2	(0%)	12	(1%)	1213	(7%)	
	Unknown		(0%)		(0%)		(0%)	1	(0%)		(0%)		(0%)	1	(0%)	
	Transitions not up to standard	459	(25%)	6423	(94%)	2917	(88%)	2047	(72%)	825	(69%)	671	(56%)	13342	(77%)	
	Transitions meet standards	163	(9%)	303	(4%)	398	(12%)	778	(27%)	365	(30%)	511	(43%)	2518	(15%)	
	Transitions not required	1185	(66%)	120	(2%)	17	(1%)	14	(0%)	14	(1%)	19	(2%)	1369	(8%)	
	Unknown		(0%)		(0%)		(0%)	1	(0%)		(0%)		(0%)	1	(0%)	
	Approach rail not to standard	456	(25%)	6445	(94%)	2924	(88%)	1984	(70%)	788	(65%)	590	(49%)	13187	(77%)	
	Approach rail meets standards	174	(10%)	285	(4%)	391	(12%)	841	(30%)	402	(33%)	592	(49%)	2685	(16%)	
	Approach rail not required	1177	(65%)	116	(2%)	17	(1%)	14	(0%)	14	(1%)	19	(2%)	1357	(8%)	
	Unknown		(0%)	1	(0%)		(0%)	1	(0%)		(0%)		(0%)	2	(0%)	
	Approach ends not to standard	460	(25%)	6458	(94%)	2942	(88%)	2086	(73%)	848	(70%)	687	(57%)	13481	(78%)	
	Approach ends meet standard	168	(9%)	269	(4%)	381	(11%)	738	(26%)	343	(28%)	501	(42%)	2400	(14%)	
	Approach ends not required	1179	(65%)	118	(2%)	9	(0%)	15	(1%)	13	(1%)	13	(1%)	1347	(8%)	
Road Surface Type	Soil surface	22	(1%)	792	(12%)	122	(4%)	58	(2%)	4	(0%)	17	(1%)	1015	(6%)	
	Gravel surface	1423	(79%)	5885	(86%)	3035	(91%)	2491	(88%)	850	(71%)	823	(69%)	14507	(84%)	
	Bituminous	46	(3%)	74	(1%)	38	(1%)	48	(2%)	21	(2%)	27	(2%)	254	(1%)	
	Asphalt	208	(12%)	61	(1%)	93	(3%)	171	(6%)	215	(18%)	182	(15%)	930	(5%)	
	Concrete	108	(6%)	34	(0%)	44	(1%)	72	(3%)	114	(9%)	152	(13%)	524	(3%)	

Table C.4. Bridge width frequency for LVR bridge crashes.

		Bridge Width, ft (IM Report)															
	Criteria	Unknown		1 to 20 (%)		20.1 to 23.9 (%)		24 to 27.9 (%)		28 to 29.9 (%)		30 or greater (%)		Total (%)		Known Info	
Crashes	# of bridge related crashes	71	(100%)	124	(100%)	49	(100%)	44	(100%)	27	(100%)	26	(100%)	341	(100%)	282	270
AADT	Unknown		(0%)	1	(1%)		(0%)		(0%)		(0%)		(0%)	1	(0%)		
	1 to 49	28	(39%)	42	(34%)	11	(22%)	8	(18%)	5	(19%)	5	(19%)	99	(29%)		
	50 to 99	19	(27%)	46	(37%)	15	(31%)	15	(34%)	2	(7%)	4	(15%)	101	(30%)		
	100 to 149	7	(10%)	16	(13%)	8	(16%)	5	(11%)		(0%)	4	(15%)	40	(12%)		
	150 to 199	6	(8%)	7	(6%)	3	(6%)	3	(7%)	2	(7%)	2	(8%)	23	(7%)		
	200 to 400	11	(15%)	12	(10%)	12	(24%)	13	(30%)	18	(67%)	11	(42%)	77	(23%)		
Bridge Width, ft	Inknown	71	(100%)		(0%)		(0%)		(0%)		(0%)		(0%)	71	(21%)		
	1 to 9.9		(0%)		(0%)		(0%)		(0%)		(0%)		(0%)	0	(0%)		(0%)
	10 to 14.9		(0%)	6	(5%)		(0%)		(0%)		(0%)		(0%)	6	(2%)		(2%)
	15 to 19.9		(0%)	83	(67%)		(0%)		(0%)		(0%)		(0%)	83	(24%)		(31%)
	20 to 24.9		(0%)	35	(28%)	49	(100%)	32	(73%)		(0%)		(0%)	116	(34%)		(43%)
	25 to 30		(0%)		(0%)		(0%)	12	(27%)	27	(100%)		(0%)	39	(11%)		(14%)
	30 to 34.9		(0%)		(0%)		(0%)		(0%)		(0%)	23	(88%)	23	(7%)		(9%)
	35 or greater		(0%)		(0%)		(0%)		(0%)		(0%)	3	(12%)	3	(1%)		(1%)
Bridge Length, ft (IM Report)	Unknown	59	(83%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	1 to 49	12	(17%)	45	(36%)	20	(41%)	14	(32%)	3	(11%)	2	(8%)	96	(28%)	(34%)	
	50 to 99		(0%)	45	(36%)	9	(18%)	11	(25%)	10	(37%)	5	(19%)	80	(23%)	(28%)	
	100 to 149		(0%)	13	(10%)	12	(24%)	9	(20%)	12	(44%)	5	(19%)	51	(15%)	(18%)	
	150 to 199		(0%)	9	(7%)	6	(12%)	4	(9%)		(0%)	4	(15%)	23	(7%)	(8%)	
	200 or greater		(0%)	12	(10%)	2	(4%)	6	(14%)	2	(7%)	10	(38%)	32	(9%)	(11%)	
Traffic Safety	Unknown	59	(83%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Bridgerail not up to standard	2	(3%)	99	(80%)	34	(69%)	29	(66%)	15	(56%)	8	(31%)	187	(55%)	(66%)	
	Bridgerail meets standards	3	(4%)	25	(20%)	15	(31%)	15	(34%)	12	(44%)	17	(65%)	87	(26%)	(31%)	
	Bridgerail not required	7	(10%)		(0%)		(0%)		(0%)		(0%)	1	(4%)	8	(2%)	(3%)	
	Unknown	59	(83%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Transitions not up to standard	4	(6%)	112	(90%)	36	(73%)	33	(75%)	18	(67%)	13	(50%)	216	(63%)	(77%)	
	Transitions meet standards	1	(1%)	9	(7%)	13	(27%)	11	(25%)	9	(33%)	12	(46%)	55	(16%)	(20%)	
	Transitions not required	7	(10%)	3	(2%)		(0%)		(0%)		(0%)	1	(4%)	11	(3%)	(4%)	
	Unknown	59	(83%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Approach rail not up to standard	4	(6%)	116	(94%)	38	(78%)	28	(64%)	14	(52%)	9	(35%)	209	(61%)	(74%)	
	Approach rail meets standards	3	(4%)	5	(4%)	11	(22%)	16	(36%)	13	(48%)	16	(62%)	64	(19%)	(23%)	
	Approach rail not required	5	(7%)	3	(2%)		(0%)		(0%)		(0%)	1	(4%)	9	(3%)	(3%)	
	Unknown	59	(83%)		(0%)		(0%)		(0%)		(0%)		(0%)	59	(17%)		
	Approach ends not up to standard	4	(6%)	116	(94%)	38	(78%)	31	(70%)	16	(59%)	13	(50%)	218	(64%)	(77%)	
	Approach ends meet standard	3	(4%)	5	(4%)	11	(22%)	13	(30%)	11	(41%)	12	(46%)	55	(16%)	(20%)	
	Approach ends not required	5	(7%)	3	(2%)		(0%)		(0%)		(0%)	1	(4%)	9	(3%)	(3%)	
Road Surface Type	Soil Surface	3	(4%)	1	(1%)		(0%)		(0%)		(0%)	1	(4%)	5	(1%)		
	Gravel Surface	57	(80%)	112	(90%)	39	(80%)	30	(68%)	7	(26%)	13	(50%)	258	(76%)		
	Bituminous	3	(4%)	8	(6%)	1	(2%)	1	(2%)	1	(4%)	3	(12%)	17	(5%)		
	Asphalt	7	(10%)	2	(2%)	8	(16%)	9	(20%)	15	(56%)	3	(12%)	44	(13%)		
	Concrete	1	(1%)	1	(1%)	1	(2%)	4	(9%)	4	(15%)	6	(23%)	17	(5%)		

Table C.4. Bridge width frequency for LVR bridge crashes (cont.).

		Bridge Width, ft (IM Report)													
	Criteria	Unknown		1 to 20 (%)		20.1 to 23.9 (%)		24 to 27.9 (%)		28 to 29.9 (%)		30 or greater (%)		Total (%)	
Crash Severity	Fatal Crash	3	(4%)	3	(2%)	3	(6%)		(0%)	2	(7%)	1	(4%)	12	(4%)
	Major Injury	3	(4%)	11	(9%)	2	(4%)	2	(5%)	1	(4%)		(0%)	19	(6%)
	Minor Injury	16	(23%)	27	(22%)	12	(24%)	11	(25%)	9	(33%)	6	(23%)	81	(24%)
	Possible or unknown	10	(14%)	24	(19%)	12	(24%)	5	(11%)	2	(7%)	4	(15%)	57	(17%)
	Property Damage only	39	(55%)	59	(48%)	20	(41%)	26	(59%)	13	(48%)	15	(58%)	172	(50%)
Object Struck	Guardrail (b/n terminal & bridge)	9	(13%)	8	(6%)	2	(4%)	6	(14%)	2	(7%)	7	(27%)	34	(10%)
	Guardrail (terminal)	4	(6%)	3	(2%)	2	(4%)		(0%)	1	(4%)	2	(8%)	12	(4%)
	Guardrail (unclear)	5	(7%)	10	(8%)	4	(8%)	6	(14%)	6	(22%)	2	(8%)	33	(10%)
	Bridge rail	28	(39%)	54	(44%)	18	(37%)	19	(43%)	12	(44%)	9	(35%)	140	(41%)
	Bridge end	14	(20%)	21	(17%)	10	(20%)	4	(9%)	2	(7%)	3	(12%)	54	(16%)
	Bridge Unclear	11	(15%)	28	(23%)	13	(27%)	9	(20%)	4	(15%)	3	(12%)	68	(20%)
Order of Strike	Primary Strike	69	(97%)	121	(98%)	49	(100%)	43	(98%)	23	(85%)	24	(92%)	329	(96%)
	Secondary Strike	2	(3%)	3	(2%)		(0%)	1	(2%)	4	(15%)	2	(8%)	12	(4%)
Light Conditions	# of crashes in Day Light	25	(35%)	57	(46%)	26	(53%)	18	(41%)	14	(52%)	13	(50%)	153	(45%)
	# of crashes Dusk	2	(3%)	6	(5%)	1	(2%)	2	(5%)		(0%)	1	(4%)	12	(4%)
	# of crashes Dawn	2	(3%)	2	(2%)		(0%)		(0%)	1	(4%)	1	(4%)	6	(2%)
	# of crashes Dark Roadway Lit		(0%)	1	(1%)	1	(2%)	1	(2%)		(0%)		(0%)	3	(1%)
	# of crashes Dark Roadway not Lit	40	(56%)	58	(47%)	20	(41%)	21	(48%)	12	(44%)	10	(38%)	161	(47%)
	# of crashes Dark unkown lighting		(0%)		(0%)		(0%)		(0%)		(0%)	1	(4%)	1	(0%)
	Unknown	2	(3%)		(0%)		(0%)		(0%)		(0%)		(0%)	2	(1%)
	Not Reported		(0%)		(0%)	1	(2%)	2	(5%)		(0%)		(0%)	3	(1%)

Table C.4. Bridge width frequency for LVR bridge crashes (cont.).

		Bridge Width, ft (IM Report)													
	Criteria	Unknown		1 to 20 (%)		20.1 to 23.9 (%)		24 to 27.9 (%)		28 to 29.9 (%)		30 or greater (%)		Total (%)	
Weather Condition #1	# of crashes on Clear day	37	(52%)	58	(47%)	29	(59%)	22	(50%)	14	(52%)	15	(58%)	175	(51%)
	# of crashes on partly cloudy day	11	(15%)	24	(19%)	4	(8%)	7	(16%)	6	(22%)	5		57	(17%)
	# of crashes on a cloudy day	6	(8%)	15	(12%)	4	(8%)	4	(9%)	4	(15%)			33	(10%)
	# of crashes on a Foggy day		(0%)	3	(2%)	1	(2%)		(0%)		(0%)	1		5	(1%)
	# of crashes on Misty day	1	(1%)	1	(1%)		(0%)	2	(5%)		(0%)	1		5	(1%)
	# of crashes on Rainy day	1	(1%)	5	(4%)	2	(4%)	1	(2%)		(0%)			9	(3%)
	# of crashes with Sleet/hail	2	(3%)	1	(1%)	1	(2%)	1	(2%)	1	(4%)	1		7	(2%)
	# of crashes on snowy day	5	(7%)	4	(3%)	2	(4%)	2	(5%)	2	(7%)	2		17	(5%)
	# of crashes on Severe Winds	1	(1%)	2	(2%)	1	(2%)	1	(2%)		(0%)	1		6	(2%)
	# of crashes w/ Blowing Soil/Snow		(0%)	1	(1%)		(0%)		(0%)		(0%)			1	(0%)
	# of crashes condition not reported	2	(3%)	2	(2%)	2	(4%)	2	(5%)		(0%)			8	(2%)
	Other		(0%)	1	(1%)		(0%)		(0%)		(0%)			1	(0%)
	# of crashes unknown	5	(7%)	7	(6%)	3	(6%)	2	(5%)		(0%)			17	(5%)
Driving Surface Conditions	# of crashes on dry surface	33	(46%)	54	(44%)	27	(55%)	20	(45%)	14	(52%)	10		158	(46%)
	# of crashes on wet surface	1	(1%)	4	(3%)	3	(6%)	2	(5%)		(0%)	2		12	(4%)
	# of crashes on icy surface	3	(4%)	13	(10%)	1	(2%)	5	(11%)	4	(15%)	4		30	(9%)
	# of crashes on snowy surface	7	(10%)	5	(4%)	4	(8%)	3	(7%)	2	(7%)	3		24	(7%)
	# of crashes on slushy surface	2	(3%)	2	(2%)		(0%)	2	(5%)	1	(4%)	1		8	(2%)
	# of crashes on dirt/oil/gravel	22	(31%)	45	(36%)	12	(24%)	6	(14%)	4	(15%)	6		95	(28%)
	other		(0%)		(0%)	1	(2%)	1	(2%)	1	(4%)			3	(1%)
	Unknown	1	(1%)		(0%)		(0%)	1	(2%)	1	(4%)			3	(1%)
	Not Reported	2	(3%)	1	(1%)	1	(2%)	4	(9%)		(0%)			8	(2%)

Table C.5. Bridge length frequency data for LVR inventoried bridge population.

Criteria		Bridge Length, ft (IM Report) 1 to 49 (%)		50 to 99(%)		100 to 149 (%)		150 to 199 (%)		200 or greater (%)		Total (%)		Known Info
Bridges	# of inventoried bridges	9004	(100%)	4102	(100%)	2343	(100%)	918	(100%)	863	(100%)	17230	(100%)	15423
AADT	Unknown	6	(0%)	3	(0%)	1	(0%)	1	(0%)		(0%)	11	(0%)	
	1 to 49	5525	(61%)	2567	(63%)	1144	(49%)	349	(38%)	207	(24%)	9792	(57%)	
	50 to 99	2178	(24%)	943	(23%)	654	(28%)	271	(30%)	291	(34%)	4337	(25%)	
	100 to 149	545	(6%)	261	(6%)	177	(8%)	90	(10%)	117	(14%)	1190	(7%)	
	150 to 199	214	(2%)	93	(2%)	93	(4%)	54	(6%)	66	(8%)	520	(3%)	
	200 to 400	536	(6%)	235	(6%)	274	(12%)	153	(17%)	182	(21%)	1380	(8%)	
Bridge Width, ft (IM Report)	Unknown	1748	(19%)	55	(1%)	2	(0%)	2	(0%)		(0%)	1807	(10%)	(-)
	1 to 20	3652	(41%)	1984	(48%)	692	(30%)	325	(35%)	193	(22%)	6846	(40%)	(44%)
	20.1 to 23.9	1841	(20%)	806	(20%)	397	(17%)	147	(16%)	141	(16%)	3332	(19%)	(22%)
	24 to 27.9	1209	(13%)	628	(15%)	612	(26%)	211	(23%)	180	(21%)	2840	(16%)	(18%)
	28 to 29.9	308	(3%)	333	(8%)	320	(14%)	105	(11%)	138	(16%)	1204	(7%)	(8%)
	30 or greater	246	(3%)	296	(7%)	320	(14%)	128	(14%)	211	(24%)	1201	(7%)	(8%)
Bridge Length, ft (IM Report)	1 to 49	9004	(100%)		(0%)		(0%)		(0%)		(0%)	9004	(52%)	
	50 to 99		(0%)	4102	(100%)		(0%)		(0%)		(0%)	4102	(24%)	
	100 to 149		(0%)		(0%)	2343	(100%)		(0%)		(0%)	2343	(14%)	
	150 to 199		(0%)		(0%)		(0%)	918	(100%)		(0%)	918	(5%)	
	200 or greater		(0%)		(0%)		(0%)		(0%)	863	(100%)	863	(5%)	
Traffic Safety	Unknown		(0%)		(0%)		(0%)		(0%)		(0%)		(0%)	
	Bridgerail not to standard	6582	(73%)	3214	(78%)	1483	(63%)	567	(62%)	466	(54%)	12312	(71%)	
	Bridgerail meets standards	1251	(14%)	852	(21%)	857	(37%)	348	(38%)	397	(46%)	3705	(22%)	
	Bridgerail not required	1171	(13%)	36	(1%)	3	(0%)	3	(0%)		(0%)	1213	(7%)	
	Unknown		(0%)		(0%)	1	(0%)		(0%)		(0%)	1	(0%)	
	Transitions not to standard	7042	(78%)	3452	(84%)	1690	(72%)	649	(71%)	509	(59%)	13342	(77%)	
	Transitions meet standards	750	(8%)	552	(13%)	614	(26%)	252	(27%)	350	(41%)	2518	(15%)	
	Transitions not required	1212	(13%)	98	(2%)	38	(2%)	17	(2%)	4	(0%)	1369	(8%)	
	Unknown		(0%)		(0%)	1	(0%)		(0%)		(0%)	1	(0%)	
	Approach rail not to standard	7051	(78%)	3425	(83%)	1626	(69%)	642	(70%)	443	(51%)	13187	(77%)	
	Approach rail meets standards	751	(8%)	579	(14%)	680	(29%)	259	(28%)	416	(48%)	2685	(16%)	
	Approach rail not required	1202	(13%)	98	(2%)	36	(2%)	17	(2%)	4	(0%)	1357	(8%)	
	Unknown	1	(0%)		(0%)	1	(0%)		(0%)		(0%)	2	(0%)	
	Approach ends not to standard	7081	(79%)	3486	(85%)	1715	(73%)	676	(74%)	523	(61%)	13481	(78%)	
	Approach ends meet standard	730	(8%)	519	(13%)	590	(25%)	225	(25%)	336	(39%)	2400	(14%)	
	Approach ends not required	1192	(13%)	97	(2%)	37	(2%)	17	(2%)	4	(0%)	1347	(8%)	
Road Surface Type	Soil surface	617	(7%)	297	(7%)	74	(3%)	21	(2%)	6	(1%)	1015	(6%)	
	Gravel surface	7706	(86%)	3477	(85%)	1949	(83%)	728	(79%)	647	(75%)	14507	(84%)	
	Bituminous	102	(1%)	55	(1%)	44	(2%)	21	(2%)	32	(4%)	254	(1%)	
	Asphalt	399	(4%)	190	(5%)	172	(7%)	92	(10%)	77	(9%)	930	(5%)	
	Concrete	180	(2%)	83	(2%)	104	(4%)	56	(6%)	101	(12%)	524	(3%)	

Table C.6. Bridge Length frequency for LVR bridge crashes.

		Bridge Length, ft (IM Report)								
	Criteria	Unknown (%)	1 to 49 (%)	50 to 99 (%)	100 to 149 (%)	150 to 199 (%)	200 or more (%)	Total (%)	Known Info	
Crashes	# fo bridge related crashes	59 (100%)	96 (100%)	80 (100%)	51 (100%)	23 (100%)	32 (100%)	341 (100%)	282	270
AADT	Unknown	(0%)	(0%)	1 (1%)	(0%)	(0%)	(0%)	1 (0%)		
	1 to 49	26 (44%)	32 (33%)	25 (31%)	7 (14%)	7 (30%)	2 (6%)	99 (29%)		
	50 to 99	15 (25%)	34 (35%)	24 (30%)	13 (25%)	4 (17%)	11 (34%)	101 (30%)		
	100 to 149	5 (8%)	11 (11%)	12 (15%)	4 (8%)	5 (22%)	3 (9%)	40 (12%)		
	150 to 199	6 (10%)	5 (5%)	4 (5%)	4 (8%)	1 (4%)	3 (9%)	23 (7%)		
	200 to 400	7 (12%)	14 (15%)	14 (18%)	23 (45%)	6 (26%)	13 (41%)	77 (23%)		
Bridge Width, ft (IM Report)	Unknown	59 (100%)	12 (13%)	(0%)	(0%)	(0%)	(0%)	71 (21%)		
	1 to 20	(0%)	45 (47%)	45 (56%)	13 (25%)	9 (39%)	12 (38%)	124 (36%)		(46%)
	20.1 to 23.9	(0%)	20 (21%)	9 (11%)	12 (24%)	6 (26%)	2 (6%)	49 (14%)		(18%)
	24 to 27.9	(0%)	14 (15%)	11 (14%)	9 (18%)	4 (17%)	6 (19%)	44 (13%)		(16%)
	28 to 29.9	(0%)	3 (3%)	10 (13%)	12 (24%)	(0%)	2 (6%)	27 (8%)		(10%)
	30 or greater	(0%)	2 (2%)	5 (6%)	5 (10%)	4 (17%)	10 (31%)	26 (8%)		(10%)
Bridge Length, ft (IM Report)	Unknown	59 (100%)	(0%)	(0%)	(0%)	(0%)	(0%)	59 (17%)		
	1 to 49	(0%)	96 (100%)	(0%)	(0%)	(0%)	(0%)	96 (28%)	(34%)	
	50 to 99	(0%)	(0%)	80 (100%)	(0%)	(0%)	(0%)	80 (23%)	(28%)	
	100 to 149	(0%)	(0%)	(0%)	51 (100%)	(0%)	(0%)	51 (15%)	(18%)	
	150 to 199	(0%)	(0%)	(0%)	(0%)	23 (100%)	(0%)	223 (65%)	(79%)	
	200 or greater	(0%)	(0%)	(0%)	(0%)	(0%)	32 (100%)	32 (9%)	(11%)	
Traffic Safety	Unknown	59 (100%)	(0%)	(0%)	(0%)	(0%)	(0%)	59 (17%)		
	Bridgerail not up to standard	(0%)	71 (74%)	56 (70%)	26 (51%)	17 (74%)	17 (53%)	187 (55%)	(66%)	
	Bridgerail meets standards	(0%)	18 (19%)	23 (29%)	25 (49%)	6 (26%)	15 (47%)	87 (26%)	(31%)	
	Bridgerail not required	(0%)	7 (7%)	1 (1%)	(0%)	(0%)	(0%)	8 (2%)	(3%)	
	Unknown	59 (100%)	(0%)	(0%)	(0%)	(0%)	(0%)	59 (17%)		
	Transitions not up to standard	(0%)	77 (80%)	69 (86%)	29 (57%)	17 (74%)	24 (75%)	216 (63%)	(77%)	
	Transitions meet standards	(0%)	11 (11%)	9 (11%)	22 (43%)	5 (22%)	8 (25%)	55 (16%)	(20%)	
	Transitions not required	(0%)	8 (8%)	2 (3%)	(0%)	1 (4%)	(0%)	11 (3%)	(4%)	
	Unknown	59 (100%)	(0%)	(0%)	(0%)	(0%)	(0%)	59 (17%)		
	Approach rail not up to standard	(0%)	76 (79%)	67 (84%)	28 (55%)	18 (78%)	20 (63%)	209 (61%)	(74%)	
	Approach rail meets standards	(0%)	14 (15%)	11 (14%)	23 (45%)	4 (17%)	12 (38%)	64 (19%)	(23%)	
	Approach rail not required	(0%)	6 (6%)	2 (3%)	(0%)	1 (4%)	(0%)	9 (3%)	(3%)	
	Unknown	59 (100%)	(0%)	(0%)	(0%)	(0%)	(0%)	59 (17%)		
	Approach ends not up to standard	(0%)	78 (81%)	68 (85%)	31 (61%)	18 (78%)	23 (72%)	218 (64%)	(77%)	
	Approach ends meet standard	(0%)	12 (13%)	10 (13%)	20 (39%)	4 (17%)	9 (28%)	55 (16%)	(20%)	
	Approach ends not required	(0%)	6 (6%)	2 (3%)	(0%)	1 (4%)	(0%)	9 (3%)	(3%)	
Road Surface Type	Soil Surface	3 (5%)	1 (1%)	1 (1%)	(0%)	(0%)	(0%)	5 (1%)		
	Gravel Surface	49 (83%)	79 (82%)	60 (75%)	28 (55%)	20 (87%)	22 (69%)	258 (76%)		
	Bituminous	3 (5%)	(0%)	8 (10%)	5 (10%)	(0%)	1 (3%)	17 (5%)		
	Asphalt	3 (5%)	14 (15%)	9 (11%)	14 (27%)	1 (4%)	3 (9%)	44 (13%)		
	Concrete	1 (2%)	2 (2%)	2 (3%)	4 (8%)	2 (9%)	6 (19%)	17 (5%)		

Table C.6. Bridge Length frequency for LVR bridge crashes (cont.).

Criteria		Bridge Length												Total (%)	
		Unknown (%)		1 to 49 (%)		50 to 99 (%)		100 to 149 (%)		150 to 199 (%)		200 or more (%)			
Crash Severity	Fatal Crash	1	(2%)	4	(4%)	3	(4%)	3	(6%)		(0%)	1	(3%)	12	(4%)
	Major Injury	3	(5%)	6	(6%)	7	(9%)	3	(6%)		(0%)		(0%)	19	(6%)
	Minor Injury	12	(20%)	25	(26%)	21	(26%)	14	(27%)	3	(13%)	6	(19%)	81	(24%)
	Possible or unknown	10	(17%)	14	(15%)	14	(18%)	2	(4%)	8	(35%)	9	(28%)	57	(17%)
	Property Damage only	33	(56%)	47	(49%)	35	(44%)	29	(57%)	12	(52%)	16	(50%)	172	(50%)
Object Struck	Guardrail (b/n terminal & bridge)	7	(12%)	10	(10%)	5	(6%)	2	(4%)	3	(13%)	7	(22%)	34	(10%)
	Guardrail (terminal)	2	(3%)	4	(4%)	1	(1%)	3	(6%)	1	(4%)	1	(3%)	12	(4%)
	Guardrail (unclear)	3	(5%)	7	(7%)	10	(13%)	8	(16%)	2	(9%)	3	(9%)	33	(10%)
	Bridge rail	23	(39%)	41	(43%)	30	(38%)	26	(51%)	11	(48%)	9	(28%)	140	(41%)
	Bridge end	13	(22%)	12	(13%)	13	(16%)	8	(16%)	1	(4%)	7	(22%)	54	(16%)
	Bridge Unclear	11	(19%)	22	(23%)	21	(26%)	4	(8%)	5	(22%)	5	(16%)	68	(20%)
Order of Strike	Primary Strike	57	(97%)	93	(97%)	77	(96%)	49	(96%)	23	(100%)	30	(94%)	329	(96%)
	Secondary Strike	2	(3%)	3	(3%)	3	(4%)	2	(4%)		(0%)	2	(6%)	12	(4%)
Light Conditions	# of crashes in Day Light	19	(32%)	44	(46%)	35	(44%)	27	(53%)	13	(57%)	15	(47%)	153	(45%)
	# of crashes Dusk	2	(3%)	4	(4%)	3	(4%)	1	(2%)	2	(9%)		(0%)	12	(4%)
	# of crashes Dawn	2	(3%)	1	(1%)		(0%)	3	(6%)		(0%)		(0%)	6	(2%)
	# of crashes Dark Roadway Lit		(0%)	3	(3%)		(0%)		(0%)		(0%)		(0%)	3	(1%)
	# of crashes Dark Roadway not Lit	34	(58%)	44	(46%)	41	(51%)	19	(37%)	8	(35%)	15	(47%)	161	(47%)
	# of crashes Dark unkown lighting		(0%)		(0%)		(0%)		(0%)		(0%)	1	(3%)	1	(0%)
	Unknown	2	(3%)		(0%)		(0%)		(0%)		(0%)		(0%)	2	(1%)
	Not Reported		(0%)		(0%)	1	(1%)	1	(2%)		(0%)	1	(3%)	3	(1%)

Table C.6. Bridge Length frequency for LVR bridge crashes (cont.).

		Bridge Length													
	Criteria	Unknown (%)		1 to 49 (%)		50 to 99 (%)		100 to 149 (%)		150 to 199 (%)		200 or more (%)		Total (%)	
Weather Condition #1	# of crashes on Clear day	29	(49%)	50	(52%)	39	(49%)	27	(53%)	16	(70%)	14	(44%)	175	(51%)
	# of crashes on partly cloudy day	11	(19%)	15	(16%)	17	(21%)	11	(22%)	2	(9%)	1	(3%)	57	(17%)
	# of crashes on a cloudy day	4	(7%)	8	(8%)	12	(15%)	3	(6%)	2	(9%)	4	(13%)	33	(10%)
	# of crashes on a Foggy day		(0%)	1	(1%)	1	(1%)	1	(2%)	1	(4%)	1	(3%)	5	(1%)
	# of crashes on Misty day	1	(2%)	2	(2%)		(0%)		(0%)	1	(4%)	1	(3%)	5	(1%)
	# of crashes on Rainy day	1	(2%)	2	(2%)	3	(4%)	1	(2%)		(0%)	2	(6%)	9	(3%)
	# of crashes with Sleet/hail	1	(2%)	4	(4%)	1	(1%)		(0%)		(0%)	1	(3%)	7	(2%)
	# of crashes on snowy day	4	(7%)	4	(4%)	2	(3%)	3	(6%)	1	(4%)	3	(9%)	17	(5%)
	# of crashes on Severe Winds	1	(2%)	3	(3%)	1	(1%)		(0%)		(0%)	1	(3%)	6	(2%)
	# of crashes w/ Blowing Dirt/Snow		(0%)	1	(1%)		(0%)		(0%)		(0%)		(0%)	1	(0%)
	# of crashes condition not reported	2	(3%)	1	(1%)	2	(3%)	2	(4%)		(0%)	1	(3%)	8	(2%)
	Other		(0%)		(0%)		(0%)		(0%)		(0%)	1	(3%)	1	(0%)
	# of crashes unknown	5	(8%)	5	(5%)	2	(3%)	3	(6%)		(0%)	2	(6%)	17	(5%)
Driving Surface Conditions	# of crashes on dry surface	27	(46%)	47	(49%)	34	(43%)	29	(57%)	12	(52%)	9	(28%)	158	(46%)
	# of crashes on wet surface	1	(2%)	2	(2%)	3	(4%)	2	(4%)		(0%)	4	(13%)	12	(4%)
	# of crashes on icy surface	3	(5%)	5	(5%)	9	(11%)	6	(12%)	3	(13%)	4	(13%)	30	(9%)
	# of crashes on snowy surface	6	(10%)	6	(6%)	5	(6%)	2	(4%)	2	(9%)	3	(9%)	24	(7%)
	# of crashes on slushy surface	1	(2%)	5	(5%)	1	(1%)		(0%)		(0%)	1	(3%)	8	(2%)
	# of crashes on dirt/oil/gravel	19	(32%)	29	(30%)	24	(30%)	8	(16%)	6	(26%)	9	(28%)	95	(28%)
	other		(0%)		(0%)	1	(1%)	2	(4%)		(0%)		(0%)	3	(1%)
	Unknown	1	(2%)	1	(1%)	1	(1%)		(0%)		(0%)		(0%)	3	(1%)
	Not Reported	1	(2%)	1	(1%)	2	(3%)	2	(4%)		(0%)	2	(6%)	8	(2%)

Table C.7. Object struck crash frequency with respect to bridge safety features.

	Criteria	Object Struck: Guardrail between terminal & bridge		Guardrail terminal (%)		Guardrail unclear (%)		Bridge rail (%)		Bridge end (%)		Bridge Unclear (%)		Total (%)		Known Info
Crashes	# of bridge related crashes	34	(100%)	12	(100%)	33	(100%)	140	(100%)	54	(100%)	68	(100%)	341	(100%)	282
Bridge Rail	Unknown	7	(21%)	2	(17%)	3	(9%)	23	(16%)	13	(24%)	11	(16%)	59	(17%)	
	Not up to standard	15	(44%)	6	(50%)	16	(48%)	75	(54%)	30	(56%)	45	(66%)	187	(55%)	(66%)
	Meets standards	10	(29%)	2	(17%)	13	(39%)	39	(28%)	11	(20%)	12	(18%)	87	(26%)	(31%)
	Not required	2	(6%)	2	(17%)	1	(3%)	3	(2%)		(0%)		(0%)	8	(2%)	(3%)
Transition	Unknown	7	(21%)	2	(17%)	3	(9%)	23	(16%)	13	(24%)	11	(16%)	59	(17%)	
	Not up to standard	18	(53%)	5	(42%)	16	(48%)	90	(64%)	36	(67%)	51	(75%)	216	(63%)	(77%)
	Meet standards	6	(18%)	3	(25%)	12	(36%)	23	(16%)	5	(9%)	6	(9%)	55	(16%)	(20%)
	Not required	3	(9%)	2	(17%)	2	(6%)	4	(3%)		(0%)		(0%)	11	(3%)	(4%)
Approach Guardrail	Unknown	7	(21%)	2	(17%)	3	(9%)	23	(16%)	13	(24%)	11	(16%)	59	(17%)	
	Not up to standard	12	(35%)	4	(33%)	16	(48%)	88	(63%)	36	(67%)	53	(78%)	209	(61%)	(74%)
	Meets standards	14	(41%)	4	(33%)	12	(36%)	25	(18%)	5	(9%)	4	(6%)	64	(19%)	(23%)
	Not required	1	(3%)	2	(17%)	2	(6%)	4	(3%)		(0%)		(0%)	9	(3%)	(3%)
Appraoch Guardrail End	Unknown	7	(21%)	2	(17%)	3	(9%)	23	(16%)	13	(24%)	11	(16%)	59	(17%)	
	Not up to standard	15	(44%)	5	(42%)	17	(52%)	91	(65%)	36	(67%)	54	(79%)	218	(64%)	(77%)
	Meet standard	11	(32%)	3	(25%)	11	(33%)	22	(16%)	5	(9%)	3	(4%)	55	(16%)	(20%)
	Not required	1	(3%)	2	(17%)	2	(6%)	4	(3%)		(0%)		(0%)	9	(3%)	(3%)

APPENDIX D: BENEFIT-COST SAFETY ANALYSIS WORKSHEETS

Rev. 5/08

Intersection or Spot Benefit / Cost Safety Analysis

Iowa DOT Office of Traffic & Safety

County: Statewide | Prepared by: Intrans | Date Prepared: Dec. 11, 2009

Intersection: Total of 12312 Inventoried Bridges with Bridge Rail Not Up to Standard

Improvement

Proposed Improvement(s): Improving All Bridge Railing Not Up to Standards (low CRF)

Scenario 1

$74,500,000	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 4,970,000	Other Annual Cost (after initial year), **AC**	5	Crash Reduction Factor (integer), **CRF**
$85,941,404	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 160,441,404	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^{Y}}\right)$$

Traffic Volume Data

Source: GIMS | Varies | Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

716,036

261,353,140	Current Annual Entering Veh., **AEV** = DEV * 365
716,036	veh / day, Final Year DEV, **FDEV**
7,840.59	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

716,036 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^{Y}\right) / 10^{6}$$

Crash Data

2001 First full year --> 2008 Last full year | 8.0 years, Time Period, **T**

Additional months | values as of Dec. 2007

Crashes		Injuries		Unit cost	Cost
4	Fatal Crashes	5	Fatalities @	$3,500,000	$ 17,500,000
		20	Major Injuries @	$240,000	$ 4,800,000
96	Injury Crashes	55	Minor Injuries @	$48,000	$ 2,640,000
		57	Possible Injuries @	$25,000	$ 1,425,000
87	Property Damage Only		(assumed cost per crash)	$2,700	$ 234,900
			-OR- enter Actual Cost of all property damage:		
187	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 26,599,900

23.38	Current Crashes / Year, **AA** = TA / T
$ 142,245	Cost per Crash, **AVC** = LOSS / TA
701.3	Total Expected Crashes, **TECR** = CR x TMEV
1.17	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 166,249	Crash Costs Avoided in First Year, AAR x AVC
35.1	Total Avoided Crashes, TECR x CRF/ 100

0.09 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$ 2,874,790 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^{Y}\right)$$

Benefit / Cost Ratio

Benefit : Cost = $2,874,790 : $160,441,404 = **0.02** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide | Prepared by: Intrans | Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving All Bridge Railing Not Up to Standards (high CRF)

Scenario 1

$74,500,000	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 4,970,000	Other Annual Cost (after initial year), **AC**	20	Crash Reduction Factor (integer), **CRF**
$85,941,404	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 160,441,404	Present Value Cost, **COST** = EC + OC

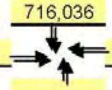
$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^Y}\right)$$

Traffic Volume Data

Source: GIMS | Varies | Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

716,036



261,353,140	Current Annual Entering Veh., **AEV** = DEV * 365
716,036	veh / day, Final Year DEV, **FDEV**
7,840.59	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0%	Projected Traffic Growth (0%-10%), **G**
716,036	Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^Y\right) \Big/ 10^6$$

Crash Data

2001	First full year -->	2008	Last full year	8.0	years, Time Period, **T**
	Additional months				values as of Dec. 2007

4	Fatal Crashes	5	Fatalities @	$3,500,000	$ 17,500,000
		20	Major Injuries @	$240,000	$ 4,800,000
96	Injury Crashes	55	Minor Injuries @	$48,000	$ 2,640,000
		57	Possible Injuries @	$25,000	$ 1,425,000
87	Property Damage Only		(assumed cost per crash)	$2,700	$ 234,900
			-OR- enter Actual Cost of all property damage:		
187	Total Crashes, **TA**		Total $ Loss, **LOSS**		$ 26,599,900

23.38	Current Crashes / Year, **AA** = TA / T
$ 142,245	Cost per Crash, **AVC** = LOSS / TA
701.3	Total Expected Crashes, **TECR** = CR x TMEV
4.68	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 664,998	Crash Costs Avoided in First Year, AAR x AVC
140.3	Total Avoided Crashes, TECR x CRF/ 100

0.09 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$11,499,159 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^Y\right)$$

Benefit / Cost Ratio

Benefit : Cost = $11,499,159 : $160,441,404 = **0.07** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide | Prepared by: Intrans | Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving All Bridge Railing Not Up to Standards for Fatal Crashes

Scenario 1

$ 74,500,000	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 4,970,000	Other Annual Cost (after initial year), **AC**	92	Crash Reduction Factor (integer), **CRF**
$ 85,941,404	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 160,441,404	Present Value Cost, **COST** = EC + OC

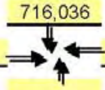
$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^{Y}}\right)$$

Traffic Volume Data

Source: GIMS | Varies | Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

716,036



261,353,140	Current Annual Entering Veh., **AEV** = DEV * 365
716,036	veh / day, Final Year DEV, **FDEV**
7,840.59	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

716,036 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1-\left(\frac{1+G}{1}\right)^{Y}\right) \Big/ 10^{6}$$

Crash Data

2001 First full year --> 2008 Last full year | 8.0 years, Time Period, **T**

Additional months | values as of Dec. 2007

4	Fatal Crashes	5	Fatalities @	$3,500,000	$ 17,500,000
			Major Injuries @	$240,000	$ -
	Injury Crashes		Minor Injuries @	$48,000	$ -
			Possible Injuries @	$25,000	$ -
	Property Damage Only		(assumed cost per crash)	$2,700	$ -
			-OR- enter Actual Cost of all property damage:		
4	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 17,500,000

0.50	Current Crashes / Year, **AA** = TA / T
$ 4,375,000	Cost per Crash, **AVC** = LOSS / TA
15.0	Total Expected Crashes, **TECR** = CR x TMEV
0.46	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 2,012,500	Crash Costs Avoided in First Year, AAR x AVC
13.8	Total Avoided Crashes, TECR x CRF/ 100

0.00 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$34,800,217 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1-\left(\frac{1+G}{1+INT}\right)^{Y}\right)$$

Benefit / Cost Ratio

Benefit : Cost = $34,800,217 : $160,441,404 = **0.22** : 1

Rev. 5/08

Intersection or Spot Benefit / Cost Safety Analysis

Iowa DOT Office of Traffic & Safety

County: Statewide — Prepared by: InTrans — Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Railings on Bridges with AADT Less Than or Equal to 99

Scenario 2

$ 59,659,020	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 3,977,268	Other Annual Cost (after initial year), **AC**	20	Crash Reduction Factor (integer), **CRF**
$ 68,775,050	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 128,434,070	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^Y}\right)$$

Traffic Volume Data

Source: GIMS — Varies — Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

379,302

138,445,230	Current Annual Entering Veh., **AEV** = DEV * 365
379,302	veh / day, Final Year DEV, **FDEV**
4,153.36	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

379,302 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^Y\right) \Big/ 10^6$$

Crash Data

2001 First full year --> 2008 Last full year — 8.0 years, Time Period, **T**

Additional months — values as of Dec. 2007

Crashes	Type	Injuries	Severity	Unit cost	Total
3	Fatal Crashes	4	Fatalities @	$3,500,000	$ 14,000,000
		15	Major Injuries @	$240,000	$ 3,600,000
35	Injury Crashes	31	Minor Injuries @	$48,000	$ 1,488,000
		36	Possible Injuries @	$25,000	$ 900,000
59	Property Damage Only		(assumed cost per crash)	$2,700	$ 159,300
			-OR- enter Actual Cost of all property damage:		
97	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 20,147,300

12.13	Current Crashes / Year, **AA** = TA / T
$ 207,704	Cost per Crash, **AVC** = LOSS / TA
363.8	Total Expected Crashes, **TECR** = CR x TMEV
2.43	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 503,683	Crash Costs Avoided in First Year, AAR x AVC
72.8	Total Avoided Crashes, TECR x CRF/ 100

0.09 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$ 8,709,694 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^Y\right)$$

Benefit / Cost Ratio

Benefit : Cost = $8,709,694 : $128,434,070 = **0.07** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide | Prepared by: InTrans | Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Railings on Bridges with AADT Less Than or Equal to 99 Fatal Cras

Scenario 2

$59,659,020	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 2,275,812	Other Annual Cost (after initial year), **AC**	92	Crash Reduction Factor (integer), **CRF**
$39,353,416	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 99,012,436	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^{Y}}\right)$$

Traffic Volume Data

Source: GIMS | Varies Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

379,302

138,445,230 Current Annual Entering Veh., **AEV** = DEV * 365

379,302 veh / day, Final Year DEV, **FDEV**

4,153.36 MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

379,302 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^{Y}\right) \Big/ 10^{6}$$

Crash Data

2001 First full year --> 2008 Last full year | 8.0 years, Time Period, **T**

Additional months | values as of Dec. 2007

3	Fatal Crashes	4	Fatalities @	$3,500,000	$ 14,000,000
			Major Injuries @	$240,000	$ -
	Injury Crashes		Minor Injuries @	$48,000	$ -
			Possible Injuries @	$25,000	$ -
	Property Damage Only		(assumed cost per crash)	$2,700	$ -
			-OR- enter Actual Cost of all property damage:		
3	Total Crashes, **TA**		Total $ Loss, **LOSS**		$ 14,000,000

0.38	Current Crashes / Year, **AA** = TA / T
$ 4,666,667	Cost per Crash, **AVC** = LOSS / TA
11.3	Total Expected Crashes, **TECR** = CR x TMEV
0.35	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 1,610,000	Crash Costs Avoided in First Year, AAR x AVC
10.4	Total Avoided Crashes, TECR x CRF/ 100

0.00 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$27,840,173 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^{Y}\right)$$

Benefit / Cost Ratio

Benefit : Cost = $27,840,173 : $99,012,436 = **0.28** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide Prepared by: InTrans Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Railings on Bridges with Bridge Width Less Than or Equal to 23.9

Scenario 3

$ 51,497,370	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 3,433,158	Other Annual Cost (after initial year), **AC**	20	Crash Reduction Factor (integer), **CRF**
$ 59,366,282	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 110,863,652	Present Value Cost, **COST** = EC + OC

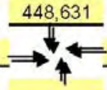
$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^{Y}}\right)$$

Traffic Volume Data

Source: GIMS Varies Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

448,631



163,750,315	Current Annual Entering Veh., **AEV** = DEV * 365
448,631	veh / day, Final Year DEV, **FDEV**
4,912.51	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

448,631 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^{Y}\right) \Big/ 10^{6}$$

Crash Data

2001 First full year --> 2008 Last full year 8.0 years, Time Period, **T**

Additional months values as of Dec. 2007

Crashes		Injuries		Cost per	Total
3	Fatal Crashes	4	Fatalities @	$3,500,000	$ 14,000,000
		17	Major Injuries @	$240,000	$ 4,080,000
70	Injury Crashes	36	Minor Injuries @	$48,000	$ 1,728,000
		48	Possible Injuries @	$25,000	$ 1,200,000
62	Property Damage Only		(assumed cost per crash)	$2,700	$ 167,400
			-OR- enter Actual Cost of all property damage:		
135	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 21,175,400

16.88	Current Crashes / Year, **AA** = TA / T
$ 156,855	Cost per Crash, **AVC** = LOSS / TA
506.3	Total Expected Crashes, **TECR** = CR x TMEV
3.38	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 529,385	Crash Costs Avoided in First Year, AAR x AVC
101.3	Total Avoided Crashes, TECR x CRF/ 100

0.10 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$ 9,154,143 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^{Y}\right)$$

Benefit / Cost Ratio

Benefit : Cost = $9,154,143 : $110,863,652 = **0.08** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide   Prepared by: InTrans   Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Railings with Bridge Width Less Than or Equal to 23.9; Fatal Crash Senario 3

$ 51,497,370	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 3,433,158	Other Annual Cost (after initial year), **AC**	92	Crash Reduction Factor (integer), **CRF**
$ 59,366,282	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 110,863,652	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^{Y}}\right)$$

Traffic Volume Data

Source: GIMS   Varies   Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

448,631

163,750,315	Current Annual Entering Veh., **AEV** = DEV * 365
448,631	veh / day, Final Year DEV, **FDEV**
4,912.51	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0%	Projected Traffic Growth (0%-10%), **G**
448,631	Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^{Y}\right) \Big/ 10^{6}$$

Crash Data

2001 First full year --> 2008 Last full year   8.0 years, Time Period, **T**

Additional months   values as of Dec. 2007

3	Fatal Crashes	4	Fatalities @	$3,500,000	$ 14,000,000
			Major Injuries @	$240,000	$ -
	Injury Crashes		Minor Injuries @	$48,000	$ -
			Possible Injuries @	$25,000	$ -
	Property Damage Only		(assumed cost per crash)	$2,700	$ -
			-OR- enter Actual Cost of all property damage:		
3	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 14,000,000

0.38	Current Crashes / Year, **AA** = TA / T
$ 4,666,667	Cost per Crash, **AVC** = LOSS / TA
11.3	Total Expected Crashes, **TECR** = CR x TMEV
0.35	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 1,610,000	Crash Costs Avoided in First Year, AAR x AVC
10.4	Total Avoided Crashes, TECR x CRF/ 100

0.00 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$ 27,840,173 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^{Y}\right)$$

Benefit / Cost Ratio

Benefit : Cost = $27,840,173 : $110,863,652 = **0.25** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide   Prepared by: InTrans   Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Railings on Bridges with length Less Than or Equal to 99

Scenario 4

$39,400,560	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 2,275,812	Other Annual Cost (after initial year), **AC**	20	Crash Reduction Factor (integer), **CRF**
$39,353,416	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 78,753,976	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^Y}\right)$$

Traffic Volume Data

Source: GIMS   Varies   Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

504,481

184,135,565	Current Annual Entering Veh., **AEV** = DEV * 365
504,481	veh / day, Final Year DEV, **FDEV**
5,524.07	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

504,481 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^Y\right) \Big/ 10^6$$

Crash Data

2001 First full year --> 2008 Last full year   8.0 years, Time Period, **T**

Additional months   values as of Dec. 2007

3	Fatal Crashes	4	Fatalities @	$3,500,000	$ 14,000,000
		20	Major Injuries @	$240,000	$ 4,800,000
90	Injury Crashes	52	Minor Injuries @	$48,000	$ 2,496,000
		46	Possible Injuries @	$25,000	$ 1,150,000
93	Property Damage Only		(assumed cost per crash)	$2,700	$ 251,100
		-OR-	enter Actual Cost of all property damage:		
186	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 22,697,100

23.25	Current Crashes / Year, **AA** = TA / T
$ 122,027	Cost per Crash, **AVC** = LOSS / TA
697.5	Total Expected Crashes, **TECR** = CR x TMEV
4.65	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 567,428	Crash Costs Avoided in First Year, AAR x AVC
139.5	Total Avoided Crashes, TECR x CRF/ 100

0.13 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$ 9,811,975 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^Y\right)$$

Benefit / Cost Ratio

Benefit : Cost = $9,811,975 : $78,753,976 = **0.12** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide | Prepared by: InTrans | Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Bridge Railings with length Less Than or Equal to 99; Fatal Crash Scenario 4

$39,400,560	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 2,275,812	Other Annual Cost (after initial year), **AC**	92	Crash Reduction Factor (integer), **CRF**
$39,353,416	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 78,753,976	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^{Y}}\right)$$

Traffic Volume Data

Source: GIMS | Varies | Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

504,481

184,135,565	Current Annual Entering Veh., **AEV** = DEV * 365
504,481	veh / day, Final Year DEV, **FDEV**
5,524.07	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

504,481 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^{Y}\right) \Big/ 10^{6}$$

Crash Data

2001 First full year --> 2008 Last full year | 8.0 years, Time Period, **T**

Additional months | values as of Dec. 2007

Crashes		Injuries		Unit cost	Loss
3	Fatal Crashes	4	Fatalities @	$3,500,000	$ 14,000,000
		0	Major Injuries @	$240,000	$ -
0	Injury Crashes	0	Minor Injuries @	$48,000	$ -
		0	Possible Injuries @	$25,000	$ -
0	Property Damage Only		(assumed cost per crash)	$2,700	$ -
		-OR-	enter Actual Cost of all property damage:		
3	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 14,000,000

0.38	Current Crashes / Year, **AA** = TA / T
$ 4,666,667	Cost per Crash, **AVC** = LOSS / TA
11.3	Total Expected Crashes, **TECR** = CR x TMEV
0.35	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 1,610,000	Crash Costs Avoided in First Year, AAR x AVC
10.4	Total Avoided Crashes, TECR x CRF/ 100

0.00 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$27,840,173 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^{Y}\right)$$

Benefit / Cost Ratio

Benefit : Cost = $27,840,173 : $78,753,976 = **0.35** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide Prepared by: InTrans Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Railings on Bridges with Relative Bridge Width Less Than Zero

Scenario 5

$ 43,527,690	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 2,901,846	Other Annual Cost (after initial year), **AC**	20	Crash Reduction Factor (integer), **CRF**
$ 50,178,817	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 93,706,507	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^{Y}}\right)$$

Traffic Volume Data

Source: GIMS Varies Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

348,099

127,056,135	Current Annual Entering Veh., **AEV** = DEV * 365
348,099	veh / day, Final Year DEV, **FDEV**
3,811.68	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

348,099 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^{Y}\right) \Big/ 10^{6}$$

Crash Data

2001 First full year --> 2008 Last full year 8.0 years, Time Period, **T**

Additional months values as of Dec. 2007

2	Fatal Crashes	3	Fatalities @	$3,500,000	$ 10,500,000
		13	Major Injuries @	$240,000	$ 3,120,000
62	Injury Crashes	29	Minor Injuries @	$48,000	$ 1,392,000
		42	Possible Injuries @	$25,000	$ 1,050,000
57	Property Damage Only		(assumed cost per crash)	$2,700	$ 153,900
		-OR-	enter Actual Cost of all property damage:		
121	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 16,215,900

15.13	Current Crashes / Year, **AA** = TA / T
$ 134,016	Cost per Crash, **AVC** = LOSS / TA
453.8	Total Expected Crashes, **TECR** = CR x TMEV
3.03	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 405,398	Crash Costs Avoided in First Year, AAR x AVC
90.8	Total Avoided Crashes, TECR x CRF/ 100

0.12 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$ 7,010,147 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^{Y}\right)$$

Benefit / Cost Ratio

Benefit : Cost = $7,010,147 : $93,706,507 = **0.07** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide — Prepared by: InTrans — Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Railings on Relative Bridge Width Less Than Zero; Fatal Crashes

Scenario 5

$43,527,690	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 2,901,846	Other Annual Cost (after initial year), **AC**	92	Crash Reduction Factor (integer), **CRF**
$50,178,817	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 93,706,507	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^{Y}}\right)$$

Traffic Volume Data

Source: GIMS — Varies — Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

348,099

127,056,135	Current Annual Entering Veh., **AEV** = DEV * 365
348,099	veh / day, Final Year DEV, **FDEV**
3,811.68	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

348,099 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^{Y}\right) \Big/ 10^{6}$$

Crash Data

2001 First full year --> 2008 Last full year — 8.0 years, Time Period, **T**

Additional months — values as of Dec. 2007

2	Fatal Crashes	3	Fatalities @	$3,500,000	$ 10,500,000
			Major Injuries @	$240,000	$ -
	Injury Crashes		Minor Injuries @	$48,000	$ -
			Possible Injuries @	$25,000	$ -
	Property Damage Only		(assumed cost per crash)	$2,700	$ -
			-OR- enter Actual Cost of all property damage:		
2	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 10,500,000

0.25	Current Crashes / Year, **AA** = TA / T
$ 5,250,000	Cost per Crash, **AVC** = LOSS / TA
7.5	Total Expected Crashes, **TECR** = CR x TMEV
0.23	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 1,207,500	Crash Costs Avoided in First Year, AAR x AVC
6.9	Total Avoided Crashes, TECR x CRF/ 100

0.00 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$20,880,130 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^{Y}\right)$$

Benefit / Cost Ratio

Benefit : Cost = $20,880,130 : $93,706,507 = **0.22** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide   Prepared by: InTrans   Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Railings on Relative Bridge Width Greater or Equal to Zero; All Crash

Scenario 5

$29,890,260	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 1,992,684	Other Annual Cost (after initial year), **AC**	20	Crash Reduction Factor (integer), **CRF**
$34,457,558	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 64,347,818	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^Y}\right)$$

Traffic Volume Data

Source: GIMS   Varies   Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

325,002

118,625,730	Current Annual Entering Veh., **AEV** = DEV * 365
325,002	veh / day, Final Year DEV, **FDEV**
3,558.77	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

325,002 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^Y\right) \Big/ 10^6$$

Crash Data

2001 First full year --> 2008 Last full year   8.0 years, Time Period, **T**

Additional months   values as of Dec. 2007

Crashes	Type	Count	Injury	Unit cost	Total
2	Fatal Crashes	2	Fatalities @	$3,500,000	$ 7,000,000
		7	Major Injuries @	$240,000	$ 1,680,000
32	Injury Crashes	24	Minor Injuries @	$48,000	$ 1,152,000
		15	Possible Injuries @	$25,000	$ 375,000
30	Property Damage Only		(assumed cost per crash)	$2,700	$ 81,000
			-OR- enter Actual Cost of all property damage:		
64	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 10,288,000

8.00	Current Crashes / Year, **AA** = TA / T
$ 160,750	Cost per Crash, **AVC** = LOSS / TA
240.0	Total Expected Crashes, **TECR** = CR x TMEV
1.60	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 257,200	Crash Costs Avoided in First Year, AAR x AVC
48.0	Total Avoided Crashes, TECR x CRF/ 100

0.07 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$ 4,447,511 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^Y\right)$$

Benefit / Cost Ratio

Benefit : Cost = $4,447,511 : $64,347,818 = **0.07** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide | Prepared by: InTrans | Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Railings on Relative Bridge Width Greater or Equal to Zero; Fatal Cra

Scenario 5

$29,890,260	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 1,992,684	Other Annual Cost (after initial year), **AC**	92	Crash Reduction Factor (integer), **CRF**
$34,457,558	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 64,347,818	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^Y}\right)$$

Traffic Volume Data

Source: GIMS | Varies | Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

325,002

118,625,730	Current Annual Entering Veh., **AEV** = DEV * 365
325,002	veh / day, Final Year DEV, **FDEV**
3,558.77	MEV, Total Million Entering Veh. Over life of Project, **TMEV**
0.0%	Projected Traffic Growth (0%-10%), **G**
325,002	Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^Y\right) \Big/ 10^6$$

Crash Data

2001 First full year --> 2008 Last full year — 8.0 years, Time Period, **T**

Additional months

values as of Dec. 2007

2	Fatal Crashes	2	Fatalities @	$3,500,000	$ 7,000,000
			Major Injuries @	$240,000	$ -
	Injury Crashes		Minor Injuries @	$48,000	$ -
			Possible Injuries @	$25,000	$ -
	Property Damage Only		(assumed cost per crash)	$2,700	$ -
			-OR- enter Actual Cost of all property damage:		
2	Total Crashes, **TA**		Total $ Loss, **LOSS**		$ 7,000,000

0.25	Current Crashes / Year, **AA** = TA / T
$ 3,500,000	Cost per Crash, **AVC** = LOSS / TA
7.5	Total Expected Crashes, **TECR** = CR x TMEV
0.23	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 805,000	Crash Costs Avoided in First Year, AAR x AVC
6.9	Total Avoided Crashes, TECR x CRF/ 100

0.00 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$13,920,087 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^Y\right)$$

Benefit / Cost Ratio

Benefit : Cost = $13,920,087 : $64,347,818 = **0.22** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Statewide | Prepared by: Intrans | Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving All Bridge Railing Not Up to Standards with B/C = 0.80

Scenario 6

$6,713,928	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 447,595	Other Annual Cost (after initial year), **AC**	20	Crash Reduction Factor (integer), **CRF**
$7,739,828	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 14,453,756	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^Y}\right)$$

Traffic Volume Data

Source: GIMS | Varies | Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

716,036

261,353,140	Current Annual Entering Veh., **AEV** = DEV * 365
716,036	veh / day, Final Year DEV, **FDEV**
7,840.59	MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

716,036 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^Y\right) \Big/ 10^6$$

Crash Data

2001 First full year --> 2008 Last full year | 8.0 years, Time Period, **T**

Additional months | values as of Dec. 2007

Crashes		Injuries		Unit cost	Total
4	Fatal Crashes	5	Fatalities @	$3,500,000	$ 17,500,000
		20	Major Injuries @	$240,000	$ 4,800,000
96	Injury Crashes	55	Minor Injuries @	$48,000	$ 2,640,000
		57	Possible Injuries @	$25,000	$ 1,425,000
87	Property Damage Only		(assumed cost per crash)	$2,700	$ 234,900
			-OR- enter Actual Cost of all property damage:		
187	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 26,599,900

23.38	Current Crashes / Year, **AA** = TA / T
$ 142,245	Cost per Crash, **AVC** = LOSS / TA
701.3	Total Expected Crashes, **TECR** = CR x TMEV
4.68	Crashes Avoided First Year **AAR** = AA x CRF / 100
$ 664,998	Crash Costs Avoided in First Year, AAR x AVC
140.3	Total Avoided Crashes, TECR x CRF/ 100

0.09 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

$ 11,499,159 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^Y\right)$$

Benefit / Cost Ratio

Benefit : Cost = $11,499,159 : $14,453,756 = **0.80** : 1

Intersection or Spot Benefit / Cost Safety Analysis

Rev. 5/08

Iowa DOT Office of Traffic & Safety

County: Unkown Prepared by: InTrans Date Prepared: Dec. 11, 2009

Intersection:

Improvement

Proposed Improvement(s): Improving Railings on an Individual Bridge with a Fatal Crash

Scenario 7

$ 6,750	Estimated Improvement Cost, **EC**	30	Est. Improvement Life, years, **Y**
$ 450	Other Annual Cost (after initial year), **AC**	92	Crash Reduction Factor (integer), **CRF**
$ 7,781	Present Value Other Annual Costs, **OC**	4.0%	Discount Rate (time value of $), **INT**
		$ 14,531	Present Value Cost, **COST** = EC + OC

$$OC = \frac{AC}{INT}\left(1 - \frac{1}{(1+INT)^{Y}}\right)$$

Traffic Volume Data

Source: GIMS Varies Date of traffic count

Daily Entering Vehicles by Approach (or AADT / 2)

50

18,250 Current Annual Entering Veh., **AEV** = DEV * 365

50 veh / day, Final Year DEV, **FDEV**

0.55 MEV, Total Million Entering Veh. Over life of Project, **TMEV**

0.0% Projected Traffic Growth (0%-10%), **G**

50 Current Daily Entering Vehicles, **DEV**

$$TMEV = \frac{AEV}{-G}\left(1 - \left(\frac{1+G}{1}\right)^{Y}\right) \Big/ 10^{6}$$

Crash Data

1980 First full year --> 2009 Last full year 30.0 years, Time Period, **T**

Additional months values as of Dec. 2007

1	Fatal Crashes	0	Fatalities @	$3,500,000	$ -
		1	Major Injuries @	$240,000	$ 240,000
0	Injury Crashes	0	Minor Injuries @	$48,000	$ -
		0	Possible Injuries @	$25,000	$ -
0	Property Damage Only		(assumed cost per crash)	$2,700	$ -
			-OR- enter Actual Cost of all property damage:		
1	Total Crashes, **TA**			Total $ Loss, **LOSS**	$ 240,000

0.03 Current Crashes / Year, **AA** = TA / T

$ 240,000 Cost per Crash, **AVC** = LOSS / TA

1.0 Total Expected Crashes, **TECR** = CR x TMEV

0.03 Crashes Avoided First Year **AAR** = AA x CRF / 100

$ 7,360 Crash Costs Avoided in First Year, AAR x AVC

0.9 Total Avoided Crashes, TECR x CRF/ 100

1.83 Crashes / MEV, Crash Rate, **CR**

CR = TA x 10^6 / (DEV x 365 x T)

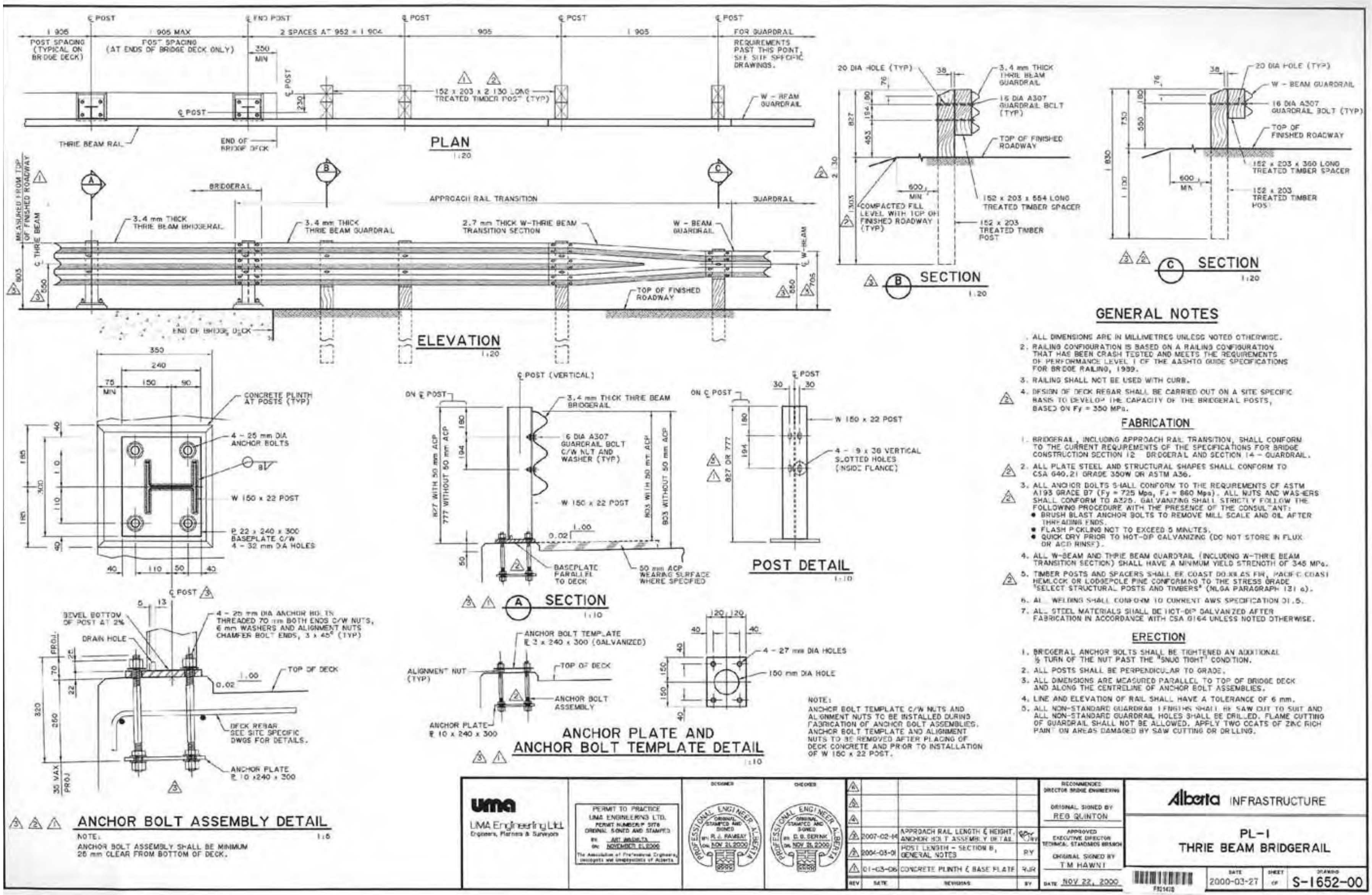
$ 127,269 Present Value of Avoided Crashes, **BENEFIT**

$$BEN. = \frac{AVC \times AAR}{(INT - G)}\left(1 - \left(\frac{1+G}{1+INT}\right)^{Y}\right)$$

Benefit / Cost Ratio

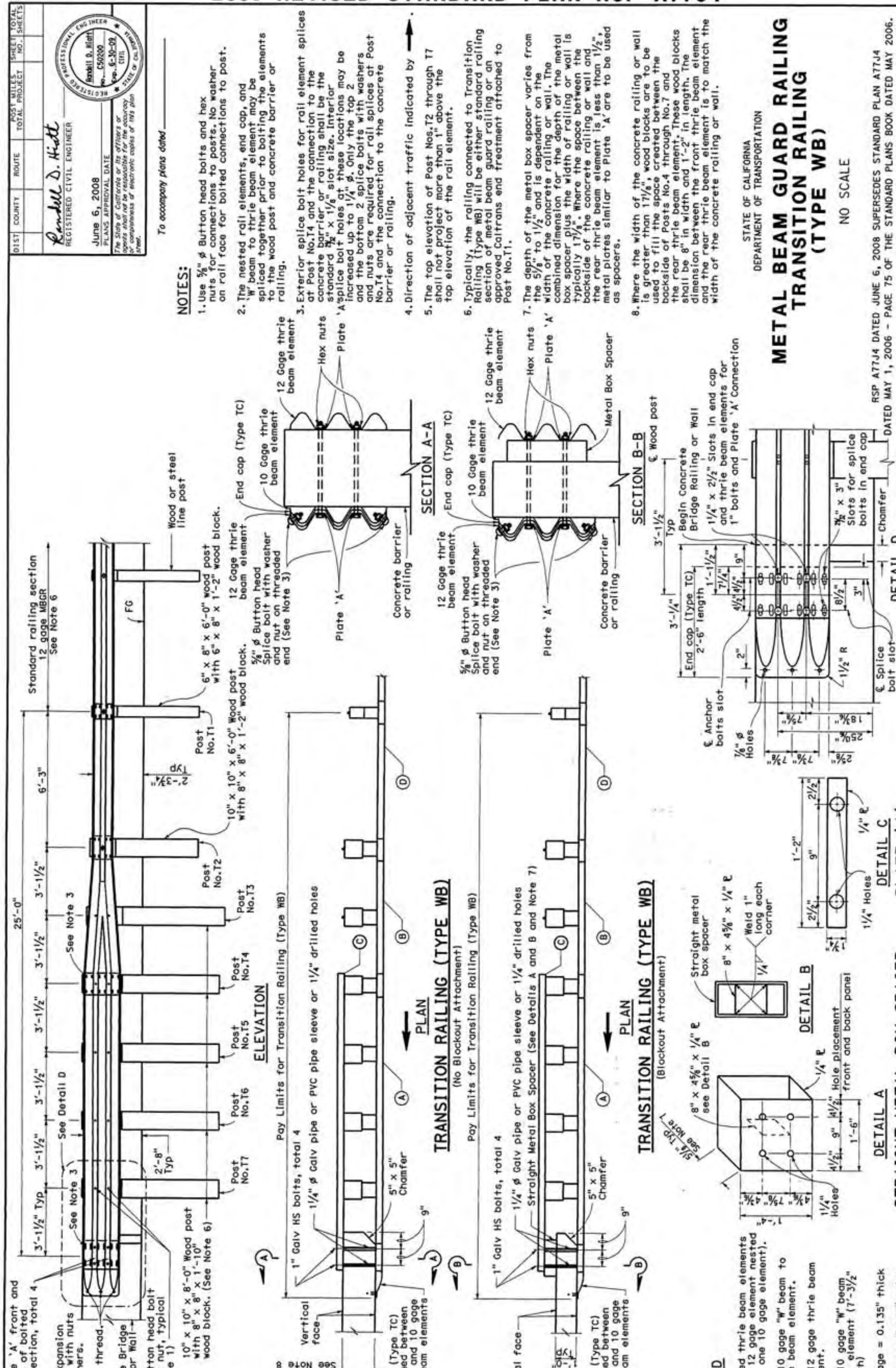
Benefit : Cost = $127,269 : $14,531 = 8.76 : 1

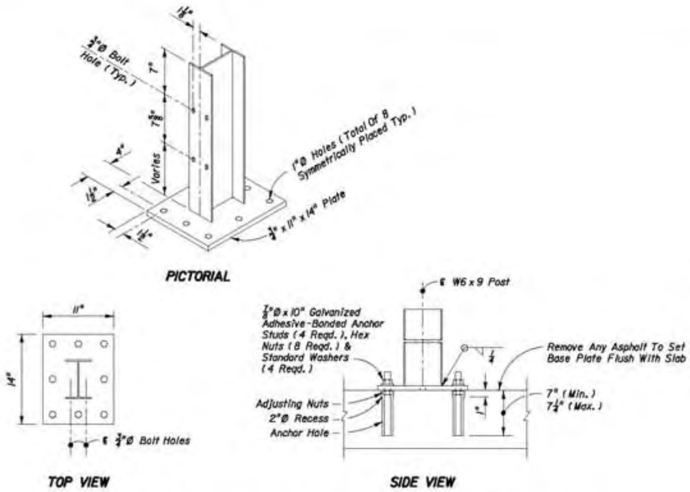
APPENDIX E: STANDARD BRIDGE RAIL AND APPROACH RAIL DRAWINGS FROM VARIOUS STATES


PLAN 1:20
ELEVATION 1:20
SECTION B 1:20
SECTION C 1:20
SECTION A 1:10
POST DETAIL 1:10
ANCHOR PLATE AND ANCHOR BOLT TEMPLATE DETAIL 1:10
ANCHOR BOLT ASSEMBLY DETAIL 1:5
NOTE: ANCHOR BOLT ASSEMBLY SHALL BE MINIMUM 25 mm CLEAR FROM BOTTOM OF DECK.
NOTE: ANCHOR BOLT TEMPLATE C/W NUTS AND ALIGNMENT NUTS TO BE INSTALLED DURING FABRICATION OF ANCHOR BOLT ASSEMBLIES. ANCHOR BOLT TEMPLATE AND ALIGNMENT NUTS TO BE REMOVED AFTER PLACING OF DECK CONCRETE AND PRIOR TO INSTALLATION OF W 150 x 22 POST.
GENERAL NOTES
1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.
2. RAILING CONFIGURATION IS BASED ON A RAILING CONFIGURATION THAT HAS BEEN CRASH TESTED AND MEETS THE REQUIREMENTS OF PERFORMANCE LEVEL 1 OF THE AASHTO GUIDE SPECIFICATIONS FOR BRIDGE RAILING, 1989.
3. RAILING SHALL NOT BE USED WITH CURB.
4. DESIGN OF DECK REBAR SHALL BE CARRIED OUT ON A SITE SPECIFIC BASIS TO DEVELOP THE CAPACITY OF THE BRIDGERAIL POSTS, BASED ON Fy = 350 MPa.
FABRICATION
1. BRIDGERAIL, INCLUDING APPROACH RAIL TRANSITION, SHALL CONFORM TO THE CURRENT REQUIREMENTS OF THE SPECIFICATIONS FOR BRIDGE CONSTRUCTION SECTION 12 BRIDGERAIL AND SECTION 14 – GUARDRAIL.
2. ALL PLATE STEEL AND STRUCTURAL SHAPES SHALL CONFORM TO CSA G40.21 GRADE 350W OR ASTM A36.
3. ALL ANCHOR BOLTS SHALL CONFORM TO THE REQUIREMENTS OF ASTM A193 GRADE B7 (Fy = 725 Mpa, Fu = 860 Mpa). ALL NUTS AND WASHERS SHALL CONFORM TO A325. GALVANIZING SHALL STRICTLY FOLLOW THE FOLLOWING PROCEDURE WITH THE PRESENCE OF THE CONSULTANT:
• BRUSH BLAST ANCHOR BOLTS TO REMOVE MILL SCALE AND OIL AFTER THREADING ENDS.
• FLASH PICKLING NOT TO EXCEED 5 MINUTES.
• QUICK DRY PRIOR TO HOT-DIP GALVANIZING (DO NOT STORE IN FLUX OR ACID RINSE).
4. ALL W-BEAM AND THRIE BEAM GUARDRAIL (INCLUDING W-THRIE BEAM TRANSITION SECTION) SHALL HAVE A MINIMUM YIELD STRENGTH OF 345 MPa.
5. TIMBER POSTS AND SPACERS SHALL BE COAST DOUGLAS FIR, PACIFIC COAST HEMLOCK OR LODGEPOLE PINE CONFORMING TO THE STRESS GRADE "SELECT STRUCTURAL POSTS AND TIMBERS" (NLGA PARAGRAPH 131 a).
6. ALL WELDING SHALL CONFORM TO CURRENT AWS SPECIFICATION D1.5.
7. ALL STEEL MATERIALS SHALL BE HOT-DIP GALVANIZED AFTER FABRICATION IN ACCORDANCE WITH CSA G164 UNLESS NOTED OTHERWISE.
ERECTION
1. BRIDGERAIL ANCHOR BOLTS SHALL BE TIGHTENED AN ADDITIONAL ½ TURN OF THE NUT PAST THE "SNUG TIGHT" CONDITION.
2. ALL POSTS SHALL BE PERPENDICULAR TO GRADE.
3. ALL DIMENSIONS ARE MEASURED PARALLEL TO TOP OF BRIDGE DECK AND ALONG THE CENTRELINE OF ANCHOR BOLT ASSEMBLIES.
4. LINE AND ELEVATION OF RAIL SHALL HAVE A TOLERANCE OF 6 mm.
5. ALL NON-STANDARD GUARDRAIL LENGTHS SHALL BE SAW CUT TO SUIT AND ALL NON-STANDARD GUARDRAIL HOLES SHALL BE DRILLED. FLAME CUTTING OF GUARDRAIL SHALL NOT BE ALLOWED. APPLY TWO COATS OF ZINC RICH PAINT ON AREAS DAMAGED BY SAW CUTTING OR DRILLING.
UMA Engineering Ltd.
Alberta INFRASTRUCTURE
PL-1
THRIE BEAM BRIDGERAIL
2000-03-27
S-1652-00

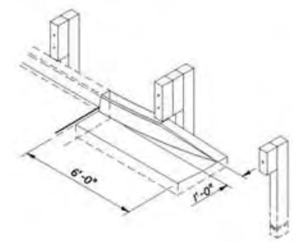
2006 REVISED STANDARD PLAN RSP A77J4

California DOT

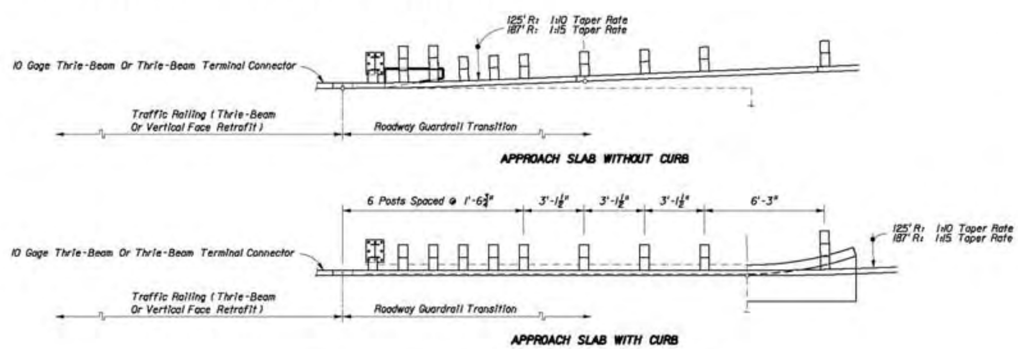




SPECIAL STEEL POST FOR ROADWAY THRIE-BEAM TRANSITIONS TO BRIDGE TRAFFIC RAILING RETROFITS



CURB TYPE F FLARE WHEN END OF EXISTING APPROACH SLAB CURB EXPOSED



Longitudinal Location Of Transition Blocks And Curb End Flares Will Vary With Scheme Type

PARTIAL PLAN VIEWS

GUARDRAIL TRANSITION ALIGNMENTS FOR BRIDGE THRIE-BEAM AND VERTICAL FACE TRAFFIC RAILING RETROFIT

GENERAL NOTES

1. This Index provides thrie-beam transition and connection details for approach end guardrail on existing bridges, and anchorage details for trailing end traffic railing retrofits and safety shapes on existing bridges. Sheets 1 through 23 apply to bridges with retrofitted traffic railings, (Sheet 23 shows the trailing end guardrail connections). Sheet 24 applies to bridges with safety shaped traffic railing.
2. The schemes identified by Arabic numerals in this Index are complementary to the bridge traffic railing barrier retrofit schemes with like numeral identification in Index Nos. 470, 471 through 476, 480 through 483. The schemes in this Index identified by Roman numerals are complementary to bridge safety shaped traffic railing barrier where determined to be in accordance with applications of criteria specified in the Structures Manual.
3. For guardrail applications and details of related hardware and accessories that are not provided on this index, refer to Index No. 400.

NOTES FOR GUARDRAIL TRANSITIONS CONNECTING TO TRAFFIC RAILING RETROFITS ON EXISTING BRIDGES

1. The transition detail shown on this sheet shows (a) the standard post spacings within the typical thrie-beam approach transitions connecting to existing bridges with retrofit traffic railings, and (b) depict the typical alignments of the approach transitions.
2. The curb and gutter flare shown on this sheet is typical of flares that are to be constructed when approach slab curbs extend to the beginning of the slab, and where other treatment to curb blunt ends are not in place.
3. The special steel post for roadway thrie-beam transitions detailed on this sheet is specific to all transition applications on this Index that require one or more steel posts.

   The special steel post and base plate assembly shall be fabricated using ASTM A36 or ASTM A709 Grade 36 steel. Welding shall conform to ANSI/AASHTO/AWS D1.5. The assembly shall be hot-dip zinc coated in accordance with Section 536 of the Specifications.

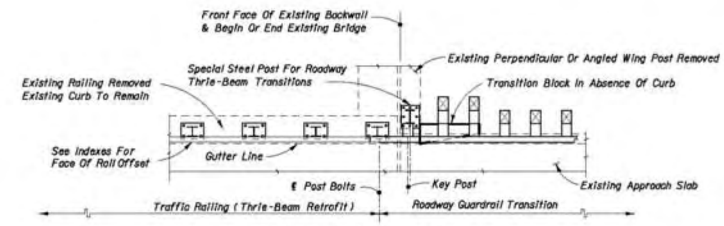
   Anchor studs shall be fully threaded rods in accordance with ASTM F1554 Grade 36 or ASTM A193 Grade B7. All nuts shall be heavy hex in accordance with ASTM A563 or ASTM A194. Anchor studs and nuts shall be hot-dip zinc coated in accordance with the Specifications. After the nuts have been snug tightened, the anchor stud threads shall be single punch distorted immediately above the top nuts to prevent loosening of the nuts. Distorted threads shall be coated with a galvanizing compound in accordance with the Specifications.

   Adhesive bonding material systems for anchors shall comply with Specification Section 937 and be installed in accordance with Specification Section 416.
4. Nested beam extensions and points for terminal connector attachments will vary for traffic railing barrier vertical face retrofits. The plan views for the vertical face retrofit barriers show the primary configurations for each particular scheme. The associated pictorial views show the variations.
5. For installing thrie-beam terminal connector to traffic railing vertical face retrofits, see notations on Sheets 12 through 15 and the flag notation on Sheet 23.
6. Payment for connections to traffic railing vertical face retrofits are to be made under the contract unit price for Bridge Anchorage Assembly, EA., and shall be full compensation for bolt hole construction, terminal connector, terminal connector plate and bolts, nuts and washers.

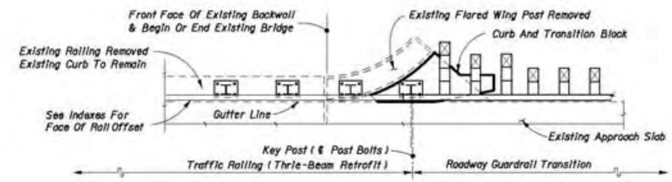
DESIGN NOTES FOR GUARDRAIL TRANSITIONS CONNECTING TO TRAFFIC RAILING RETROFITS ON EXISTING BRIDGES

1. For selection of an appropriate transition scheme, see the Structures Manual for instructions to the Structures and Roadway engineers.

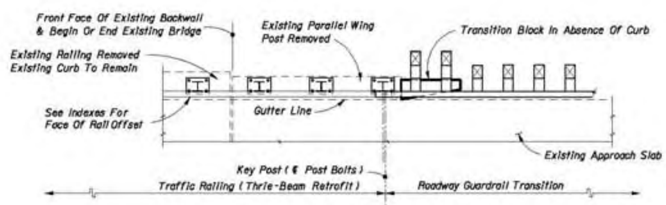
2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	1 of 24
	Index No.	402



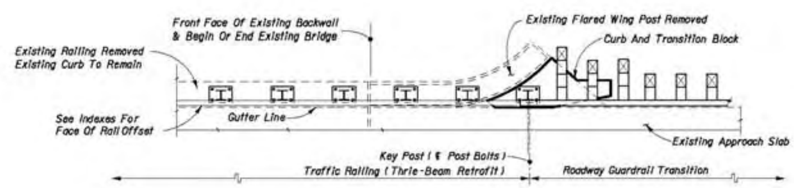
SEE INDEX NO. 471 - SCHEME 1



SEE INDEX NO. 471 - SCHEME 3



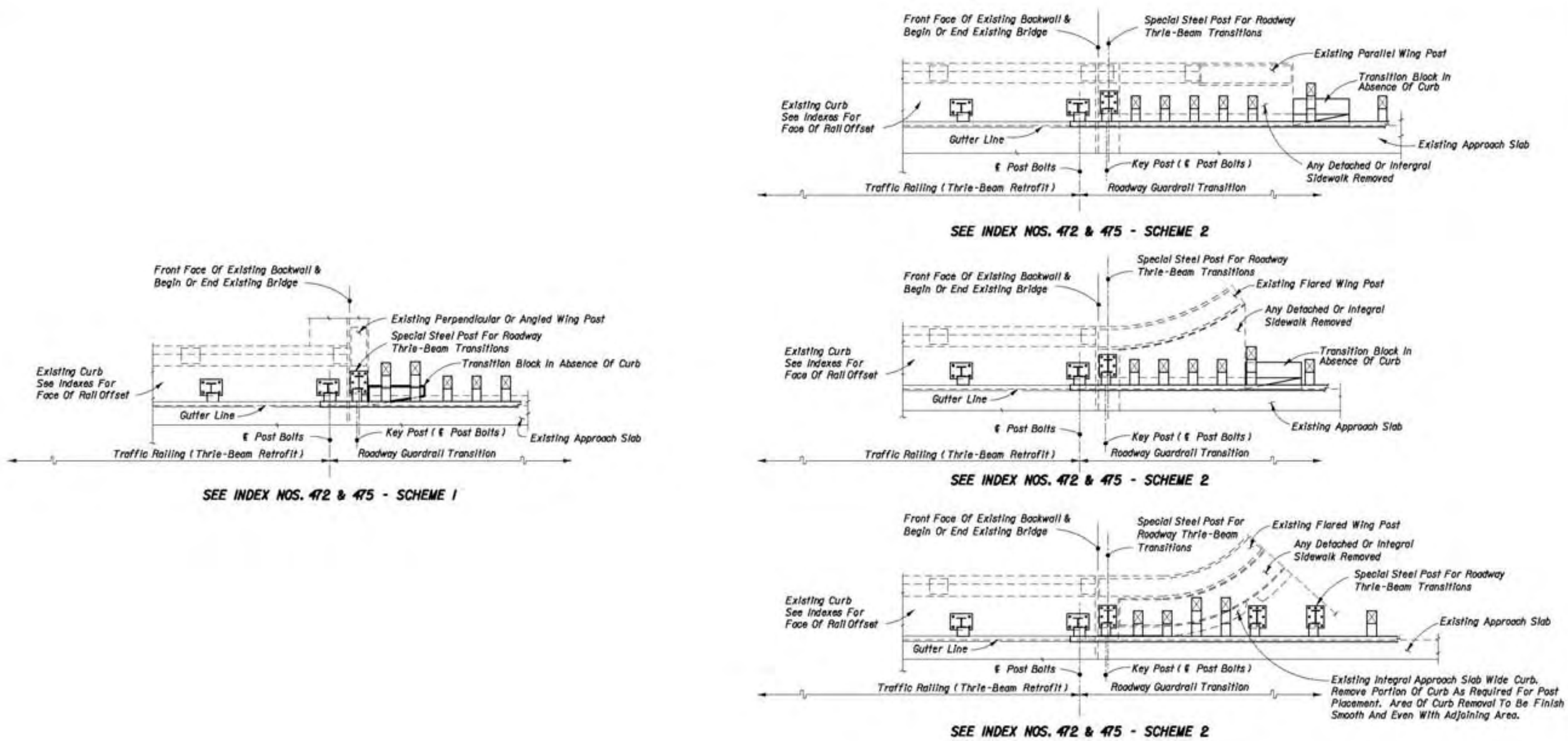
SEE INDEX NO. 471 - SCHEME 2



SEE INDEX NO. 471 - SCHEME 3

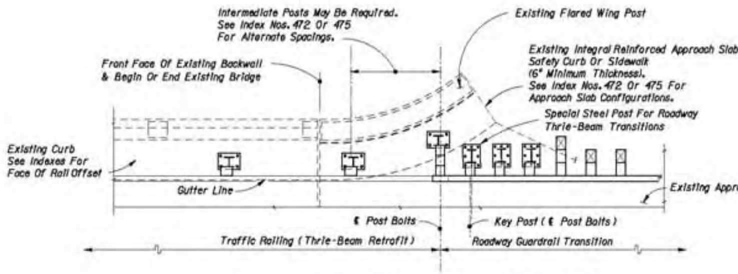
PARTIAL PLAN VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (THRIE-BEAM RETROFIT)

2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	2 of 24
	Index No.	402

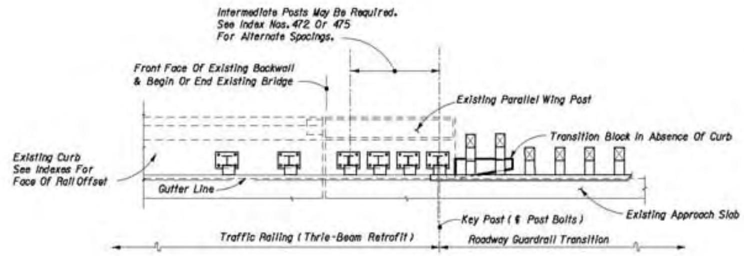


PARTIAL PLAN VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (THRIE-BEAM RETROFIT)

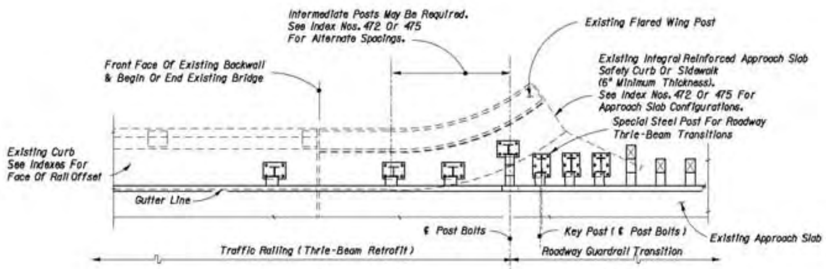
2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	3 of 24
	Index No. 402	



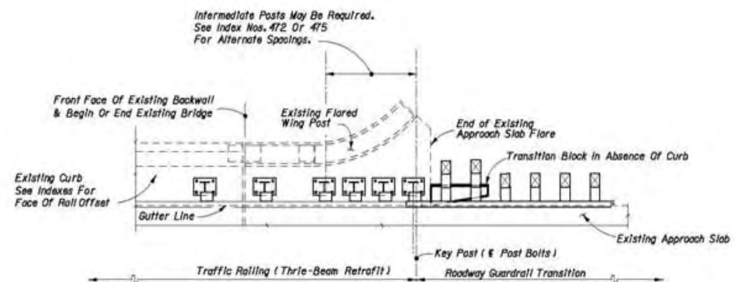
SEE INDEX NOS. 472 & 475 - SCHEMES 3 & 4



SEE INDEX NOS. 472 & 475 - SCHEMES 5 & 6



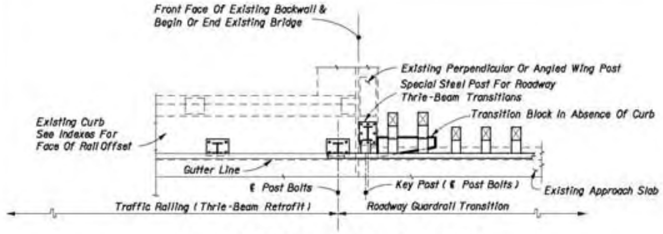
SEE INDEX NOS. 472 & 475 - SCHEMES 3 & 4



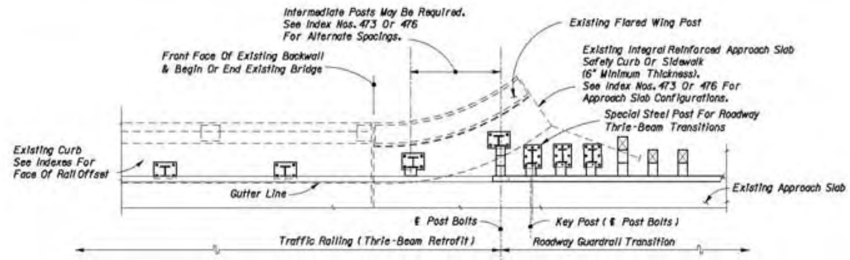
SEE INDEX NOS. 472 & 475 - SCHEMES 5 & 6

PARTIAL PLAN VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (THRIE-BEAM RETROFIT)

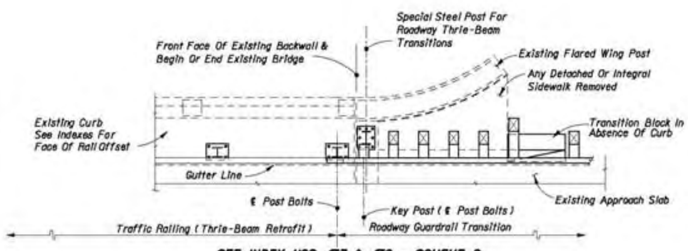
2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	4 of 24
	Index No.	402



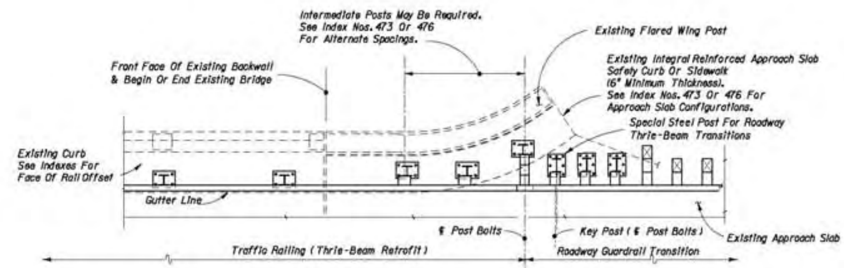
SEE INDEX NOS. 473 & 476 - SCHEME 1



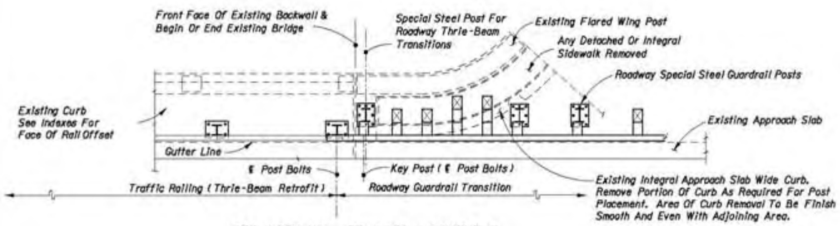
SEE INDEX NOS. 473 & 476 - SCHEMES 3 & 4



SEE INDEX NOS. 473 & 476 - SCHEME 2

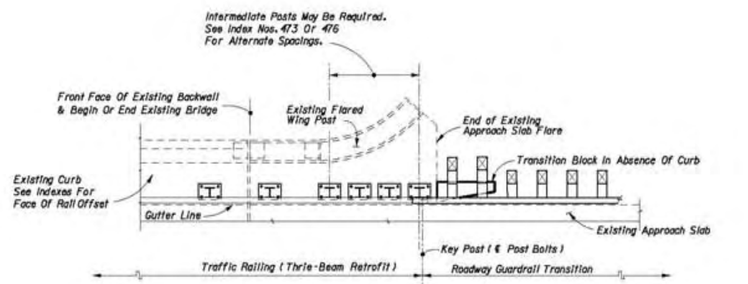


SEE INDEX NOS. 473 & 476 - SCHEMES 3 & 4

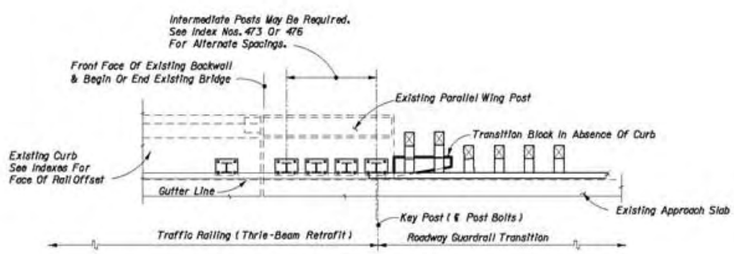


SEE INDEX NOS. 473 & 476 - SCHEME 2

PARTIAL PLAN VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (THRIE-BEAM RETROFIT)



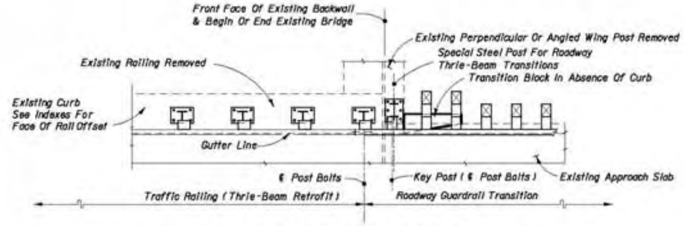
SEE INDEX NOS. 473 & 476 - SCHEMES 5 & 6



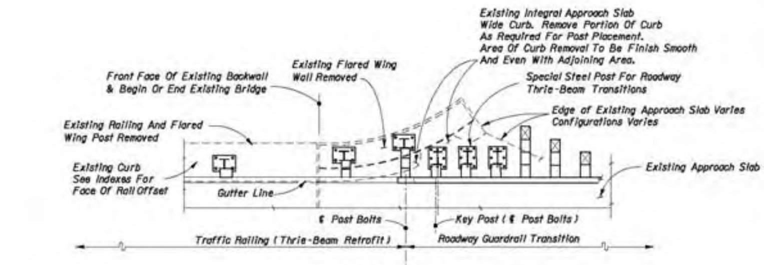
SEE INDEX NOS. 473 & 476 - SCHEMES 5 & 6

PARTIAL PLAN VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (THRIE-BEAM RETROFIT)

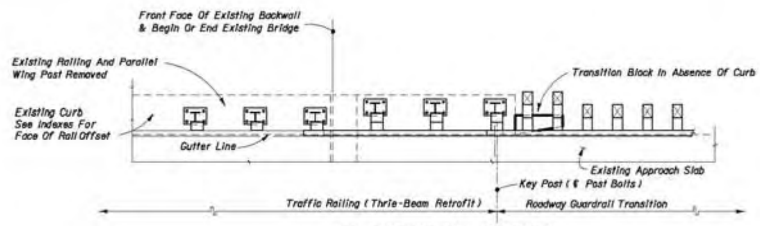
2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	6 of 24
	Index No.	402



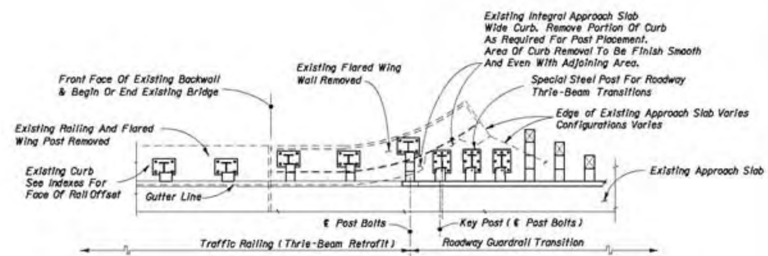
SEE INDEX NO. 474 - SCHEME 1



SEE INDEX NO. 474 - SCHEME 3



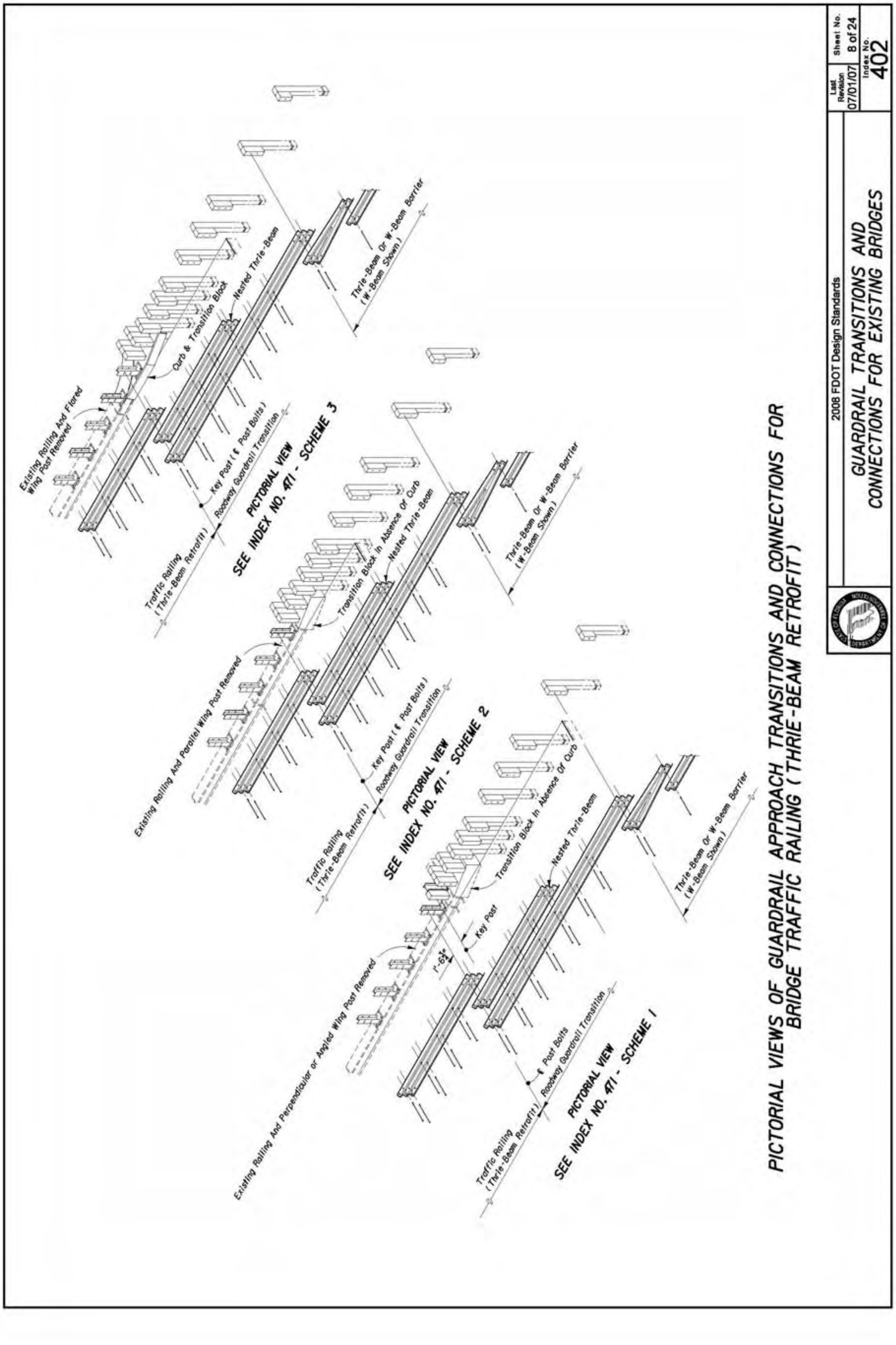
SEE INDEX NO. 474 - SCHEME 2



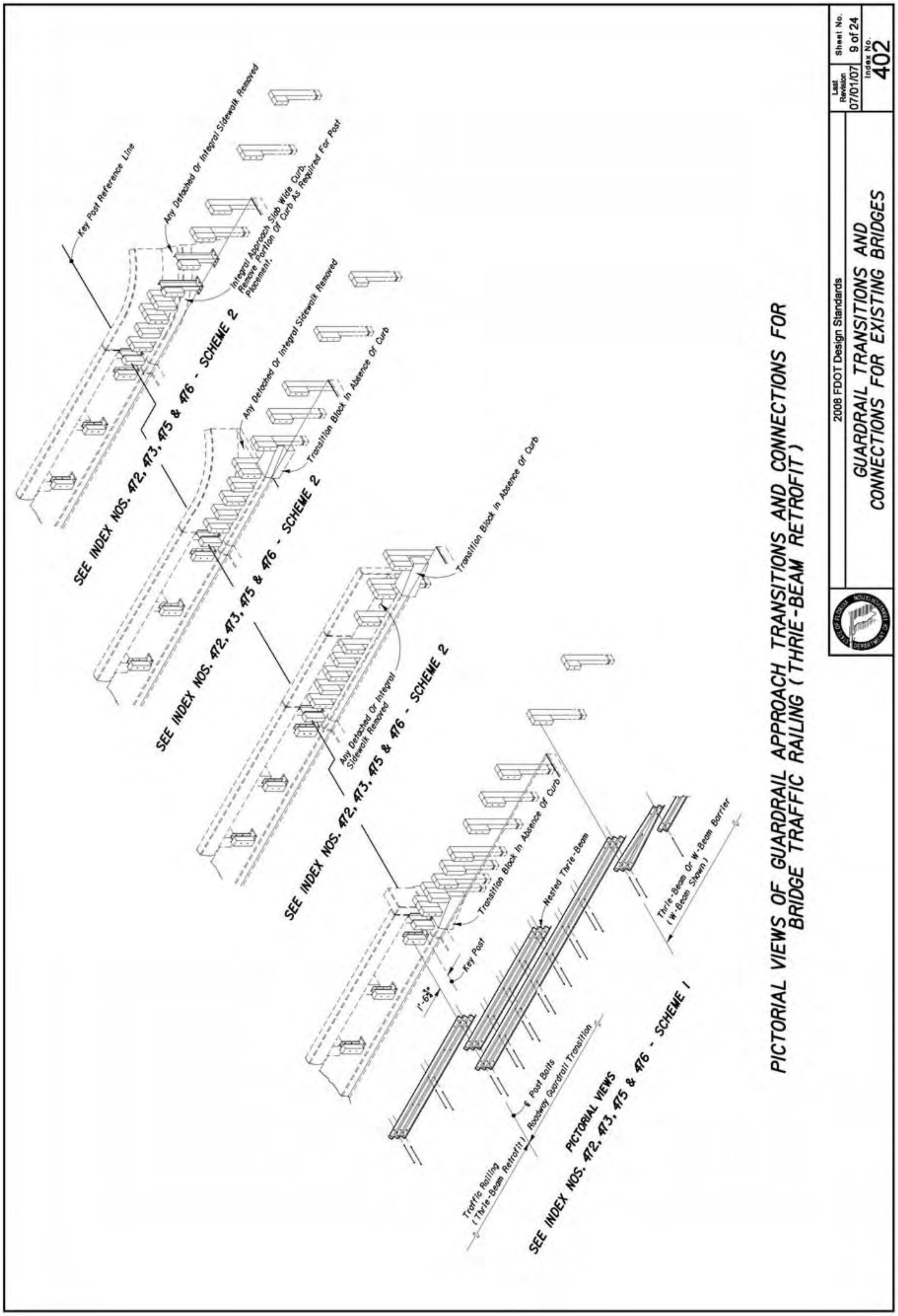
SEE INDEX NO. 474 - SCHEME 3

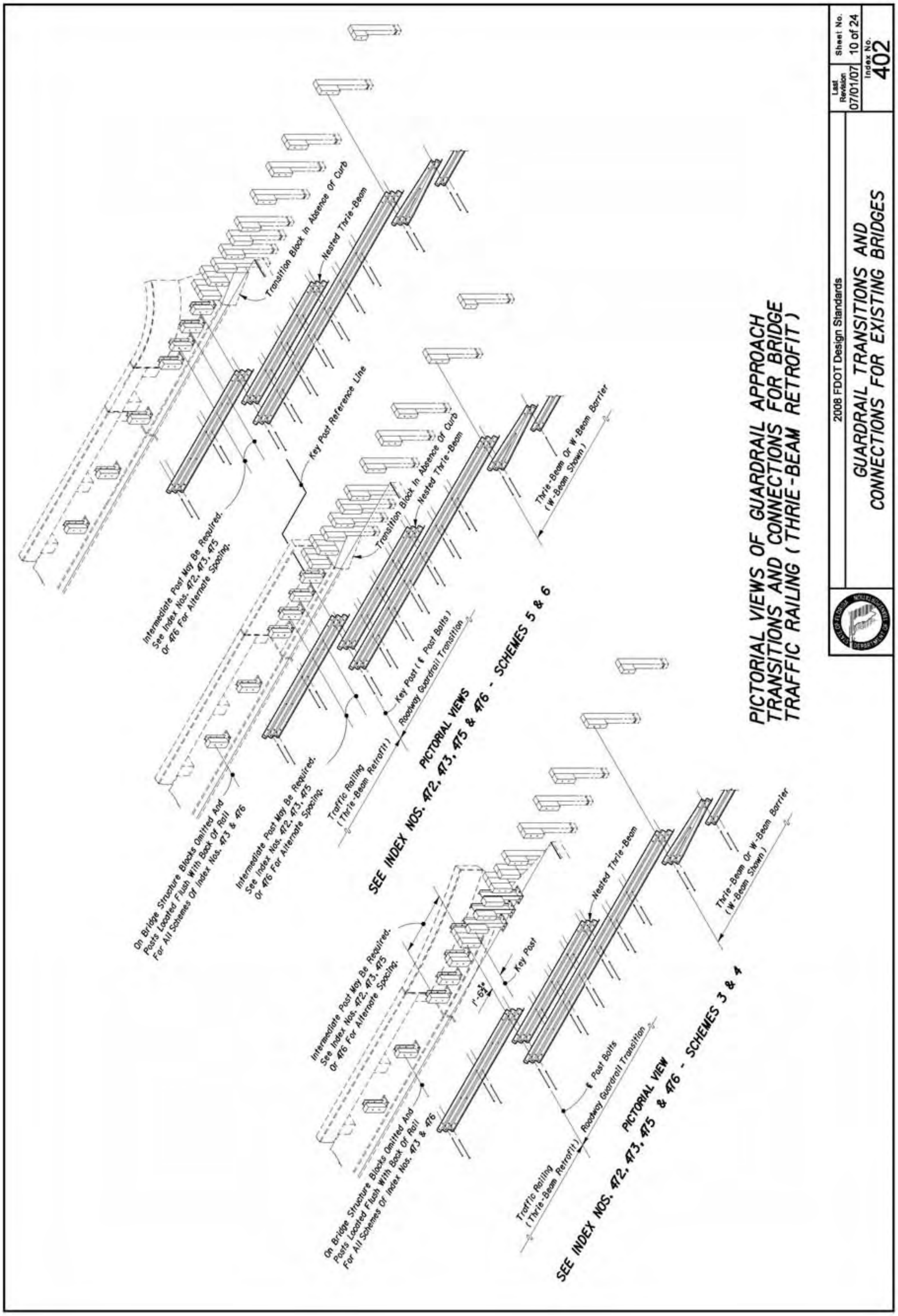
PARTIAL PLAN VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (THRIE-BEAM RETROFIT)

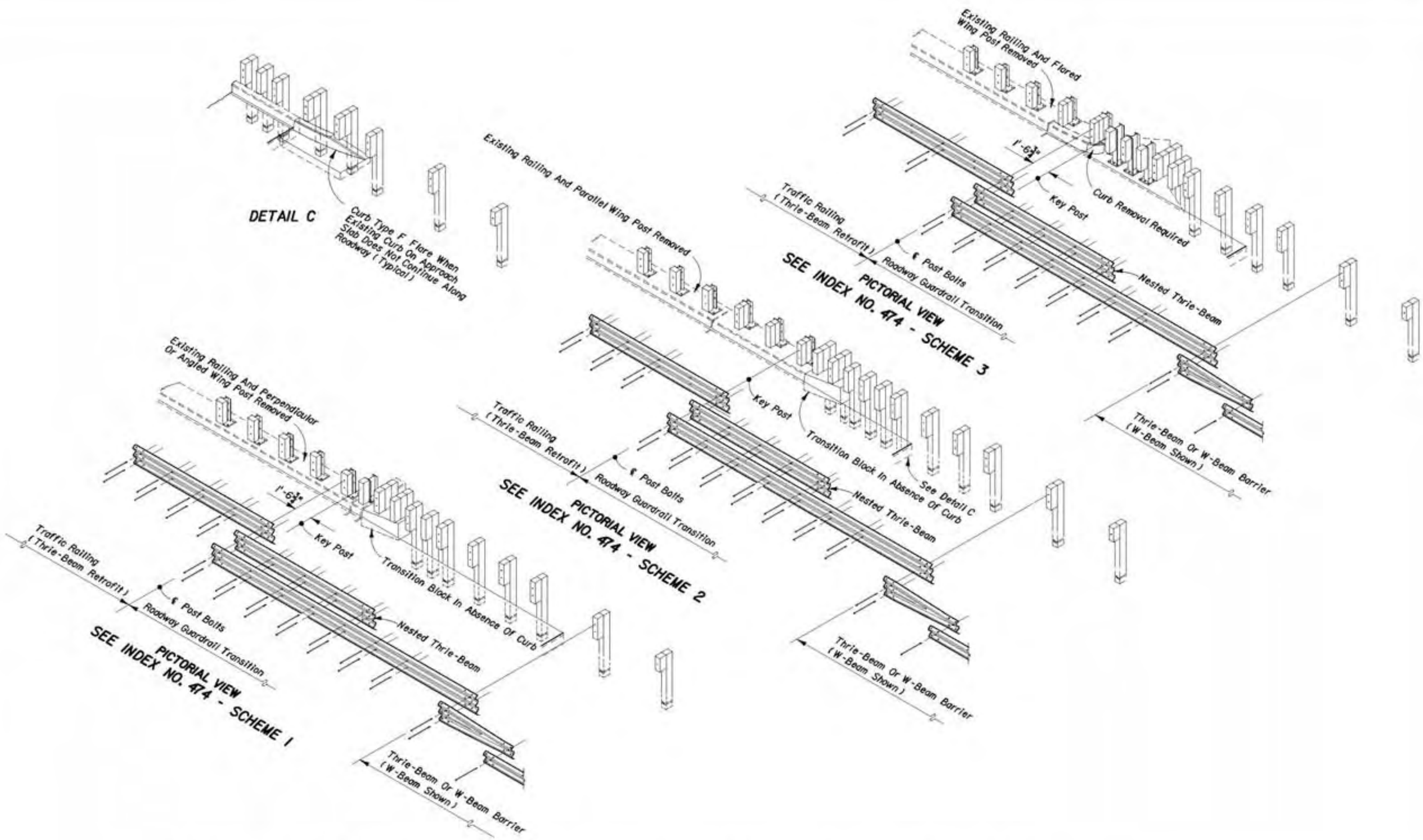
2008 FDOT Design Standards		Last Revision 07/01/07	Sheet No. 7 of 24
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES		Index No. 402	



PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (THRIE-BEAM RETROFIT)
Existing Railing And Flared Wing Post Removed
Curb & Transition Block
Nested Thrie-Beam
Thrie-Beam Or W-Beam Barrier (W-Beam Shown)
Key Post (℄ Post Bolts)
Roadway Guardrail Transition
Traffic Railing (Thrie-Beam Retrofit)
PICTORIAL VIEW
SEE INDEX NO. 471 - SCHEME 3
Existing Railing And Parallel Wing Post Removed
Transition Block In Absence Of Curb
Nested Thrie-Beam
Thrie-Beam Or W-Beam Barrier (W-Beam Shown)
Key Post (℄ Post Bolts)
Roadway Guardrail Transition
Traffic Railing (Thrie-Beam Retrofit)
PICTORIAL VIEW
SEE INDEX NO. 471 - SCHEME 2
Existing Railing And Perpendicular or Angled Wing Post Removed
Transition Block In Absence Of Curb
Nested Thrie-Beam
Key Post
1'-6¼"
Thrie-Beam Or W-Beam Barrier (W-Beam Shown)
℄ Post Bolts
Roadway Guardrail Transition
Traffic Railing (Thrie-Beam Retrofit)
PICTORIAL VIEW
SEE INDEX NO. 471 - SCHEME 1
2008 FDOT Design Standards
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES
Last Revision
07/01/07
Sheet No.
8 of 24
Index No.
402

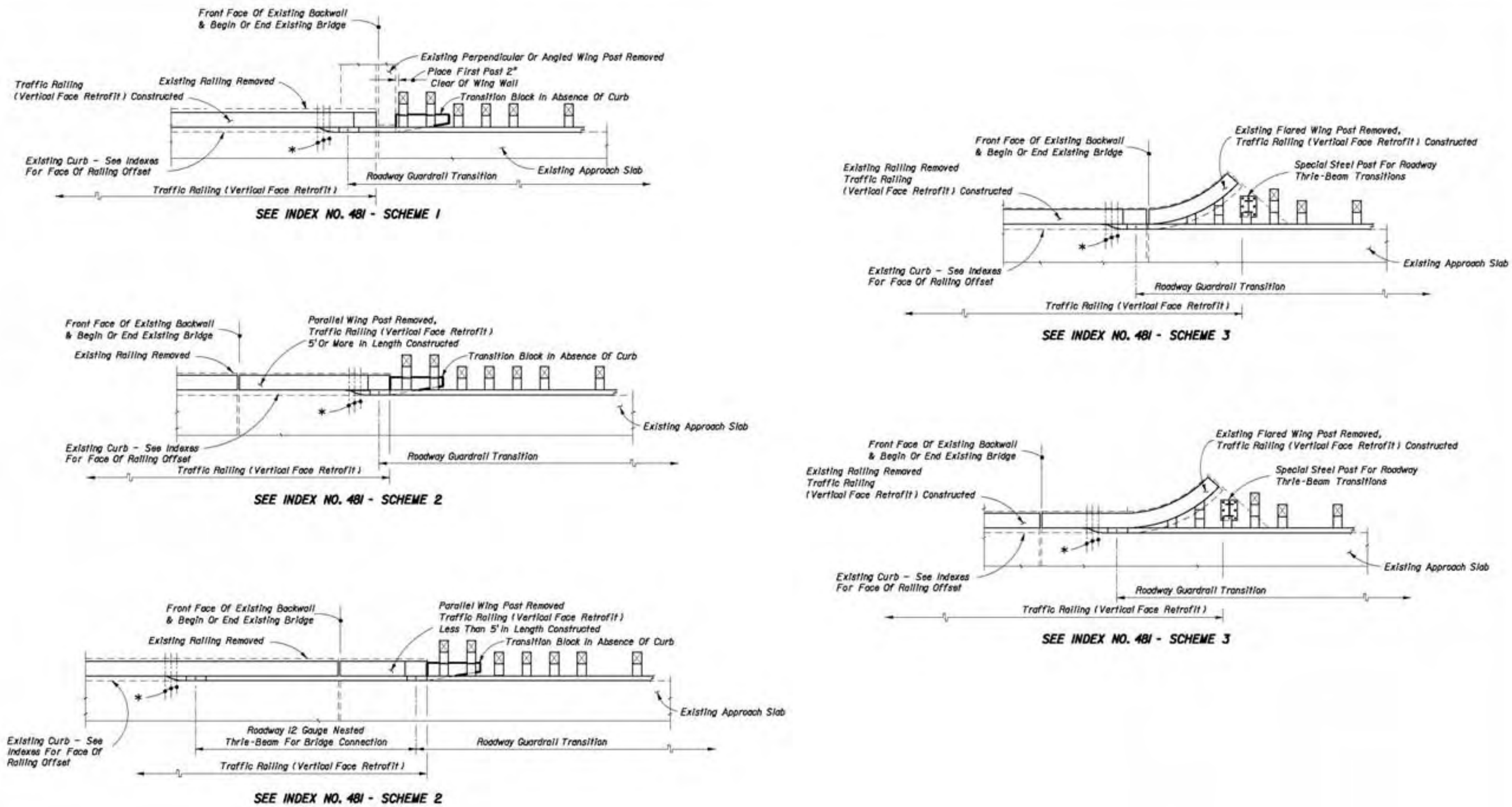

PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (THRIE-BEAM RETROFIT)
SEE INDEX NOS. 472, 473, 475 & 476 - SCHEME 1
PICTORIAL VIEWS
SEE INDEX NOS. 472, 473, 475 & 476 - SCHEME 2
SEE INDEX NOS. 472, 473, 475 & 476 - SCHEME 2
SEE INDEX NOS. 472, 473, 475 & 476 - SCHEME 2
Traffic Railing (Thrie-Beam Retrofit)
Roadway Guardrail Transition
℄ Post Bolts
Nested Thrie-Beam
Thrie-Beam Or W-Beam Barrier (W-Beam Shown)
Key Post
1'-6¾"
Transition Block In Absence Of Curb
Any Detached Or Integral Sidewalk Removed
Any Detached Or Integral Sidewalk Removed
Integral Approach Slab Wide Curb. Remove Portion Of Curb As Required For Post Placement.
Key Post Reference Line
2008 FDOT Design Standards
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES
Last Revision 07/01/07
Sheet No. 9 of 24
Index No. 402


PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (THRIE-BEAM RETROFIT)
Transition Block In Absence Of Curb
Nested Thrie-Beam
Key Post Reference Line
Intermediate Post May Be Required. See Index Nos. 472, 473, 475 Or 476 For Alternate Spacing.
On Bridge Structure Blocks Omitted And Posts Located Flush With Back Of Rail For All Schemes Of Index Nos. 473 & 476
Traffic Railing (Thrie-Beam Retrofit)
Key Post (℄ Post Bolts)
Roadway Guardrail Transition
Thrie-Beam Or W-Beam Barrier (W-Beam Shown)
PICTORIAL VIEWS
SEE INDEX NOS. 472, 473, 475 & 476 - SCHEMES 5 & 6
Key Post
1'-6½"
℄ Post Bolts
PICTORIAL VIEW
SEE INDEX NOS. 472, 473, 475 & 476 - SCHEMES 3 & 4
2008 FDOT Design Standards
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES
Last Revision 07/01/07
Sheet No. 10 of 24
Index No. 402



PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (THRIE-BEAM RETROFIT)

2008 FDOT Design Standards		Last Revision 07/01/07	Sheet No. 11 of 24
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES		Index No. 402	



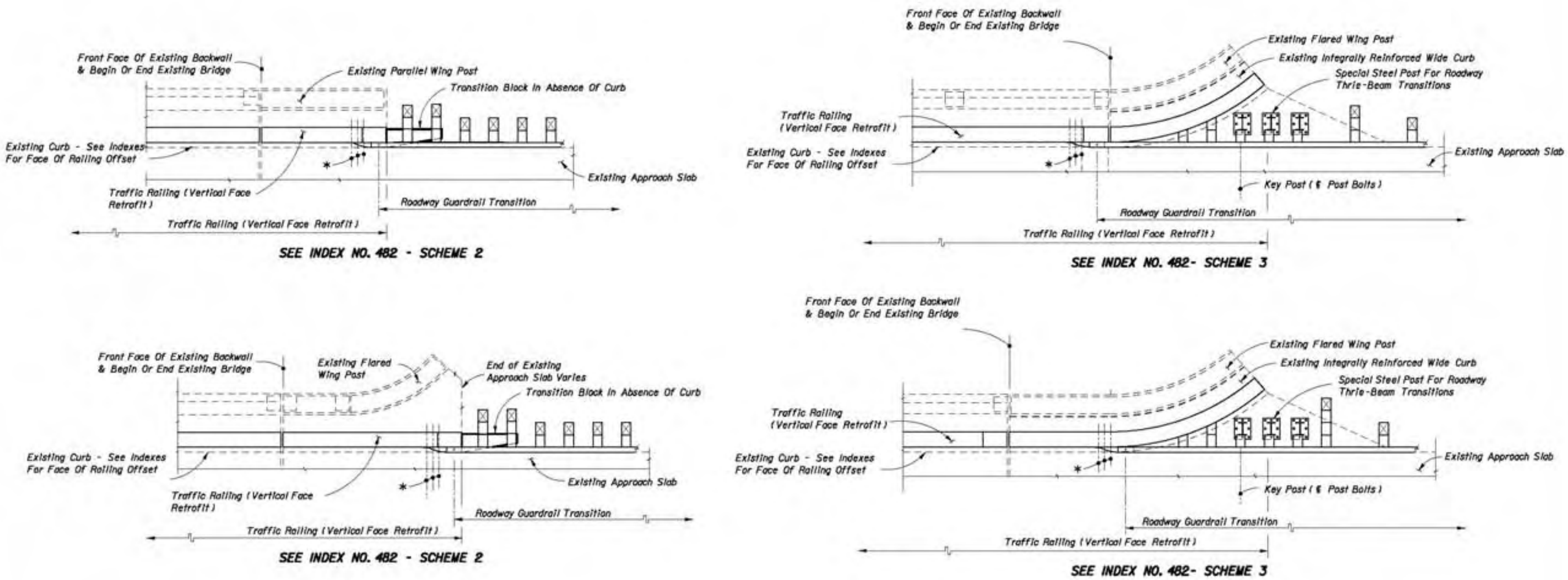
Note:
*21"x 12" x $\frac{3}{8}$" Thrie-Beam Terminal Connector Plate (Back-Up Plate), And $\frac{7}{8}$" Ø x 12" Long HS Hex Bolts And Nuts (5 Reqd.) With $2\frac{1}{4}$" OD Plain Round Washers Under Heads And Nuts

PARTIAL PLAN VIEWS OF TRAFFIC RAILING (VERTICAL FACE RETROFIT)

2008 FDOT Design Standards

GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES

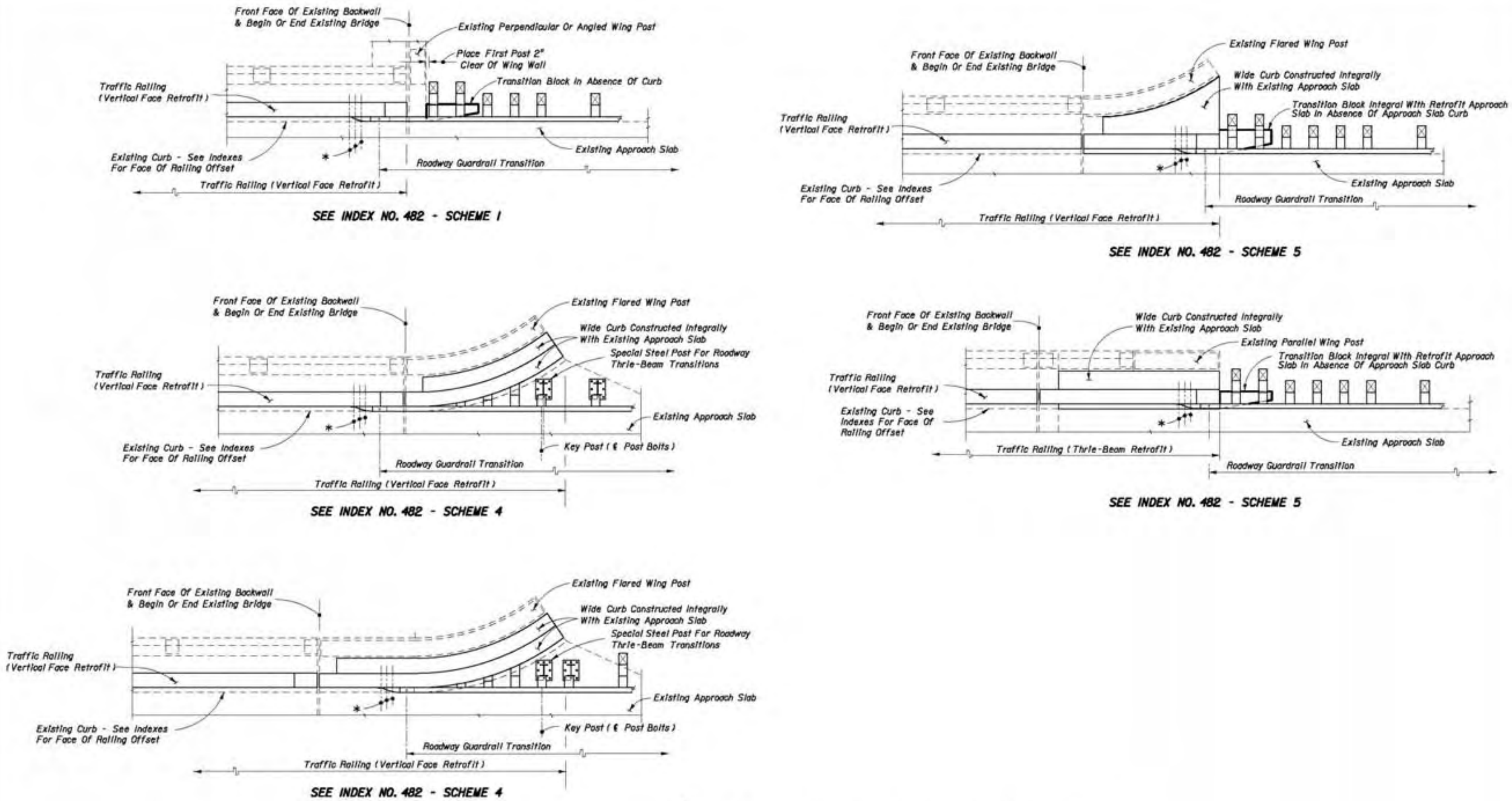
Last Revision	Sheet No.
07/01/07	12 of 24
Index No. 402	



Note:
*21" x 12" x 5/8" Thrie-Beam Terminal Connector Plate (Back-Up Plate), And 7/8" Ø x 12" Long HS Hex Bolts And Nuts (5 Reqd.) With 2 1/4" OD Plain Round Washers Under Heads And Nuts

PARTIAL PLAN VIEWS OF TRAFFIC RAILING (VERTICAL FACE RETROFIT)

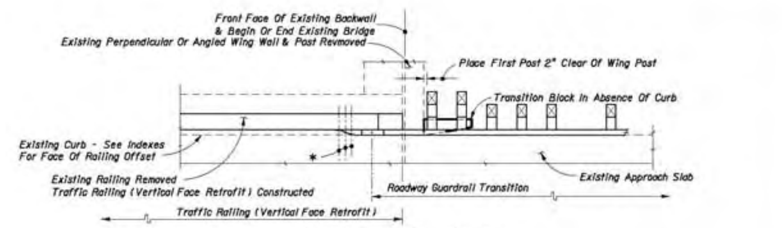
2008 FDOT Design Standards		Last Revision 07/01/07	Sheet No. 13 of 24
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES		Index No. 402	



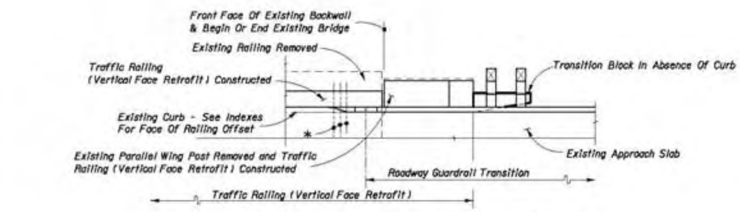
Note:
*21" x 12" x 5/8" Thrie-Beam Terminal Connector Plate (Back-Up Plate), And 7/8" Ø x 12" Long HS Hex Bolts And Nuts (5 Reqd.) With 2 1/4" OD Plain Round Washers Under Heads And Nuts

PARTIAL PLAN VIEWS OF TRAFFIC RAILING (VERTICAL FACE RETROFIT)

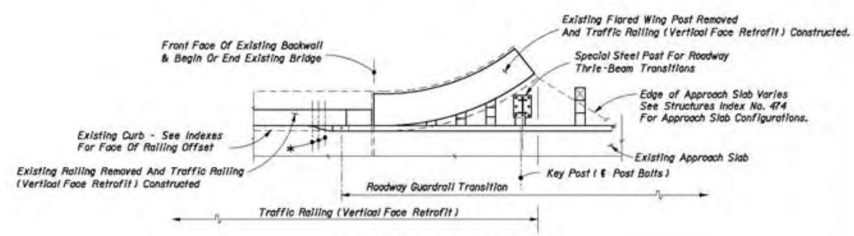
2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	14 of 24
	Index No.	402



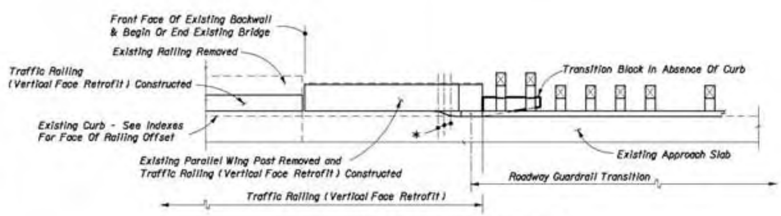
SEE INDEX NO. 483 - SCHEME 1



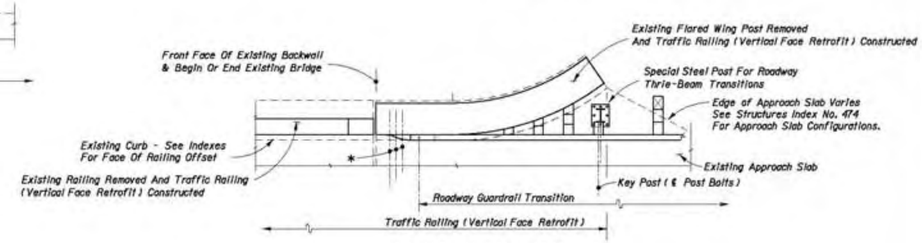
SEE INDEX NO. 483 - SCHEME 2



SEE INDEX NO. 483 - SCHEME 3



SEE INDEX NO. 483 - SCHEME 2

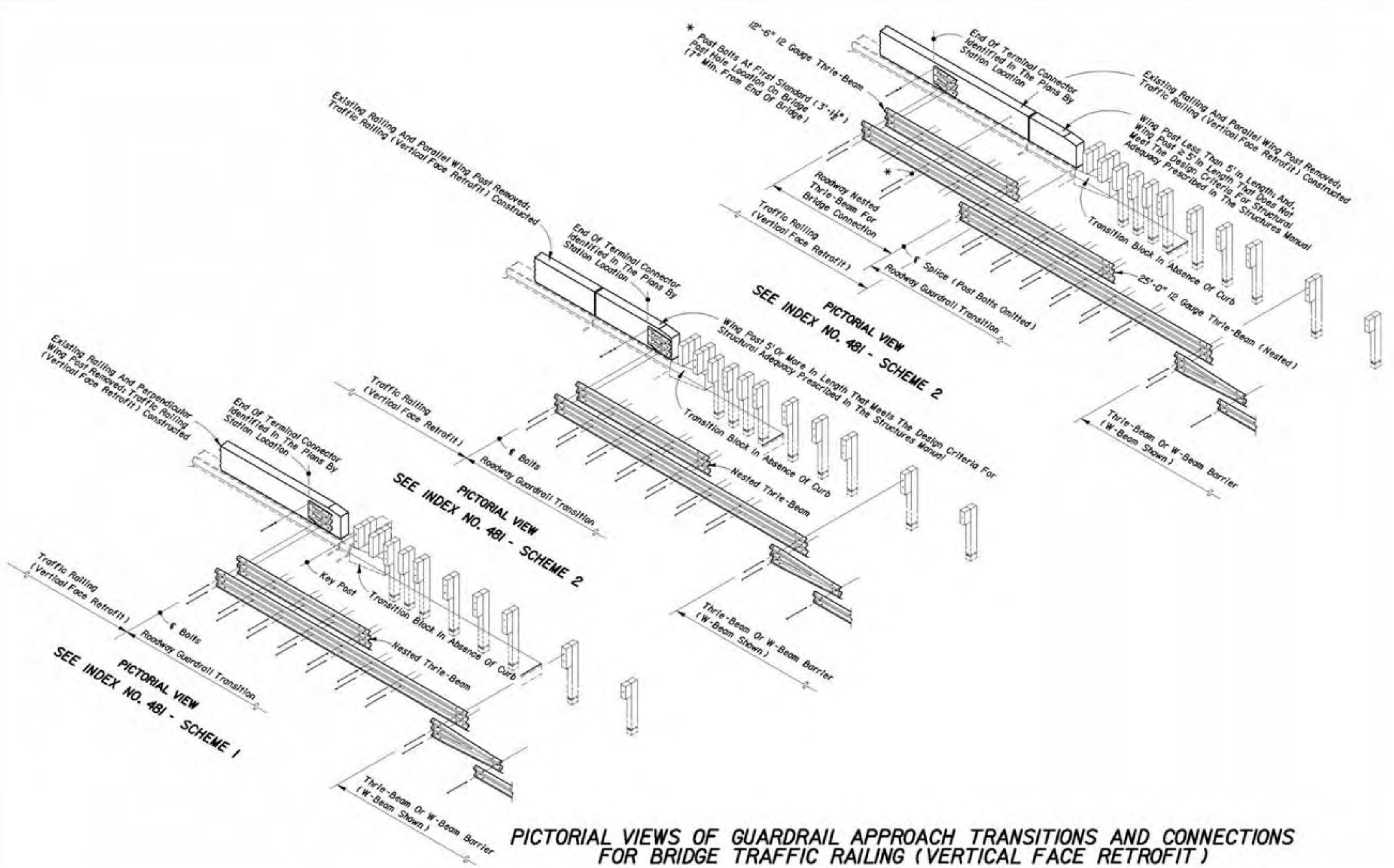


SEE INDEX NO. 483 - SCHEME 3

Note:
*21" x 12" x $\frac{5}{8}$" Thrie-Beam Terminal Connector Plate (Back-Up Plate), And $\frac{7}{8}$" Ø HS Hex Bolts And Nuts (12" Long For Scheme 1 And Length To Fit For Schemes 2 And 3) (5 Reqd.) With $2\frac{1}{4}$" OD Plain Round Washers Under Heads And Nuts

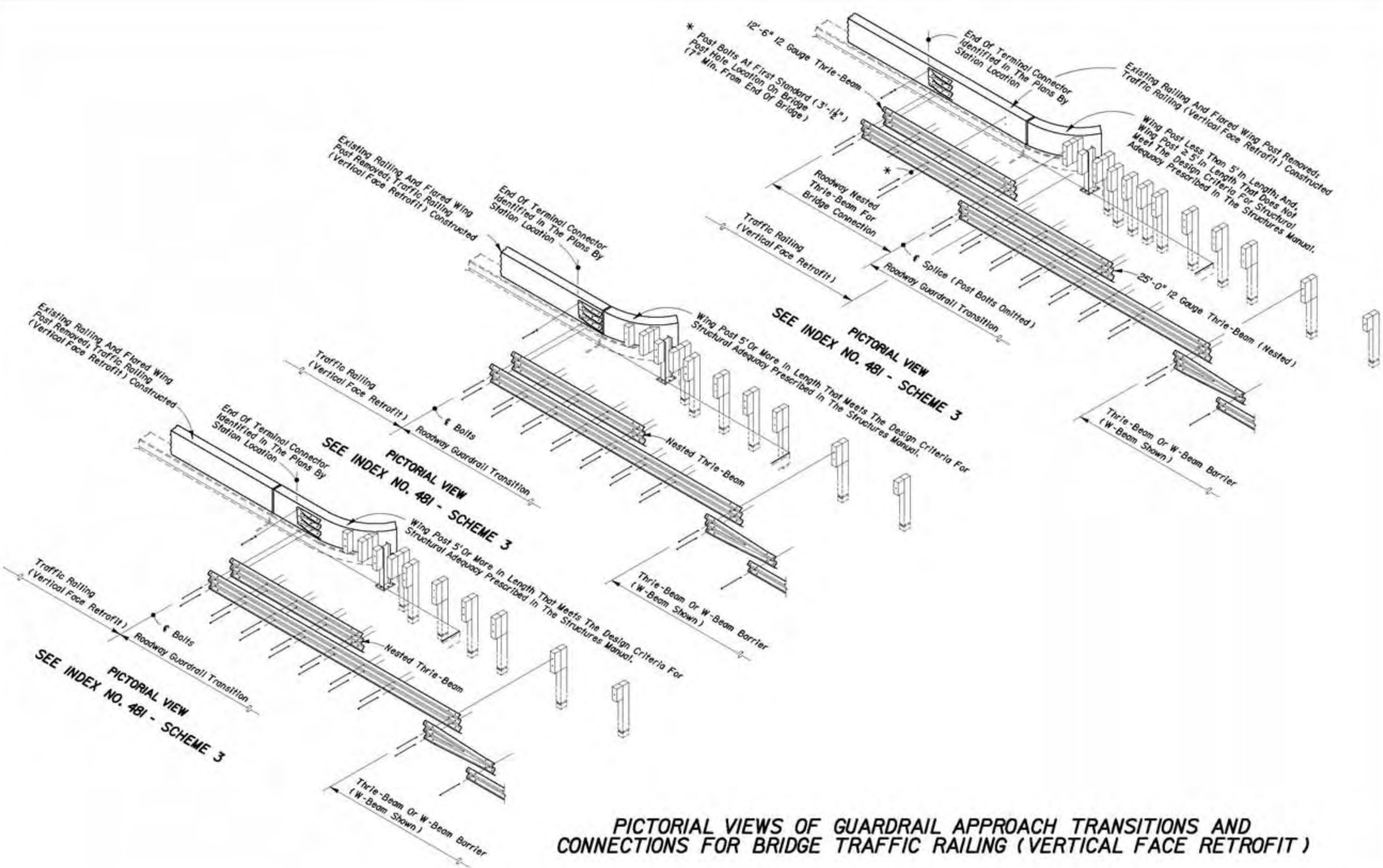
PARTIAL PLAN VIEWS OF TRAFFIC RAILING (VERTICAL FACE RETROFIT)

2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	15 of 24
	Index No.	402



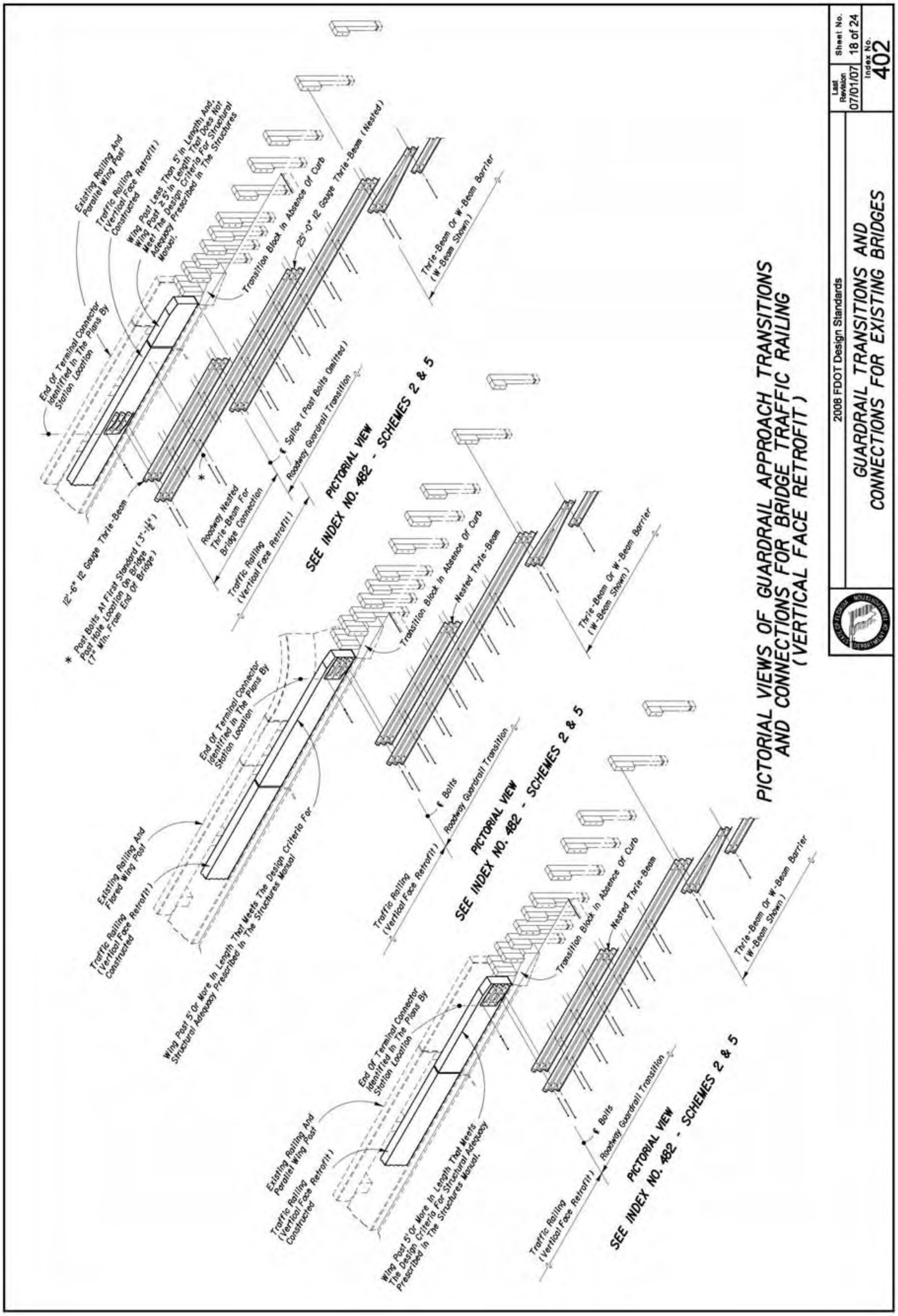
PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (VERTICAL FACE RETROFIT)

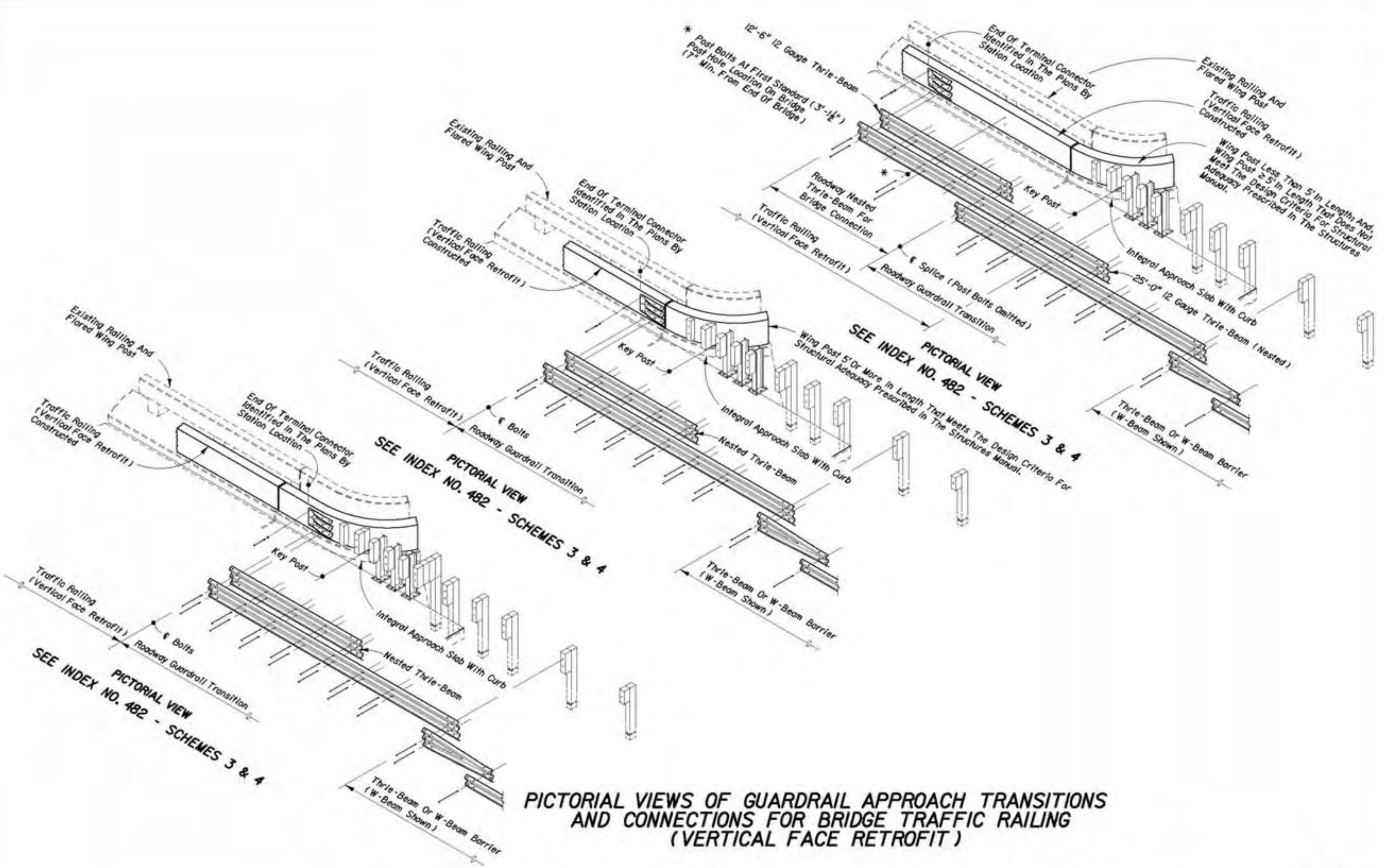
2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	16 of 24
	Index No.	402



PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (VERTICAL FACE RETROFIT)

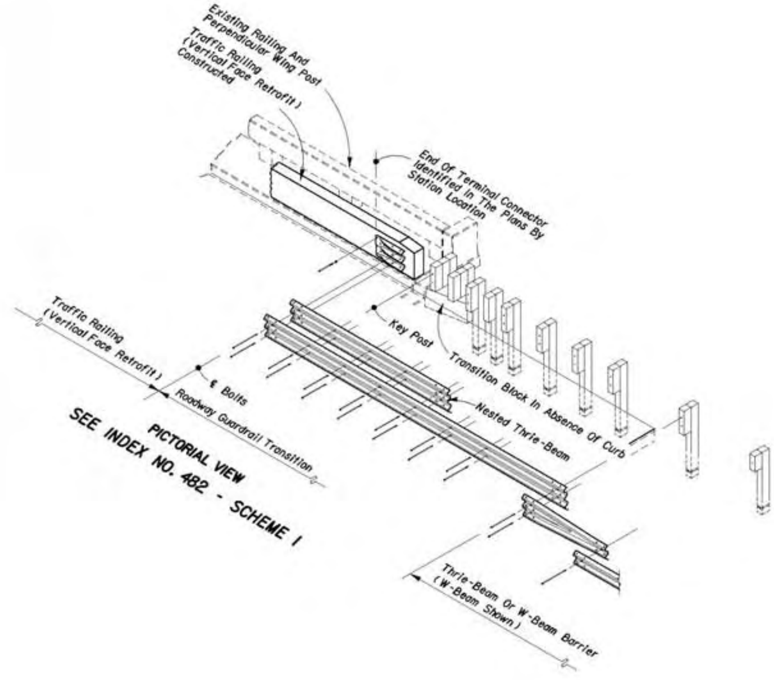
2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	17 of 24
	Index No.	402


PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (VERTICAL FACE RETROFIT)
PICTORIAL VIEW
SEE INDEX NO. 482 - SCHEMES 2 & 5
End Of Terminal Connector Identified In The Plans By Station Location
Existing Railing And Parallel Wing Post
Traffic Railing (Vertical Face Retrofit) Constructed
Wing Post Less Than 5' In Length; And, Wing Post ≥ 5' In Length That Does Not Meet The Design Criteria For Structural Adequacy Prescribed In The Structures Manual.
Transition Block In Absence Of Curb
25'-0" 12 Gauge Thrie-Beam (Nested)
12'-6" 12 Gauge Thrie-Beam
Roadway Nested Thrie-Beam For Bridge Connection
℄ Splice (Post Bolts Omitted)
Traffic Railing (Vertical Face Retrofit)
Roadway Guardrail Transition
Thrie-Beam Or W-Beam Barrier (W-Beam Shown)
* Post Bolts At First Standard (3'-1½") Post Hole Location On Bridge (7" Min. From End Of Bridge)
Existing Railing And Flared Wing Post
Wing Post 5' Or More In Length That Meets The Design Criteria For Structural Adequacy Prescribed In The Structures Manual
Nested Thrie-Beam
℄ Bolts
Wing Post 5' Or More In Length That Meets The Design Criteria For Structural Adequacy Prescribed In The Structures Manual.
2008 FDOT Design Standards
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES
Last Revision 07/01/07
Sheet No. 18 of 24
Index No. 402



PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (VERTICAL FACE RETROFIT)

2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	19 of 24
	Index No.	402

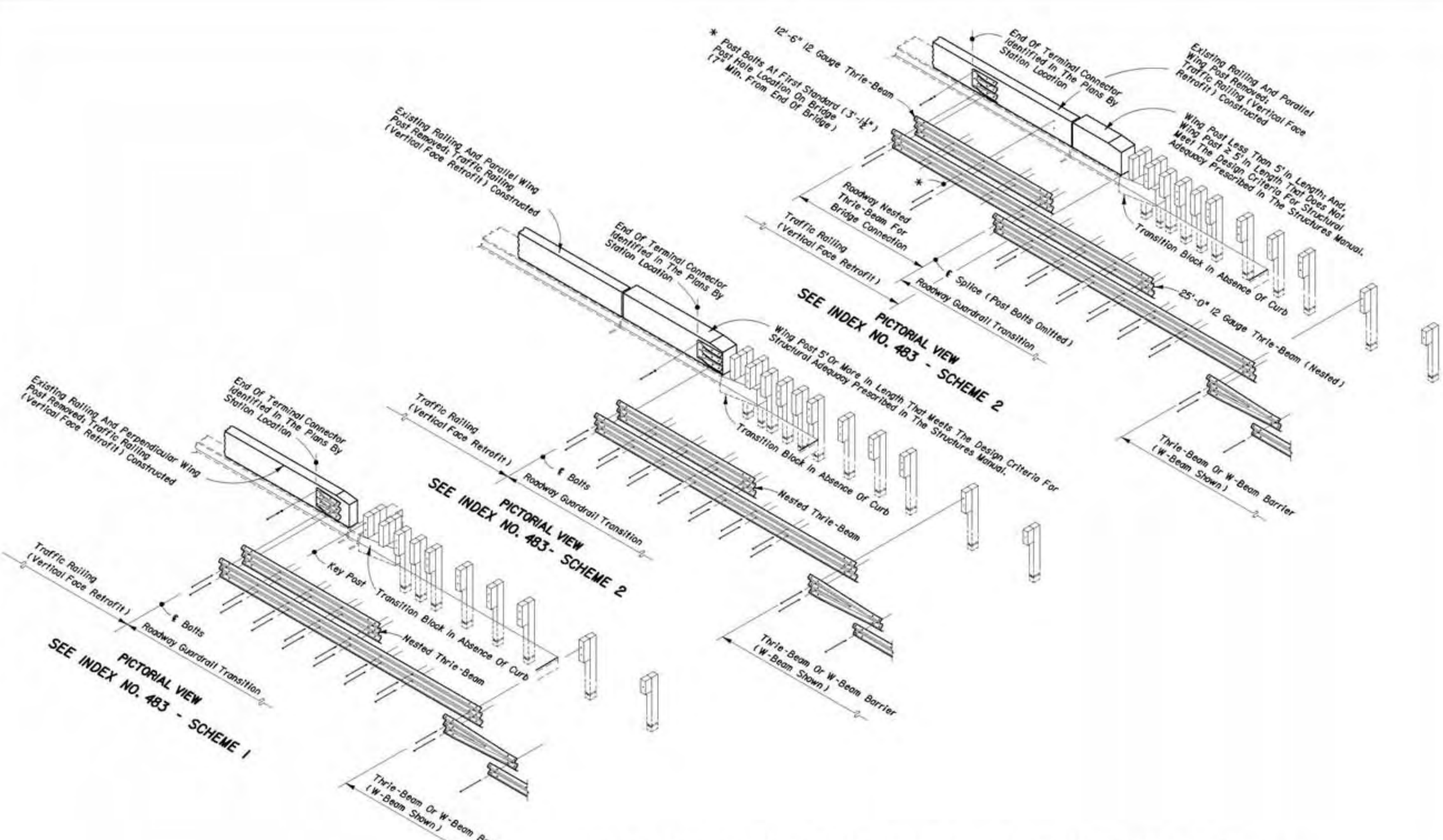


PICTORIAL VIEW

SEE INDEX NO. 482 - SCHEME I

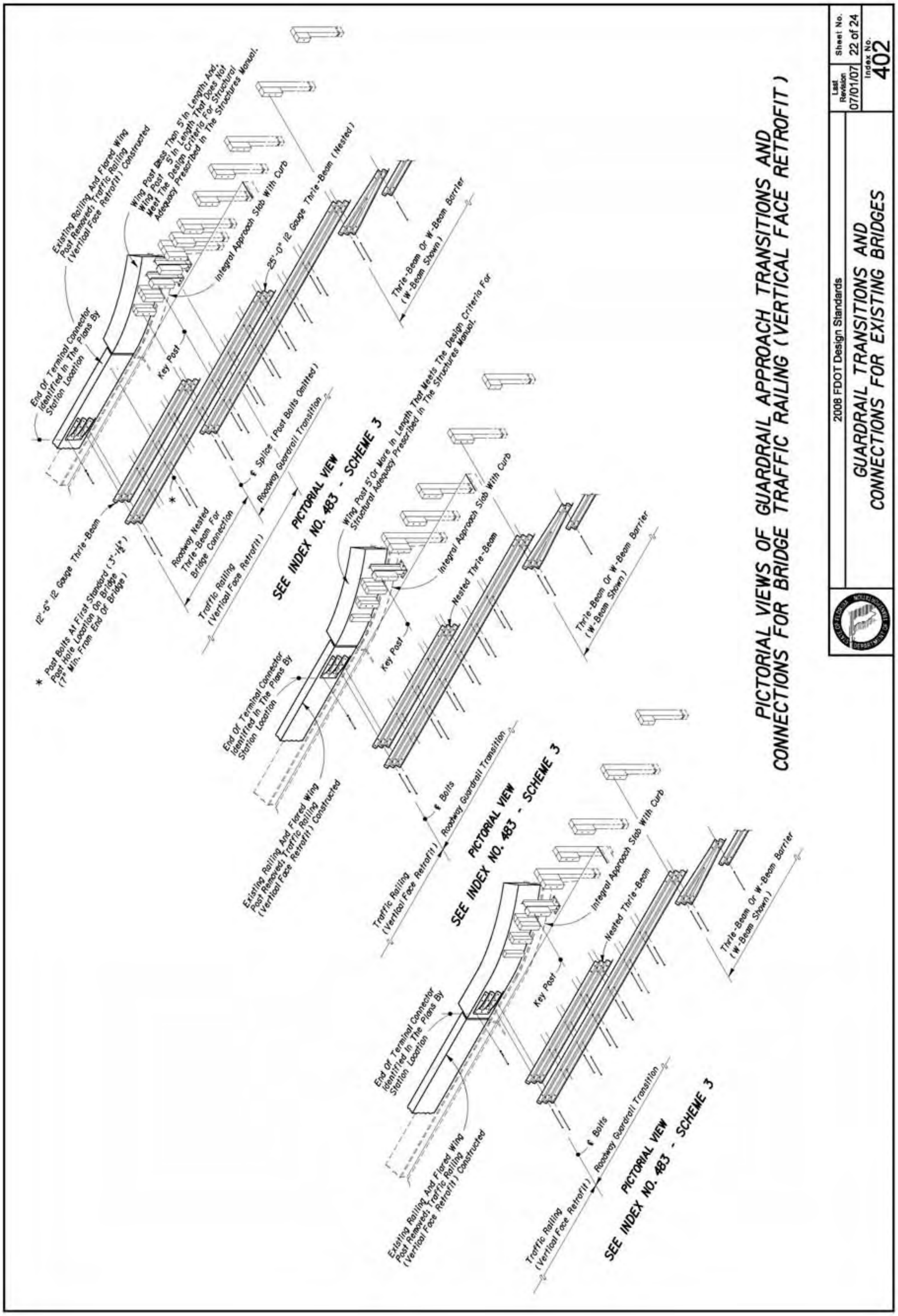
PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (VERTICAL FACE RETROFIT)

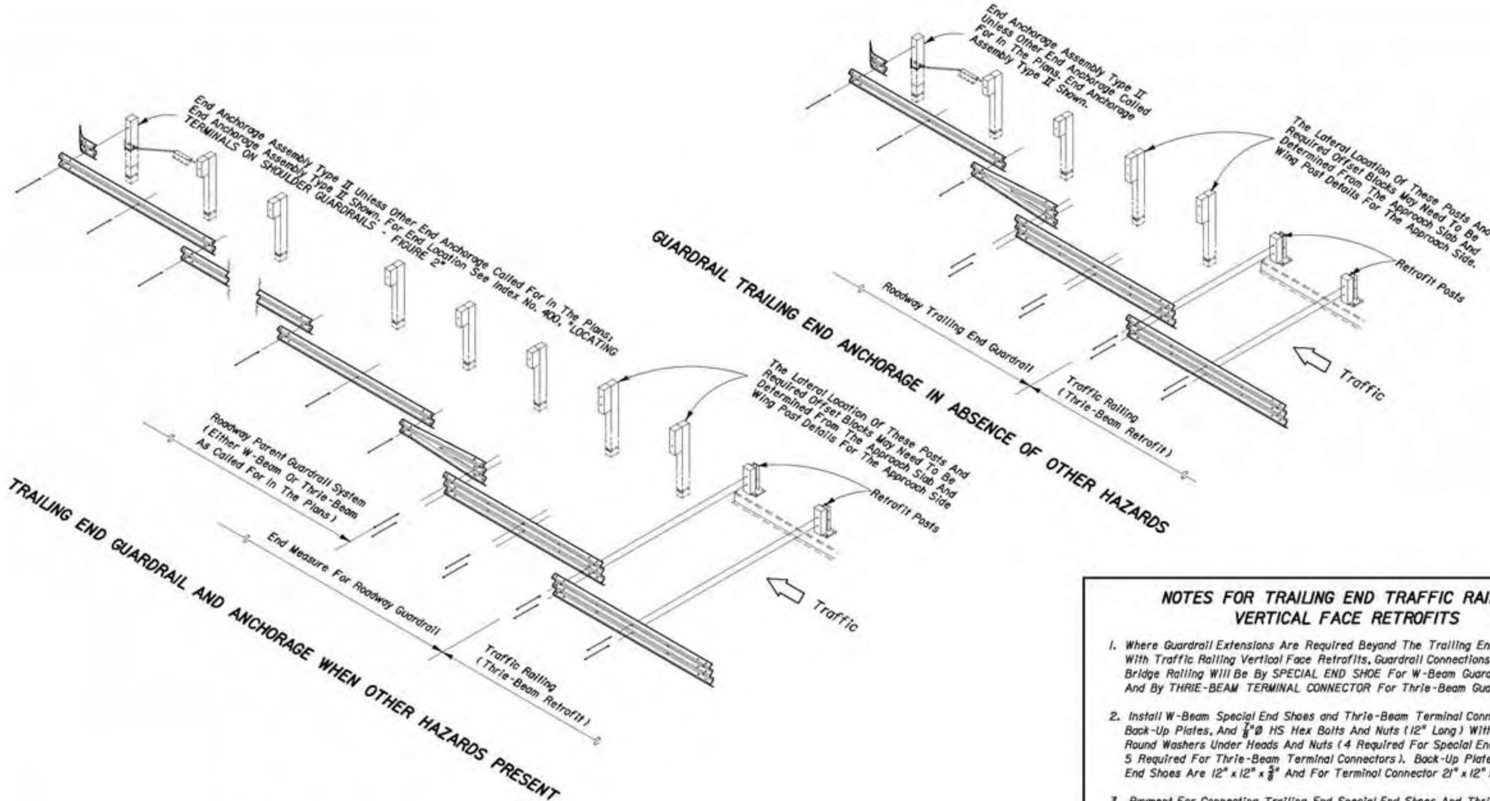
2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	20 of 24
	Index No.	402



PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (VERTICAL FACE RETROFIT)

2008 FDOT Design Standards		Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES		07/01/07	21 of 24
		Index No. 402	


PICTORIAL VIEWS OF GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR BRIDGE TRAFFIC RAILING (VERTICAL FACE RETROFIT)
2008 FDOT Design Standards
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES
Last Revision 07/01/07
Sheet No. 22 of 24
Index No. 402
PICTORIAL VIEW
SEE INDEX NO. 483 - SCHEME 3
End Of Terminal Connector Identified In The Plans By Station Location
Existing Railing And Flared Wing Post Removed; Traffic Railing (Vertical Face Retrofit) Constructed
Wing Post Less Than 5' In Length; And, Wing Post 5' In Length That Does Not Meet The Design Criteria For Structural Adequacy Prescribed In The Structures Manual.
Wing Post 5'0" Or More In Length That Meets The Design Criteria For Structural Adequacy Prescribed In The Structures Manual.
Integral Approach Slab With Curb
25'-0" 12 Gauge Thrie-Beam (Nested)
12'-6" 12 Gauge Thrie-Beam
Nested Thrie-Beam
Integral Thrie-Beam
Key Post
Thrie-Beam Or W-Beam Barrier (W-Beam Shown)
Roadway Nested Thrie-Beam For Bridge Connection
Traffic Railing (Vertical Face Retrofit)
℄ Splice (Post Bolts Omitted)
℄ Bolts
Roadway Guardrail Transition
* Post Bolts At First Standard (3'-1½") Post Hole Location On Bridge (7" Min. From End Of Bridge)



NOTES FOR TRAILING END TRAFFIC RAILING VERTICAL FACE RETROFITS

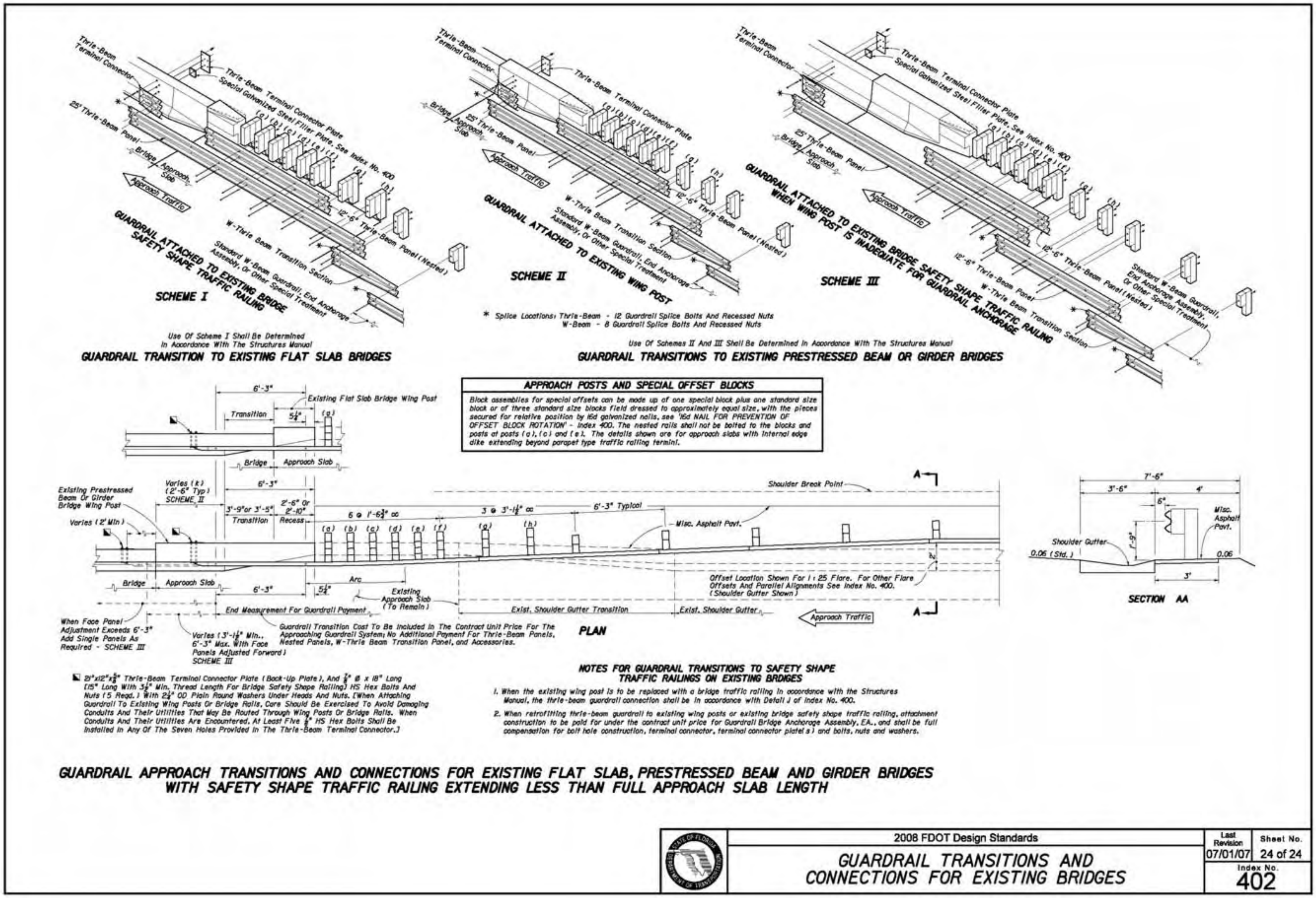
1. Where Guardrail Extensions Are Required Beyond The Trailing End Of Bridges With Traffic Railing Vertical Face Retrofits, Guardrail Connections To The Bridge Railing Will Be By SPECIAL END SHOE For W-Beam Guardrail Extensions And By THRIE-BEAM TERMINAL CONNECTOR For Thrie-Beam Guardrail Extensions.
2. Install W-Beam Special End Shoes and Thrie-Beam Terminal Connectors With Back-Up Plates, And $\frac{7}{8}$"Ø HS Hex Bolts And Nuts (12" Long) With $2\frac{1}{4}$" OD Plain Round Washers Under Heads And Nuts (4 Required For Special End Shoes And 5 Required For Thrie-Beam Terminal Connectors). Back-Up Plates For Special End Shoes Are 12" x 12" x $\frac{3}{8}$" And For Terminal Connector 21" x 12" x $\frac{3}{8}$".
3. Payment For Connecting Trailing End Special End Shoes And Thrie-Beam Terminal Connectors To Traffic Railing Vertical Face Retrofits Will Be Made Under The Contract Unit Price For Guardrail Bridge Anchorage Assembly, EA..

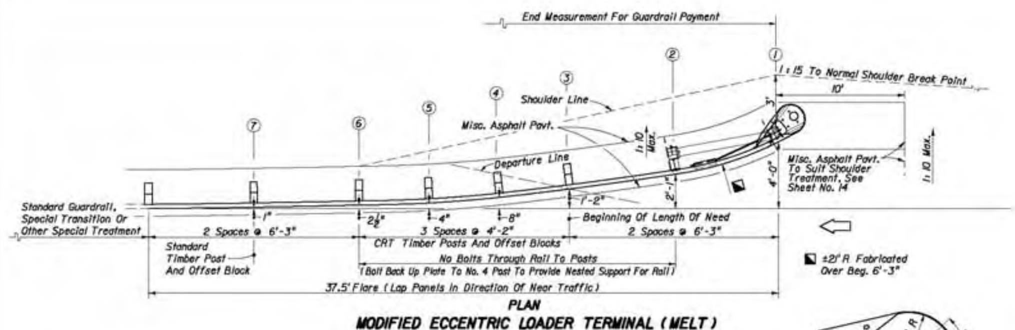
THRIE-BEAM RETROFIT NOTES

1. See indexes for bridge thrie-beam traffic railing retrofits.
2. Trailing end guardrail to be paid for under the contract unit price for the parent roadway guardrail; end measure includes length of end anchorage assembly; additional payment made for end anchorage assembly. No additional payment for connecting roadway thrie-beam to bridge thrie-beam retrofit.

TRAILING END GUARDRAIL AND ANCHORAGE FOR BRIDGE TRAFFIC RAILING (THRIE BEAM RETROFITS)

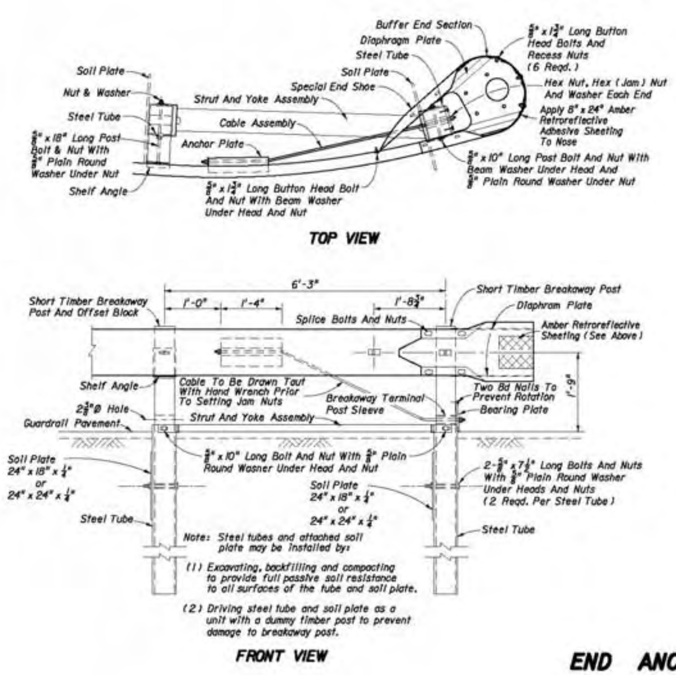
2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES	07/01/07	23 of 24
	Index No.	402

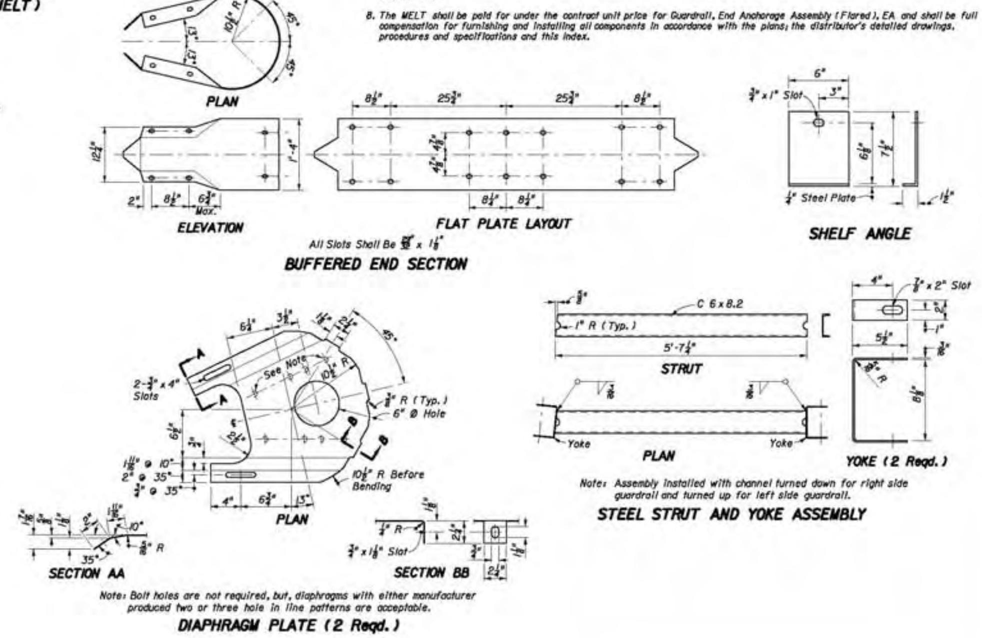

SCHEME I
GUARDRAIL ATTACHED TO EXISTING BRIDGE SAFETY SHAPE TRAFFIC RAILING
Use Of Scheme I Shall Be Determined In Accordance With The Structures Manual
GUARDRAIL TRANSITION TO EXISTING FLAT SLAB BRIDGES
SCHEME II
GUARDRAIL ATTACHED TO EXISTING WING POST
SCHEME III
GUARDRAIL ATTACHED TO EXISTING BRIDGE SAFETY SHAPE TRAFFIC RAILING WHEN WING POST IS INADEQUATE FOR GUARDRAIL ANCHORAGE
* Splice Locations: Thrie-Beam - 12 Guardrail Splice Bolts And Recessed Nuts
W-Beam - 8 Guardrail Splice Bolts And Recessed Nuts
Use Of Schemes II And III Shall Be Determined In Accordance With The Structures Manual
GUARDRAIL TRANSITIONS TO EXISTING PRESTRESSED BEAM OR GIRDER BRIDGES
Thrie-Beam Terminal Connector
Thrie-Beam Terminal Connector Plate
Special Galvanized Steel Filler Plate, See Index No. 400
25' Thrie-Beam Panel
12'-6" Thrie-Beam Panel (Nested)
W-Thrie Beam Transition Section
Standard W-Beam Guardrail, End Anchorage Assembly, Or Other Special Treatment
Bridge
Approach Slab
Approach Traffic
APPROACH POSTS AND SPECIAL OFFSET BLOCKS
Block assemblies for special offsets can be made up of one special block plus one standard size block or of three standard size blocks field dressed to approximately equal size, with the pieces secured for relative position by 16d galvanized nails, see '16d NAIL FOR PREVENTION OF OFFSET BLOCK ROTATION' - Index 400. The nested rails shall not be bolted to the blocks and posts at posts (a), (c) and (e). The details shown are for approach slabs with internal edge dike extending beyond parapet type traffic railing termini.
Existing Flat Slab Bridge Wing Post
Existing Prestressed Beam Or Girder Bridge Wing Post
Varies (2' Min)
Varies (k) (2'-6" Typ) SCHEME II
3'-9" or 3'-5"
2'-6" Or 2'-10"
Transition
Recess
6 @ 1'-6¾" cc
3 @ 3'-1½" cc
6'-3" Typical
Shoulder Break Point
Misc. Asphalt Pavt.
Arc
Existing Approach Slab (To Remain)
End Measurement For Guardrail Payment
Exist. Shoulder Gutter Transition
Exist. Shoulder Gutter
Offset Location Shown For 1:25 Flare. For Other Flare Offsets And Parallel Alignments See Index No. 400. (Shoulder Gutter Shown)
When Face Panel Adjustment Exceeds 6'-3" Add Single Panels As Required - SCHEME III
Varies (3'-1½" Min., 6'-3" Max. With Face Panels Adjusted Forward) SCHEME III
Guardrail Transition Cost To Be Included In The Contract Unit Price For The Approaching Guardrail System; No Additional Payment For Thrie-Beam Panels, Nested Panels, W-Thrie Beam Transition Panel, and Accessories.
PLAN
SECTION AA
7'-6"
3'-6"
4'
Shoulder Gutter
0.06 (Std.)
Misc. Asphalt Pavt.
0.06
3'
25"x12"x⅜" Thrie-Beam Terminal Connector Plate (Back-Up Plate), And ⅞" Ø x 18" Long (15" Long With 3½" Min. Thread Length For Bridge Safety Shape Railing) HS Hex Bolts And Nuts (5 Reqd.) With 2¼" OD Plain Round Washers Under Heads And Nuts. [When Attaching Guardrail To Existing Wing Posts Or Bridge Rails, Care Should Be Exercised To Avoid Damaging Conduits And Their Utilities That May Be Routed Through Wing Posts Or Bridge Rails. When Conduits And Their Utilities Are Encountered, At Least Five ⅞" HS Hex Bolts Shall Be Installed In Any Of The Seven Holes Provided In The Thrie-Beam Terminal Connector.]
NOTES FOR GUARDRAIL TRANSITIONS TO SAFETY SHAPE TRAFFIC RAILINGS ON EXISTING BRIDGES
1. When the existing wing post is to be replaced with a bridge traffic railing in accordance with the Structures Manual, the thrie-beam guardrail connection shall be in accordance with Detail J of Index No. 400.
2. When retrofitting thrie-beam guardrail to existing wing posts or existing bridge safety shape traffic railing, attachment construction to be paid for under the contract unit price for Guardrail Bridge Anchorage Assembly, EA., and shall be full compensation for bolt hole construction, terminal connector, terminal connector plate(s) and bolts, nuts and washers.
GUARDRAIL APPROACH TRANSITIONS AND CONNECTIONS FOR EXISTING FLAT SLAB, PRESTRESSED BEAM AND GIRDER BRIDGES WITH SAFETY SHAPE TRAFFIC RAILING EXTENDING LESS THAN FULL APPROACH SLAB LENGTH
2008 FDOT Design Standards
GUARDRAIL TRANSITIONS AND CONNECTIONS FOR EXISTING BRIDGES
Last Revision 07/01/07
Sheet No. 24 of 24
Index No. 402



MODIFIED ECCENTRIC LOADER TERMINAL NOTES

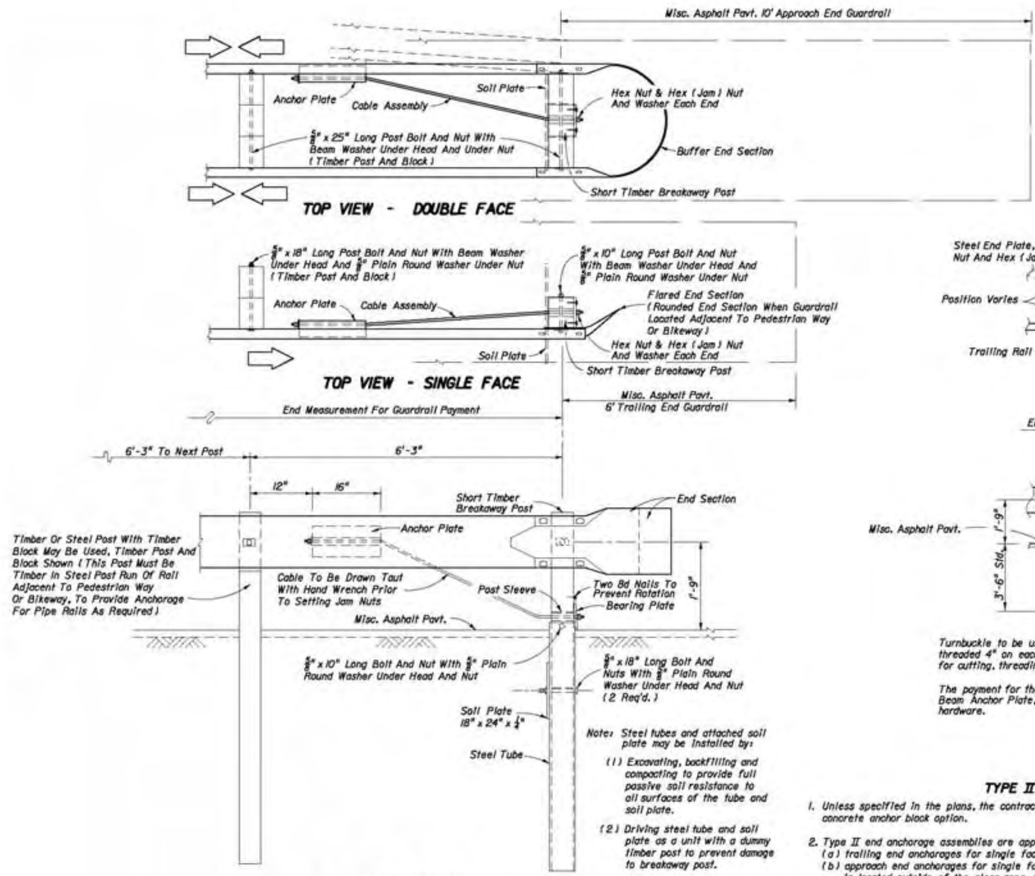
1. The MELT is applicable for design speeds up to 45 mph. The MELT is intended for use as an approach end guardrail anchorage for shoulder guardrail. Its alignment is a flare from the normal guardrail alignment with an effective length of 37.5' including three standard W-beam panel outside of any standard guardrail, guardrail transitions or other special treatments.
2. This standard drawing is produced by the Florida Department Of Transportation solely for use by the Department and its assignees. This standard drawing provides the general graphics and information necessary to field identify component parts of the MELT and their incorporation into a whole system.
3. This standard drawing is sufficient for plan details for the MELT when installed in connection with shoulder guardrail and precludes the requirement for shop drawing submittals unless the plans otherwise call for such submittals. The MELT shall be assembled in accordance with the distributor's detailed drawings, procedures and specifications.
4. The first two post must be short timber breakaway posts with steel foundation tubes and soil plates, post Nos. 3 thru 6 must be CRT timber posts and post No. 7 must be a standard timber post.
5. The MELT can not be used in medians where horizontal clearance requires the use of a backrail.
6. See the General Notes for galvanizing requirements of metallic components.
7. If the plans call for the MELT at a specific location, substitutions with other end anchorage assemblies will not be permitted unless approved by the Engineer. If the plans call for end anchorage assembly 'flared' at a specific location, the contractor has the option to construct any FDOT approved flared assembly that meet the applications for that location. Where a flared end anchorage is called for in the plans, any approved substitution with a parallel end anchorage will not be eligible for VECP consideration.
8. The MELT shall be paid for under the contract unit price for Guardrail, End Anchorage Assembly (Flared), EA and shall be full compensation for furnishing and installing all components in accordance with the plans; the distributor's detailed drawings, procedures and specifications and this index.





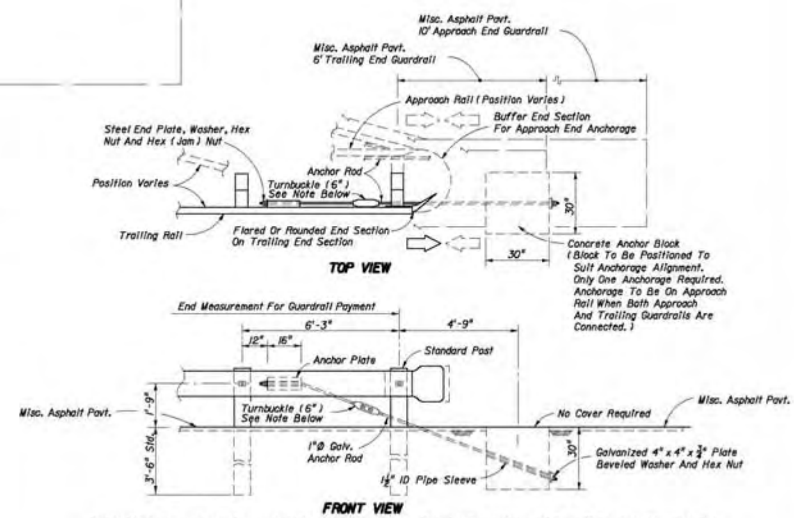
END ANCHORAGE ASSEMBLY TYPE MELT

2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL	02	22 of 24
		Index No. 400



The payment for the items of End Anchorage Assembly Type II shall be full compensation for furnishing and installing either the Round or the Buffer End Section, the Beam Anchor Plate, Cable Assembly, Pipe Sleeve, SoilPlate, Steel Tube, Bearing Plate, Short Timber Breakaway Post, Offset Blocks and the necessary hardware.

CABLE ANCHOR OPTION



Turnbuckle to be used only for guardrail that is reset vertically. The existing anchor rod (1" or 1¼" Dia.) shall be field cut, threaded 4" on each end, and, metalized in accordance with Sections 562 and 971 of the Standard Specifications. The cost for cutting, threading, metalizing and the turnbuckle shall be included in the contract unit price for Reset Guardrail, LF.

The payment for the items of End Anchorage Assembly Type II shall be full compensation for furnishing and installing the Beam Anchor Plate, Anchor Rod, Pipe Sleeve, Anchor Block, either Flared, Rounded or Buffer End Section, and the necessary hardware.

CONCRETE ANCHOR BLOCK OPTION

TYPE II NOTES

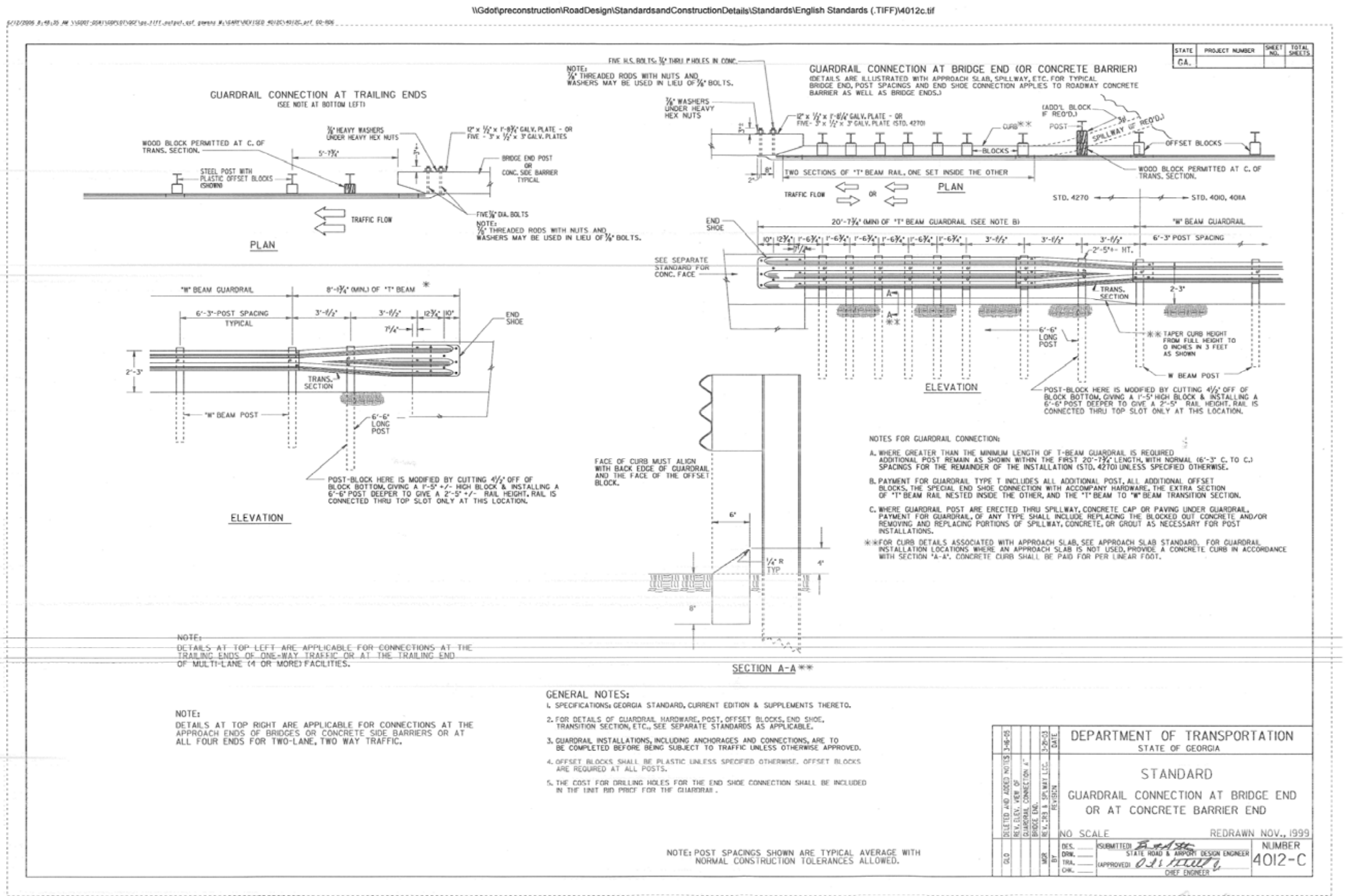
1. Unless specified in the plans, the contractor can supply either the cable anchor option or the concrete anchor block option.
2. Type II end anchorage assemblies are approved for all speeds and are intended for use as:
   (a) trailing end anchorages for single face free standing guardrail systems;
   (b) approach end anchorages for single face free standing guardrail systems when end anchorage is located outside of the clear zone; and,
   (c) both approach and trailing ends of double face guardrail systems.
   Crash cushions shall be constructed at or in lieu of approach Type II end anchorages located inside the clear zone.

   End anchorage for thrie beam guardrail shall be constructed the same as detailed for W-beam, except use thrie beam rail and end section; and the Anchor Plate is to be attached to the bottom corrugation of the thrie beam.
3. These end anchors are to be paid for under the contract unit price for Guardrail, End Anchorage Assembly (Type II), EA as called for in the plans or by permit.

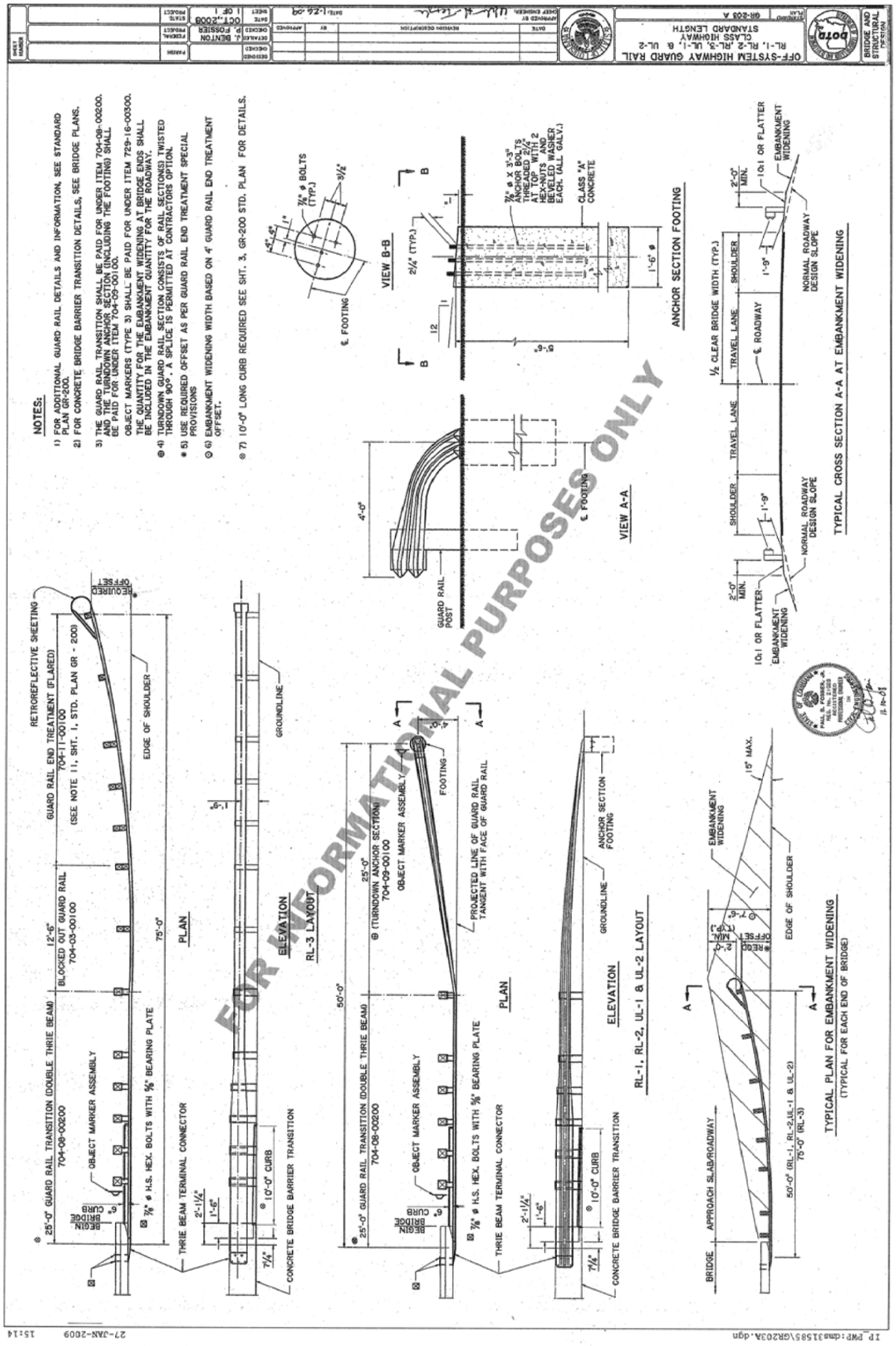
END ANCHORAGE ASSEMBLY TYPE II

2008 FDOT Design Standards	Last Revision	Sheet No.
GUARDRAIL	07/01/05	21 of 24
	Index No.	400

Georgia DOT
Georgia guardrail details 1

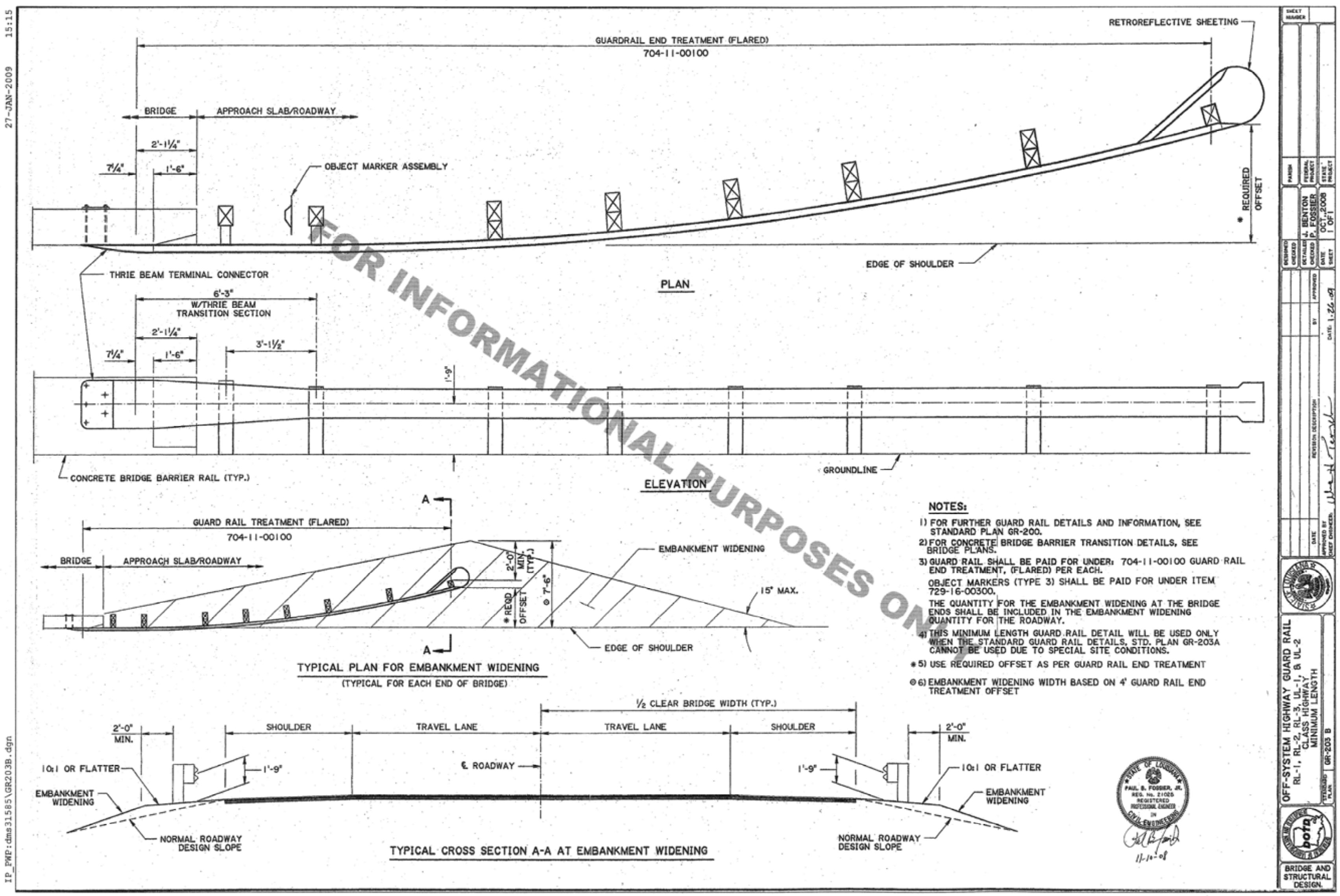


1 of 1

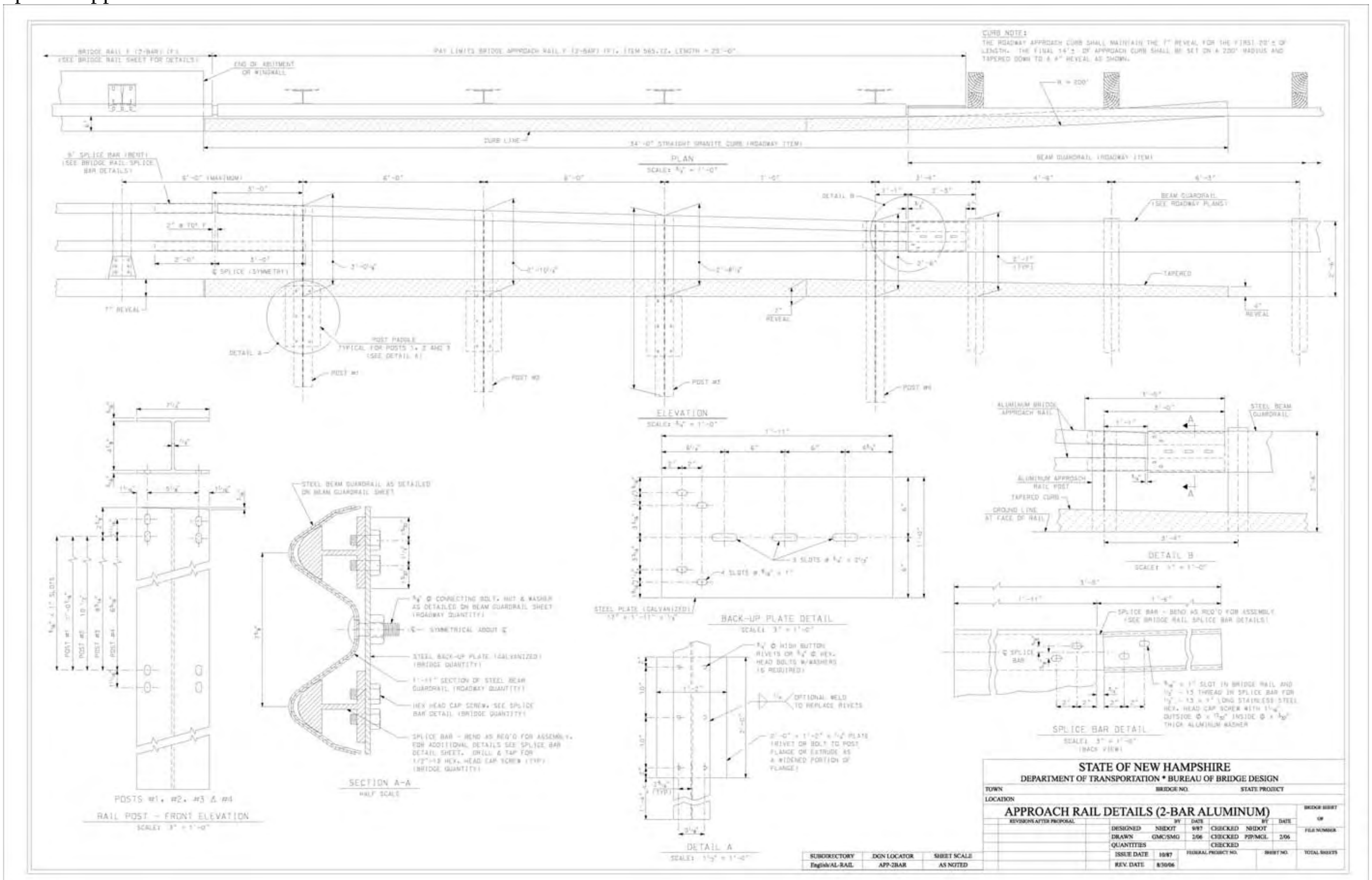


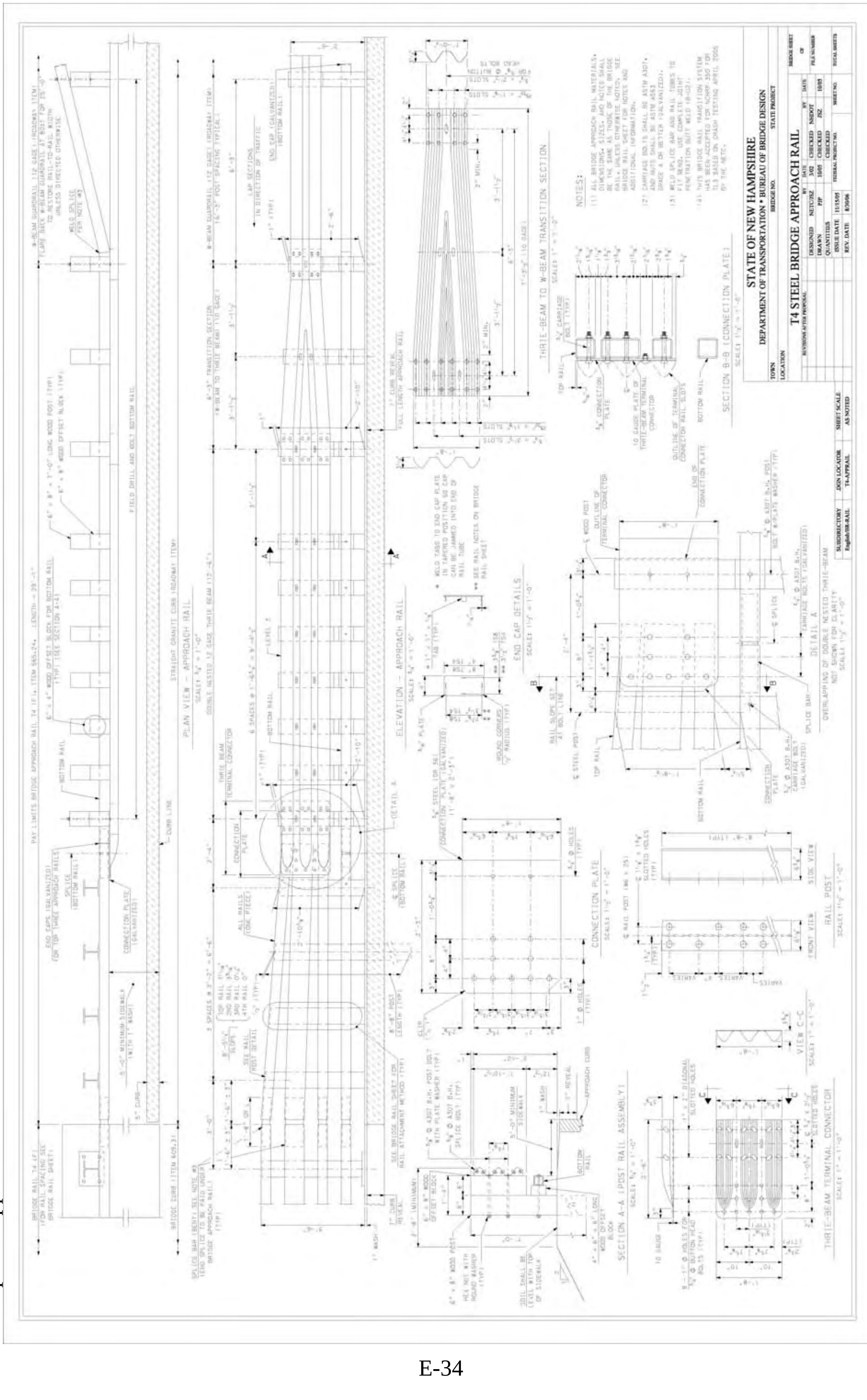
Louisiana DOT
Louisiana GR203A

Louisiana GR203B



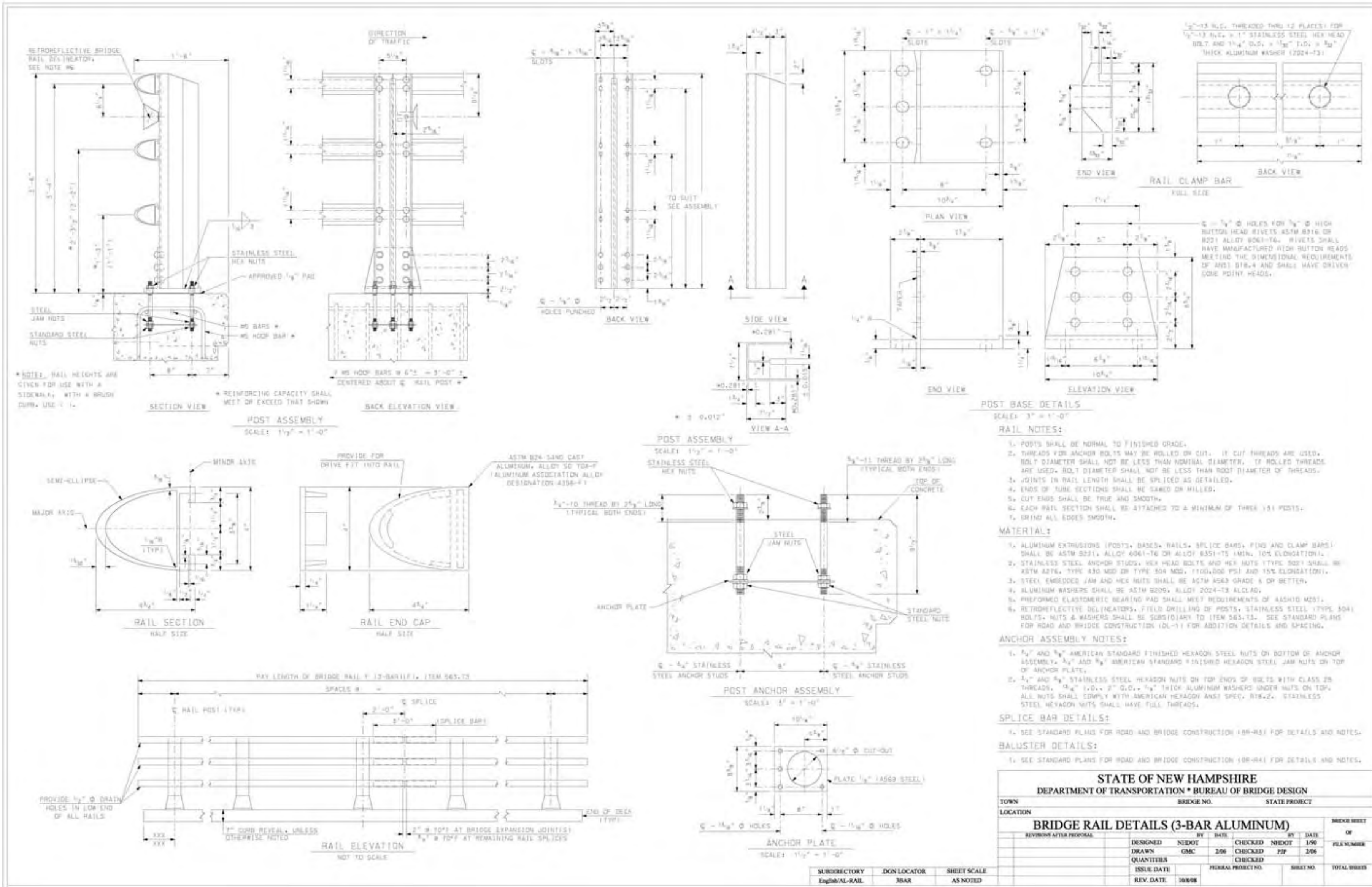
New Hampshire DOT
New Hampshire approach rail



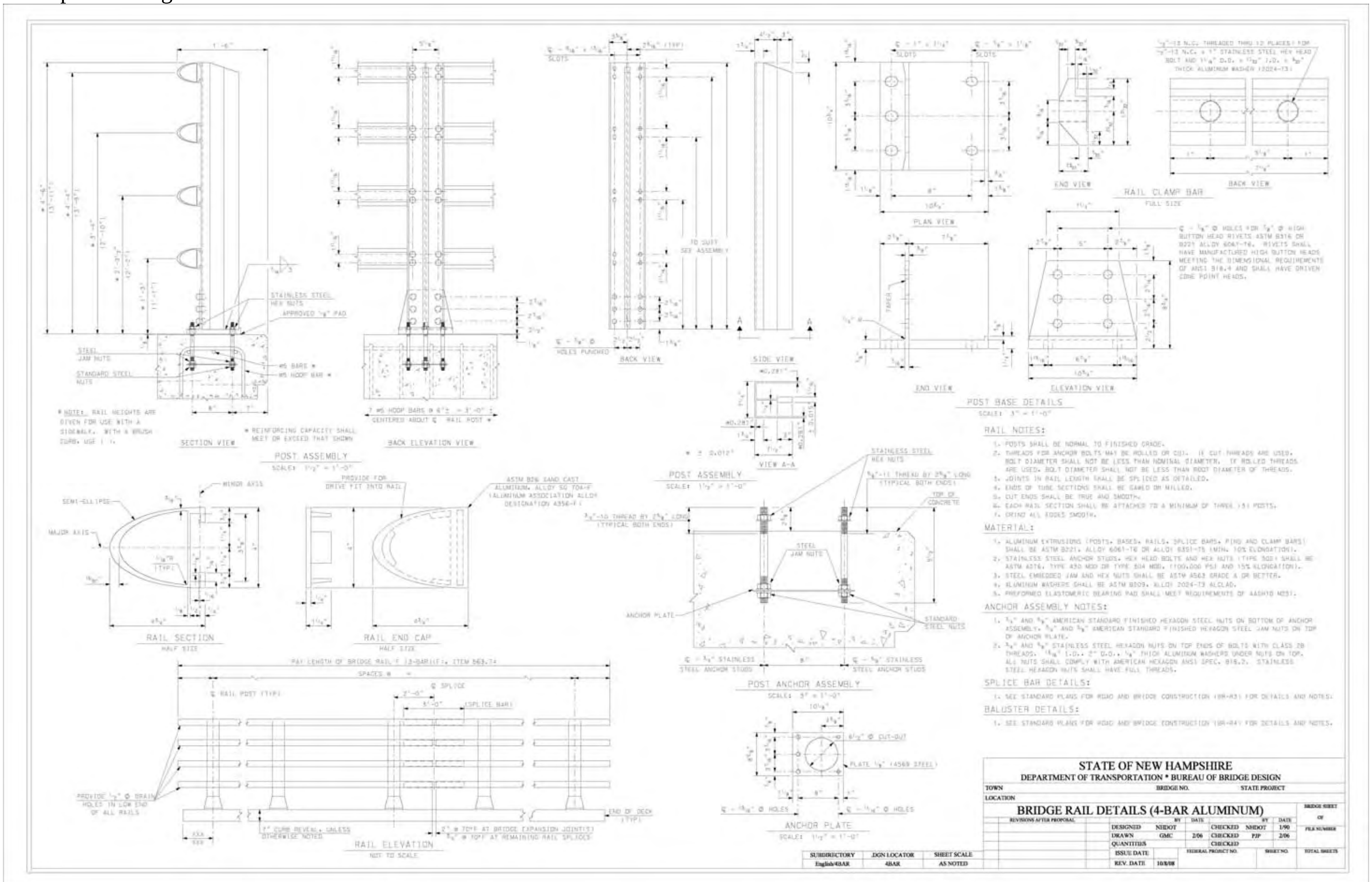


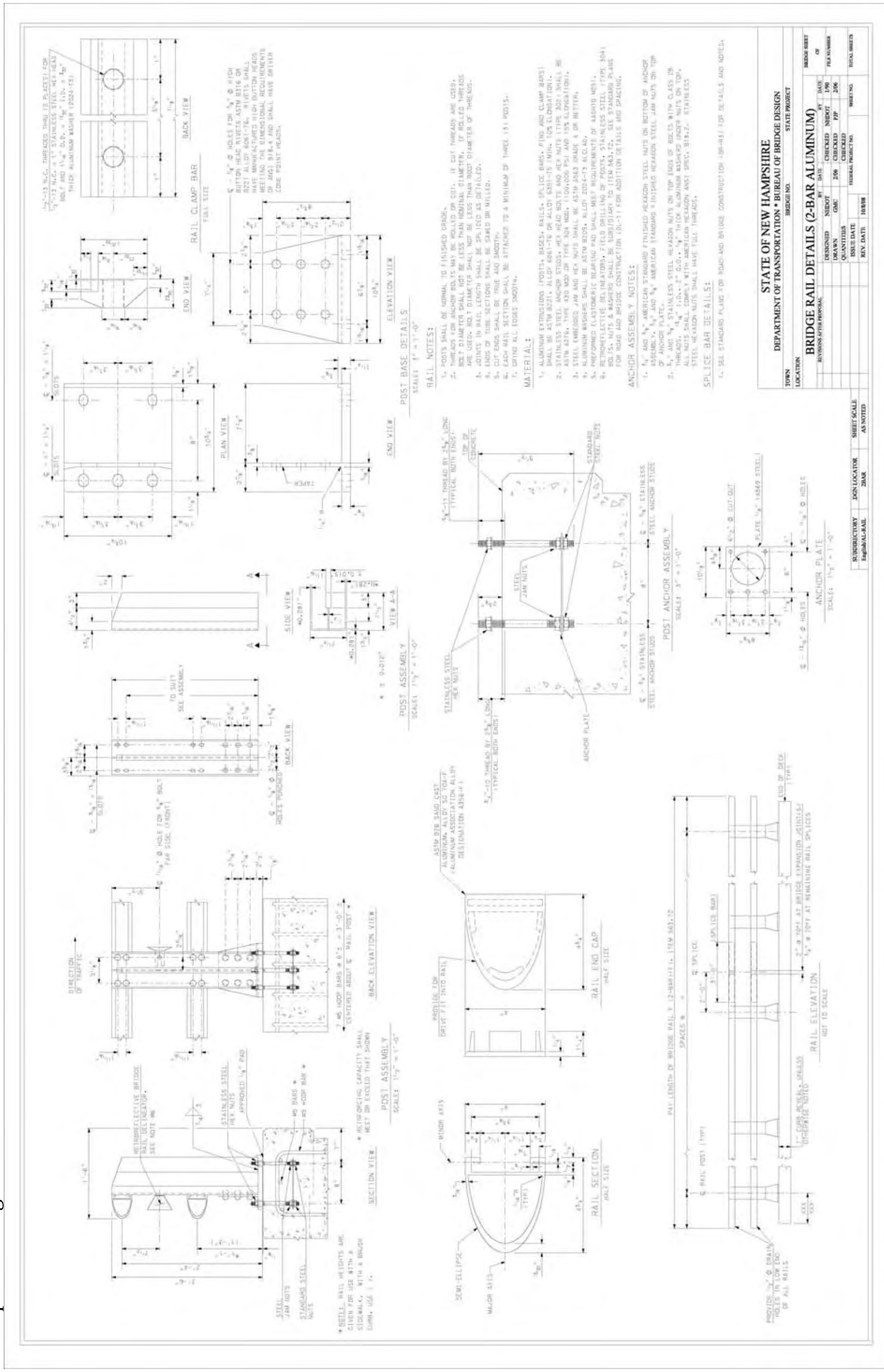
New Hampshire approach rail

New Hampshire bridge rail



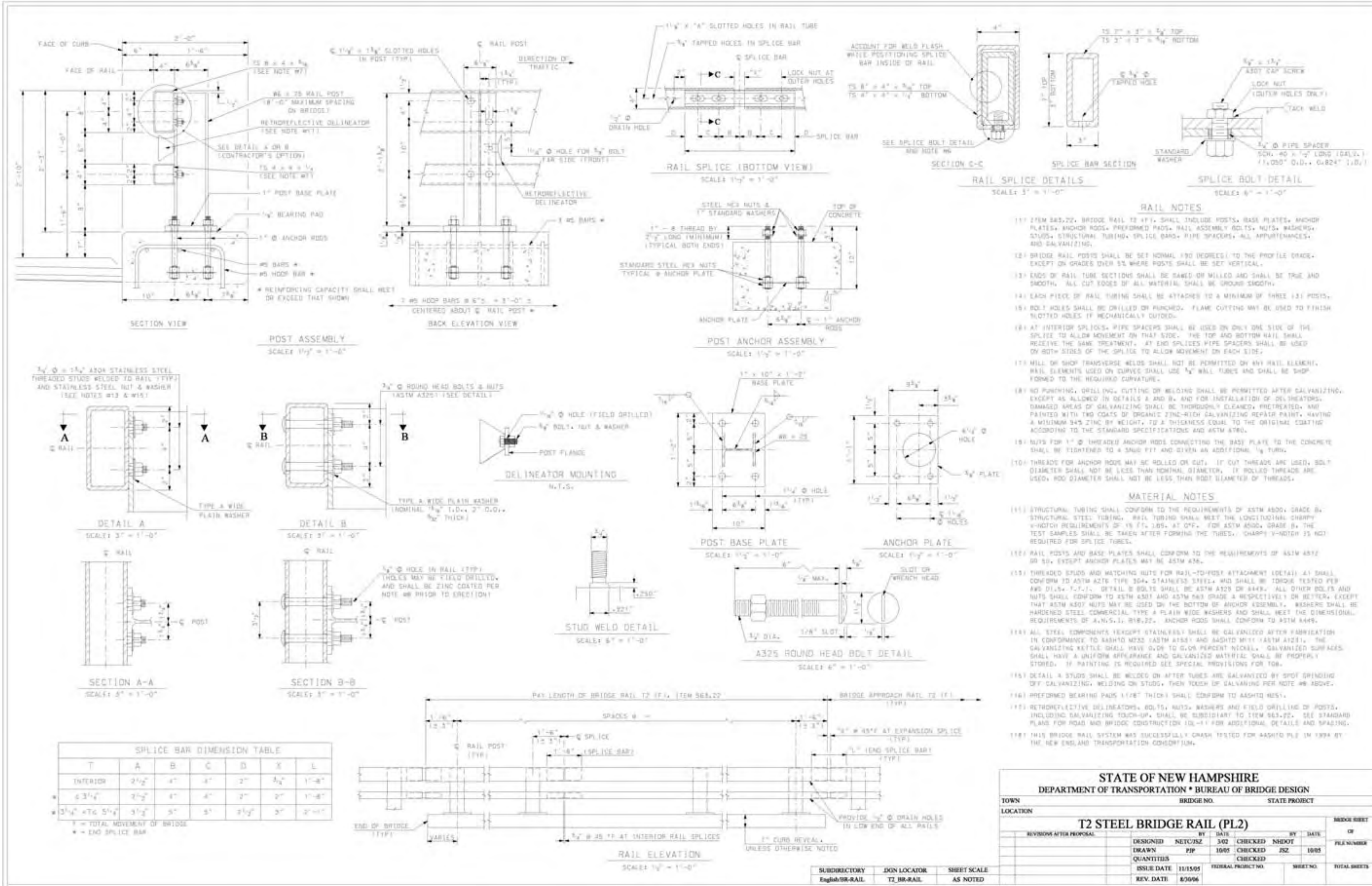
New Hampshire bridge rail

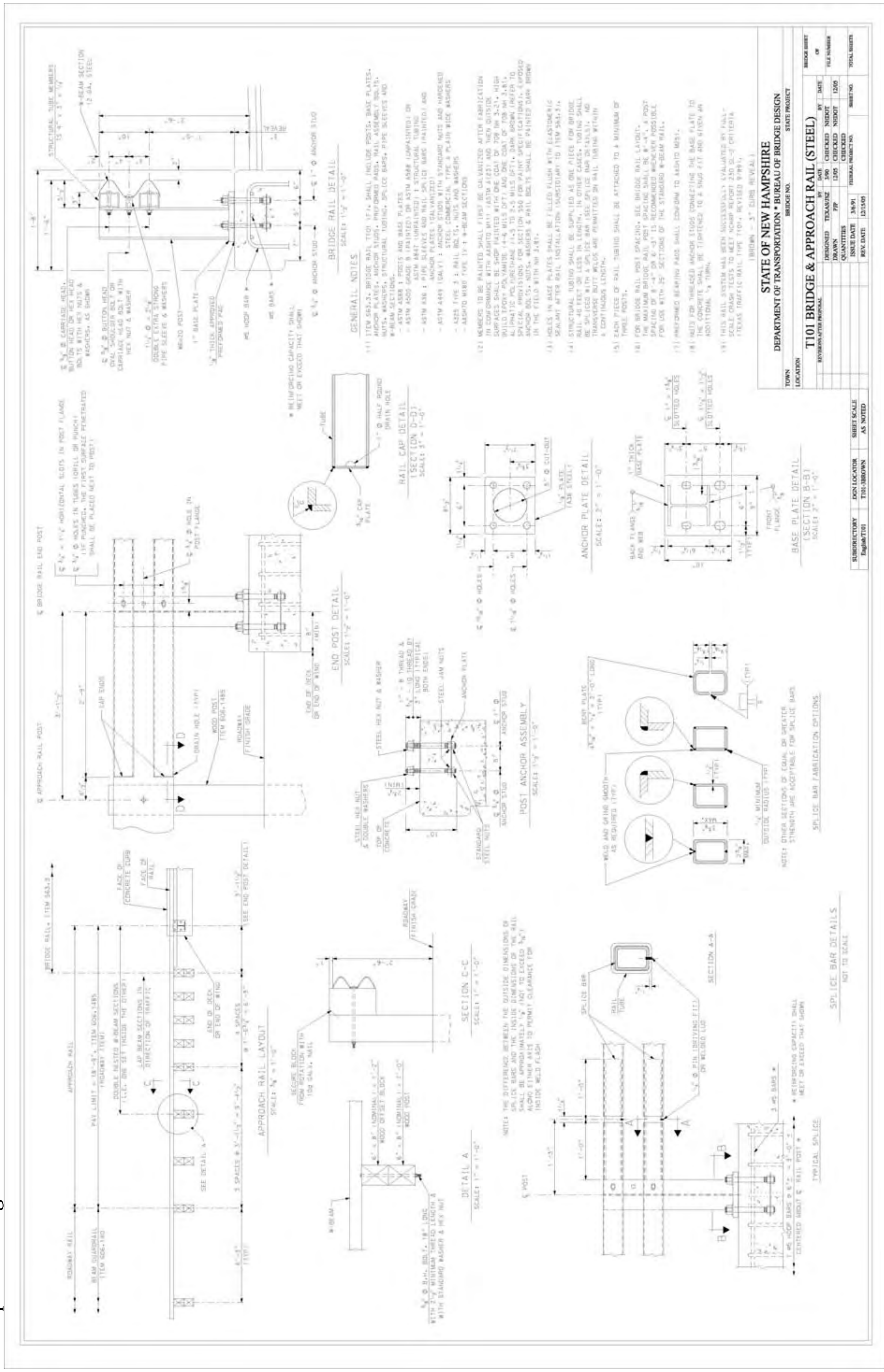




New Hampshire bridge rail

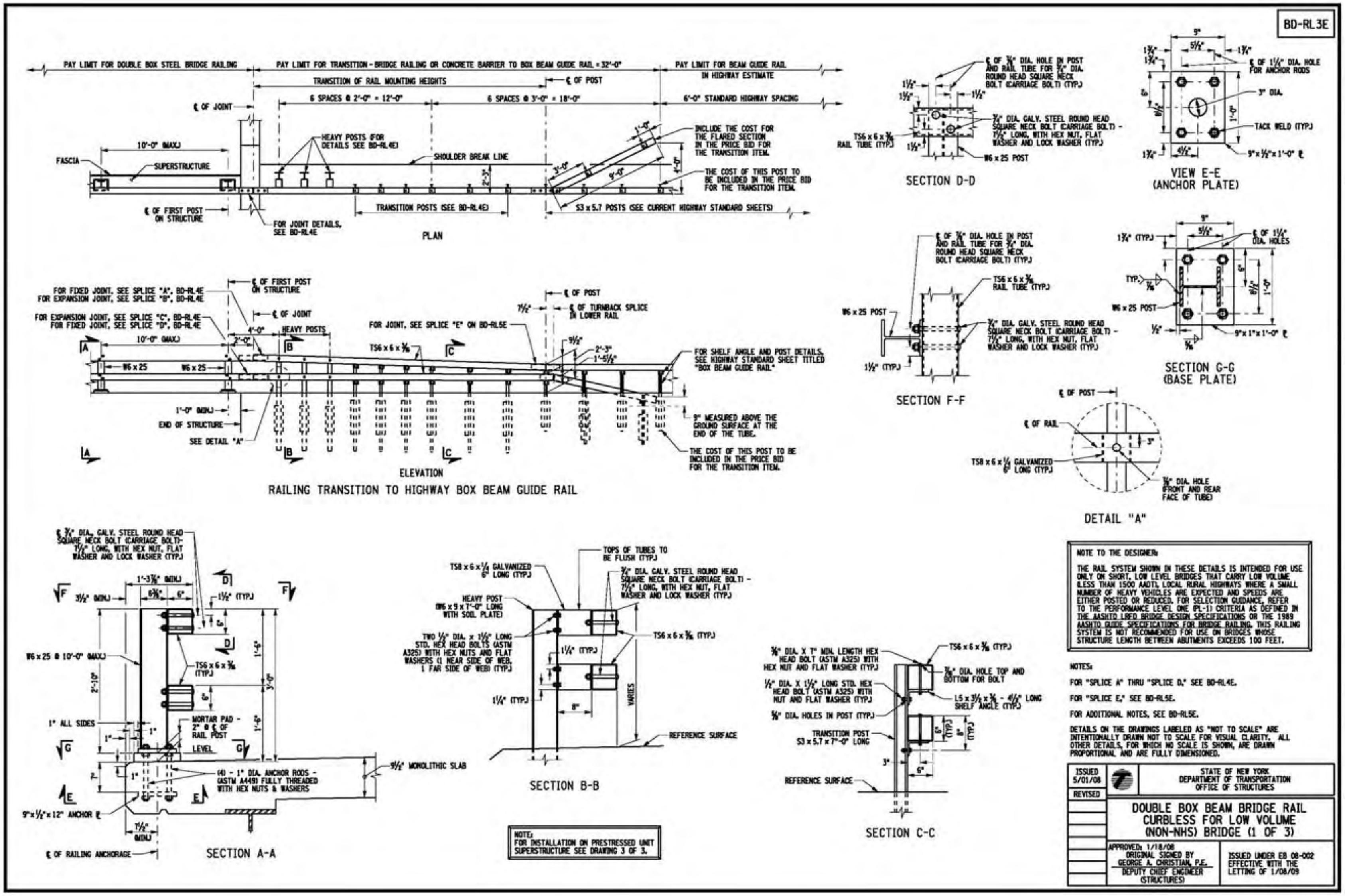
New Hampshire bridge rail



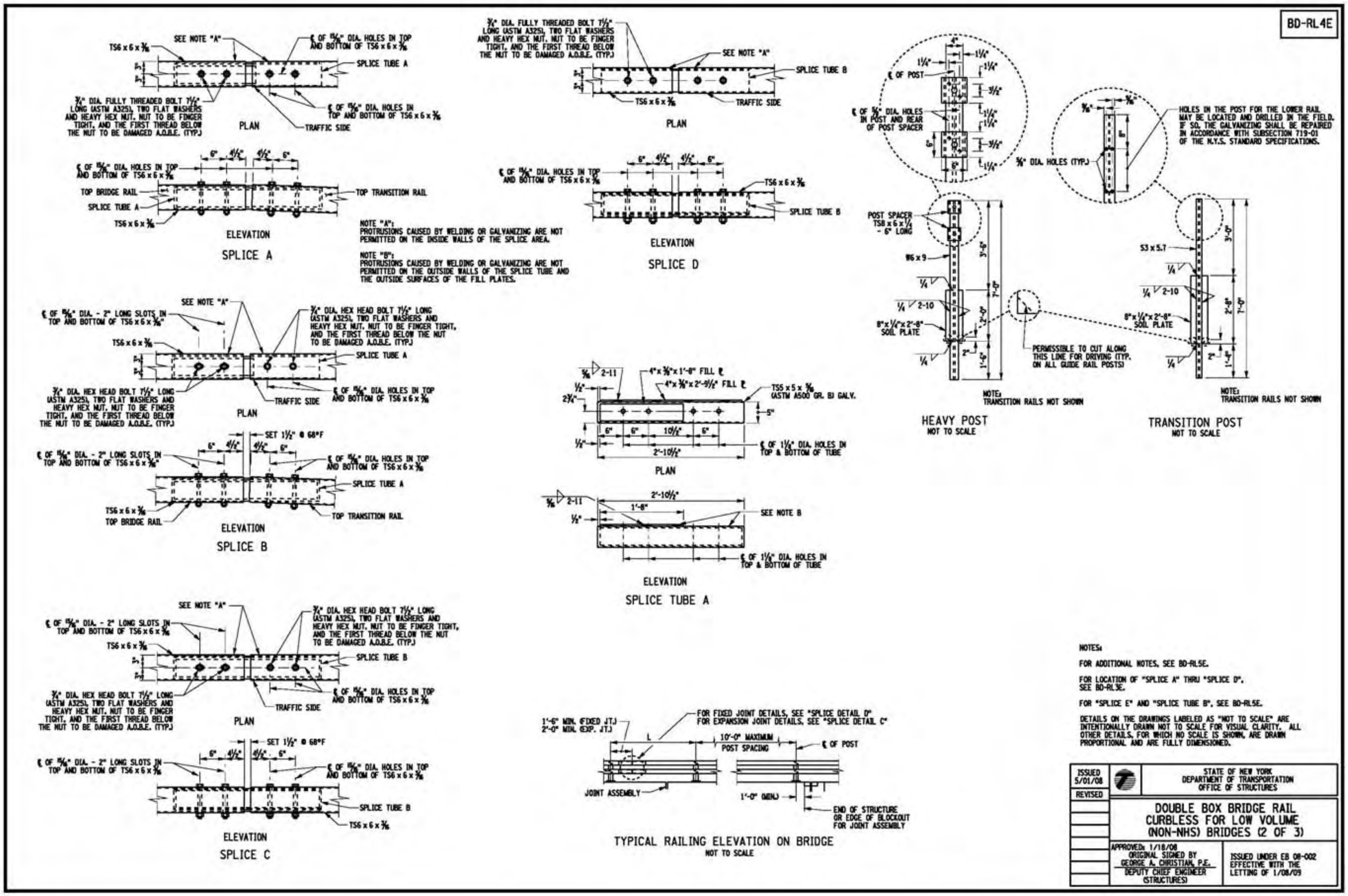


New Hampshire bridge rail

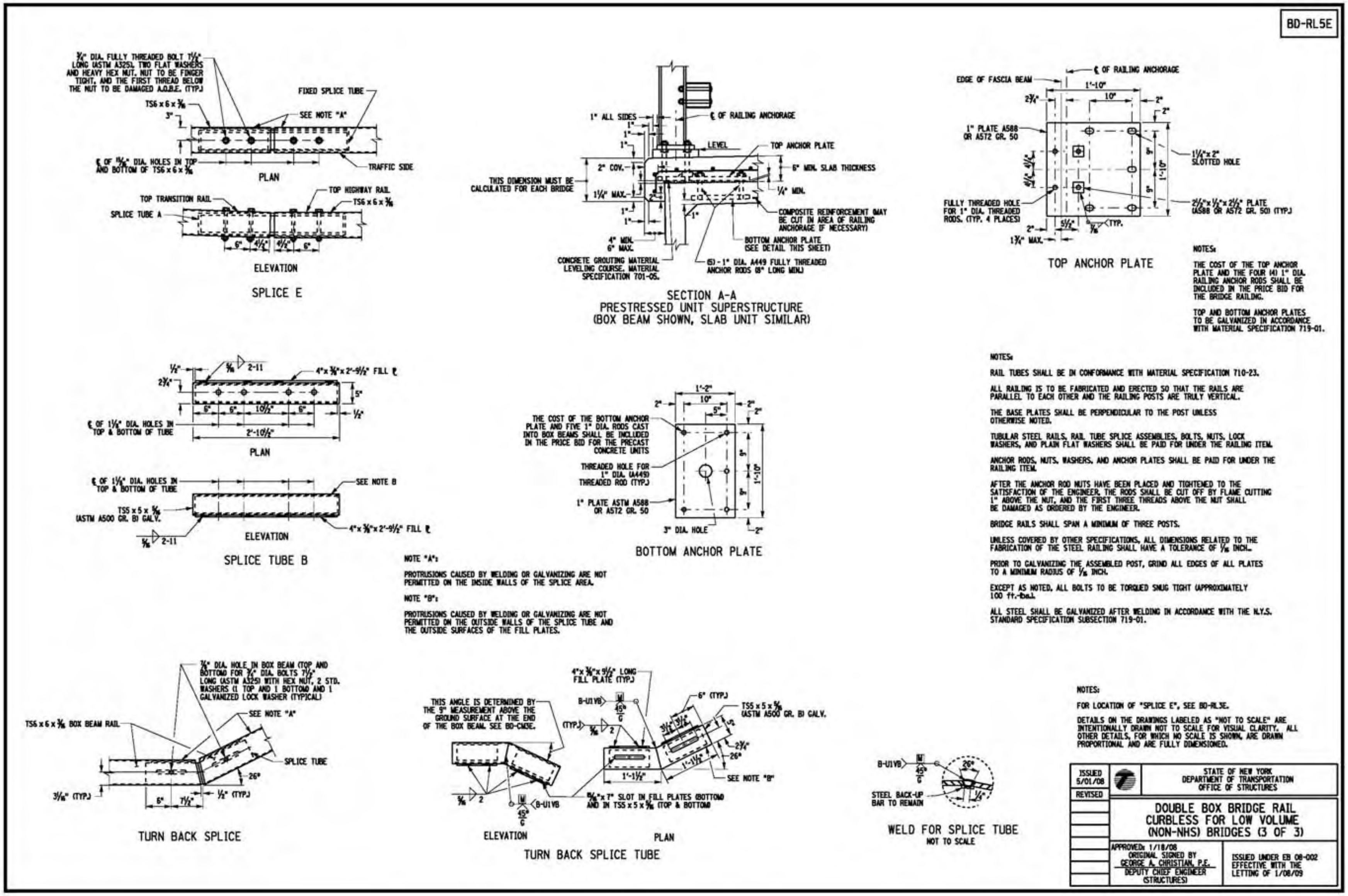
New York DOT
New York standard double box beam



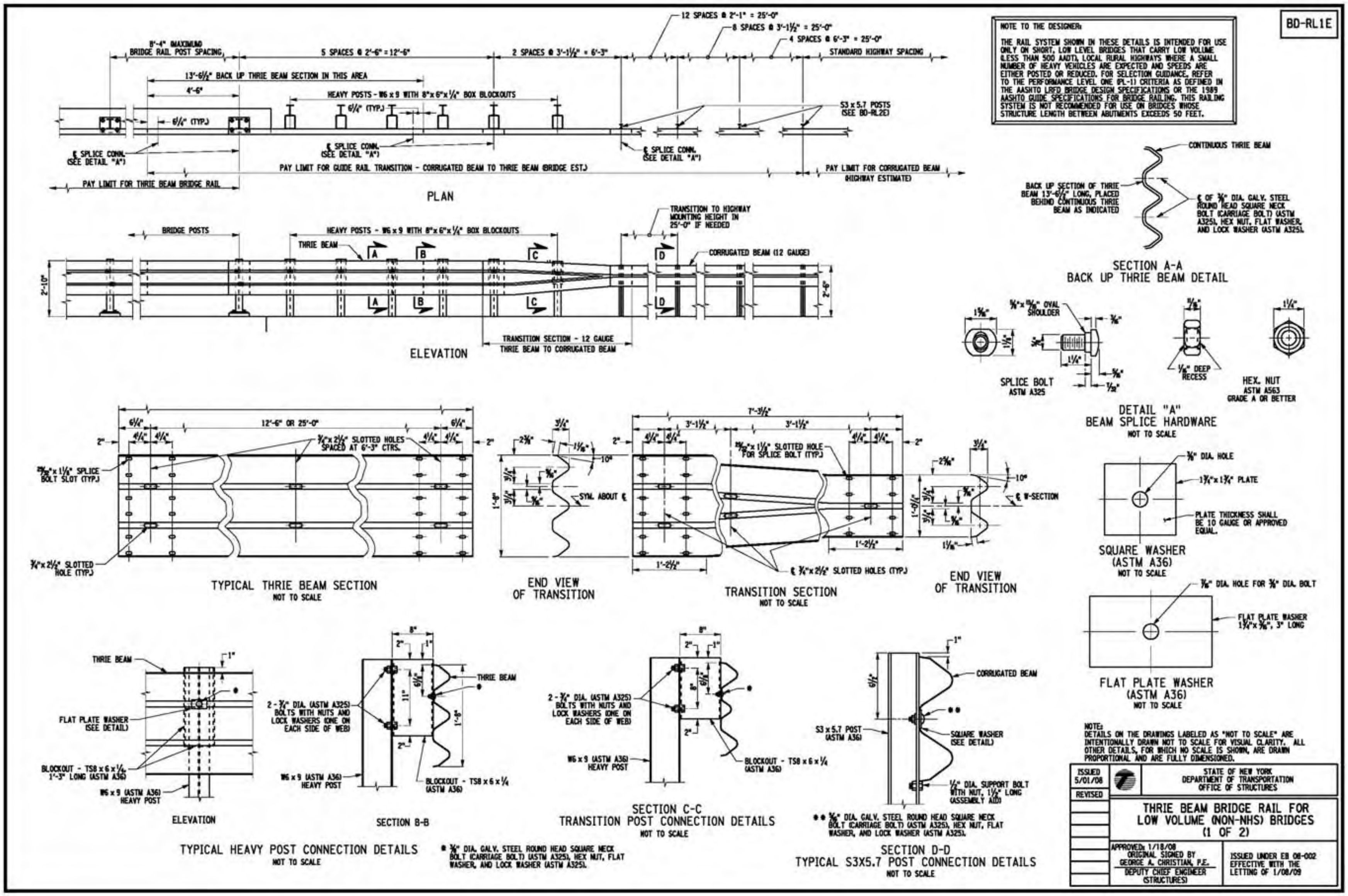
New York standard double box beam



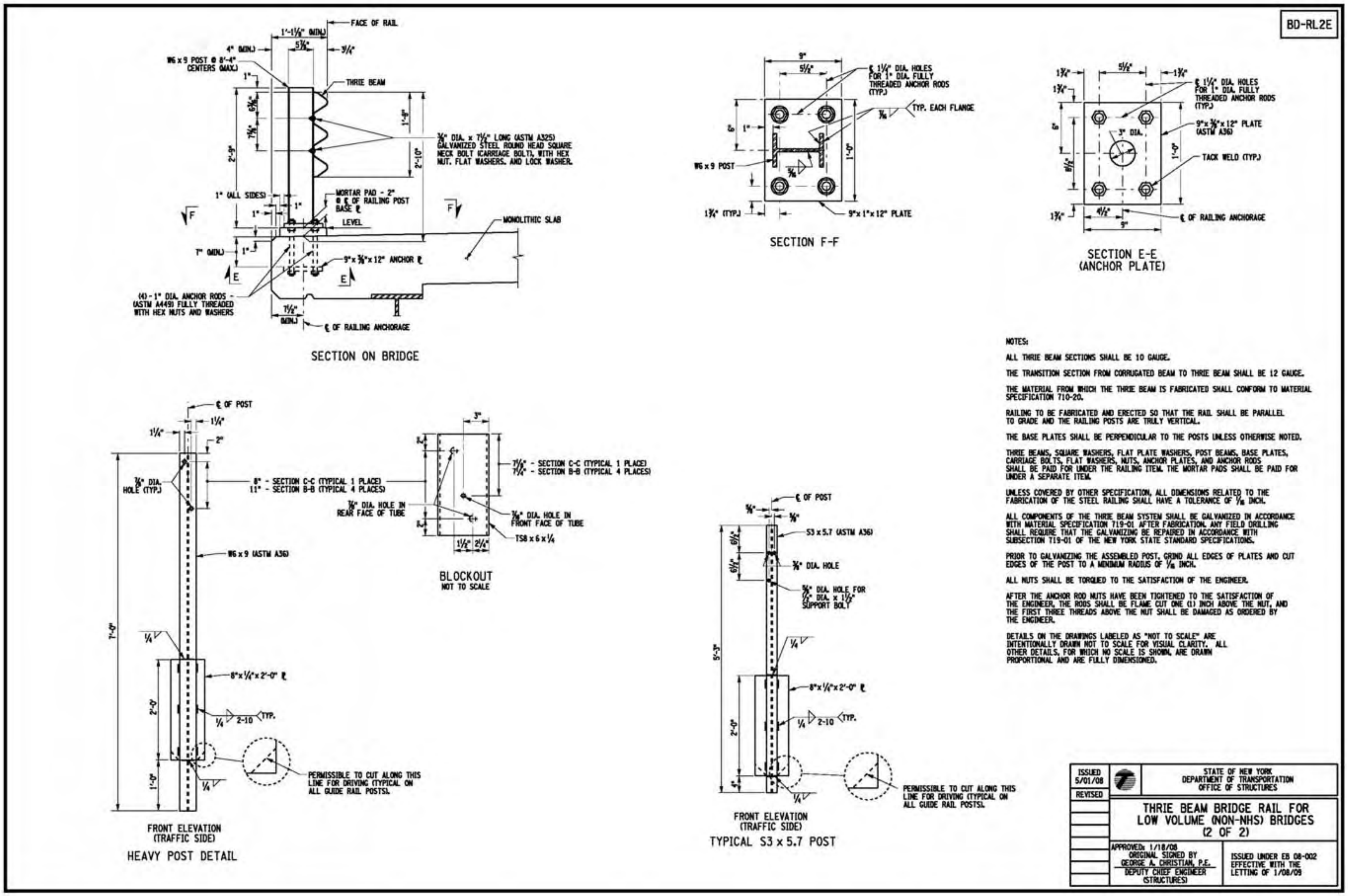
New York standard double box beam



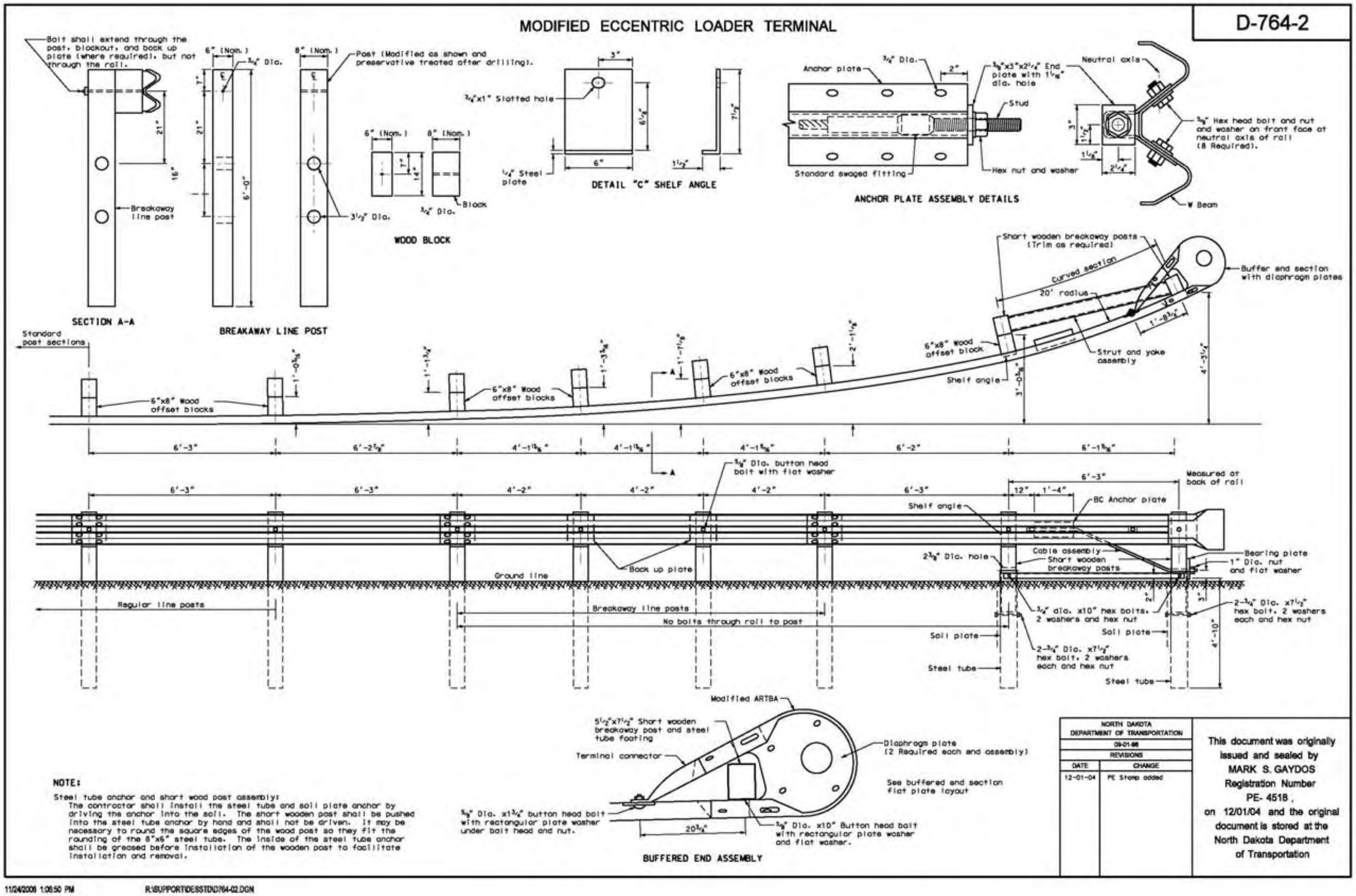
New York standard thrie-beam



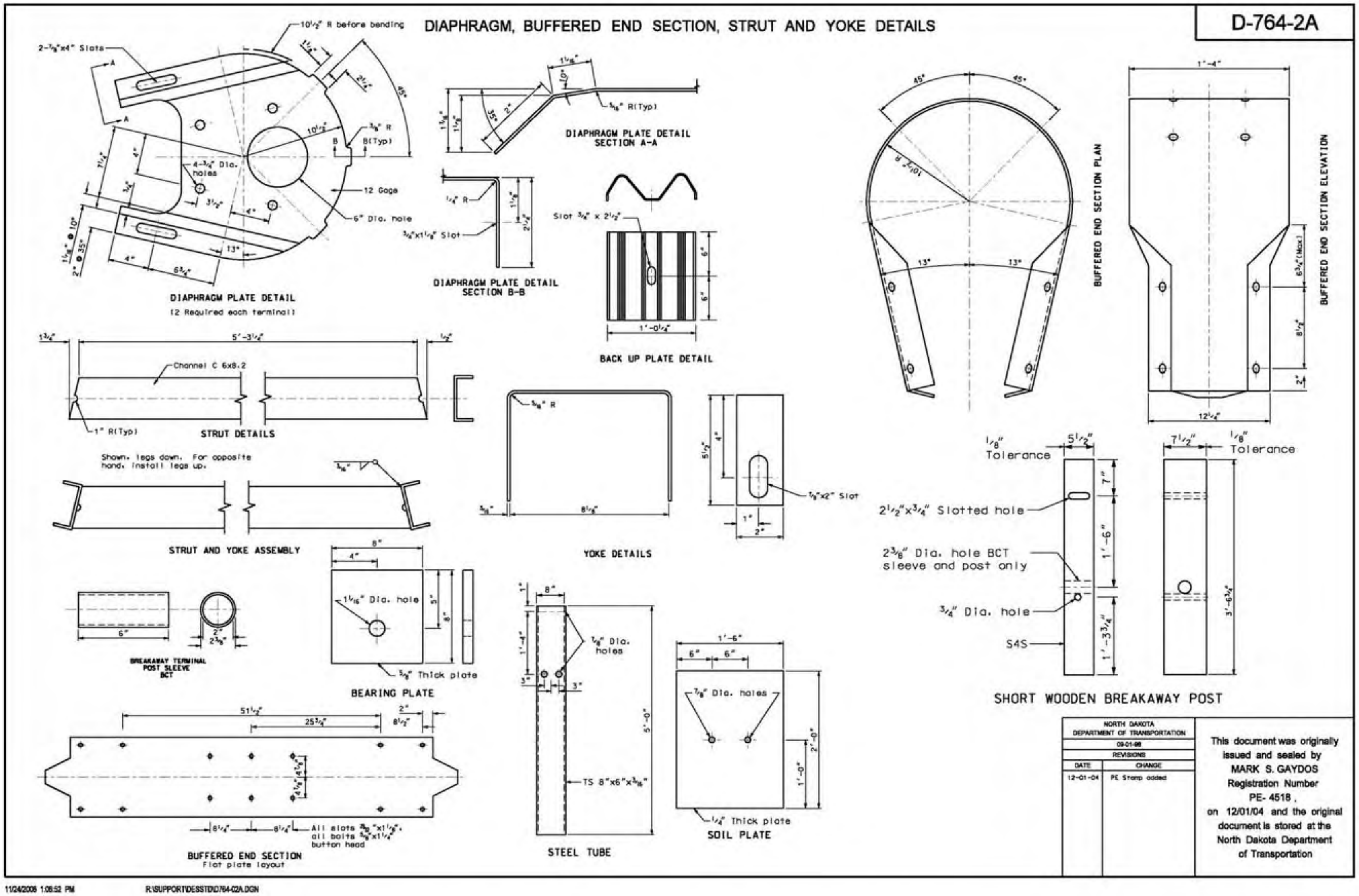
New York standard thrie-beam



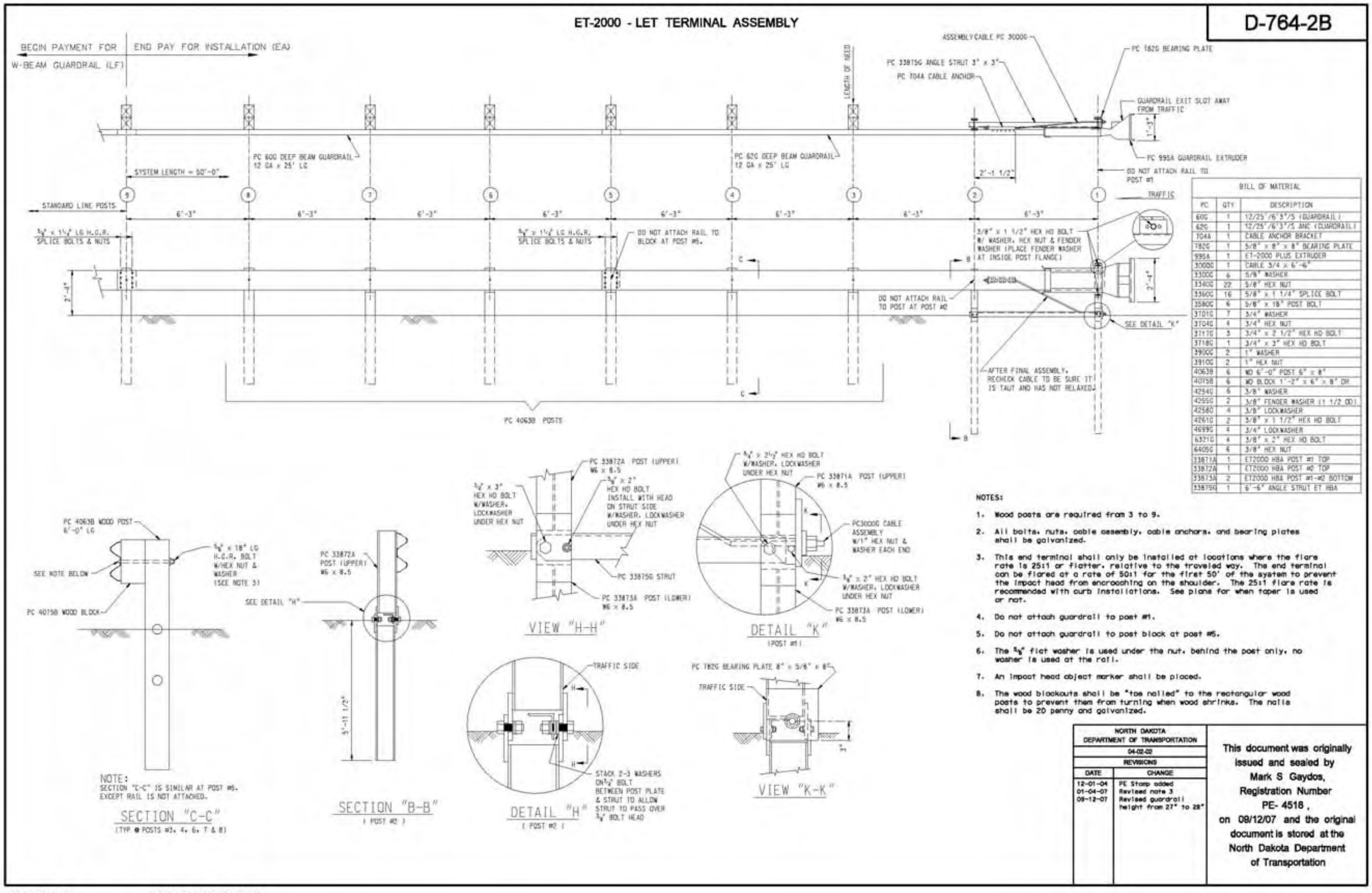
North Dakota DOT
North Dakota standard drawing



North Dakota standard drawing



North Dakota standard drawing



BILL OF MATERIAL		
PC	QTY	DESCRIPTION
60G	1	12/25'/6'3"/S (GUARDRAIL)
62G	1	12/25'/6'3"/S ANC (GUARDRAIL)
704A	1	CABLE ANCHOR BRACKET
782G	1	5/8" x 8" x 8" BEARING PLATE
995A	1	ET-2000 PLUS EXTRUDER
3000G	1	CABLE 3/4 x 6'-6"
3300G	6	5/8" WASHER
3340G	22	5/8" HEX NUT
3360G	16	5/8" x 1 1/4" SPLICE BOLT
3580G	6	5/8" x 18" POST BOLT
3701G	7	3/4" WASHER
3704G	4	3/4" HEX NUT
3717G	3	3/4" x 2 1/2" HEX HD BOLT
3718G	1	3/4" x 3" HEX HD BOLT
3900G	2	1" WASHER
3910G	2	1" HEX NUT
4063B	6	WD 6'-0" POST 6" x 8"
4075B	6	WD BLOCK 1'-2" x 6" x 8" DR
4254G	6	3/8" WASHER
4255G	2	3/8" FENDER WASHER (1 1/2 OD)
4258G	4	3/8" LOCKWASHER
4261G	2	3/8" x 1 1/2" HEX HD BOLT
4699G	4	3/4" LOCKWASHER
6321G	4	3/8" x 2" HEX HD BOLT
6405G	6	3/8" HEX NUT
33871A	1	ET2000 HBA POST #1 TOP
33872A	1	ET2000 HBA POST #2 TOP
33873A	2	ET2000 HBA POST #1-#2 BOTTOM
33875G	1	6'-6" ANGLE STRUT ET HBA

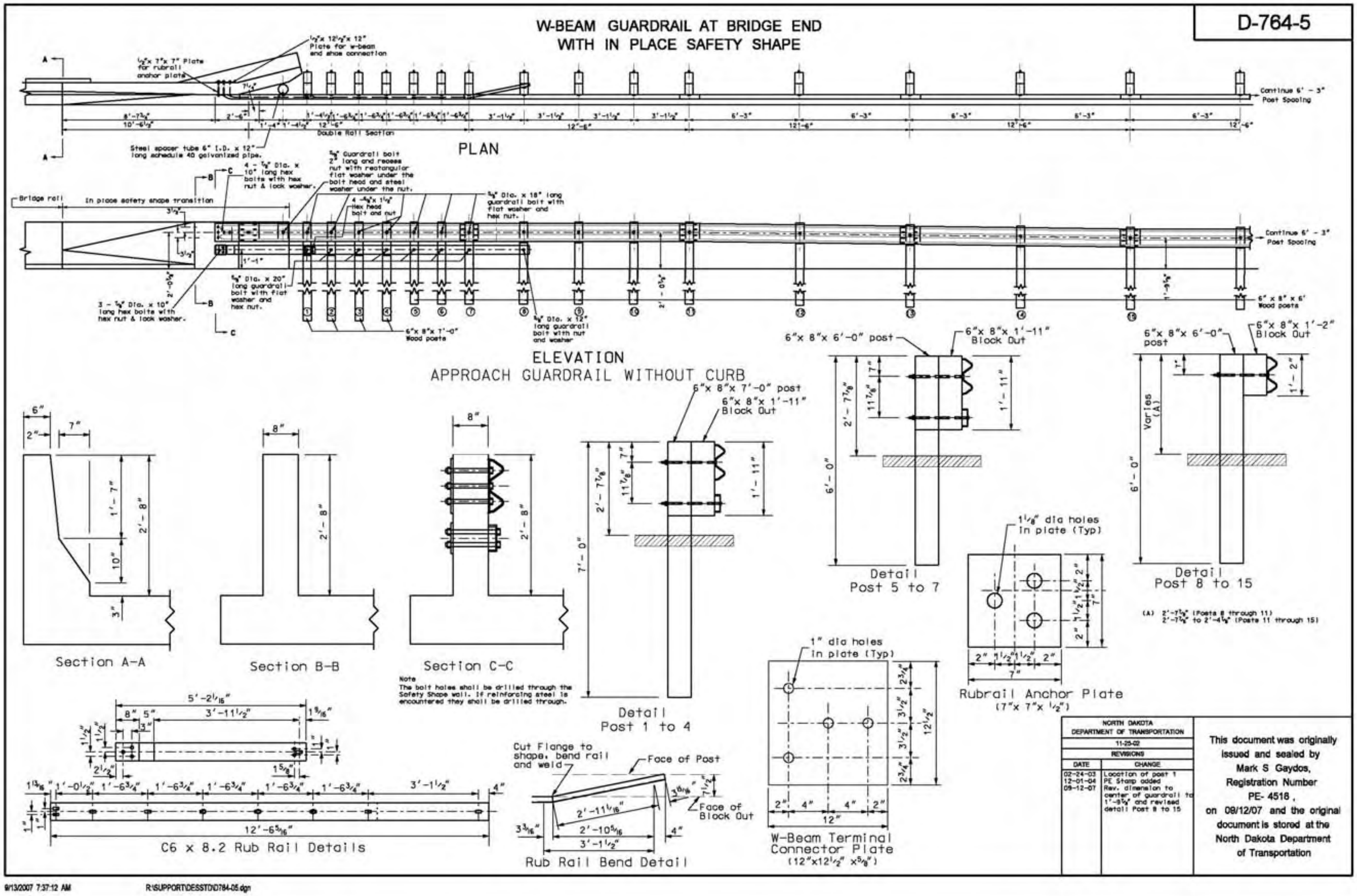
NOTES:

1. Wood posts are required from 3 to 9.
2. All bolts, nuts, cable assembly, cable anchors, and bearing plates shall be galvanized.
3. This end terminal shall only be installed at locations where the flare rate is 25:1 or flatter, relative to the traveled way. The end terminal can be flared at a rate of 50:1 for the first 50' of the system to prevent the impact head from encroaching on the shoulder. The 25:1 flare rate is recommended with curb installations. See plans for when taper is used or not.
4. Do not attach guardrail to post #1.
5. Do not attach guardrail to post block at post #5.
6. The 5/8" flat washer is used under the nut, behind the post only, no washer is used at the rail.
7. An impact head object marker shall be placed.
8. The wood blockouts shall be "toe nailed" to the rectangular wood posts to prevent them from turning when wood shrinks. The nails shall be 20 penny and galvanized.

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION	
04-02-02	
REVISIONS	
DATE	CHANGE
12-01-04	PE Stamp added
01-04-07	Revised note 3
09-12-07	Revised guardrail height from 27" to 28"

This document was originally issued and sealed by Mark S Gaydos, Registration Number PE- 4518, on 09/12/07 and the original document is stored at the North Dakota Department of Transportation

North Dakota standard drawing

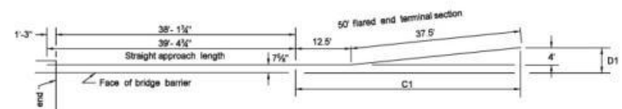


GUARDRAIL AT BRIDGE ENDS 55 MPH DESIGN SPEED

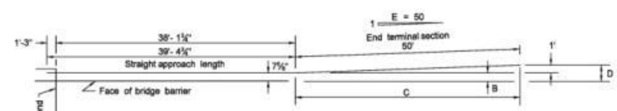
D-764-7A

LENGTH OF NEED TABLE 55 MPH DESIGN SPEED

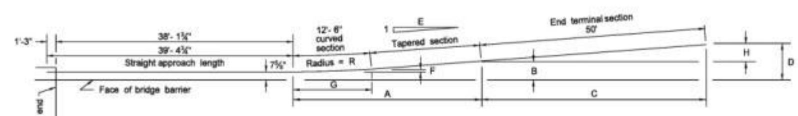
DESIGN TRAFFIC VOLUME	CLEAR ROADWAY WIDTH OF BRIDGE	② STRAIGHT APPROACH LENGTH	APPROACH SIDE A	APPROACH SIDE ③ B	APPROACH SIDE C	APPROACH SIDE ③ D	APPROACH SIDE C1	APPROACH SIDE ③ D1	APPROACH SIDE E	APPROACH SIDE ① TOTAL W-BEAM LENGTH	OPPOSITE SIDE A	OPPOSITE SIDE ③ B	OPPOSITE SIDE C	OPPOSITE SIDE ③ D	OPPOSITE SIDE C1	OPPOSITE SIDE ③ D1	OPPOSITE SIDE E	OPPOSITE SIDE ① TOTAL W-BEAM LENGTH
		FT	FT	FT	FT	FT	FT	FT		FT	FT	FT	FT	FT	FT	FT		FT
UNDER 750 ADT	48	39.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	46	39.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	44	39.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	42	39.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	40	39.4	12.49	1.15	49.83	5.31			12	51.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	38	39.4	12.49	1.15	49.83	5.31			12	51.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	36	39.4	12.49	1.15	49.83	5.31			12	51.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	34	39.4	24.95	2.19	49.83	6.35			12	64.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	32	39.4	24.95	2.19	49.83	6.35			12	64.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	30	39.4	37.40	3.23	49.83	7.38			12	76.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	28	39.4	49.86	4.27	49.83	8.42			12	89.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	26	39.4	49.86	4.27	49.83	8.42			12	89.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	24	39.4	62.32	5.31	49.83	9.46			12	101.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
750 - 1500 ADT	48	39.4	12.49	1.15	49.83	5.31			12	51.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	46	39.4	12.49	1.15	49.83	5.31			12	51.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	44	39.4	12.49	1.15	49.83	5.31			12	51.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	42	39.4	12.49	1.15	49.83	5.31			12	51.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	40	39.4	24.95	2.19	49.83	6.35			12	64.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	38	39.4	24.95	2.19	49.83	6.35			12	64.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	36	39.4	37.40	3.23	49.83	7.38			12	76.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	34	39.4	49.86	4.27	49.83	8.42			12	89.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	32	39.4	49.86	4.27	49.83	8.42			12	89.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	30	39.4	62.32	5.31	49.83	9.46			12	101.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	28	39.4	62.32	5.31	49.83	9.46			12	101.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	26	39.4	74.77	6.35	49.83	10.50			12	114.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	24	39.4	74.77	6.35	49.83	10.50			12	114.4	12.49	1.15	49.83	5.31			12	51.9
1500 - 2000 ADT	48	39.4	12.49	1.15	49.83	5.31			12	51.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	46	39.4	24.95	2.19	49.83	6.35			12	64.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	44	39.4	24.95	2.19	49.83	6.35			12	64.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	42	39.4	37.40	3.23	49.83	7.38			12	76.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	40	39.4	37.40	3.23	49.83	7.38			12	76.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	38	39.4	49.86	4.27	49.83	8.42			12	89.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	36	39.4	49.86	4.27	49.83	8.42			12	89.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	34	39.4	62.32	5.31	49.83	9.46			12	101.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	32	39.4	62.32	5.31	49.83	9.46			12	101.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	30	39.4	74.77	6.35	49.83	10.50			12	114.4	12.49	1.15	49.83	5.31			12	51.9
	28	39.4	87.23	7.38	49.83	11.54			12	126.9	12.49	1.15	49.83	5.31			12	51.9
	26	39.4	87.23	7.38	49.83	11.54			12	126.9	12.49	1.15	49.83	5.31			12	51.9
	24	39.4	99.69	8.42	49.83	12.57			12	139.4	12.49	1.15	49.83	5.31			12	51.9
2000 - 6000 ADT	48	39.4	24.95	2.19	49.83	6.35			12	64.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	46	39.4	24.95	2.19	49.83	6.35			12	64.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	44	39.4	37.40	3.23	49.83	7.38			12	76.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	42	39.4	37.40	3.23	49.83	7.38			12	76.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	40	39.4	49.86	4.27	49.83	8.42			12	89.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	38	39.4	49.86	4.27	49.83	8.42			12	89.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	36	39.4	62.32	5.31	49.83	9.46			12	101.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	34	39.4	62.32	5.31	49.83	9.46			12	101.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	32	39.4	74.77	6.35	49.83	10.50			12	114.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	30	39.4	74.77	6.35	49.83	10.50			12	114.4	12.49	1.15	49.83	5.31			12	51.9
	28	39.4	87.23	7.38	49.83	11.54			12	126.9	12.49	1.15	49.83	5.31			12	51.9
	26	39.4	99.69	8.42	49.83	12.57			12	139.4	12.49	1.15	49.83	5.31			12	51.9
	24	39.4	99.69	8.42	49.83	12.57			12	139.4	24.95	2.19	49.83	6.35			12	64.4
OVER 6000 ADT	48	39.4	24.95	2.19	49.83	6.35			12	64.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	46	39.4	37.40	3.23	49.83	7.38			12	76.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	44	39.4	49.86	4.27	49.83	8.42			12	89.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	42	39.4	49.86	4.27	49.83	8.42			12	89.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	40	39.4	62.32	5.31	49.83	9.46			12	101.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	38	39.4	62.32	5.31	49.83	9.46			12	101.9	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	36	39.4	74.77	6.35	49.83	10.50			12	114.4	0.00	0.64	49.99	1.64	49.79	4.64	50	39.4
	34	39.4	74.77	6.35	49.83	10.50			12	114.4	12.49	1.15	49.83	5.31			12	51.9
	32	39.4	87.23	7.38	49.83	11.54			12	126.9	12.49	1.15	49.83	5.31			12	51.9
	30	39.4	87.23	7.38	49.83	11.54			12	126.9	12.49	1.15	49.83	5.31			12	51.9
	28	39.4	99.69	8.42	49.83	12.57			12	139.4	12.49	1.15	49.83	5.31			12	51.9
	26	39.4	99.69	8.42	49.83	12.57			12	139.4	24.95	2.19	49.83	6.35			12	64.4
	24	39.4	112.14	9.46	49.83	13.61			12	151.9	24.95	2.19	49.83	6.35			12	64.4



W-BEAM GUARDRAIL DIMENSION LAYOUT WITH FLARED END TERMINAL



W-BEAM GUARDRAIL DIMENSION LAYOUT WITH 50:1 TAPERED END TERMINAL



W-BEAM GUARDRAIL DIMENSION LAYOUT WITH TAPERED SECTION AND NONFLARED END TERMINAL

DESIGN SPEED	F	G	H	R
	FT	FT	FT	FT
55	0.52	12.49	4.15	150.35

NOTES:

On divided highways use distance from roadway centerline to bridge rail x 2 and use this as clear roadway width of the bridge to determine guardrail length.

The contractor shall use wood posts for W-beam guardrail.

① Does not include end terminal section

② The 39.4' straight approach length is for use with the transition shown on Standard Drawing D-764-3.

For the transition shown on Standard Drawing D-764-3A, revise straight approach length to 45.65'.

③ Dimensions "B", "D" and "D1" include the 7⅝" (0.64') offset from the lower face of jersey barrier to the rear face of the W-beam guardrail.

For installations using the transition shown on Standard Drawing D-764-3A, subtract 0.64' from the dimensions "B", "D" and "D1", to obtain offset from face of guardrail connection plate.

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

08-01-98

REVISIONS

DATE	CHANGE
08-01-99	Values in D1
12-21-00	Revised flared end treatment
08-09-01	Revised note
07-05-02	Values in column C
12-13-02	Revised table
12-01-04	PE Stamp added
01-04-07	Revised length of need table and layouts
02-16-07	Added notes ② and ③, revised length of need table
07-31-07	Revised note ②

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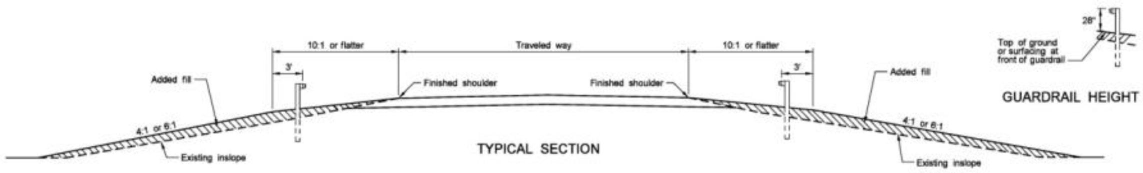
D-764-11A

TYPICAL GRADING AT BRIDGE ENDS WITH FLARED W-BEAM GUARDRAIL 55 MPH DESIGN SPEED

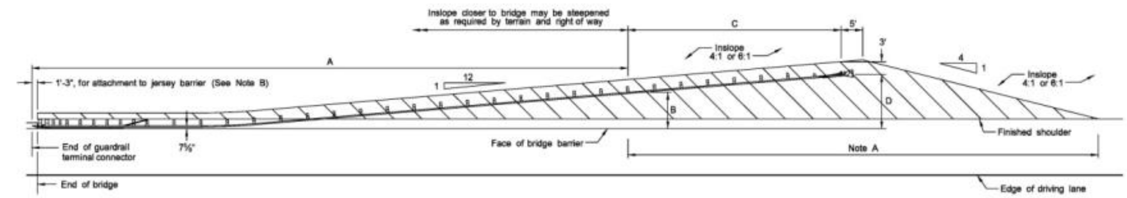
GUARDRAIL EMBANKMENT DIMENSION TABLE

DESIGN TRAFFIC VOLUME	CLEAR ROADWAY WIDTH OF BRIDGE	APPROACH SIDE: STRAIGHT AND FLARED GUARDRAIL ① A	APPROACH SIDE: STRAIGHT AND FLARED GUARDRAIL ② B	APPROACH SIDE: END TREATMENT TERMINAL NON-FLARED C	APPROACH SIDE: END TREATMENT TERMINAL NON-FLARED ② D	APPROACH SIDE: END TREATMENT TERMINAL FLARED C1	APPROACH SIDE: END TREATMENT TERMINAL FLARED ② D1	OPPOSITE SIDE: STRAIGHT AND FLARED GUARDRAIL ① A	OPPOSITE SIDE: STRAIGHT AND FLARED GUARDRAIL ② B	OPPOSITE SIDE: END TREATMENT TERMINAL NON-FLARED C	OPPOSITE SIDE: END TREATMENT TERMINAL NON-FLARED ② D	OPPOSITE SIDE: END TREATMENT TERMINAL FLARED C1	OPPOSITE SIDE: END TREATMENT TERMINAL FLARED ② D1
		FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT
UNDER 750 ADT	48	39.4	0.6	50.0	1.6	49.8	4.6	38.2	0.6	50.0	1.6	49.8	4.6
	46	39.4	0.6	50.0	1.6	49.8	4.6	38.2	0.6	50.0	1.6	49.8	4.6
	44	39.4	0.6	50.0	1.6	49.8	4.6	38.2	0.6	50.0	1.6	49.8	4.6
	42	39.4	0.6	50.0	1.6	49.8	4.6	38.2	0.6	50.0	1.6	49.8	4.6
	40	51.9	1.2	49.8	5.3			38.2	0.6	50.0	1.6	49.8	4.6
	38	51.9	1.2	49.8	5.3			38.2	0.6	50.0	1.6	49.8	4.6
	36	51.9	1.2	49.8	5.3			38.2	0.6	50.0	1.6	49.8	4.6
	34	64.4	2.2	49.8	6.4			38.2	0.6	50.0	1.6	49.8	4.6
	32	64.4	2.2	49.8	6.4			38.2	0.6	50.0	1.6	49.8	4.6
	30	76.8	3.2	49.8	7.4			38.2	0.6	50.0	1.6	49.8	4.6
	28	89.3	4.3	49.8	8.4			38.2	0.6	50.0	1.6	49.8	4.6
	26	89.3	4.3	49.8	8.4			38.2	0.6	50.0	1.6	49.8	4.6
	24	101.7	5.3	49.8	9.5			38.2	0.6	50.0	1.6	49.8	4.6
750 - 1500 ADT	48	51.9	1.2	49.8	5.3			38.2	0.6	50.0	1.6	49.8	4.6
	46	51.9	1.2	49.8	5.3			38.2	0.6	50.0	1.6	49.8	4.6
	44	51.9	1.2	49.8	5.3			38.2	0.6	50.0	1.6	49.8	4.6
	42	51.9	1.2	49.8	5.3			38.2	0.6	50.0	1.6	49.8	4.6
	40	64.4	2.2	49.8	6.4			38.2	0.6	50.0	1.6	49.8	4.6
	38	64.4	2.2	49.8	6.4			38.2	0.6	50.0	1.6	49.8	4.6
	36	76.8	3.2	49.8	7.4			38.2	0.6	50.0	1.6	49.8	4.6
	34	89.3	4.3	49.8	8.4			38.2	0.6	50.0	1.6	49.8	4.6
	32	89.3	4.3	49.8	8.4			38.2	0.6	50.0	1.6	49.8	4.6
	30	101.7	5.3	49.8	9.5			38.2	0.6	50.0	1.6	49.8	4.6
	28	101.7	5.3	49.8	9.5			38.2	0.6	50.0	1.6	49.8	4.6
	26	114.2	6.4	49.8	10.5			38.2	0.6	50.0	1.6	49.8	4.6
	24	114.2	6.4	49.8	10.5			63.1	1.2	49.8	5.3		
1500 - 2000 ADT	48	51.9	1.2	49.8	5.3			38.2	0.6	50.0	1.6	49.8	4.6
	46	64.4	2.2	49.8	6.4			38.2	0.6	50.0	1.6	49.8	4.6
	44	64.4	2.2	49.8	6.4			38.2	0.6	50.0	1.6	49.8	4.6
	42	76.8	3.2	49.8	7.4			38.2	0.6	50.0	1.6	49.8	4.6
	40	76.8	3.2	49.8	7.4			38.2	0.6	50.0	1.6	49.8	4.6
	38	89.3	4.3	49.8	8.4			38.2	0.6	50.0	1.6	49.8	4.6
	36	89.3	4.3	49.8	8.4			38.2	0.6	50.0	1.6	49.8	4.6
	34	101.7	5.3	49.8	9.5			38.2	0.6	50.0	1.6	49.8	4.6
	32	101.7	5.3	49.8	9.5			38.2	0.6	50.0	1.6	49.8	4.6
	30	114.2	6.4	49.8	10.5			63.1	1.2	49.8	5.3		
	28	126.6	7.4	49.8	11.5			63.1	1.2	49.8	5.3		
	26	126.6	7.4	49.8	11.5			63.1	1.2	49.8	5.3		
	24	139.1	8.4	49.8	12.6			63.1	1.2	49.8	5.3		
2000 - 6000 ADT	48	64.4	2.2	49.8	6.4			38.2	0.6	50.0	1.6	49.8	4.6
	46	64.4	2.2	49.8	6.4			38.2	0.6	50.0	1.6	49.8	4.6
	44	76.8	3.2	49.8	7.4			38.2	0.6	50.0	1.6	49.8	4.6
	42	76.8	3.2	49.8	7.4			38.2	0.6	50.0	1.6	49.8	4.6
	40	89.3	4.3	49.8	8.4			38.2	0.6	50.0	1.6	49.8	4.6
	38	89.3	4.3	49.8	8.4			38.2	0.6	50.0	1.6	49.8	4.6
	36	101.7	5.3	49.8	9.5			38.2	0.6	50.0	1.6	49.8	4.6
	34	101.7	5.3	49.8	9.5			38.2	0.6	50.0	1.6	49.8	4.6
	32	114.2	6.4	49.8	10.5			38.2	0.6	50.0	1.6	49.8	4.6
	30	114.2	6.4	49.8	10.5			63.1	1.2	49.8	5.3		
	28	126.6	7.4	49.8	11.5			63.1	1.2	49.8	5.3		
	26	139.1	8.4	49.8	12.6			63.1	1.2	49.8	5.3		
	24	139.1	8.4	49.8	12.6			75.6	2.2	49.8	6.4		
OVER 6000 ADT	48	64.4	2.2	49.8	6.4			38.2	0.6	50.0	1.6	49.8	4.6
	46	76.8	3.2	49.8	7.4			38.2	0.6	50.0	1.6	49.8	4.6
	44	89.3	4.3	49.8	8.4			38.2	0.6	50.0	1.6	49.8	4.6
	42	89.3	4.3	49.8	8.4			38.2	0.6	50.0	1.6	49.8	4.6
	40	101.7	5.3	49.8	9.5			38.2	0.6	50.0	1.6	49.8	4.6
	38	101.7	5.3	49.8	9.5			38.2	0.6	50.0	1.6	49.8	4.6
	36	114.2	6.4	49.8	10.5			38.2	0.6	50.0	1.6	49.8	4.6
	34	114.2	6.4	49.8	10.5			63.1	1.2	49.8	5.3		
	32	126.6	7.4	49.8	11.5			63.1	1.2	49.8	5.3		
	30	126.6	7.4	49.8	11.5			63.1	1.2	49.8	5.3		
	28	139.1	8.4	49.8	12.6			63.1	1.2	49.8	5.3		
	26	139.1	8.4	49.8	12.6			75.6	2.2	49.8	6.4		
	24	151.5	9.5	49.8	13.6			75.6	2.2	49.8	6.4		

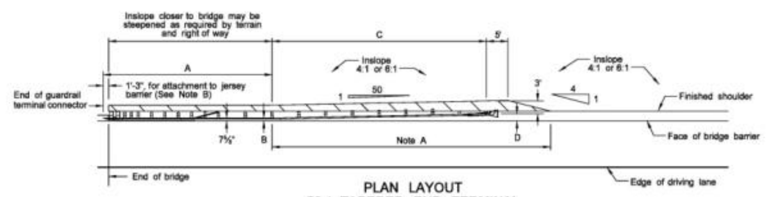


TYPICAL SECTION

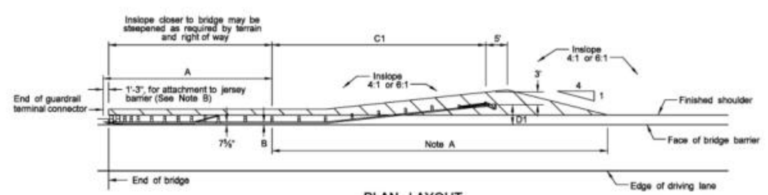
GUARDRAIL HEIGHT



PLAN LAYOUT
NON-FLARED END TERMINAL



PLAN LAYOUT
50:1 TAPERED END TERMINAL
(WHERE "C" = 50')



PLAN LAYOUT
FLARED END TERMINAL

Note A: This area may have to be placed at flatter than 10:1 to provide the proper guardrail height.

Note B: For guardrail installed in accordance with Standard Drawing D-764-3A, the thrie beam terminal connector installation location must be determined from the bridge railing plans.

NOTES:

The design traffic volumes (ADT) shall be as shown on title sheet under traffic forecast.

Where normal inslope is 4:1, the added fill shall be 4:1.
Where normal inslope is 6:1, the added fill shall be 6:1.

① The values shown for dimension "A" are applicable for W-beam guardrail installations attached to jersey barrier as shown on Standard Drawing D-764-3.

When the guardrail installation is in accordance with Standard Drawing D-764-3A, dimension "A" shall be revised by adding 6.3' to the tabulated value.

② The values shown for dimensions "B", "D" and "D1" are applicable for W-beam guardrail installations attached to jersey barrier as shown on Standard Drawing D-764-3.

When the guardrail installation is in accordance with Standard Drawing D-764-3A, dimensions "B", "D", and "D1" shall be revised by subtracting 0.6' from the tabulated value.

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
09-01-98

REVISIONS

DATE	CHANGE
10-29-98	Offset dimensions
12-21-00	Revise flared end treatment
04-02-02	Revised table
12-13-02	Revised table
12-17-03	Revised flared rate detail
12-01-04	PE Stamp added
01-04-07	Revised table and layouts
02-16-07	Added notes ①, ②, B, revised table and layouts
09-13-07	Revised guardrail height from 27" to 28"

This document was originally issued and sealed by Mark S Gaydos, Registration Number PE- 4518, on 09/13/07 and the original document is stored at the North Dakota Department of Transportation

9/14/2007 7:13:20 AM R:\SUPPORT\DESSTD\D764-11A.dgn

South Carolina DOT
South Carolina standard rail

REFERENCES

NATIONAL DOCUMENTS
AASHTO M180, AASHTO M270, AASHTO M160, AASHTO M111, ASTM A709, ASTM 6A, ASTM A123

SCDOT DOCUMENTS
SECTION 706 SCDOT STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION

RELATED DRAWINGS & KEYWORDS
805-005-00, 805-310-00

PRECONSTRUCTION SUPPORT ENGINEER

SOUTH CAROLINA PROFESSIONAL ENGINEER REGISTERED NO. 8858 EDWIN SYLVESTER EARGLE, II

SIGNATURE

MARCH 3, 2008
DATE

#	DATE	CHK	DESCRIPTION
6			
5			
4			
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2			
1			
0	3/2008	DSO	GENERAL REVISIONS

SCDOT
SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION
DESIGN STANDARDS OFFICE
955 PARK STREET
ROOM 405
COLUMBIA, SC 29201

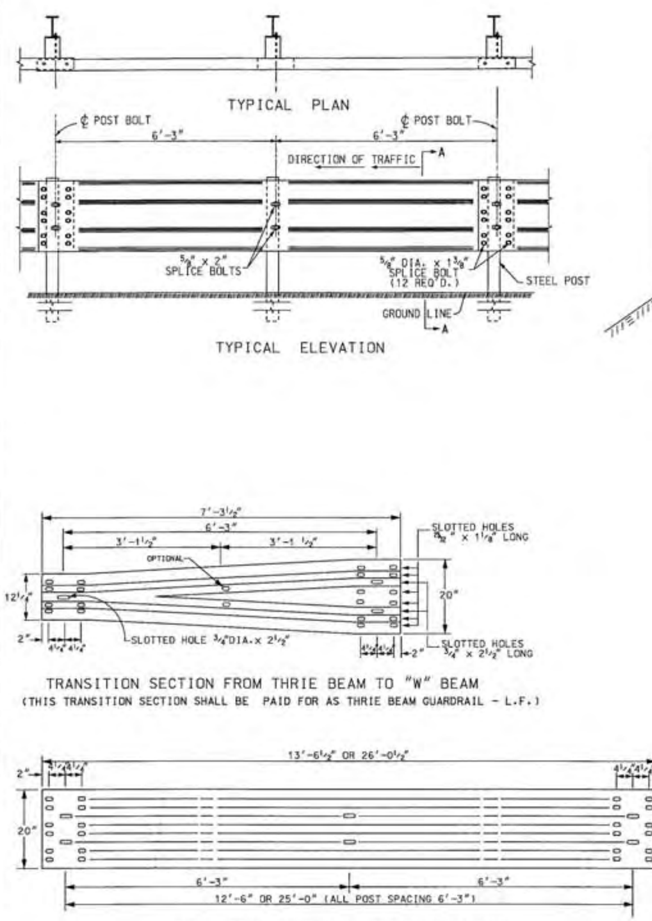
STANDARD DRAWING

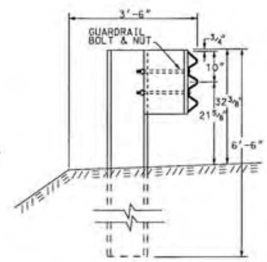
GUARDRAIL (THRIE BEAM) TYPICAL INSTALLATION

805-305-00

EFFECTIVE LETTING DATE MAY 2008

THIS DRAWING IS NOT TO SCALE





NOTES:

1. THRIE BEAM GUARDRAIL SHALL COMPLY WITH THE REQUIREMENTS OF SECTION 805 OF THE SCDOT STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION (LATEST EDITION) AND CONFORM TO AASHTO M 180 FOR CLASS A, TYPE 2.

2. WHERE LAPS IN RAIL ARE NECESSARY THEY SHALL BE PLACED IN THE SAME DIRECTION AS THE FLOW OF TRAFFIC. GUARDRAIL SECTIONS MAY BE FURNISHED AND INSTALLED IN STANDARD LENGTHS OF 12'-6", AND 25'-0" SECTIONS. LAY LENGTH IS BASED ON POST SPACING.

3. WHERE GUARDRAIL IS ERECTED ON CURVES OF 150 FT. RADIUS OR LESS THE RAIL SHALL BE PRE-CURVED IN THE SHOP TO FIT THE REQUIRED RADIUS.

4. FOR HARDWARE SEE DRAWING 805-005-00.

5. FOR POST AND BLOCKOUT DETAILS SEE DRAWING 805-310-00 .

6. STEEL POSTS SHALL CONFORM TO AASHTO M270(ASTM A709), GRADE 36, AND DIMENSIONS CONFORM TO AASHTO M 160(ASTM 6A). STEEL POSTS SHALL BE GALVANIZED (ZINC-COATED) ACCORDING TO AASHTO M 111(ASTM A123). WOOD POSTS ARE NOT ALLOWED WITH THRIE BEAM GUARDRAIL, EXCEPT FOR TYPE "B" END TREATMENT.

7. BACKUP PLATES ARE NOT REQUIRED WITH WOOD, COMPOSITE, OR PLASTIC BLOCKOUTS.

8. NO STEEL BLOCKOUTS ARE ALLOWED. ONLY WOOD BLOCKOUTS MEETING THESE SPECIFICATIONS AND DIMENSIONS OR AN APPROVED PLASTIC OR COMPOSITE BLOCKOUT FOUND ON QUALIFIED PRODUCT LIST 49 MAY BE USED. BLOCKOUTS SHALL BE 6"x8"X21 1/2" NOMINAL DIMENSIONS FOR THRIE BEAM GUARDRAIL. BLOCKOUTS ARE TO BE INSTALLED ON THE TRAFFIC SIDE OF THE POSTS.

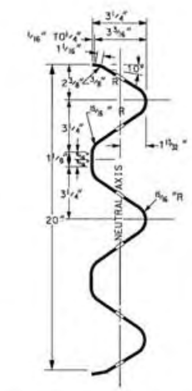
9. WHEN THRIE BEAM GUARDRAIL IS INSTALLED ACROSS A BRIDGE THE FACE OF THE GUARDRAIL SHOULD LINE UP AS CLOSE AS POSSIBLE WITH THE BACK OF THE CURB, WHEN PRESENT. BLOCKOUTS SHOULD BE USED ACROSS BRIDGES WHEN POSSIBLE. BLOCKOUTS MAY BE REMOVED WHEN TRAVEL LANE IS OVERLY COMPROMISED.

10. BLOCKOUTS SHALL MEET THE REQUIREMENTS OF SECTIONS 706, AND 805 OF THE STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION (LATEST EDITION). ALL TIMBER SHALL RECEIVE A PRESERVATION TREATMENT IN ACCORDANCE WITH SECTION 707 OF THE SCDOT STANDARD SPECIFICATIONS. BLOCKOUTS SHALL BE EITHER ROUGH SAWN (UN-PLANED) OR S4S WITH NOMINAL DIMENSIONS INDICATED.

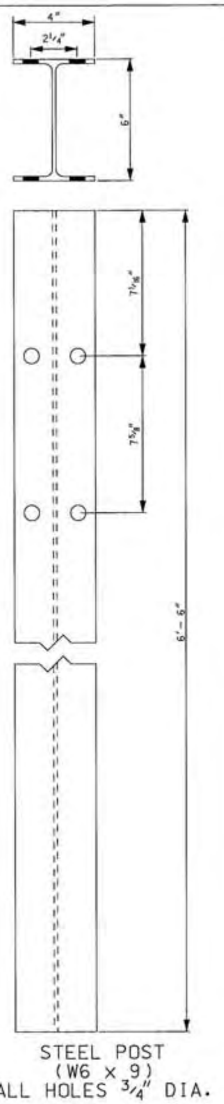
11. TOLERANCE FOR WOODEN BLOCKOUTS SHALL NOT BE MORE THAN 1/4 INCH. DIMENSIONAL TOLERANCES ARE INTENDED TO BE THOSE CONSISTENT WITH THE PROPER FUNCTIONING OF THE PART, INCLUDING ITS APPEARANCE AND ACCEPTED MANUFACTURING PRACTICES. THE DEPARTMENT RESERVES THE RIGHT TO REVISE BLOCKOUT DIMENSIONS AS IT DEEMS NECESSARY.

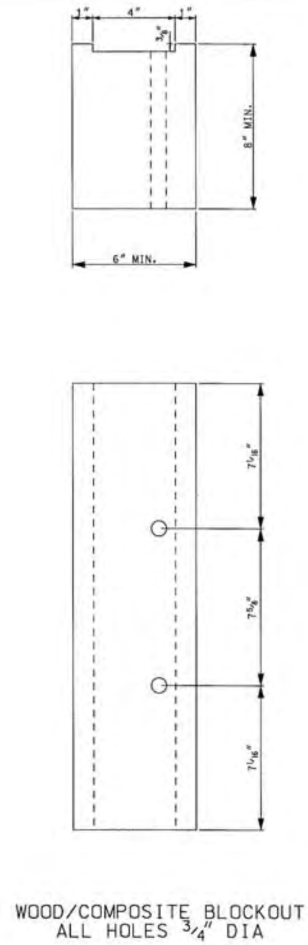
12. WHERE A STRUCTURE PREVENTS USE OF STANDARD LENGTH POST, A BASE PLATE SHALL BE ATTACHED TO THE BOTTOM OF POST AND CONNECTED TO THE STRUCTURE AS SHOWN ON DRAWING 805-120-00 AT NO ADDITIONAL COST TO THE DEPARTMENT.

13. THE UNIT PRICE BID FOR GUARDRAIL SHALL INCLUDE ALL COST OF FURNISHING AND PLACING POST, BLOCKOUT, AND ALSO OF FURNISHING GALVANIZING AND PLACING THE STEEL GUARDRAIL (INCLUDING POST BOLTS, NUTS, AND WASHERS NECESSARY FOR SPLICES AND FOR FASTENING RAIL TO POST) AS CALLED FOR ON PLANS. ALL HARDWARE SHALL COMPLY WITH THE REQUIREMENTS GIVEN ON STANDARD DRAWING 805-005-00.



SECTION THROUGH THRIE BEAM GUARDRAIL





NOTES:

1. THRIE BEAM GUARDRAIL SHALL COMPLY WITH THE REQUIREMENTS GIVEN ON STANDARD DRAWING 805-305-00.

2. ALL HARDWARE SHALL COMPLY WITH THE REQUIREMENTS GIVEN ON STANDARD DRAWING 805-005-00.

3. BACKUP PLATES ARE NOT REQUIRED WITH WOOD, COMPOSITE, OR PLASTIC BLOCKOUTS.

4. NO STEEL BLOCKOUTS ARE ALLOWED. ONLY APPROVED WOOD, COMPOSITE, OR PLASTIC BLOCKOUTS MAY BE USED WITH STEEL OR WOOD POSTS. SEE QUALIFIED PRODUCT LIST 49 FOR A LIST OF APPROVED MANUFACTURERS OF PLASTIC/COMPOSITE BLOCKOUTS. BLOCKOUTS ARE TO BE INSTALLED ON THE TRAFFIC SIDE OF THE POSTS. ONLY ONE COMBINATION OF POST AND BLOCKOUT FINISH SHALL BE USED FOR ANY ONE CONTINUOUS USE OF GUARDRAIL.

5. ALL TIMBER SHALL RECEIVE A PRESERVATION TREATMENT IN ACCORDANCE WITH SECTION 707 OF THE SCDOT STANDARD SPECIFICATIONS. BOTH WOODEN POSTS AND BLOCKOUTS SHALL MEET THE REQUIREMENTS OF SECTIONS 706 AND 805 AND SHALL BE EITHER ROUGH SAWN (UN-PLANED) OR S4S WITH NOMINAL DIMENSIONS INDICATED AND MEET THE STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION (LATEST EDITION).

6. HOLES IN COMPOSITE/PLASTIC BLOCKOUTS USED WITH STEEL POST MAY BE MANUFACTURED ON BOTH THE LEFT AND/OR RIGHT SIDE. HOLES IN WOODEN BLOCKOUTS USED WITH STEEL POSTS SHOULD BE LIMITED TO EITHER THE LEFT OR RIGHT SIDE OF THE BLOCKOUT. HOLES IN ALL BLOCKOUTS USED WITH WOODEN POSTS MUST HAVE HOLES DRILLED IN CENTER OF BLOCKOUT.

7. STEEL POSTS SHALL CONFORM TO AASHTO M 270 (ASTM A709),GRADE 36, AND DIMENSIONS CONFORM TO AASHTO M 160 (ASTM 6A). STEEL POSTS SHALL BE GALVANIZED (ZINC-COATED) ACCORDING TO AASHTO M 111(ASTM A123). DRILL HOLES IN STEEL POSTS ON BOTH LEFT AND RIGHT SIDE AND FRONT AND BACK OF POST.

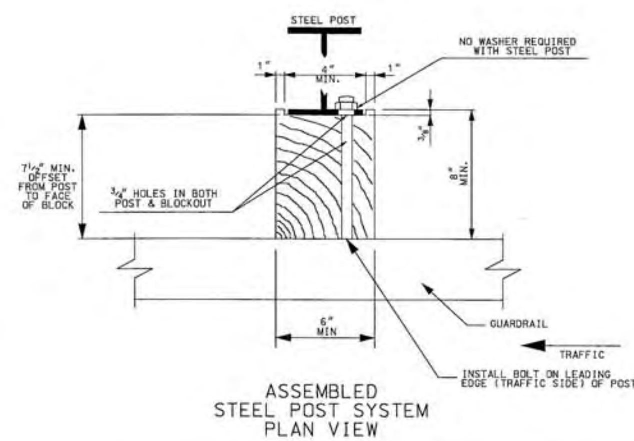
8. TOLERANCE FOR WOODEN BLOCKOUTS SHALL NOT BE MORE THAN ¼ INCH. DIMENSIONAL TOLERANCES ARE INTENDED TO BE THOSE CONSISTENT WITH THE PROPER FUNCTIONING OF THE PART, INCLUDING ITS APPEARANCE AND ACCEPTED MANUFACTURING PRACTICES. THE DEPARTMENT RESERVES THE RIGHT TO REVISE BLOCKOUT DIMENSIONS AS IT DEEMS NECESSARY.

9. WHEN GUARDRAIL IS REQUIRED AND THE PROPER SHOULDER DISTANCE BEHIND THE GUARDRAIL CANNOT BE OBTAINED, ADDITIONAL LENGTH POSTS ARE REQUIRED. SEE TABLE 805-010F ON DRAWING 805-010-00.

10. THE UNIT PRICE BID FOR GUARDRAIL SHALL INCLUDE ALL COSTS OF FURNISHING AND PLACING POST, BLOCKOUTS, AND ALSO OF FURNISHING, GALVANIZING, AND PLACING THE GUARDRAIL (INCLUDING POST BOLTS, NUTS, AND WASHERS NECESSARY FOR SPLICES AND FOR FASTENING RAIL TO POSTS) AS CALLED FOR ON PLANS.

11. WHERE GEOSYNTHETIC REINFORCEMENT IN AN EMBANKMENT IS LESS THAN 4.0 FEET FROM THE TOP OF THE FINISHED GRADE, DIG THE POST HOLE DOWN TO THE GEOSYNTHETIC REINFORCEMENT. THEN CUT OR PUNCH THE GEOSYNTHETIC MATERIAL IN ORDER TO ERECT THE GUARDRAIL POST. THIS WORK IS INCLUDED IN THE BID PRICE OF THE ITEM OF WORK FOR WHICH THE POSTS ARE BEING INSTALLED. THE POST SHALL BE INCLUDED IN THE UNIT BID PRICE OF THE GUARDRAIL.

12. THE PAY ITEM SHALL BE:
THRIE BEAM GUARDRAIL__________L.F.



REFERENCES

NATIONAL DOCUMENTS

AASHTO M270, AASHTO M160, AASHTO M111, ASTM A709, ASTM 6A, ASTM A123, TASK FORCE 13 REPORT- WWW.AASHTOTF13.ORG

SCDOT DOCUMENTS

SECTION 706 & 707 SCDOT STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION, QUALIFIED PRODUCT LIST 49

RELATED DRAWINGS & KEYWORDS

805-105-00, 805-005-00

PRECONSTRUCTION SUPPORT ENGINEER

SOUTH CAROLINA PROFESSIONAL ENGINEER REGISTERED NO. 8858 EDWIN SYLVESTER EARGLE, II

SIGNATURE

MARCH 3, 2009
DATE

#	DATE	CHK	DESCRIPTION
6			
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1	3/2009	DSO	CHANGED NOTE 1
0	3/2008	DSO	NEW STANDARD

SCDOT

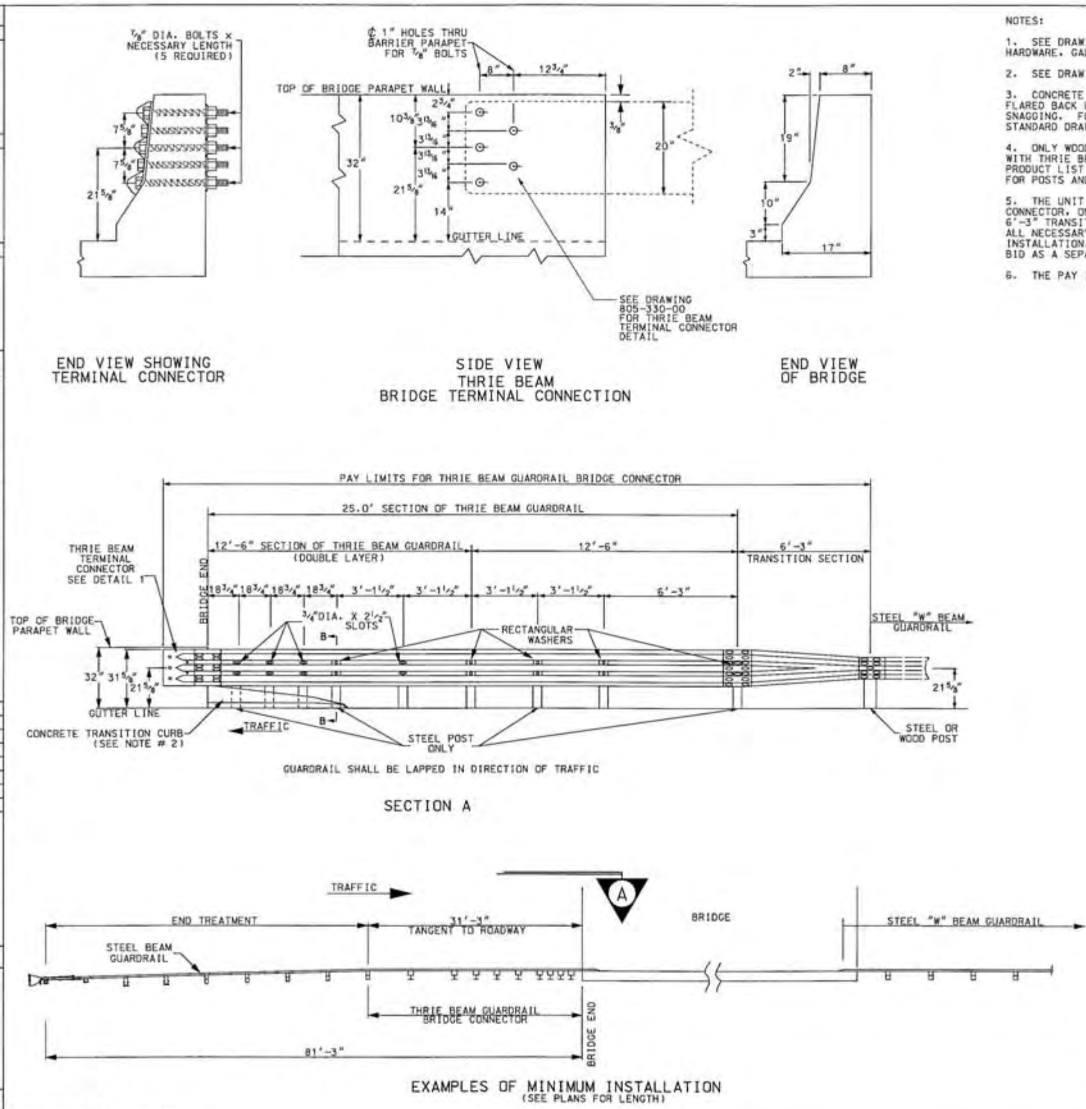
SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION
DESIGN STANDARDS OFFICE
955 PARK STREET
ROOM 405
COLUMBIA, SC 29201

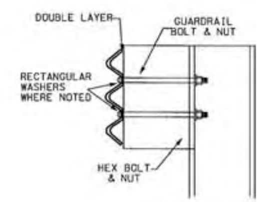
STANDARD DRAWING

GUARDRAIL (THRIE BEAM) POST & BLOCKOUT DETAILS

805-310-00

EFFECTIVE LETTING DATE MAY 2009





SECTION B-B

NOTES:

1. SEE DRAWINGS 805-305-00 & 805-775-02 FOR THRIE BEAM GUARDRAIL DETAILS, HARDWARE, GALVANIZING, ETC.

2. SEE DRAWING 805-330-00 FOR DETAIL OF THRIE BEAM TERMINAL CONNECTOR.

3. CONCRETE TRANSITION CURB SHALL BE PLACED AT ALL BRIDGE APPROACHES AND FLARED BACK UNDER THE GUARDRAIL AT A RATE OF 8:1 TO PREVENT VEHICLE SNAGGING. FOR CONCRETE TRANSITION CURB AND/OR FLUME INFORMATION, SEE STANDARD DRAWINGS 403-205-01 & 403-205-02.

4. ONLY WOOD, COMPOSITE, OR PLASTIC BLOCKOUTS ON STEEL POSTS SHALL BE USED WITH THRIE BEAM GUARDRAIL. STEEL BLOCKOUTS ARE NOT APPROVED (SEE QUALIFIED PRODUCT LIST 49 FOR LIST OF APPROVED MANUFACTURERS). SEE DRAWING 805-305-00 FOR POSTS AND BLOCKOUT REQUIREMENTS.

5. THE UNIT PRICE BID FOR THIS ITEM SHALL INCLUDE ONE THRIE BEAM TERMINAL CONNECTOR, ONE 25'-0' THRIE BEAM RAIL, ONE 12'-6" THRIE BEAM RAIL, ONE 6'-3" TRANSITION SECTION (THRIE BEAM TO W-BEAM), STEEL POSTS AND BLOCKOUTS, ALL NECESSARY NUTS, BOLTS, WASHERS, HARDWARE, AND LABOR FOR COMPLETE INSTALLATION. W-BEAM GUARDRAIL TO CONNECT TO THIS INSTALLATION SHALL BE BID AS A SEPARATE ITEM.

6. THE PAY ITEMS SHALL BE:
THRIE BEAM G.R. BRIDGE CONNECTOR ________ EA.
CONCRETE TRANSITION CURB ______________ LF

THIS DRAWING IS NOT TO SCALE

REFERENCES

NATIONAL DOCUMENTS

SCDOT DOCUMENTS
QUALIFIED PRODUCT LIST 49

RELATED DRAWINGS & KEYWORDS
805-305-00, 805-775-02, 403-205-01, 403-205-02, 805-330-00

PRECONSTRUCTION SUPPORT ENGINEER

SOUTH CAROLINA PROFESSIONAL ENGINEER REGISTERED NO. 8858 EDWIN SYLVESTER EARGLE, II

SIGNATURE

MARCH 3, 2008
DATE

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SCDOT

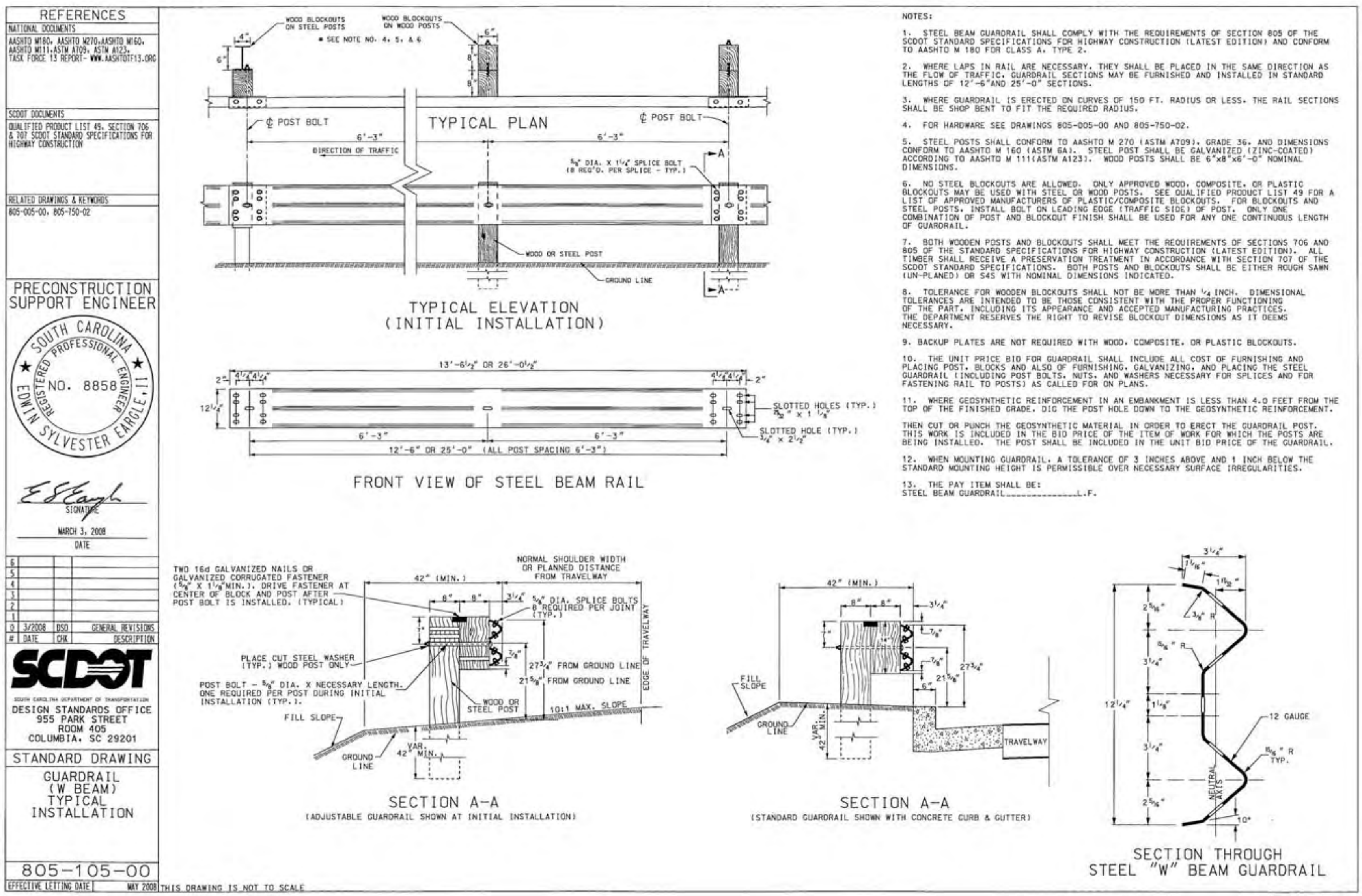
SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION
DESIGN STANDARDS OFFICE
955 PARK STREET
ROOM 405
COLUMBIA, SC 29201

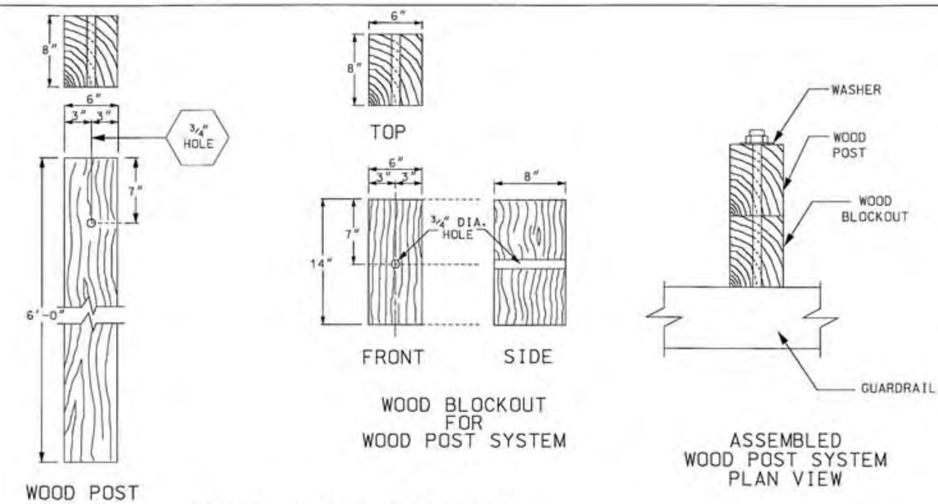
STANDARD DRAWING

GUARDRAIL (THRIE BEAM) BRIDGE CONNECTOR (SAFETY SHAPE)

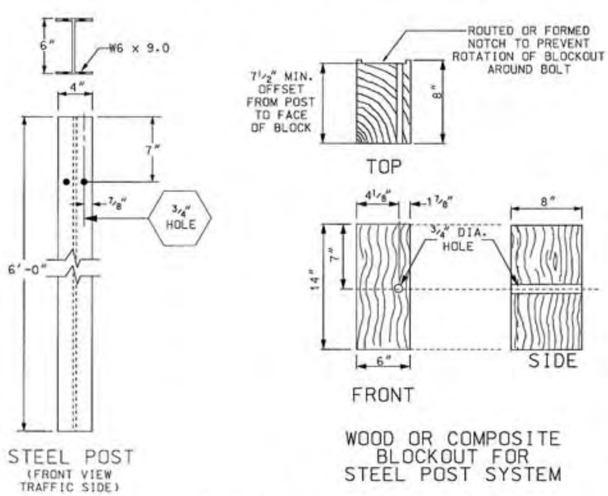
805-325-00

EFFECTIVE LETTING DATE MAY 2008


REFERENCES
NATIONAL DOCUMENTS
AASHTO M180, AASHTO M270, AASHTO M160, AASHTO M111, ASTM A709, ASTM A123, TASK FORCE 13 REPORT - WWW.AASHTOTF13.ORG
SCDOT DOCUMENTS
QUALIFIED PRODUCT LIST 49, SECTION 706 & 707 SCDOT STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION
RELATED DRAWINGS & KEYWORDS
805-005-00, 805-750-02
PRECONSTRUCTION SUPPORT ENGINEER
SOUTH CAROLINA PROFESSIONAL ENGINEER REGISTERED NO. 8858 EDWIN SYLVESTER EARGLE, II
SIGNATURE
MARCH 3, 2008
DATE
0 3/2008 DSO GENERAL REVISIONS
DATE CHK DESCRIPTION
SCDOT
SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION
DESIGN STANDARDS OFFICE
955 PARK STREET
ROOM 405
COLUMBIA, SC 29201
STANDARD DRAWING
GUARDRAIL (W BEAM) TYPICAL INSTALLATION
805-105-00
EFFECTIVE LETTING DATE MAY 2008
THIS DRAWING IS NOT TO SCALE
TYPICAL PLAN
TYPICAL ELEVATION (INITIAL INSTALLATION)
FRONT VIEW OF STEEL BEAM RAIL
SECTION A-A (ADJUSTABLE GUARDRAIL SHOWN AT INITIAL INSTALLATION)
SECTION A-A (STANDARD GUARDRAIL SHOWN WITH CONCRETE CURB & GUTTER)
SECTION THROUGH STEEL "W" BEAM GUARDRAIL
NOTES:
1. STEEL BEAM GUARDRAIL SHALL COMPLY WITH THE REQUIREMENTS OF SECTION 805 OF THE SCDOT STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION (LATEST EDITION) AND CONFORM TO AASHTO M 180 FOR CLASS A, TYPE 2.
2. WHERE LAPS IN RAIL ARE NECESSARY, THEY SHALL BE PLACED IN THE SAME DIRECTION AS THE FLOW OF TRAFFIC. GUARDRAIL SECTIONS MAY BE FURNISHED AND INSTALLED IN STANDARD LENGTHS OF 12'-6" AND 25'-0" SECTIONS.
3. WHERE GUARDRAIL IS ERECTED ON CURVES OF 150 FT. RADIUS OR LESS, THE RAIL SECTIONS SHALL BE SHOP BENT TO FIT THE REQUIRED RADIUS.
4. FOR HARDWARE SEE DRAWINGS 805-005-00 AND 805-750-02.
5. STEEL POSTS SHALL CONFORM TO AASHTO M 270 (ASTM A709), GRADE 36, AND DIMENSIONS CONFORM TO AASHTO M 160 (ASTM 6A). STEEL POST SHALL BE GALVANIZED (ZINC-COATED) ACCORDING TO AASHTO M 111(ASTM A123). WOOD POSTS SHALL BE 6"x8"x6'-0" NOMINAL DIMENSIONS.
6. NO STEEL BLOCKOUTS ARE ALLOWED. ONLY APPROVED WOOD, COMPOSITE, OR PLASTIC BLOCKOUTS MAY BE USED WITH STEEL OR WOOD POSTS. SEE QUALIFIED PRODUCT LIST 49 FOR A LIST OF APPROVED MANUFACTURERS OF PLASTIC/COMPOSITE BLOCKOUTS. FOR BLOCKOUTS AND STEEL POSTS, INSTALL BOLT ON LEADING EDGE (TRAFFIC SIDE) OF POST. ONLY ONE COMBINATION OF POST AND BLOCKOUT FINISH SHALL BE USED FOR ANY ONE CONTINUOUS LENGTH OF GUARDRAIL.
7. BOTH WOODEN POSTS AND BLOCKOUTS SHALL MEET THE REQUIREMENTS OF SECTIONS 706 AND 805 OF THE STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION (LATEST EDITION). ALL TIMBER SHALL RECEIVE A PRESERVATION TREATMENT IN ACCORDANCE WITH SECTION 707 OF THE SCDOT STANDARD SPECIFICATIONS. BOTH POSTS AND BLOCKOUTS SHALL BE EITHER ROUGH SAWN (UN-PLANED) OR S4S WITH NOMINAL DIMENSIONS INDICATED.
8. TOLERANCE FOR WOODEN BLOCKOUTS SHALL NOT BE MORE THAN 1/4 INCH. DIMENSIONAL TOLERANCES ARE INTENDED TO BE THOSE CONSISTENT WITH THE PROPER FUNCTIONING OF THE PART, INCLUDING ITS APPEARANCE AND ACCEPTED MANUFACTURING PRACTICES. THE DEPARTMENT RESERVES THE RIGHT TO REVISE BLOCKOUT DIMENSIONS AS IT DEEMS NECESSARY.
9. BACKUP PLATES ARE NOT REQUIRED WITH WOOD, COMPOSITE, OR PLASTIC BLOCKOUTS.
10. THE UNIT PRICE BID FOR GUARDRAIL SHALL INCLUDE ALL COST OF FURNISHING AND PLACING POST, BLOCKS AND ALSO OF FURNISHING, GALVANIZING, AND PLACING THE STEEL GUARDRAIL (INCLUDING POST BOLTS, NUTS, AND WASHERS NECESSARY FOR SPLICES AND FOR FASTENING RAIL TO POSTS) AS CALLED FOR ON PLANS.
11. WHERE GEOSYNTHETIC REINFORCEMENT IN AN EMBANKMENT IS LESS THAN 4.0 FEET FROM THE TOP OF THE FINISHED GRADE, DIG THE POST HOLE DOWN TO THE GEOSYNTHETIC REINFORCEMENT.
THEN CUT OR PUNCH THE GEOSYNTHETIC MATERIAL IN ORDER TO ERECT THE GUARDRAIL POST. THIS WORK IS INCLUDED IN THE BID PRICE OF THE ITEM OF WORK FOR WHICH THE POSTS ARE BEING INSTALLED. THE POST SHALL BE INCLUDED IN THE UNIT BID PRICE OF THE GUARDRAIL.
12. WHEN MOUNTING GUARDRAIL, A TOLERANCE OF 3 INCHES ABOVE AND 1 INCH BELOW THE STANDARD MOUNTING HEIGHT IS PERMISSIBLE OVER NECESSARY SURFACE IRREGULARITIES.
13. THE PAY ITEM SHALL BE:
STEEL BEAM GUARDRAIL_______________L.F.



WOOD POST SYSTEM



STEEL POST SYSTEM

(SEE NOTE 6)

NOTES:

1. STEEL BEAM GUARDRAIL SHALL COMPLY WITH THE REQUIREMENTS GIVEN ON STANDARD DRAWING 805-105-00.

2. ALL HARDWARE SHALL COMPLY WITH THE REQUIREMENTS GIVEN ON STANDARD DRAWINGS 805-005-00.

3. BACKUP PLATES ARE NOT REQUIRED WITH WOOD, COMPOSITE, OR PLASTIC BLOCKOUTS.

4. NO STEEL BLOCKOUTS ARE ALLOWED. ONLY APPROVED WOOD, COMPOSITE, OR PLASTIC BLOCKOUTS MAY BE USED WITH STEEL OR WOOD POSTS. SEE QUALIFIED PRODUCT LIST 49 FOR A LIST OF APPROVED MANUFACTURERS OF PLASTIC/COMPOSITE BLOCKOUTS. BLOCKOUTS ARE TO BE INSTALLED ON THE TRAFFIC SIDE OF THE POSTS. ONLY ONE COMBINATION OF POST AND BLOCKOUT FINISH SHALL BE USED FOR ANY ONE CONTINUOUS USE OF GUARDRAIL.

5. ALL TIMBER SHALL RECEIVE A PRESERVATION TREATMENT IN ACCORDANCE WITH SECTION 707 OF THE SCDOT STANDARD SPECIFICATIONS. BOTH WOODEN POSTS AND BLOCKOUTS SHALL MEET THE REQUIREMENTS OF SECTIONS 706 AND 805 AND SHALL BE EITHER ROUGH SAWN (UN- PLANED) OR S4S WITH NOMINAL DIMENSIONS INDICATED AND MEET THE STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION (LATEST EDITION).

6. HOLES IN COMPOSITE/PLASTIC BLOCKOUTS USED WITH STEEL POST MAY BE MANUFACTURED ON BOTH THE LEFT AND/OR RIGHT SIDE. HOLES IN WOODEN BLOCKOUTS USED WITH STEEL POSTS SHOULD BE LIMITED TO EITHER THE LEFT OR RIGHT SIDE OF THE BLOCKOUT. HOLES IN ALL BLOCKOUTS USED WITH WOODEN POSTS MUST HAVE HOLES DRILLED IN CENTER OF BLOCKOUT.

7. TOLERANCE FOR WOODEN BLOCKOUTS SHALL NOT BE MORE THAN 1/4 INCH. DIMENSIONAL TOLERANCES ARE INTENDED TO BE THOSE CONSISTENT WITH THE PROPER FUNCTIONING OF THE PART, INCLUDING ITS APPEARANCE AND ACCEPTED MANUFACTURING PRACTICES. THE DEPARTMENT RESERVES THE RIGHT TO REVISE BLOCKOUT DIMENSIONS AS IT DEEMS NECESSARY.

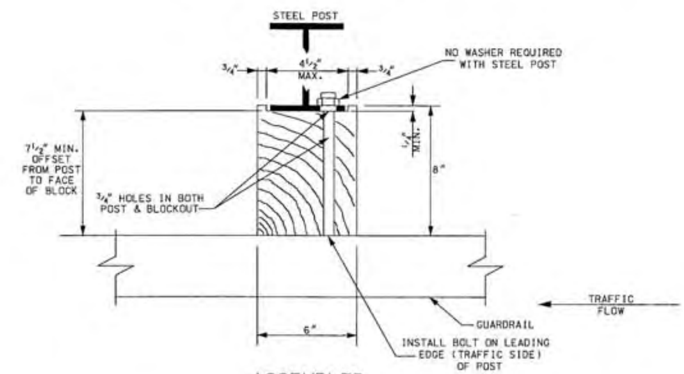
8. STEEL POSTS SHALL CONFORM TO AASHTO M 270 (ASTM A709), GRADE 36, AND DIMENSIONS CONFORM TO AASHTO M 160 (ASTM 6A). STEEL POSTS SHALL BE GALVANIZED (ZINC-COATED) ACCORDING TO AASHTO M 111(ASTM A123). DRILL HOLES IN STEEL POSTS ON BOTH LEFT AND RIGHT SIDE AND FRONT AND BACK OF POST.

9. WHEN GUARDRAIL IS REQUIRED AND THE PROPER SHOULDER DISTANCE BEHIND THE GUARDRAIL CANNOT BE OBTAINED, ADDITIONAL LENGTH POSTS ARE REQUIRED. SEE TABLE 805-010F ON DRAWING 805-010-00.

10. THE UNIT PRICE BID FOR GUARDRAIL SHALL INCLUDE ALL COSTS OF FURNISHING AND PLACING POST, BLOCKOUTS, AND ALSO OF FURNISHING, GALVANIZING, AND PLACING THE STEEL GUARDRAIL (INCLUDING POST BOLTS, NUTS, AND WASHERS NECESSARY FOR SPLICES AND FOR FASTENING RAIL TO POSTS) AS CALLED FOR ON PLANS.

11. WHERE GEOSYNTHETIC REINFORCEMENT IN AN EMBANKMENT IS LESS THAN 4.0 FEET FROM THE TOP OF THE FINISHED GRADE, DIG THE POST HOLE DOWN TO THE GEOSYNTHETIC REINFORCEMENT. THEN CUT OR PUNCH THE GEOSYNTHETIC MATERIAL IN ORDER TO ERECT THE GUARDRAIL POST. THIS WORK IS INCLUDED IN THE BID PRICE OF THE ITEM OF WORK FOR WHICH THE POSTS ARE BEING INSTALLED. THE POST SHALL BE INCLUDED IN THE UNIT BID PRICE OF THE GUARDRAIL.

12. THE PAY ITEM SHALL BE:
STEEL BEAM GUARDRAIL__________L.F.



ASSEMBLED STEEL POST SYSTEM PLAN VIEW

THIS DRAWING IS NOT TO SCALE

REFERENCES

NATIONAL DOCUMENTS
AASHTO M270, AASHTO M160, AASHTO M111, ASTM A709, ASTM 6A, ASTM A123, TASK FORCE 13 REPORT- WWW.AASHTOTF13.ORG

SCDOT DOCUMENTS
SECTION 706 & 707 SCDOT STANDARD SPECIFICATIONS FOR HIGHWAY CONSTRUCTION, QUALIFIED PRODUCT LIST 49

RELATED DRAWINGS & KEYWORDS
805-105-00, 805-005-00

PRECONSTRUCTION SUPPORT ENGINEER

SOUTH CAROLINA PROFESSIONAL ENGINEER REGISTERED NO. 8858 EDWIN SYLVESTER EARGLE, II

SIGNATURE

MARCH 3, 2008
DATE

#	DATE	CHK	DESCRIPTION
6			
5			
4			
3			
2			
1			
0	3/2008	DSO	GENERAL REVISIONS

SCDOT
SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION
DESIGN STANDARDS OFFICE
955 PARK STREET
ROOM 405
COLUMBIA, SC 29201

STANDARD DRAWING
GUARDRAIL (W BEAM) POST & BLOCKOUT DETAILS

805-110-00

EFFECTIVE LETTING DATE MAY 2008

REFERENCES

NATIONAL DOCUMENTS
ASTM E488,
TASK FORCE 13 REPORT- WWW.AASHTOTF13.ORG

SCDOT DOCUMENTS

RELATED DRAWINGS & KEYWORDS

PRECONSTRUCTION SUPPORT ENGINEER

SOUTH CAROLINA PROFESSIONAL ENGINEER REGISTERED NO. 8858 EDWIN SYLVESTER EARGLE, II

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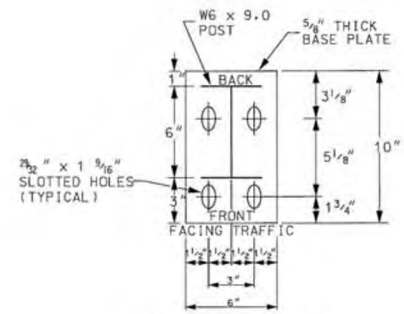
SCDOT
SOUTH CAROLINA DEPARTMENT OF TRANSPORTATION
DESIGN STANDARDS OFFICE
955 PARK STREET
ROOM 405
COLUMBIA, SC 29201

STANDARD DRAWING

GUARDRAIL (W BEAM) BASE PLATE CONNECTION

805-120-00

EFFECTIVE LETTING DATE MAY 2008 THIS DRAWING IS NOT TO SCALE



DETAIL OF BASE PLATE

BASE PLATE SHOULD BE DRILLED AS SHOWN.
BUT MAY BE FLIPPED 180° TO FIT CONDITIONS AS DIRECTED BY THE ENGINEER.
DO NOT ROTATE 90°!

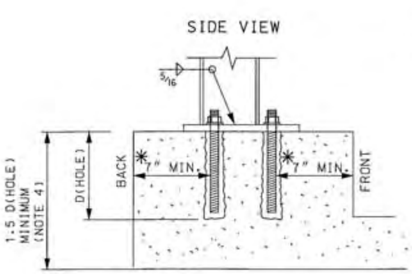
NOTES FOR ATTACHING TO STRUCTURES:

1. WHERE A STANDARD LENGTH GUARDRAIL POST CANNOT BE ERECTED OVER A STRUCTURE OR UN-WEATHERED ROCK, GUARDRAIL AND POSTS SHALL BE ATTACHED AS SHOWN HEREON. RESIN ANCHOR DETAIL MAY BE USED WHEN THE STRUCTURE OR UN-WEATHERED ROCK THICKNESS IS GREATER THAN 7 INCHES. BOLTING THROUGH DECK DETAIL MAY BE USED FOR STRUCTURES WHERE SPECIFIED BY THE ENGINEER.

2. THE MINIMUM EMBEDMENT OF THE STEEL ANCHOR BOLT INTO THE EXISTING CONCRETE OR UN-WEATHERED ROCK IS 5 INCHES WHEN CONCRETE OR UN-WEATHERED ROCK HAS A COMPRESSIVE STRENGTH OF 4000 psi. IF THE CONCRETE OR UN-WEATHERED ROCK HAS A COMPRESSIVE STRENGTH OTHER THAN 4000 psi, CONSULT WITH THE DESIGN ENGINEER.

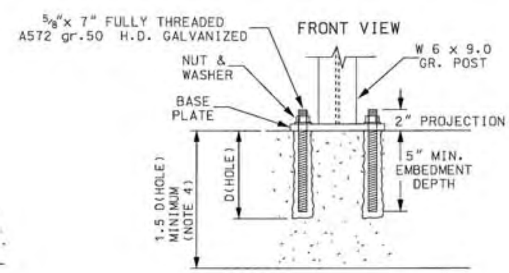
3. RESIN ANCHORS SHALL COMPLY WITH ASTM E 488 AND AS SET FORTH IN THE SPECIAL PROVISIONS FOR RESIN ANCHORS. PAYMENT AND ALL INFORMATION CONCERNING RESIN ANCHORS IS DISCUSSED WITHIN THE SPECIAL PROVISIONS FOR RESIN ANCHORS.

4. CONNECTING STRUCTURE MUST BE AT LEAST 50% THICKER THAN THE DRILL HOLE DEPTH AT THE RESIN ANCHORS OR THICKNESS REQUIRED BY RESIN MANUFACTURER (WHICHEVER IS GREATER).

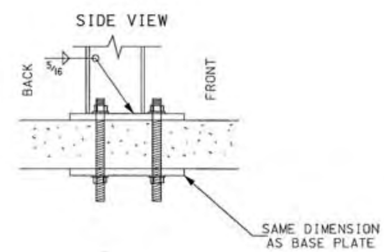


*MUST HAVE 7 INCHES OF CLEARANCE FROM EMBEDDED ANCHOR TO EDGE OF STRUCTURE (FRONT OR BACK).

RESIN ANCHORS TO CURB OR EDGE OF STRUCTURE

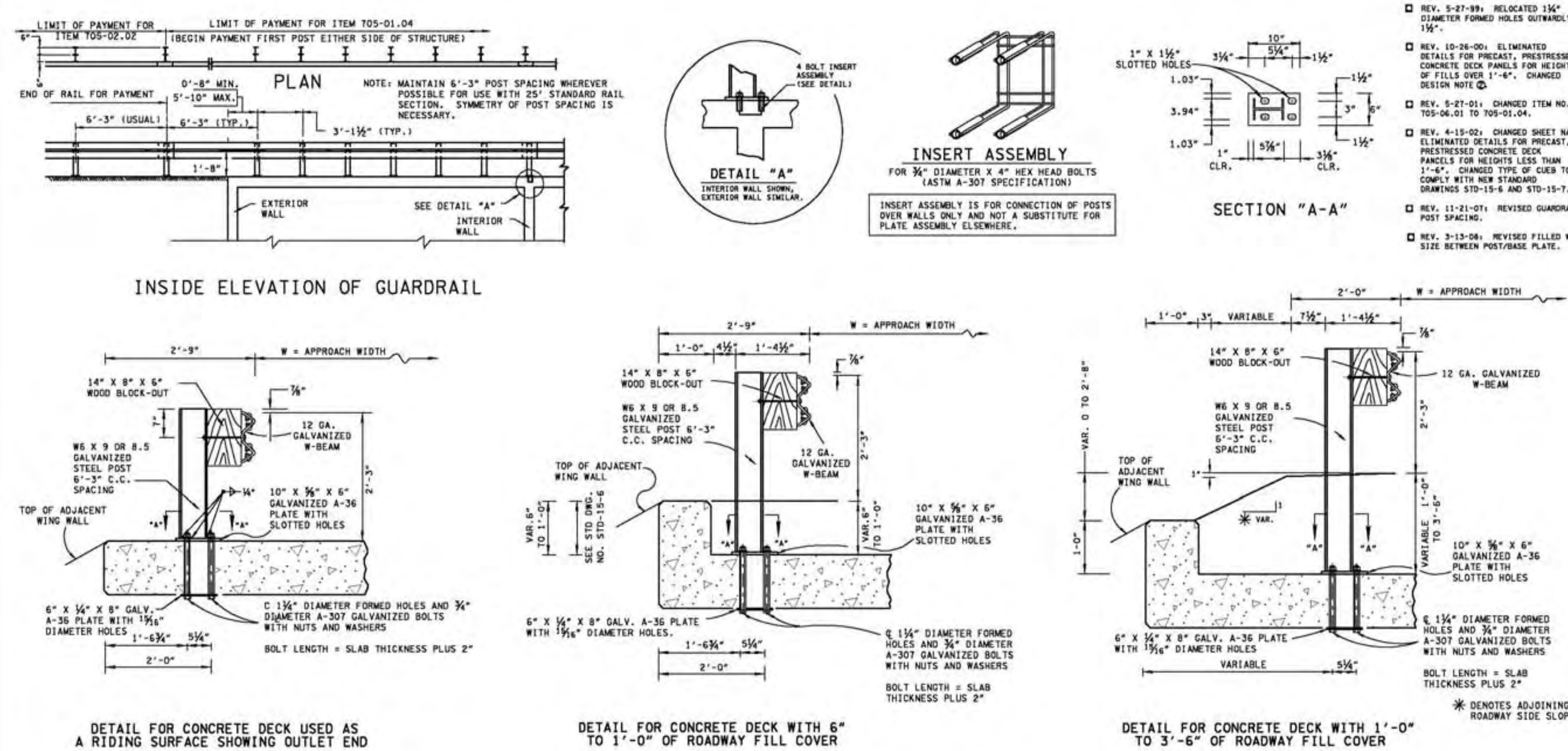


RESIN ANCHORS TO LARGER STRUCTURES



DETAIL OF BOLTING THROUGH DECK

ATTACHMENTS TO STRUCTURES OR UN-WEATHERED ROCK



- ☐ REV. 9-5-97: MODIFIED INSIDE ELEVATION OF GUARDRAIL DETAIL.

  REV. 7-29-98: CHANGED STEEL BLOCK-OUTS TO WOOD BLOCK-OUTS IN ALL DETAILS AND NOTES.
- ☐ REV. 5-27-99: RELOCATED 1¼" DIAMETER FORMED HOLES OUTWARDLY 1½".
- ☐ REV. 10-26-00: ELIMINATED DETAILS FOR PRECAST, PRESTRESSED CONCRETE DECK PANELS FOR HEIGHT OF FILLS OVER 1'-6". CHANGED DESIGN NOTE ②.
- ☐ REV. 5-27-01: CHANGED ITEM NO. 705-06.01 TO 705-01.04.
- ☐ REV. 4-15-02: CHANGED SHEET NAME. ELIMINATED DETAILS FOR PRECAST, PRESTRESSED CONCRETE DECK PANCELS FOR HEIGHTS LESS THAN 1'-6". CHANGED TYPE OF CUEB TO COMPLY WITH NEW STANDARD DRAWINGS STD-15-6 AND STD-15-7.
- ☐ REV. 11-21-07: REVISED GUARDRAIL POST SPACING.
- ☐ REV. 3-13-08: REVISED FILLED WELD SIZE BETWEEN POST/BASE PLATE.

GENERAL NOTES

Ⓐ THE EXACT POSITION OF GUARDRAIL SHALL BE AS SHOWN ELSEWHERE ON THE PLANS OR AS DIRECTED BY THE ENGINEER. GUARDRAIL SHALL BE TRANSITIONED TO A SMOOTH CONNECTION WITH OTHER GUARDRAIL OR STRUCTURE RAILING AS SHOWN ELSEWHERE ON PLANS.

Ⓑ AT THE OPTION OF THE CONTRACTOR THE RAIL ELEMENTS FOR THE GUARDRAIL MAY BE FURNISHED IN EITHER 12½ OR 25 FOOT NOMINAL LENGTHS WITH POST BOLT SLOTS FOR CONNECTION TO POSTS.

Ⓒ BOLTS SHALL BE OF SUFFICIENT LENGTH TO EXTEND THROUGH THE FULL THICKNESS OF THE NUT AND NO MORE THAN ¾" BEYOND IT.

Ⓓ GUARDRAIL THAT IS INSTALLED ON CURVE WITH A RADIUS OF 150 FEET OR LESS SHALL BE SHOP CURVED.

Ⓔ STEEL POST SHALL BE BLOCKED OUT. A 8" X 6" WOOD BLOCK-OUT SHALL BE USED WITH EACH STEEL POST. SEE STANDARD DRAWING S-GR-13 FOR SPECIFICATIONS AND DETAILS.

Ⓕ WELDED STEEL POSTS SHALL MEET THE REQUIREMENTS OF ASTM A-769. THE FLANGE WIDTH AND THICKNESS, WEB THICKNESS, AND DEPTH OF WELDED POSTS SHALL EQUAL OR EXCEED THE DIMENSIONS OF A STANDARD ROLLED W6 X 8.5 OR W6 X 9.0 STEEL POST.

Ⓖ STEEL POSTS SHALL MEET THE REQUIREMENTS OF ASTM A-36. BOLT HOLES SHALL BE APPROXIMATELY CENTERED BETWEEN WEB AND EDGE OF FLANGE OF SPACERS AND POSTS.

Ⓗ FOR DIMENSIONS AND DETAILS NOT SHOWN SEE STANDARD DRAWING NOS. STD-15-6, STD-15-7, AND THE S-GR-SERIES.

DESIGN NOTES

① GUARDRAIL POST SPACING SHALL BE REDUCED TO 3'-1½" AT CONCRETE DECK ATTACHMENTS.

② WHEN DEPTH OF FILL AT FACE OF GUARDRAIL EXCEEDS 3'-6" DELETE THE USE OF BOLTED BASE PLATES AND DRIVE POSTS.

③ THE USE OF PRECAST, PRESTRESSED CONCRETE DECK PANELS IN BOX AND SLAB TYPE CULVERTS IS PROHIBITED.

④ THIS RAIL SYSTEM HAS BEEN TESTED IN ACCORDANCE WITH THE CRITERIA SET FORTH IN NCHRP REPORT NUMBER 230, MARCH 1981, AND SUCCESSFULLY CONTAINED A 4,450 POUND VEHICLE AT A VELOCITY OF 61.8 MPH AND AN IMPACT ANGLE OF 25.3 DEGREES. REFERENCE REPORT FHWA/TX-86/64-405-2F, NOVEMBER 1986.

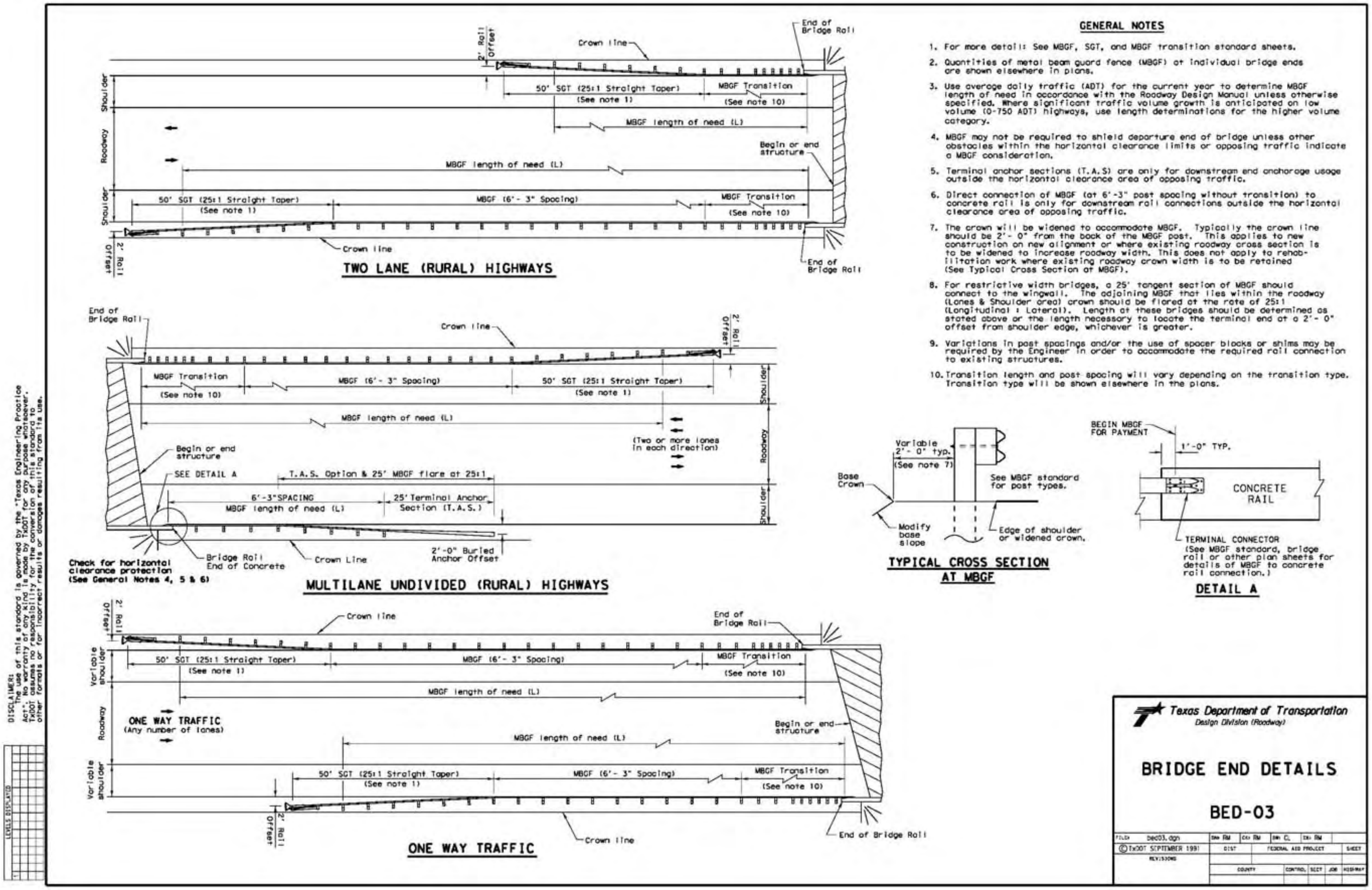
⑤ ANY REINFORCING STEEL THAT INTERFERES WITH THE 1¼" DIAMETER FORMED HOLES SHALL BE MOVED HORIZONTALLY TO PROVIDE A 1" MINIMUM CLEARANCE TO THE HOLE.

☐ MINOR REVISION -- FHWA APPROVAL NOT REQUIRED.

STATE OF TENNESSEE
DEPARTMENT OF TRANSPORTATION

GUARDRAIL ATTACHMENT TO CONCRETE DECKS OF BOX AND SLAB CULVERTS AND BRIDGES

6-22-89 | S-GR-22


GENERAL NOTES
1. For more detail: See MBGF, SGT, and MBGF transition standard sheets.
2. Quantities of metal beam guard fence (MBGF) at individual bridge ends are shown elsewhere in plans.
3. Use average daily traffic (ADT) for the current year to determine MBGF length of need in accordance with the Roadway Design Manual unless otherwise specified. Where significant traffic volume growth is anticipated on low volume (0-750 ADT) highways, use length determinations for the higher volume category.
4. MBGF may not be required to shield departure end of bridge unless other obstacles within the horizontal clearance limits or opposing traffic indicate a MBGF consideration.
5. Terminal anchor sections (T.A.S) are only for downstream end anchorage usage outside the horizontal clearance area of opposing traffic.
6. Direct connection of MBGF (at 6'-3" post spacing without transition) to concrete rail is only for downstream rail connections outside the horizontal clearance area of opposing traffic.
7. The crown will be widened to accommodate MBGF. Typically the crown line should be 2'- 0" from the back of the MBGF post. This applies to new construction on new alignment or where existing roadway cross section is to be widened to increase roadway width. This does not apply to rehabilitation work where existing roadway crown width is to be retained (See Typical Cross Section at MBGF).
8. For restrictive width bridges, a 25' tangent section of MBGF should connect to the wingwall. The adjoining MBGF that lies within the roadway (Lanes & Shoulder area) crown should be flared at the rate of 25:1 (Longitudinal : Lateral). Length at these bridges should be determined as stated above or the length necessary to locate the terminal end at a 2'- 0" offset from shoulder edge, whichever is greater.
9. Variations in post spacings and/or the use of spacer blocks or shims may be required by the Engineer in order to accommodate the required rail connection to existing structures.
10. Transition length and post spacing will vary depending on the transition type. Transition type will be shown elsewhere in the plans.
TWO LANE (RURAL) HIGHWAYS
Crown line
End of Bridge Rail
2' Rail Offset
50' SGT (25:1 Straight Taper) (See note 1)
MBGF Transition (See note 10)
MBGF length of need (L)
MBGF (6'- 3" Spacing)
Begin or end structure
Shoulder
Roadway
MULTILANE UNDIVIDED (RURAL) HIGHWAYS
(Two or more lanes in each direction)
SEE DETAIL A
T.A.S. Option & 25' MBGF flare at 25:1
6'-3"SPACING
25' Terminal Anchor Section (T.A.S.)
2'-0" Buried Anchor Offset
Bridge Rail End of Concrete
Crown Line
Check for horizontal clearance protection (See General Notes 4, 5 & 6)
ONE WAY TRAFFIC
ONE WAY TRAFFIC (Any number of lanes)
Variable shoulder
TYPICAL CROSS SECTION AT MBGF
Variable 2'- 0" typ. (See note 7)
Base Crown
Modify base slope
See MBGF standard for post types.
Edge of shoulder or widened crown.
DETAIL A
BEGIN MBGF FOR PAYMENT
1'-0" TYP.
CONCRETE RAIL
TERMINAL CONNECTOR (See MBGF standard, bridge rail or other plan sheets for details of MBGF to concrete rail connection.)
Texas Department of Transportation
Design Division (Roadway)
BRIDGE END DETAILS
BED-03
FILE: bed03.dgn
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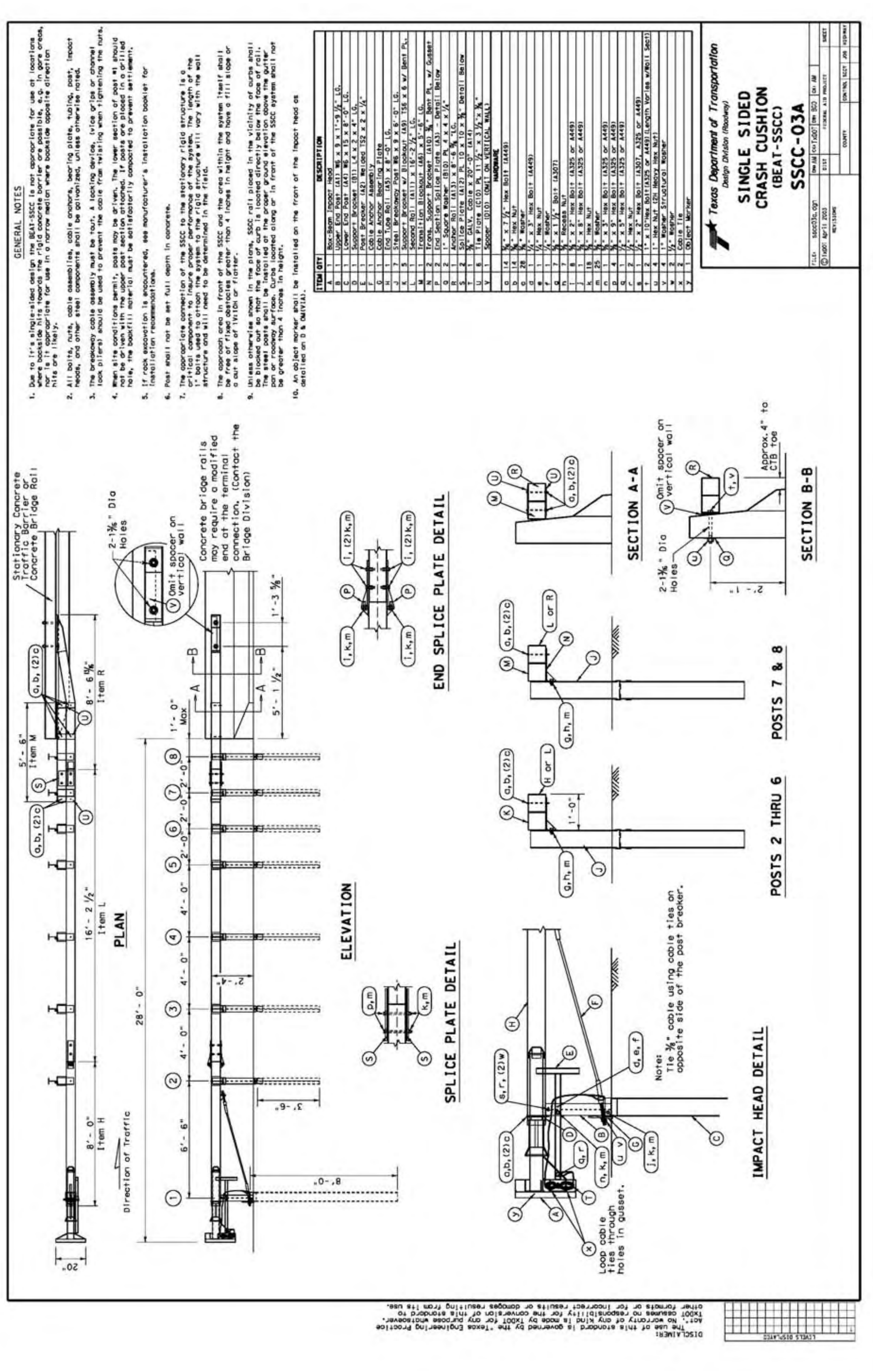
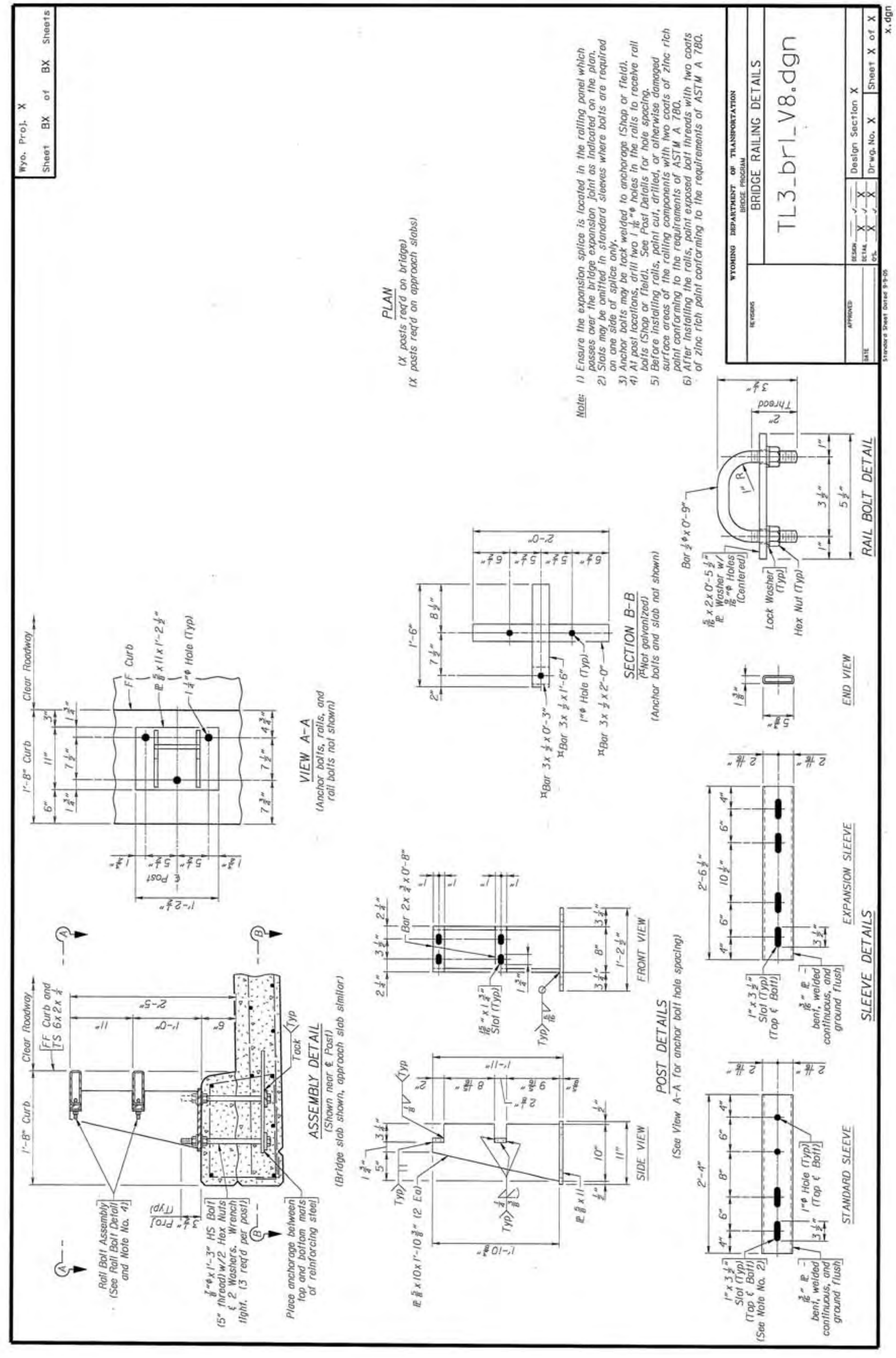
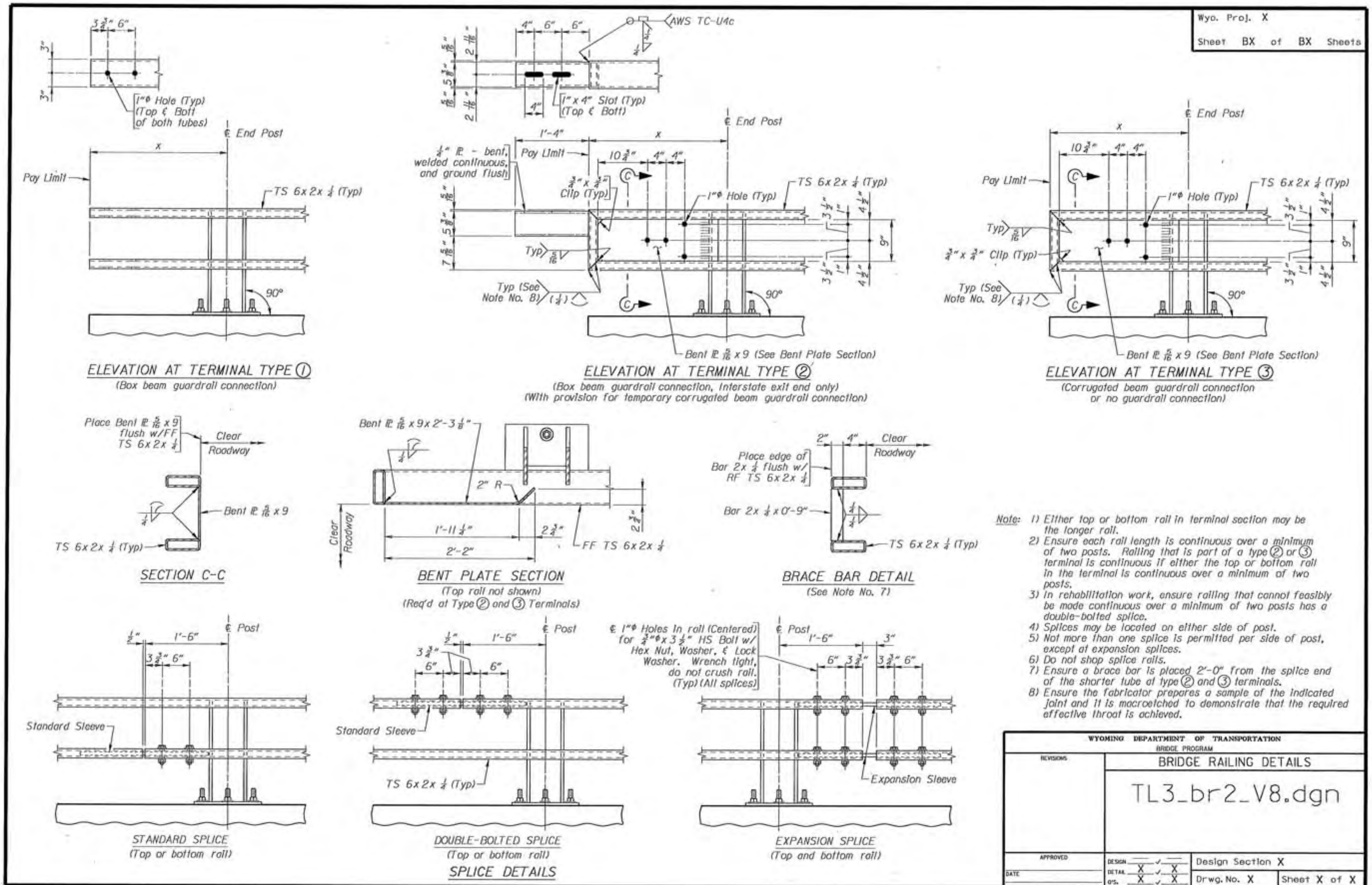
DISCLAIMER:
The use of this standard is governed by the "Texas Engineering Practice Act". No warranty of any kind is made by TxDOT for any purpose whatsoever. TxDOT assumes no responsibility for the conversion of this standard to other formats or for incorrect results or damages resulting from its use.

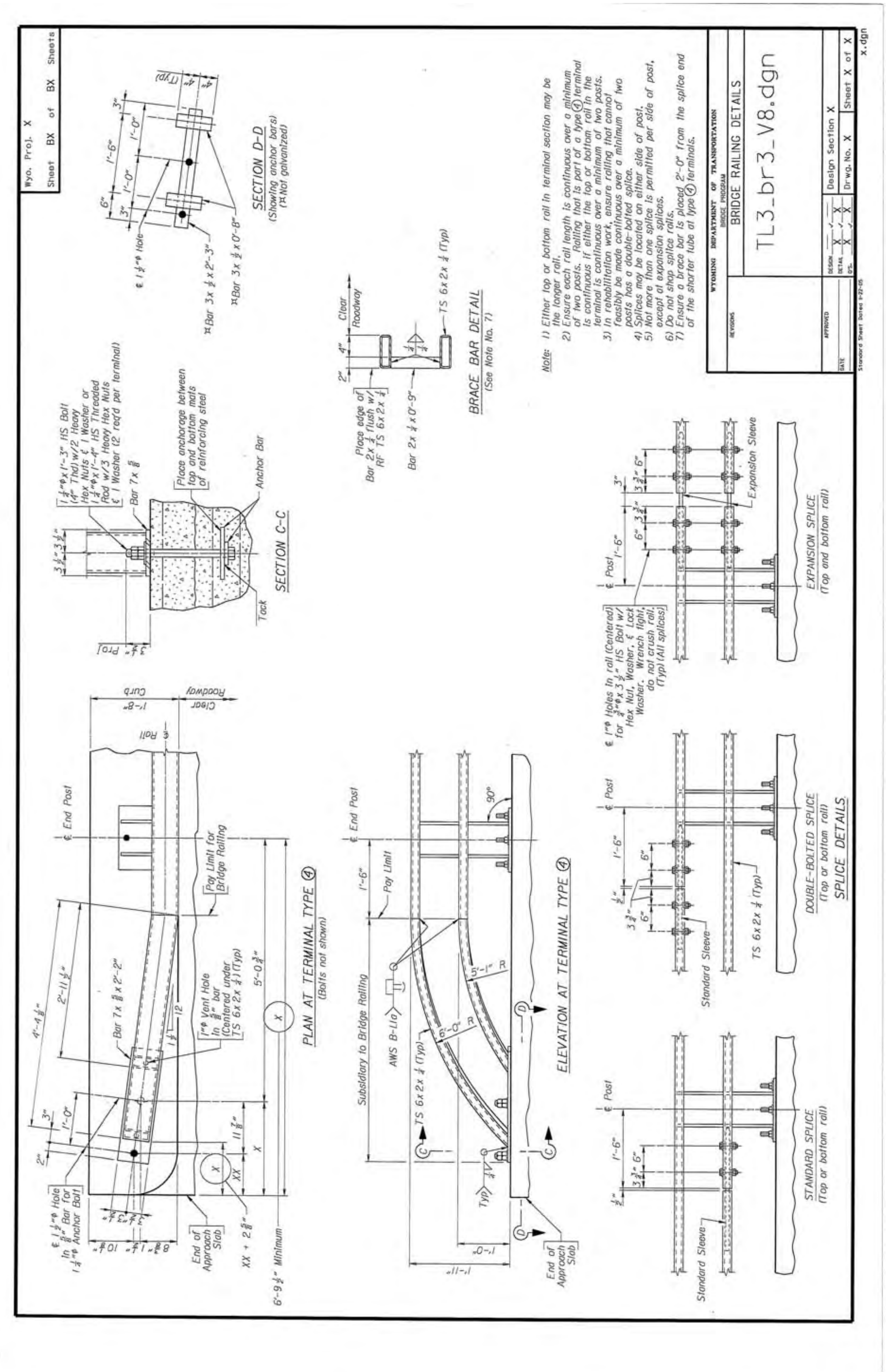


Texas single sided crash cushion

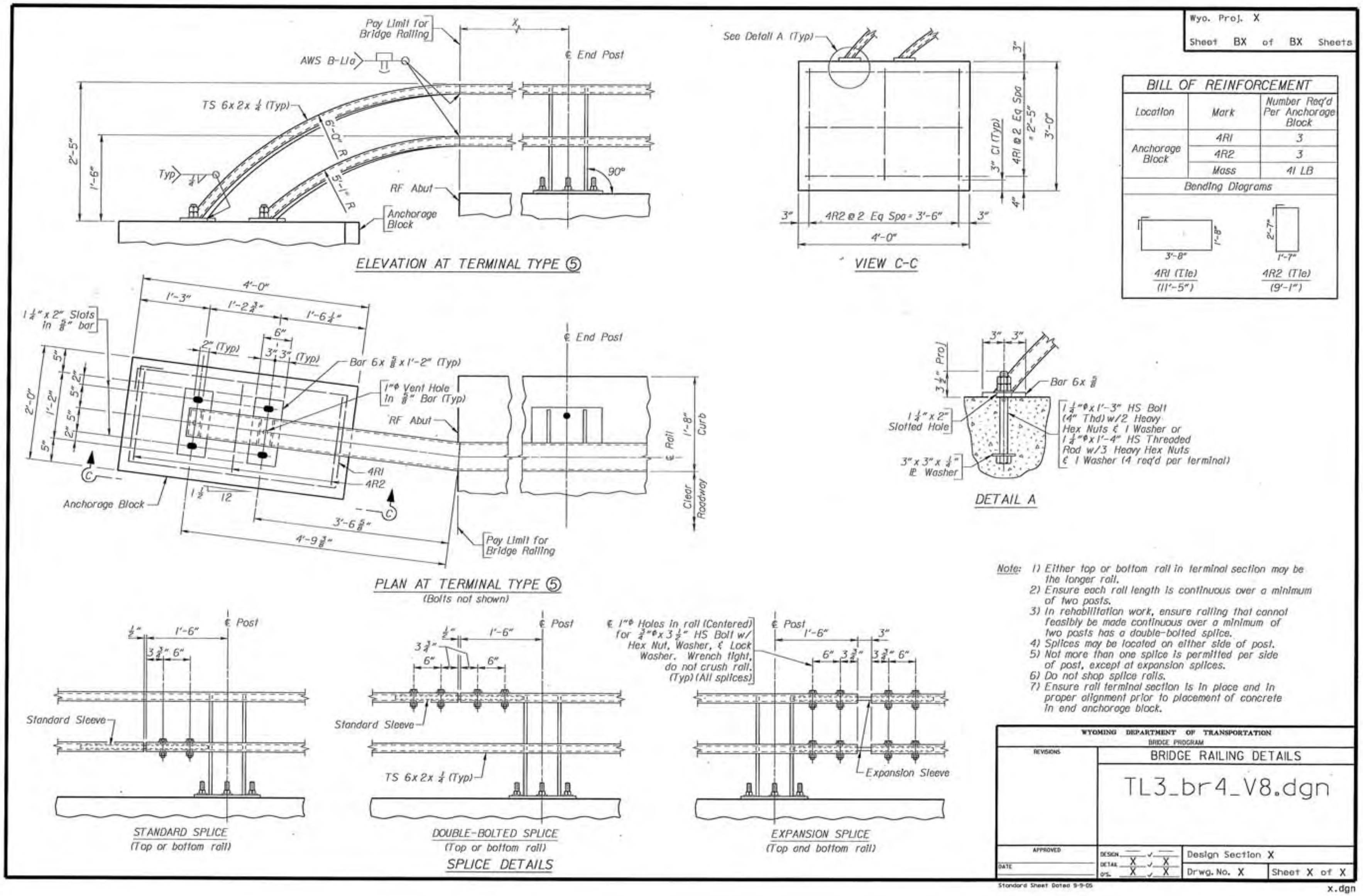


Wyoming DOT
Wyoming TL3 railing


Wyo. Proj. X
Sheet BX of BX Sheets
1"Φ Hole (Typ) (Top ℄ Bott of both tubes)
℄ End Post
Pay Limit
TS 6x2x ¼ (Typ)
90°
ELEVATION AT TERMINAL TYPE ①
(Box beam guardrail connection)
AWS TC-U4c
1" x 4" Slot (Typ) (Top ℄ Bott)
¼" ℞ - bent, welded continuous, and ground flush
Pay Limit
¾" x ¾" Clip (Typ)
Typ (See Note No. 8)
1"Φ Hole (Typ)
Bent ℞ 5/16 x 9 (See Bent Plate Section)
ELEVATION AT TERMINAL TYPE ②
(Box beam guardrail connection, interstate exit end only)
(With provision for temporary corrugated beam guardrail connection)
ELEVATION AT TERMINAL TYPE ③
(Corrugated beam guardrail connection or no guardrail connection)
Place Bent ℞ 5/16 x 9 flush w/FF TS 6x2x ¼
Clear Roadway
Bent ℞ 5/16 x 9
SECTION C-C
Bent ℞ 5/16 x 9x 2'-3 1/8"
FF TS 6x2x ¼
BENT PLATE SECTION
(Top rail not shown)
(Req'd at Type ② and ③ Terminals)
Place edge of Bar 2x ¼ flush w/ RF TS 6x2x ¼
Bar 2x ¼ x 0'-9"
BRACE BAR DETAIL
(See Note No. 7)
Note: 1) Either top or bottom rail in terminal section may be the longer rail.
2) Ensure each rail length is continuous over a minimum of two posts. Railing that is part of a type ② or ③ terminal is continuous if either the top or bottom rail in the terminal is continuous over a minimum of two posts.
3) In rehabilitation work, ensure railing that cannot feasibly be made continuous over a minimum of two posts has a double-bolted splice.
4) Splices may be located on either side of post.
5) Not more than one splice is permitted per side of post, except at expansion splices.
6) Do not shop splice rails.
7) Ensure a brace bar is placed 2'-0" from the splice end of the shorter tube at type ② and ③ terminals.
8) Ensure the fabricator prepares a sample of the indicated joint and it is macroetched to demonstrate that the required effective throat is achieved.
Standard Sleeve
℄ Post
STANDARD SPLICE
(Top or bottom rail)
℄ 1"Φ Holes in rail (Centered) for ¾"Φ x 3 ½" HS Bolt w/ Hex Nut, Washer, ℄ Lock Washer. Wrench tight, do not crush rail. (Typ) (All splices)
DOUBLE-BOLTED SPLICE
(Top or bottom rail)
Expansion Sleeve
EXPANSION SPLICE
(Top and bottom rail)
SPLICE DETAILS
WYOMING DEPARTMENT OF TRANSPORTATION
BRIDGE PROGRAM
BRIDGE RAILING DETAILS
TL3_br2_V8.dgn
Design Section X
Drwg. No. X
Sheet X of X
Standard Sheet Dated 9-9-05
x.dgn

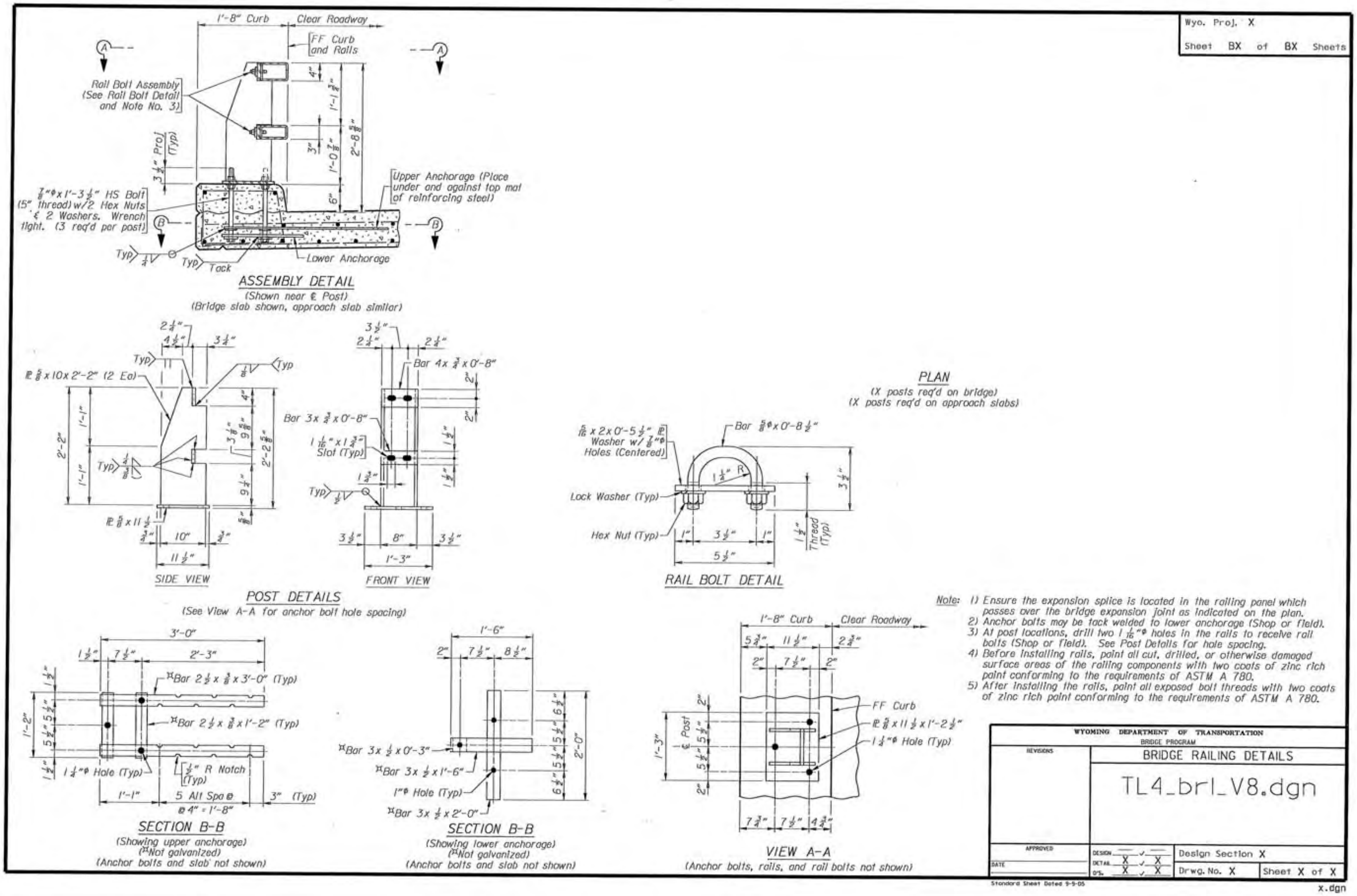


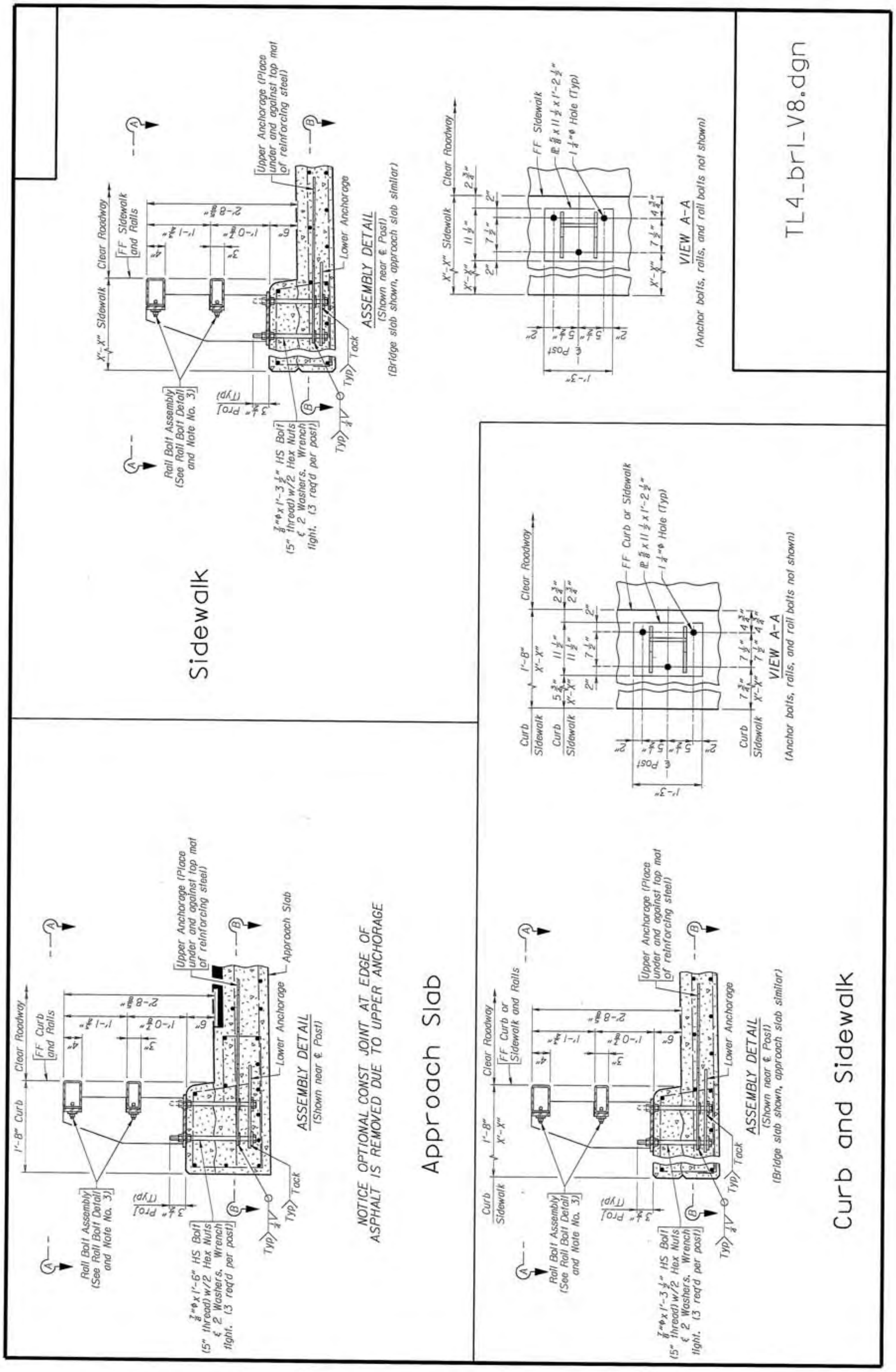
Wyo. Proj. X
Sheet BX of BX Sheets
PLAN AT TERMINAL TYPE ④
(Bolts not shown)
ELEVATION AT TERMINAL TYPE ④
SECTION C-C
SECTION D-D
(Showing anchor bars)
(¤ Not galvanized)
BRACE BAR DETAIL
(See Note No. 7)
STANDARD SPLICE
(Top or bottom rail)
DOUBLE-BOLTED SPLICE
(Top or bottom rail)
EXPANSION SPLICE
(Top and bottom rail)
SPLICE DETAILS
℄ End Post
Pay Limit for Bridge Railing
Pay Limit
Subsidiary to Bridge Railing
End of Approach Slab
Bar 7 x ⅝ x 2'-2"
TS 6 x 2 x ¼ (Typ)
Standard Sleeve
Expansion Sleeve
Anchor Bar
Tack
Clear Roadway
Curb
℄ Rail
Note: 1) Either top or bottom rail in terminal section may be the longer rail.
2) Ensure each rail length is continuous over a minimum of two posts. Railing that is part of a type ④ terminal is continuous if either the top or bottom rail in the terminal is continuous over a minimum of two posts.
3) In rehabilitation work, ensure railing that cannot feasibly be made continuous over a minimum of two posts has a double-bolted splice.
4) Splices may be located on either side of post, except at expansion splices.
5) Not more than one splice is permitted per side of post.
6) Do not shop splice rails.
7) Ensure a brace bar is placed 2'-0" from the splice end of the shorter tube at type ④ terminals.
WYOMING DEPARTMENT OF TRANSPORTATION
BRIDGE PROGRAM
BRIDGE RAILING DETAILS
TL3_br3_V8.dgn
Design Section X
Drwg. No. X
Sheet X of X
x.dgn



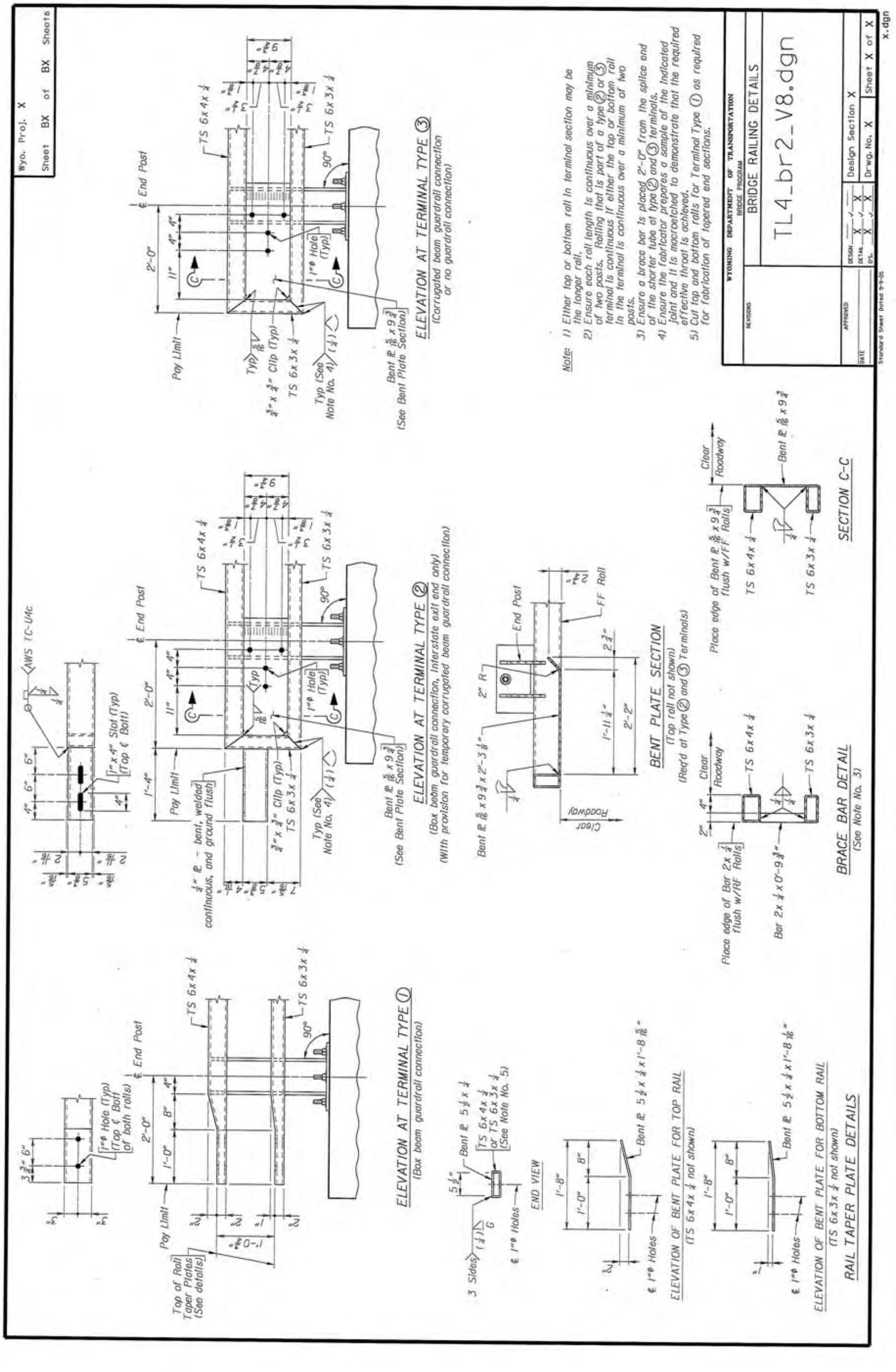
Wyo. Proj. X
Sheet BX of BX Sheets
Pay Limit for Bridge Railing
AWS B-1.1a
TS 6x2x ¼ (Typ)
Typ
6'-0" R
5'-1" R
2'-5"
1'-6"
RF Abut
Anchorage Block
℄ End Post
90°
ELEVATION AT TERMINAL TYPE ⑤
See Detail A (Typ)
4R1 @ 2 Eq Spa = 2'-5"
3" Cl (Typ)
3'-0"
4R2 @ 2 Eq Spa = 3'-6"
4'-0"
VIEW C-C
BILL OF REINFORCEMENT
Location | Mark | Number Req'd Per Anchorage Block
Anchorage Block | 4R1 | 3
4R2 | 3
Mass | 41 LB
Bending Diagrams
4R1 (Tie) (11'-5")
4R2 (Tie) (9'-1")
1½" x 2" Slots in ⅝" bar
Bar 6x ⅝ x 1'-2" (Typ)
1"φ Vent Hole in ⅝" Bar (Typ)
Anchorage Block
4'-9⅜"
3'-6⅝"
4R1
4R2
℄ Rail
1'-8"
Curb
Clear Roadway
Pay Limit for Bridge Railing
PLAN AT TERMINAL TYPE ⑤
(Bolts not shown)
Bar 6x ⅝
3½" Proj
1½" x 2" Slotted Hole
3" x 3" x ¼" ℙ Washer
1¼"φ x 1'-3" HS Bolt (4" Thd) w/2 Heavy Hex Nuts & 1 Washer or 1¼"φ x 1'-4" HS Threaded Rod w/3 Heavy Hex Nuts & 1 Washer (4 req'd per terminal)
DETAIL A
Note: 1) Either top or bottom rail in terminal section may be the longer rail.
2) Ensure each rail length is continuous over a minimum of two posts.
3) In rehabilitation work, ensure railing that cannot feasibly be made continuous over a minimum of two posts has a double-bolted splice.
4) Splices may be located on either side of post.
5) Not more than one splice is permitted per side of post, except at expansion splices.
6) Do not shop splice rails.
7) Ensure rail terminal section is in place and in proper alignment prior to placement of concrete in end anchorage block.
℄ 1"φ Holes in rail (Centered) for ¾"φ x 3½" HS Bolt w/ Hex Nut, Washer, & Lock Washer. Wrench tight, do not crush rail. (Typ) (All splices)
Standard Sleeve
TS 6x2x ¼ (Typ)
Expansion Sleeve
℄ Post
STANDARD SPLICE
(Top or bottom rail)
DOUBLE-BOLTED SPLICE
(Top or bottom rail)
EXPANSION SPLICE
(Top and bottom rail)
SPLICE DETAILS
WYOMING DEPARTMENT OF TRANSPORTATION
BRIDGE PROGRAM
REVISIONS
BRIDGE RAILING DETAILS
TL3_br4_V8.dgn
APPROVED
DATE
Design Section X
Drwg. No. X
Sheet X of X
Standard Sheet Dated 9-9-05
x.dgn

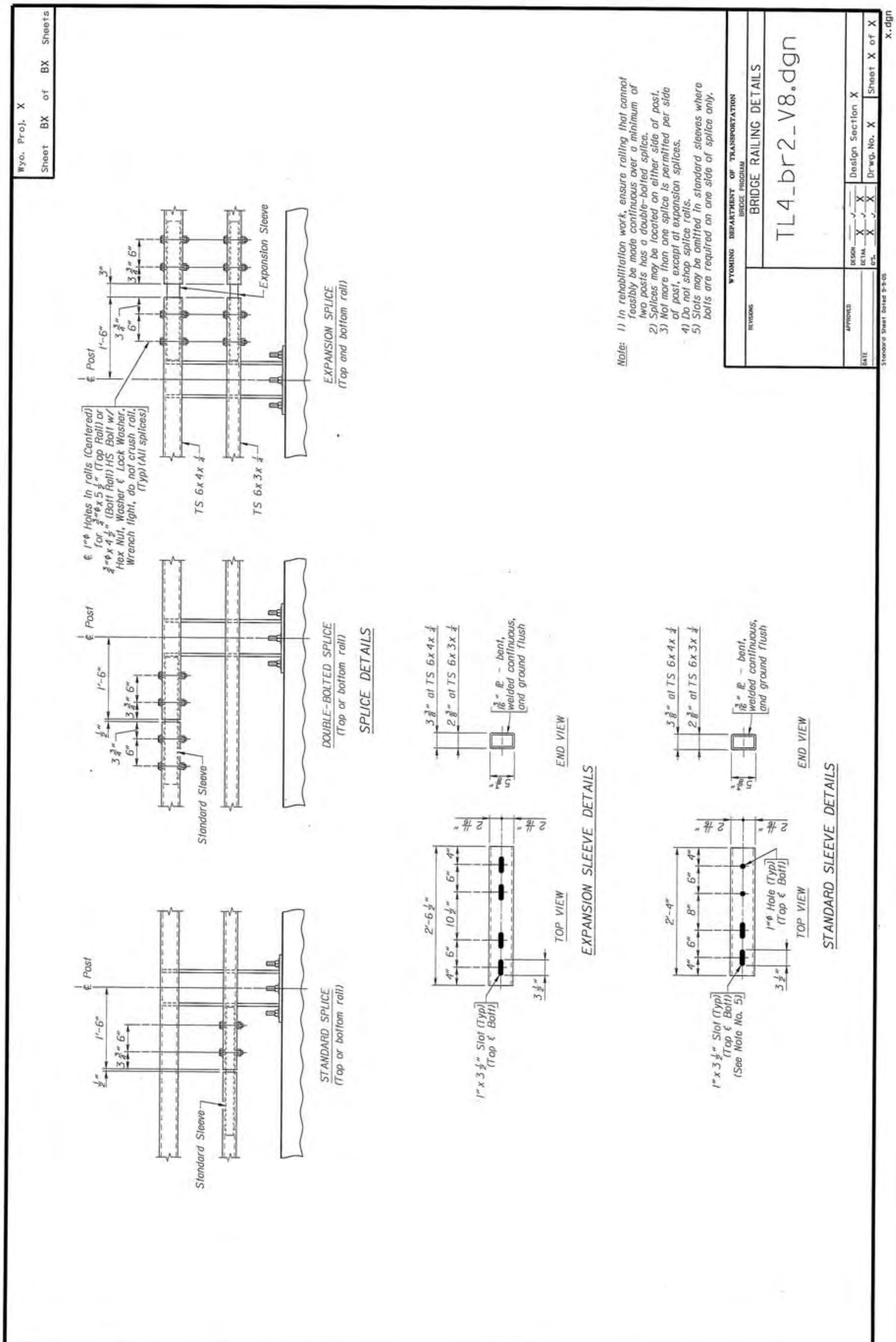
Wyoming TL4 details





Sidewalk
ASSEMBLY DETAIL
(Shown near ℄ Post)
(Bridge slab shown, approach slab similar)
Upper Anchorage (Place under and against top mat of reinforcing steel)
Lower Anchorage
Rail Bolt Assembly (See Rail Bolt Detail and Note No. 3)
7/8"φ x 1'-3 1/2" HS Bolt (5" thread) w/2 Hex Nuts & 2 Washers. Wrench tight. (3 req'd per post)
FF Sidewalk and Rails
Clear Roadway
VIEW A-A
(Anchor bolts, rails, and rail bolts not shown)
FF Sidewalk
PL 5/8 x 11 1/2 x 1'-2 1/2"
1 1/4"φ Hole (Typ)
TL4_brl_V8.dgn
Approach Slab
ASSEMBLY DETAIL
(Shown near ℄ Post)
7/8"φ x 1'-6" HS Bolt (5" thread) w/2 Hex Nuts & 2 Washers. Wrench tight. (3 req'd per post)
FF Curb and Rails
Approach Slab
NOTICE OPTIONAL CONST. JOINT AT EDGE OF ASPHALT IS REMOVED DUE TO UPPER ANCHORAGE
Curb and Sidewalk
ASSEMBLY DETAIL
(Shown near ℄ Post)
(Bridge slab shown, approach slab similar)
FF Curb or Sidewalk and Rails
VIEW A-A
FF Curb or Sidewalk
(Anchor bolts, rails, and rail bolts not shown)


Wyo. Proj. X
Sheet BX of BX Sheets
ELEVATION AT TERMINAL TYPE ①
(Box beam guardrail connection)
ELEVATION AT TERMINAL TYPE ②
(Box beam guardrail connection, Interstate exit end only)
(With provision for temporary corrugated beam guardrail connection)
ELEVATION AT TERMINAL TYPE ③
(Corrugated beam guardrail connection or no guardrail connection)
END VIEW
ELEVATION OF BENT PLATE FOR TOP RAIL
(TS 6x4x ¼ not shown)
ELEVATION OF BENT PLATE FOR BOTTOM RAIL
(TS 6x3x ¼ not shown)
RAIL TAPER PLATE DETAILS
BENT PLATE SECTION
(Top rail not shown)
(Req'd at Type ② and ③ Terminals)
BRACE BAR DETAIL
(See Note No. 3)
SECTION C-C
Note: 1) Either top or bottom rail in terminal section may be the longer rail.
2) Ensure each rail length is continuous over a minimum of two posts. Railing that is part of a type ② or ③ terminal is continuous if either the top or bottom rail in the terminal is continuous over a minimum of two posts.
3) Ensure a brace bar is placed 2'-0" from the splice end of the shorter tube at type ② and ③ terminals.
4) Ensure the fabricator prepares a sample of the indicated joint and it is macroetched to demonstrate that the required effective throat is achieved.
5) Cut top and bottom rails for Terminal Type ① as required for fabrication of tapered end sections.
WYOMING DEPARTMENT OF TRANSPORTATION
BRIDGE PROGRAM
BRIDGE RAILING DETAILS
TL4_br2_V8.dgn
Design Section X
Drwg. No. X
Sheet X of X
x.dgn
Standard Sheet Dated 9-9-05


Wyo. Proj. X
Sheet BX of BX Sheets
STANDARD SPLICE
(Top or bottom rail)
DOUBLE-BOLTED SPLICE
(Top or bottom rail)
EXPANSION SPLICE
(Top and bottom rail)
SPLICE DETAILS
Standard Sleeve
Expansion Sleeve
℄ Post
1'-6"
3 3/4" 6"
1/2"
3"
℄ 1"φ Holes in rails (Centered) for 7/8"φ x 5 1/2" (Top Rail) or 7/8"φ x 4 1/2" (Bott Rail) HS Bolt w/ Hex Nut, Washer & Lock Washer. Wrench tight, do not crush rail. (Typ) (All splices)
TS 6x4x 1/4
TS 6x3x 1/4
1" x 3 1/2" Slot (Typ) (Top ℄ Bolt)
2'-6 1/2"
4" 6" 10 1/2" 6" 4"
3 1/2"
TOP VIEW
3 3/8" at TS 6x4x 1/4
2 3/8" at TS 6x3x 1/4
3/16" ℗ - bent, welded continuous, and ground flush
END VIEW
EXPANSION SLEEVE DETAILS
1" x 3 1/2" Slot (Typ) (Top ℄ Bolt) (See Note No. 5)
1"φ Hole (Typ) (Top ℄ Bolt)
2'-4"
4" 6" 8" 6" 4"
STANDARD SLEEVE DETAILS
Note: 1) In rehabilitation work, ensure railing that cannot feasibly be made continuous over a minimum of two posts has a double-bolted splice.
2) Splices may be located on either side of post.
3) Not more than one splice is permitted per side of post, except at expansion splices.
4) Do not shop splice rails.
5) Slots may be omitted in standard sleeves where bolts are required on one side of splice only.
WYOMING DEPARTMENT OF TRANSPORTATION
BRIDGE PROGRAM
BRIDGE RAILING DETAILS
TL4_br2_V8.dgn
Design Section X
Drwg. No. X
Sheet X of X
x.dgn