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CRASH-TESTED BRIDGE RAILINGS AND TRANSITIONS FOR WOOD BRIDGES – PHASE I

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16. Abstract

In the past, many timber bridge railings, bridge railings for use on timber deck bridges, and approach guardrail transition systems to accompany these railings have been developed to meet different impact safety criteria. Through an extensive literature review, the design details of these systems were identified and organized. A survey was then developed and distributed to multiple government agencies and timber industry members to identify the desire for such bridge railing and approach guardrail transition systems to be developed to meet current American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH) impact safety criteria. The data provided from the survey was analyzed by a research team, and a list of 15 systems with accompanying approach guardrail transitions was created. This list prioritizes the bridge railing systems based upon the number of survey respondents requesting such a bridge railing system. Cost estimates for the development of each bridge railing system were also provided in order to proceed into Phase II of this research project.

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1 INTRODUCTION

1.1 Background

Between 1988 and 2013, numerous bridge railing systems were developed for use on wood deck bridges in accordance with the impact safety criteria found in National Cooperative Highway Research Program (NCHRP) Report No. 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features* [1]; the American Association of State Highway and Transportation Officials (AASHTO) *Guide Specifications for Bridge Railings* [2]; and the AASHTO *Manual for Assessing Safety Hardware (MASH) 2009* [3]. In 2016, AASHTO's MASH was updated. Both MASH 2009 and MASH 2016 [4] included updated safety criteria which reflected current vehicles and characteristics, as well as new hardware categories, improved crash test documentation, objective vehicle damage criteria, and refined occupant risk limits. To date, only two bridge railing systems have been developed, only one of which has been crash tested, for use on wood bridges using the updated MASH 2016 testing conditions and criteria. Thus, there exists a need to develop new and/or modify existing bridge railing and approach guardrail transition systems for use on wood bridges under the MASH 2016 impact safety standards. For this effort, these systems would need to be subjected to crash testing along with an evaluation of the results.

In collaboration with the United States Department of Agriculture – Forest Service – Forest Products Laboratory (USDA – FS – FPL), the Midwest Roadside Safety Facility (MwRSF) of the University of Nebraska-Lincoln (UNL) initiated a project to (1) identify bridge railing systems that have been previously developed under prior safety criteria, (2) document bridge railings currently in use in the field, and (3) create a research plan to update selected bridge railing and approach guardrail transition systems to meet current AASHTO MASH 2016 impact safety standards.

1.2 Project Objectives & Scope

The primary objectives of this Phase I research study were to identify previous cooperative projects that resulted in the development and crash testing of bridge railings for use on wood bridges in order to formulate a new design and crash testing program to develop new and/or upgrade existing bridge railings and approach guardrail transitions to meet current national impact safety standards.

This project focused on commonly-used, non-proprietary bridge railing systems. The systems consisted of sawn timber, glue-laminated (glulam) timber, steel, concrete, or any combination of the aforementioned materials. The future systems would be installed on many different deck types, including longitudinal or transverse glulam, nail-laminated, spike-laminated, or stress-laminated timber decks. In the past, some systems had even been modified for implementation on reinforced concrete or fiber-reinforced polymer decks.

1.3 Research Approach

The first step in this research process was to perform a literature review. This investigation was completed by searching through MwRSF's expansive library of research and test reports, journal articles, and conference papers written on bridge railing and approach guardrail transition

systems. Multiple searches were also performed using online databases, including but not limited to, the Transportation Research Board's (TRB) Transport Research International Documentation (TRID) database and Google Scholar. In searching through these sources, all reports and papers covering bridge railing systems attached to timber bridge decks, timber bridge railings anchored to concrete bridge decks, or approach guardrail transitions developed for these systems were acquired, reviewed, and compiled into Sections 2 through 5 of this report.

An electronic informational survey was also developed and submitted to consultants and contractors, as well as Federal and State government agencies to obtain details regarding bridge railing systems currently in use. The survey also served as a means to obtain feedback from these groups in regard to the systems that they would like to see updated and/or developed to meet the current AASHTO MASH 2016 standards. More information on this survey can be found in Section 6 of this report, and a copy of the survey can be found in Appendix A.

Using information gathered from the literature review and survey, as well as the opinions of the research team, a priority listing of bridge railing and approach guardrail transition systems was created for guiding the future redesign, upgrade, testing, and evaluation under the AASHTO MASH 2016 impact safety criteria. A global priority list of research projects with rough estimated budgets and bulleted lists of tasks was created for each set of bridge railing and approach guardrail transition systems. This summary is tabulated in Section 7 of this report.

2 LITERATURE REVIEW

2.1 Literature Review

For this research project, an in-depth investigation was conducted to identify all crashworthy bridge railing systems developed for use on wood bridge decks, wood bridge railings that were developed for reinforced concrete decks, as well as approach guardrail transitions that were developed for use with the existing bridge railings. To do so, a common literature review was performed, as well as searches through multiple web-based, online sources of standard details and plans, research reports, test reports, journal articles, conference papers, and webpages. From this literature review, 25 bridge railing systems were discovered, 14 of which were also developed with a guardrail to bridge railing transition or end treatment. For each bridge railing, transition, or end treatment, multiple pieces of information were collected, including:

- System name,
- Test specification,
- Test or performance level,
- Test details,
- Deck type,
- System materials,
- Research sponsor, and
- Research or test agency.

The test specification refers to the standards that were used to crash test and evaluate the system. For example, NCHRP Report No. 350 [1] or AASHTO *Guide Specifications for Bridge Railings* [2] would both be considered test specifications. The test details contain information about the type and weight of vehicle used in testing, the impact speed, and the impact angle. Further, schematics and photographs of each system were gathered, if available.

A search was also performed to find consulting groups, contractors, and fabricators that design, supply, and build wood bridges across the United States. Using commercial websites, additional information and images of existing bridge railing systems were collected. The organizations that were found and investigated included the following:

- Alamco Wood Products, LLC/Bell Structural Solutions; Albert Lea, MN;
- Backwoods Bridges; Freeport, FL;
- Bridge Builders USA, Inc.; Otto, NC;
- Laminated Concepts Inc.; Big Flats, NY;
- Nature Bridges; Monticello, FL;
- Western Wood Structures; Tualatin, OR;
- Wheeler Lumber LLC/Erickson Engineering; Eden Prairie, MN; and

- York Bridge Concepts; Lutz, FL.

It was found that many of these companies use bridge railing systems similar to those that have been tested in the past, but with slight modifications or deviations. For this reason, these companies were also contacted during the survey portion of this research project in order to obtain more information.

Systems found through the literature review were then organized based on key characteristics and broken down into families of systems. The research team identified seven different families of systems, six of which were later considered for new research and development in the survey portion of this project. These seven families will be identified and examples will be shown in the next section of this report.

3 BRIDGE RAILING SYSTEMS

3.1 Introduction

Section 3 provides an overview of 25 bridge railings for timber deck bridges or timber bridge railings for other deck types, such as reinforced concrete. As previously stated, seven families of systems were identified through the literature review. The seven families of systems are as follows: (1) Low-Height, Curb-Type Systems, (2) Timber Railing without Curb Systems, (3) Timber Railing with Curb Systems, (4) Timber Barrier Systems, (5) W-Beam Systems, (6) Thrie Beam Systems, and (7) Steel-Backed Timber Systems. In this chapter, Sections 3.2 through 3.4 detail Low-Height, Curb-Type Systems, Sections 3.5 through 3.7 detail Timber Railing without Curb Systems, Sections 3.8 through 3.13 detail Timber Railing with Curb Systems, Section 3.14 details a Timber Barrier System, Sections 3.15 through 3.18 detail W-Beam Systems, Sections 3.19 through 3.23 detail Thrie Beam Systems, and Sections 3.24 through 3.26 detail Steel-Backed Timber Systems. It should be noted that the Timber Barrier System family was not offered for future development in the survey portion of this research project.

3.2 Low-Height, Curb-Type, Timber Bridge Railing [5-11]

Test Specification: NCHRP Report No. 350 [1]

Test Level: Sub-Test Level 1 (TL-1)

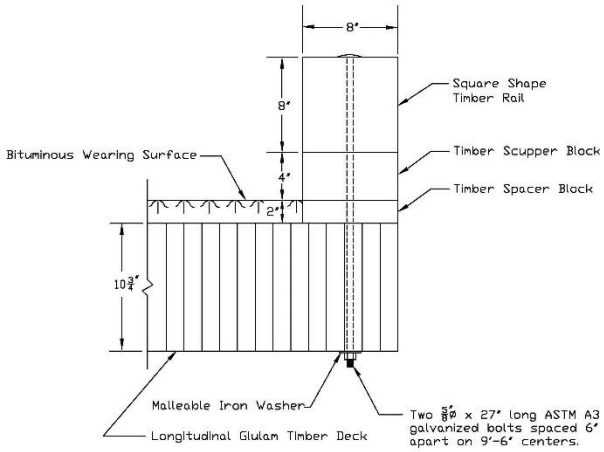
Test Details: 4,406-lb pickup truck, 14.4 mph, 15 degrees

Deck Type: Longitudinal, Glue-Laminated (Glulam) Timber Deck

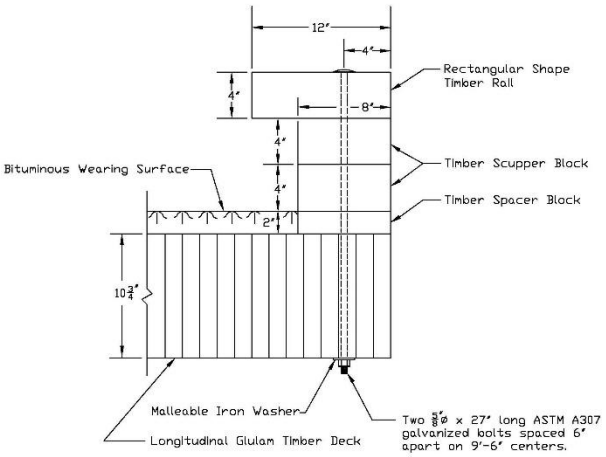
System Material: Sawn Timber Rail and Scuppers

Research Sponsor: USDA – FS – FPL

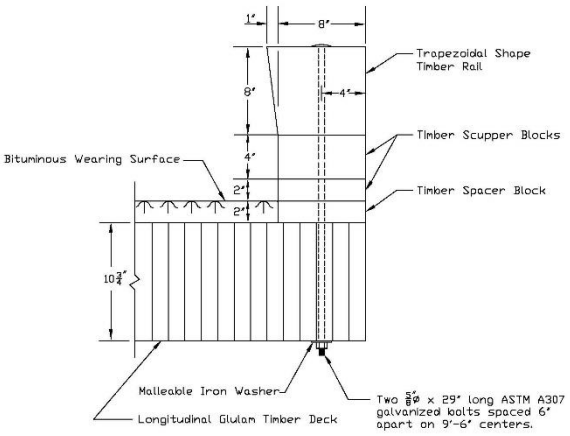
Research/Test Agency: MwRSF – UNL



(a) 12-in. Tall Square



(b) 12-in. Tall Rectangle



(c) 14-in. Tall Trapezoid

Figure 1. Schematics of Low-Height, Curb-Type, Timber Bridge Railing: (a) 12-in. Tall Square; (b) 12-in. Tall Rectangle; and (c) 14-in. Tall Trapezoid

Figure 2. Low-Height, Curb-Type, Timber Bridge Railing: 12-in. Tall Square

3.3 Low-Height, Curb-Type, Glulam Bridge Railing [7-13]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-1

Test Details: 4,435-lb pickup truck, 31.6 mph, 24.3 degrees

Deck Type: Longitudinal, Glulam Timber Deck

System Details: Glulam Timber Rail with Sawn Timber Scuppers

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

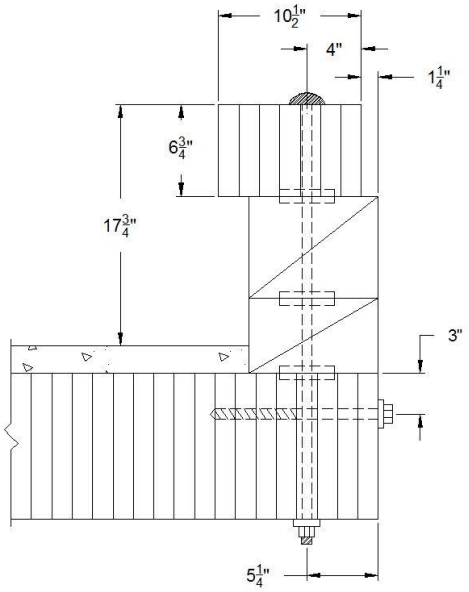


Figure 3. Schematic of Low-Height, Curb-Type, Glulam Bridge Railing

Figure 4. Low-Height, Curb-Type, Glulam Bridge Railing

3.4 Low-Height, Curb-Type, Glulam Bridge Railing [14, 15]

Test Specification: AASHTO MASH 2009 [3]

Test Level: TL-1

Test Details: 5,007-lb pickup truck, 30.8 mph, 26.1 degrees

Deck Type: Transverse, Nail-Laminated Timber Deck

System Materials: Glulam Timber Rail with Sawn Timber Scuppers

Research Sponsor: West Virginia Department of Transportation (WVDOT)

Research/Test Agency: MwRSF – UNL

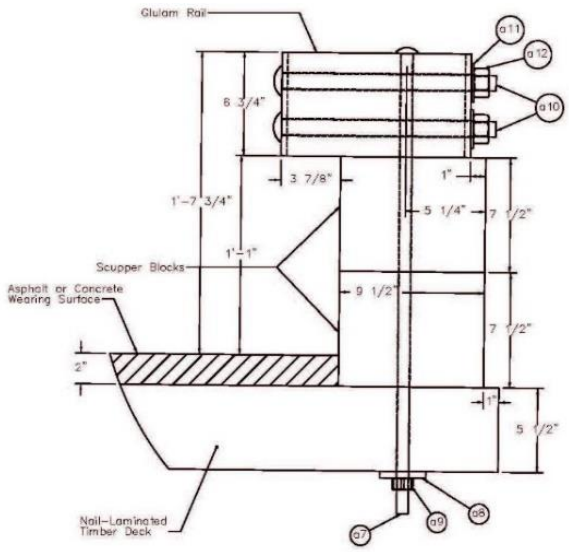


Figure 5. Schematic of Low-Height, Curb-Type, Glulam Bridge Railing

Figure 6. Low-Height, Curb-Type, Glulam Bridge Railing

Note: This bridge rail was developed for use with the Low-Height, Curb-Type, Glulam Bridge Railing End Treatment found in Section 4.2 of this report.

3.5 "Shoe Box System"/Glulam Timber Rail without Curb Bridge Railing [7, 9, 11, 13, 16-22]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: Performance Level 1 (PL-1)

Test Details: 5,400-lb pickup truck, 45.0 mph, 21.8 degrees; 1,849-lb car, 50.1 mph, 21.5 degrees

Deck Type: Longitudinal, Glulam Timber Deck

System Material: Glulam Timber Rail with Sawn Timber Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

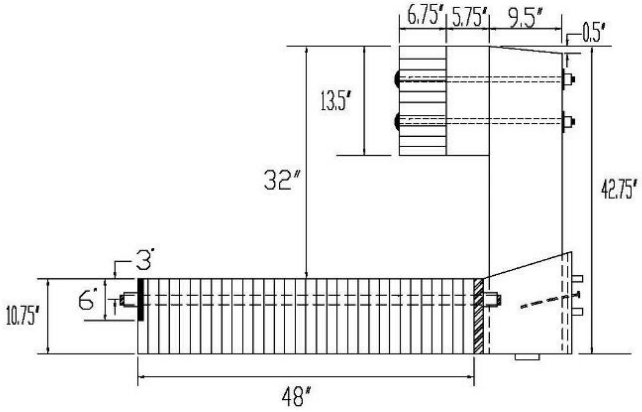


Figure 7. Schematic of "Shoe Box System" Bridge Railing

Figure 8. "Shoe Box System" Bridge Railing

Note: This bridge railing was developed for use with the "Shoe Box System" Transition found in Section 4.3 of this report.

3.6 Timber Bridge Rail System I [23, 24]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-1

Test Details: 1,800-lb car, 50.1 mph, 18.6 degrees; 5,400-lb pickup truck, 46.0 mph, 20.3 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Glulam Timber Rail with Sawn Timber Posts

Research Sponsor: United States Department of Transportation – Federal Highway Administrations (USDOT – FHWA) – Office of Engineering and Highway Operations

Research/Test Agency: Constructed Facilities Center – West Virginia University (CFC – WVU) and Texas A&M Transportation Institute (TTI)

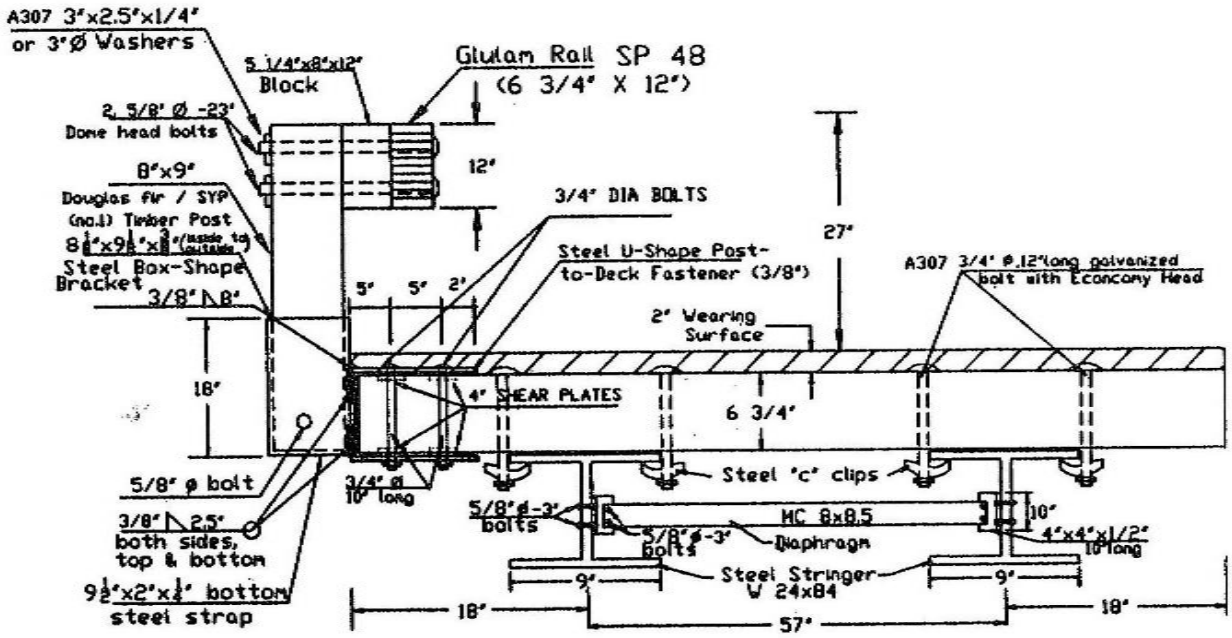


Figure 9. Schematic of Timber Bridge Rail System I (No Photographs Available)

Note: This bridge railing was developed for use with the Timber Bridge Rail System I Transition found in Section 4.4 of this report.

3.7 Glulam Timber Bridge Railing [25, 26]

Test Specification: NCHRP Report No. 350 [1]

Test Level: Test Level 2 (TL-2)

Test Details: 4,478-lb pickup truck, 42.9 mph, 26.2 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Glulam Timber Rail and Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

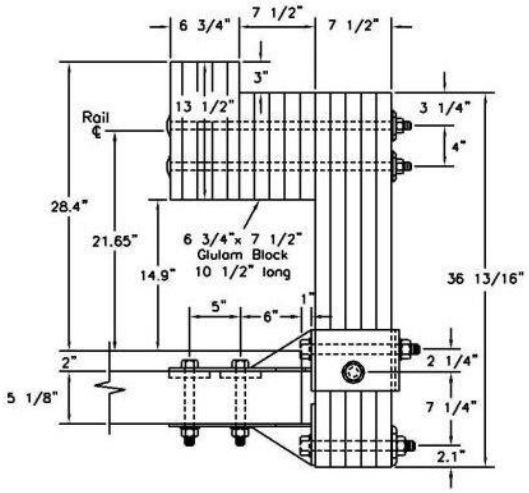


Figure 10. Schematic of Glulam Timber Bridge Railing

Figure 11. Glulam Timber Bridge Railing

Note: This bridge railing was developed for use with the Glulam Timber Bridge Railing/Nested W-Beam Guardrail Transition found in Section 4.5 of this report.

3.8 Glulam Bridge Rail [27]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-1 (Preliminary Guidelines)

Test Details: 1,983-lb car, 59.2 mph, 20.0 degrees; 5,419-lb pickup truck, 47.5 mph, 20.0 degrees

Deck Type: Glulam Timber Deck

System Material: Glulam Timber Rail with Sawn Timber Curb and Posts

Research Sponsor USDOT – FHWA – Office of Traffic and Safety Operations

Research/Test Agency: The Scientex Corporation

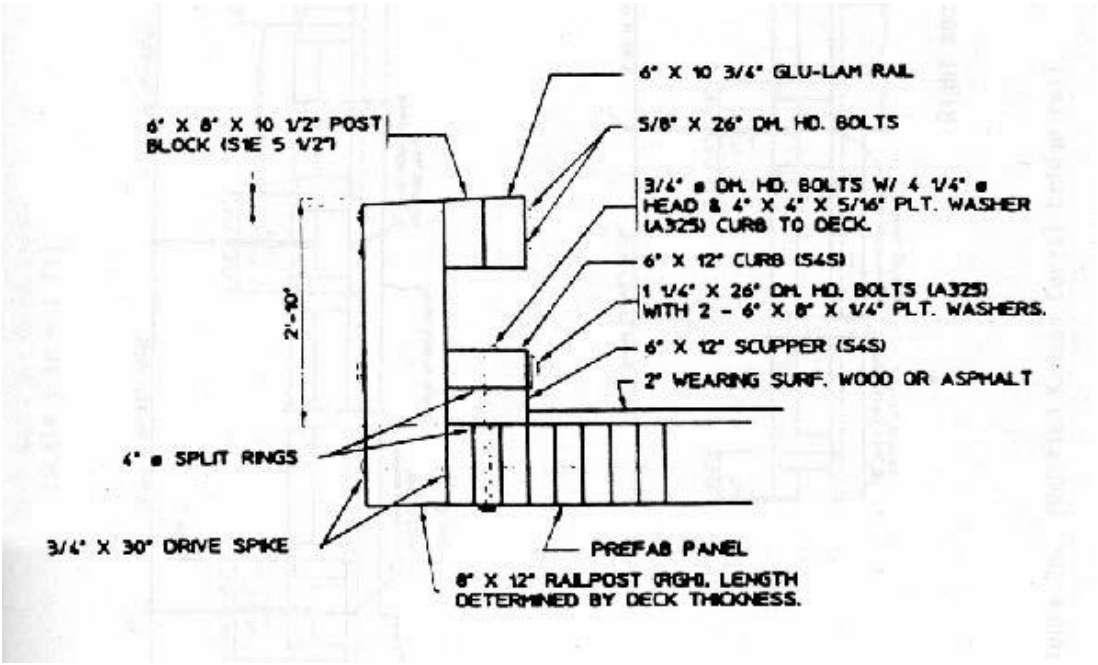


Figure 12. Schematic of Glulam Bridge Rail

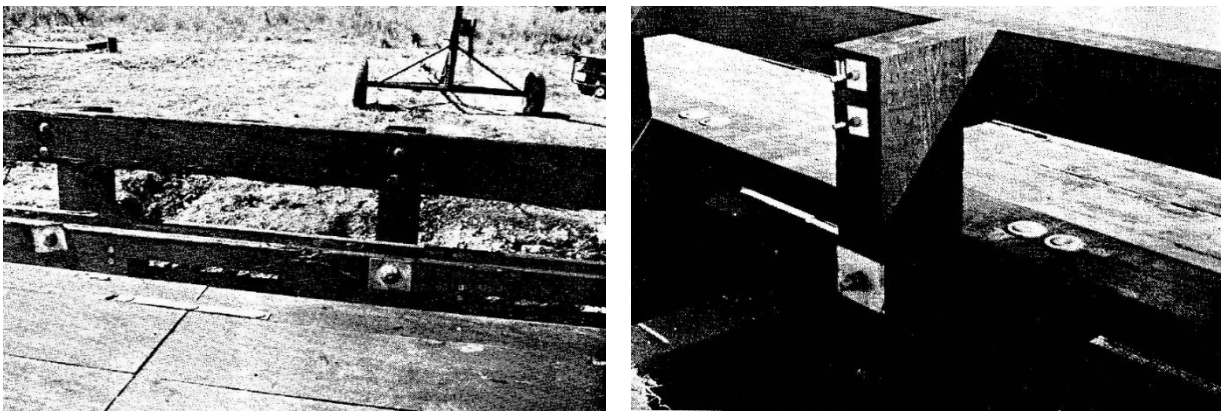


Figure 13. Glulam Bridge Rail

3.9 Weyerhaeuser Traffic Rail [28]

Test Specification: 1975 AASHTO Interim Specifications for Highway Bridges [29]

Performance Level: NA

Test Details: Static Load Testing Only

Deck Type: Longitudinal, Glulam Timber Deck

System Materials: Glulam Timber Curb and Rail with Sawn Timber Posts

Research Sponsor: Weyerhaeuser Company

Research/Test Agency: Weyerhaeuser Company

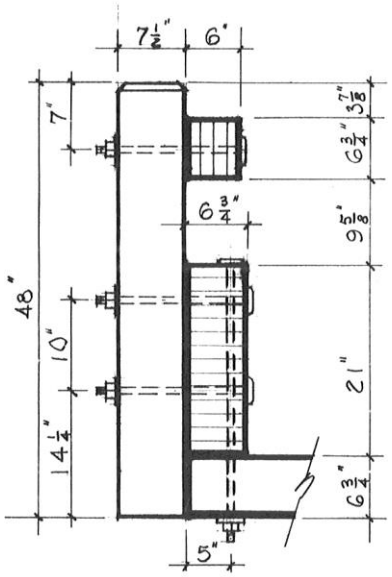


Figure 14. Schematic of Weyerhaeuser Traffic Rail

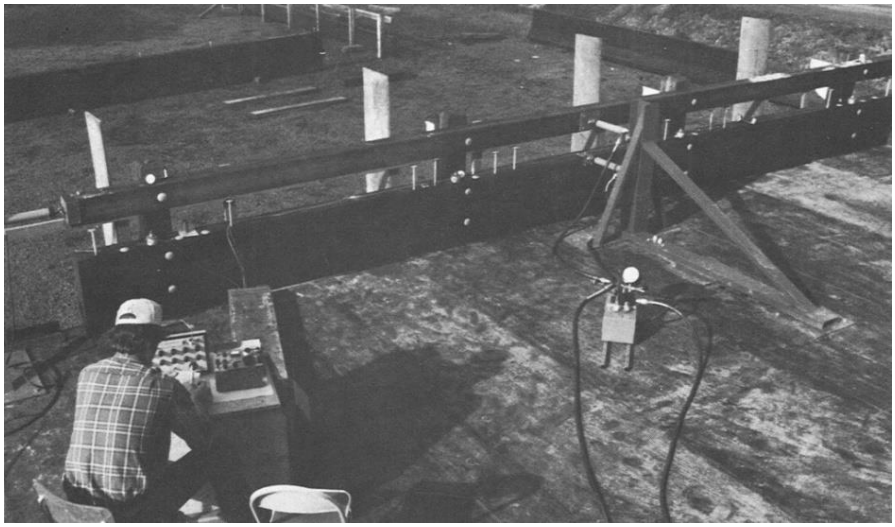


Figure 15. Weyerhaeuser Traffic Rail

3.10 "Curb System"/Glulam Timber Rail with Curb Bridge Railing [7, 9, 11, 13, 16-22]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-1

Test Details: 5,400-lb pickup truck, 44.1 mph, 23.4 degrees

Deck Type: Longitudinal, Glulam Timber Deck

System Materials: Glulam Timber Rail with Sawn Timber Curb and Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

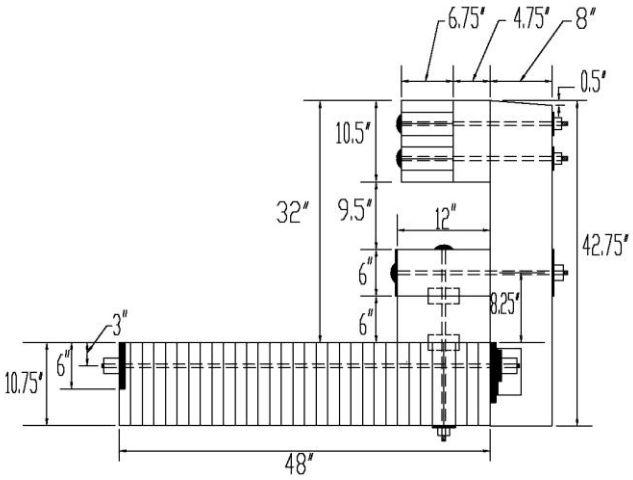


Figure 16. Schematic of "Curb System" Bridge Railing

Figure 17. "Curb System" Bridge Railing

Note: This bridge railing was developed for use with the "Curb System" Transition found in Section 4.6 of this report.

3.11 Timber Bridge Rail System II [23, 24]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-1

Test Details: 1,800-lb car, 49.7 mph, 21.0 degrees; 5,400-lb pickup truck, 46.1 mph, 19.1 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Glulam Timber Rail with Sawn Timber Curb and Posts

Research Sponsor: USDOT – FHWA – Office of Engineering and Highway Operations

Research/Test Agency: CFC – WVU and TTI

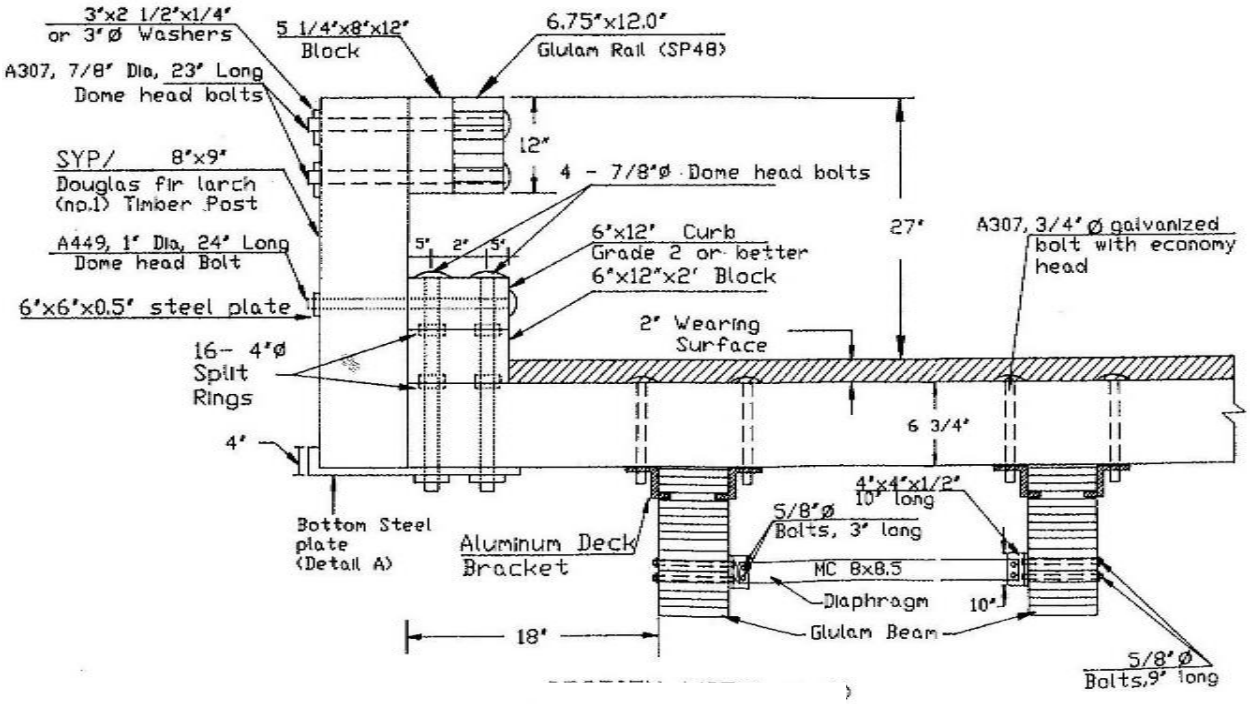


Figure 18. Schematic of Timber Bridge Rail System II (No Photographs Available)

Note: This bridge railing was developed for use with the Timber Bridge Rail System II Transition found in Section 4.7 of this report.

3.12 Glulam Timber Rail with Curb Bridge Railing (GC-8000) [7, 9, 11, 13, 20-22, 30, 31]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2] and NCHRP Report No. 350 [1]

Test Level: Performance Level 2 (PL-2) and Test Level 4 (TL-4)

Test Details: 18,000-lb single-unit truck, 51.2 mph, 16.8 degrees; 4,509-lb pickup truck, 57.5 mph, 21.8 degrees; 4,600-lb pickup truck, 60.9 mph, 24.9 degrees

Deck Type: Longitudinal, Glulam Timber Deck

System Materials: Glulam Timber Rail with Sawn Timber Curb and Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

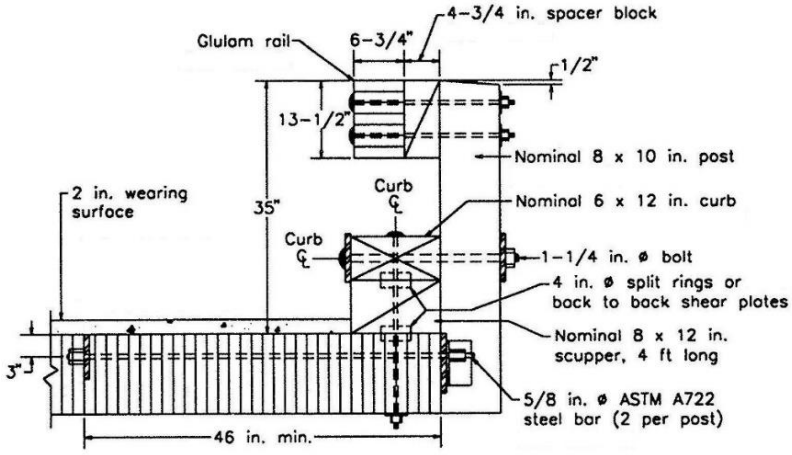


Figure 19. Schematic of GC-8000 Bridge Railing

Figure 20. GC-8000 Bridge Railing

Note: This bridge railing was developed for use with the GC-8000/Standard W-Beam Guardrail Transition found in Section 4.8 of this report.

3.13 Glulam Timber Rail with Curb Bridge Railing [9-11, 32, 33]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-4

Test Details: 17,637-lb single-unit truck, 46.5 mph, 16.0 degrees; 4,394-lb pickup truck, 61.6 mph, 27.4 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Glulam Timber Rail, Curb, and Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

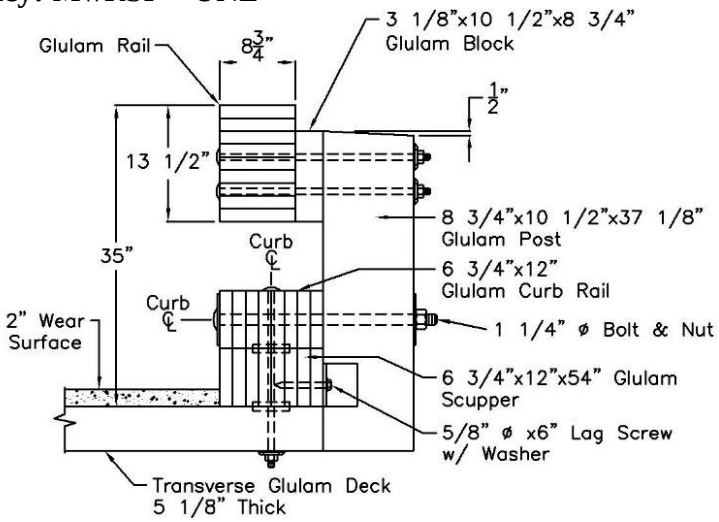


Figure 21. Schematic of Glulam Timber Rail with Curb Bridge Railing

Figure 22. Glulam Timber Rail with Curb Bridge Railing

Note: This bridge railing was developed for use with the Glulam Timber Rail with Curb Bridge Railing/Standard W-Beam Guardrail Transition found in Section 4.9 of this report.

3.14 Weyerhaeuser Traffic Barrier [28]

Test Specification: 1975 AASHTO Interim Specifications for Highway Bridges [29]

Performance Level: NA

Test Details: Static Load Testing Only

Deck Type: Longitudinal, Glulam Timber Deck

System Materials: Glulam Timber Components

Research Sponsor: Weyerhaeuser Company

Research/Test Agency: Weyerhaeuser Company

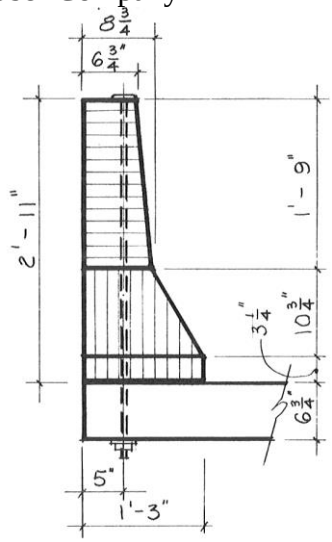


Figure 23. Schematic of Weyerhaeuser Traffic Barrier

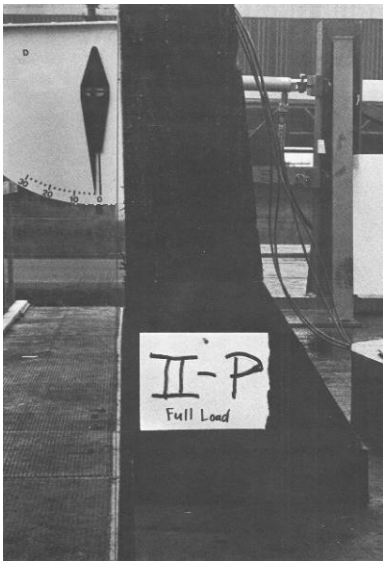


Figure 24. Weyerhaeuser Traffic Barrier

3.15 Flexible, W-Beam Bridge Railing [6-11, 34]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-1

Test Details: 4,504-lb pickup truck, 30.6 mph, 24.9 degrees

Deck Type: Longitudinal, Glulam Timber Deck

System Materials: Steel Rail with Sawn Timber Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

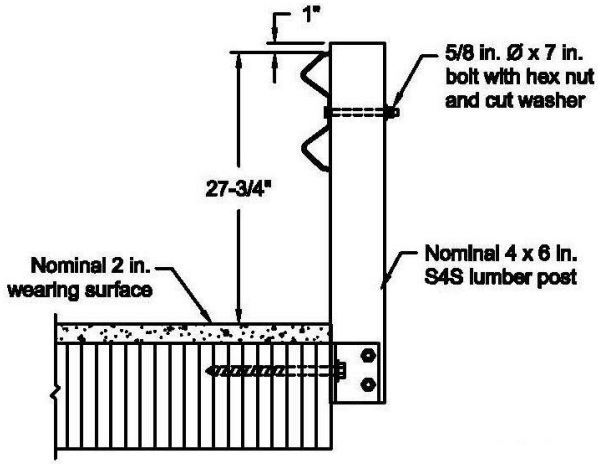


Figure 25. Schematic of Flexible, W-Beam Bridge Railing

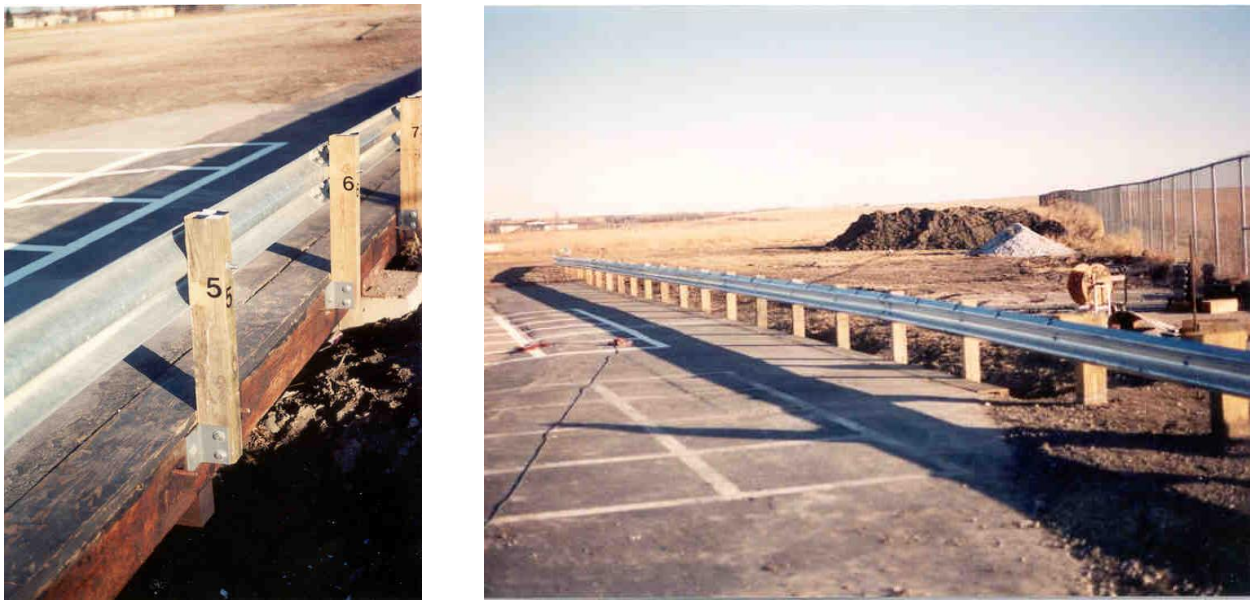


Figure 26. Flexible, W-Beam Bridge Railing

3.16 Semi-Rigid, Top-Mounted, W-Beam Bridge Railing [7-11, 35]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-1

Test Details: 4,412-lb pickup truck, 31.8 mph, 25.2 degrees

Deck Type: Longitudinal, Glulam Timber Deck

System Material: Steel Rail and Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

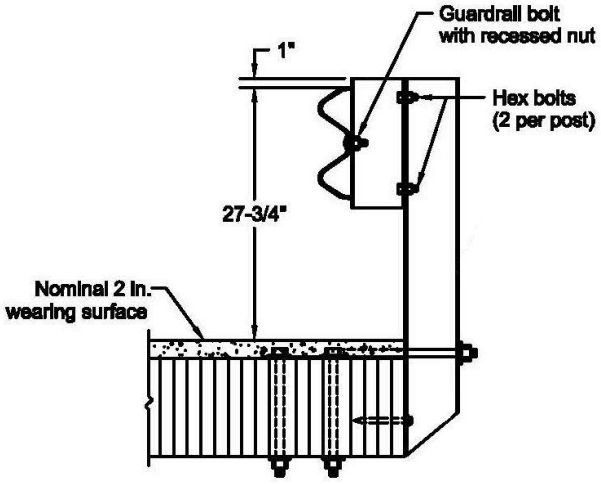


Figure 27. Schematic of Semi-Rigid, Top-Mounted, W-Beam Bridge Railing

Figure 28. Semi-Rigid, Top-Mounted, W-Beam Bridge Railing

3.17 W-Beam Bridge Rail [36]

Test Specification: AASHTO MASH 2009 [3]

Test Level: Test Level 3 (TL-3)

Test Details: Not Tested

Deck Type: Transverse, Glulam Timber Deck

System Material: Steel Rail and Posts

Research Sponsor: Roadside Safety Research Program Pooled Fund

Research/Test Agency: TTI

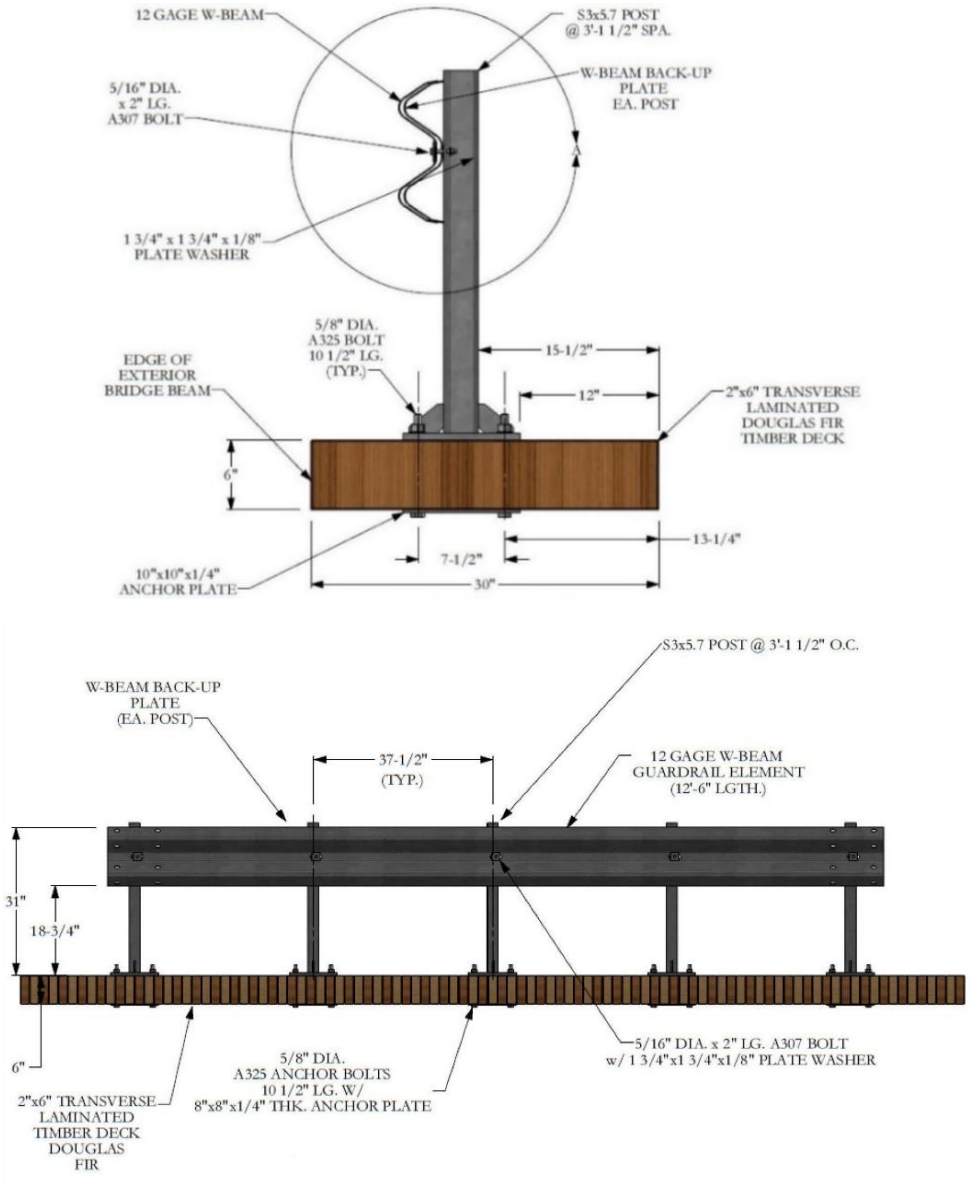


Figure 29. Schematics of W-Beam Bridge Rail (No Photographs Available)

3.18 Timber Bridge Rail System III [23, 24]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-1

Test Details: 1,800-lb car, 51.0 mph, 20.4 degrees; 5,400-lb pickup truck, 47.0 mph, 20.5 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Steel Rail with Sawn Timber Posts

Research Sponsor: USDOT – FHWA – Office of Engineering and Highway Operations

Research/Test Agency: CFC – WVU and TTI

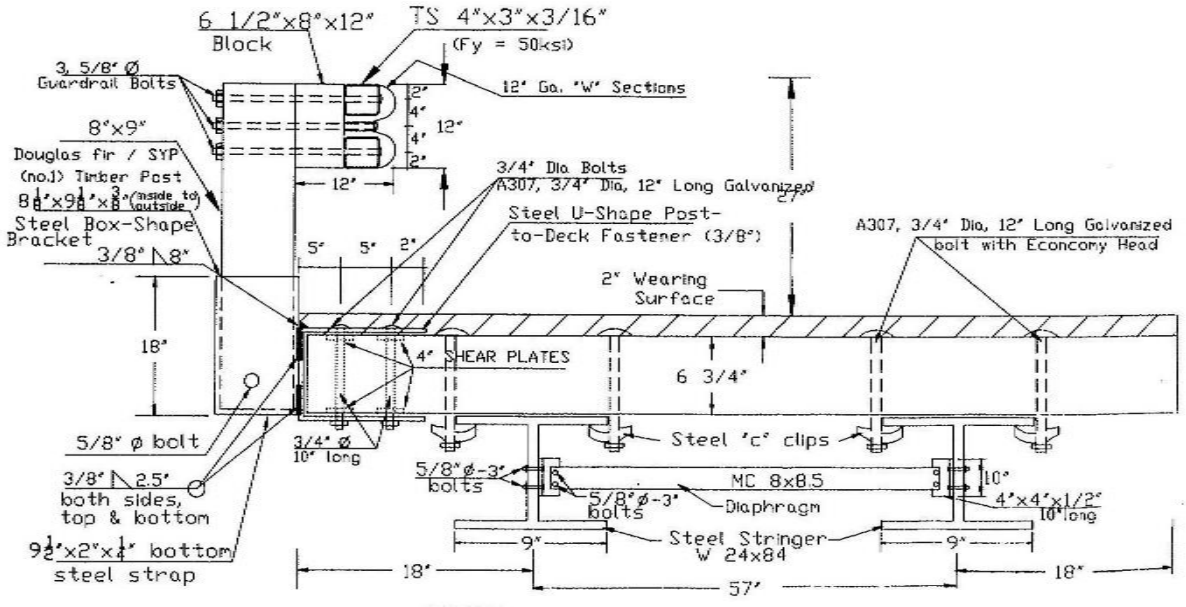


Figure 30. Schematic of Timber Bridge Rail System III (No Photographs Available)

Note: This bridge railing was developed for use with the Timber Bridge Rail System III Transition found in Section 4.10 of this report.

3.19 "Steel System"/Steel Thrie Beam Bridge Railing [7, 9, 11, 16-22]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-1

Test Details: 5,600-lb pickup truck, 44.2 mph, 19.1 degrees

Deck Type: Longitudinal, Glulam Timber Deck

System Material: Steel Rail and Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

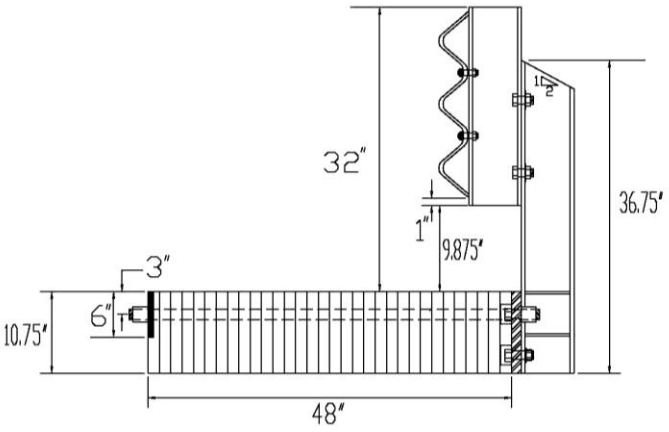


Figure 31. Schematic of "Steel System" Bridge Railing

Figure 32. "Steel System" Bridge Railing

Note: This bridge railing was developed for use with the "Steel System" Transition found in Section 4.11 of this report.

3.20 Steel Thrie Beam with Structural Channel Bridge Railing (TBC-8000) [7, 9, 11, 20-22, 30, 37]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-2

Test Details: 18,001-lb single-unit truck, 47.4 mph, 16.1 degrees

Deck Type: Longitudinal, Glulam Timber Deck

System Material: Steel Rail and Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

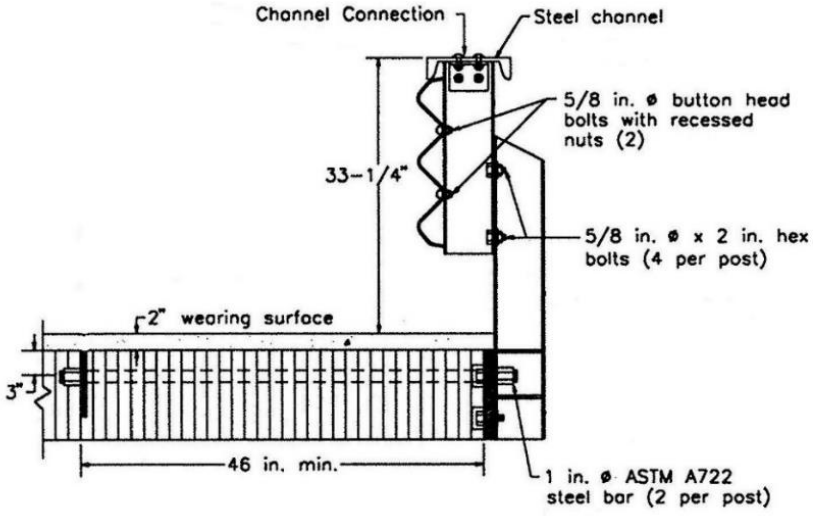


Figure 33. Schematic of TBC-8000 Bridge Railing

Figure 34. TBC-8000 Bridge Railing

Note: This bridge railing was developed for use with the TBC-8000/Standard W-Beam Guardrail Transition found in Section 4.12 of this report.

3.21 Steel Thrie Beam with Structural Channel Bridge Railing [25, 26]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-2

Test Details: 4,434-lb pickup truck, 41.4 mph, 25.6 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Steel Rail and Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

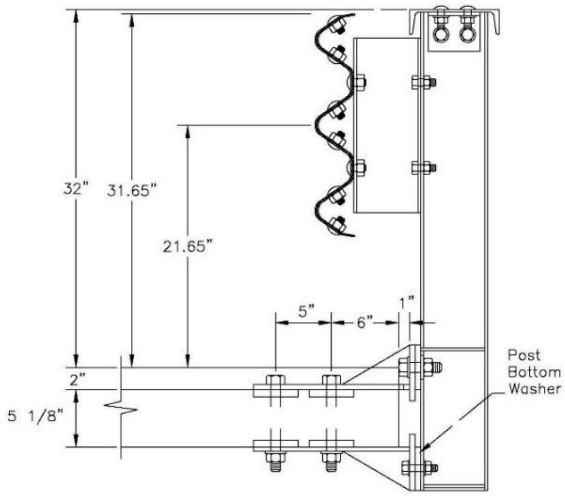


Figure 35. Schematic of Steel Thrie Beam with Structural Channel Bridge Railing

Figure 36. Steel Thrie Beam with Structural Channel Bridge Railing

Note: This bridge railing was developed for use with the Steel Thrie Beam with Structural Channel Bridge Railing/Standard W-Beam Guardrail Transition found in Section 4.13 of this report.

3.22 Steel Thrie Beam with Structural Channel Bridge Railing [38, 39]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-2

Test Details: Dynamic Component Testing Only

Deck Type: Transverse, Nail-Laminated Timber Deck

System Material: Steel Rail and Posts

Research Sponsor: WVDOT

Research/Test Agency: MwRSF – UNL

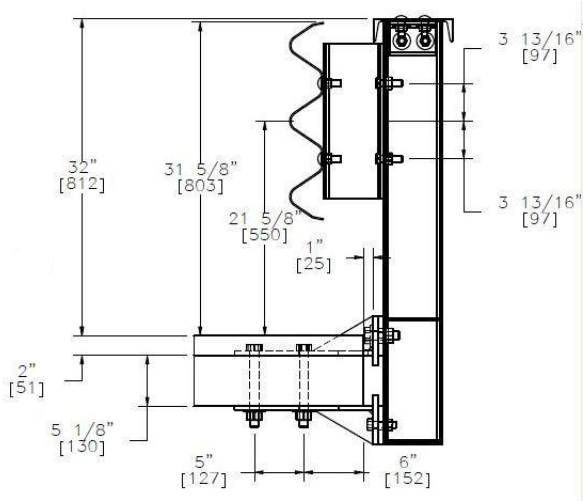


Figure 37. Schematic of Steel Thrie Beam with Structural Channel Bridge Railing

Figure 38. Steel Thrie Beam with Structural Channel Bridge Railing
(Adapted from original system on Transverse, Glulam Timber Bridge Deck, and only subjected to dynamic component testing)

3.23 Steel Thrie Beam with Structural Tube Bridge Railing [9-11, 32, 33, 40]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-4

Test Details: 4,496-lb pickup truck, 58.2 mph, 25.5 degrees; 18,975-lb single-unit truck, 47.5 mph, 14.6 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Steel Rail and Posts

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

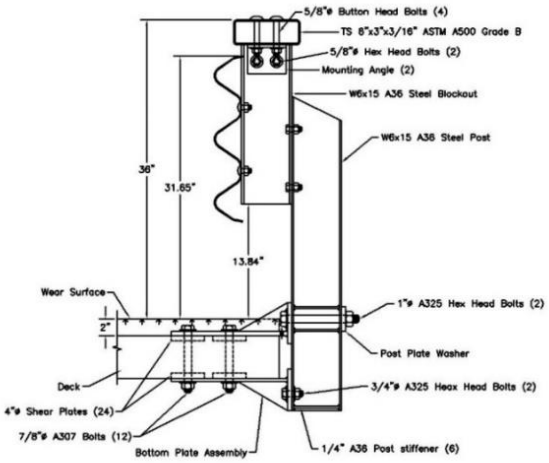


Figure 39. Schematic of Steel Thrie Beam with Structural Tube Bridge Railing

Figure 40. Steel Thrie Beam with Structural Tube Bridge Railing

Note: This bridge railing was developed for use with the Steel Thrie Beam with Structural Tube Bridge Railing/Standard W-Beam Guardrail Transition found in Section 4.14 of this report.

3.24 Glacier Removable Rail [41]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-1

Test Details: 1,843-lb car, 31.6 mph, 19.4 degrees; 4,409-lb pickup truck, 32.1 mph, 24.7 degrees

Deck Type: Concrete Deck

System Material: Timber Rail with Steel Posts

Research Sponsor: USDOT – FHWA – Office of Safety and Traffic Operations

Research/Test Agency: TTI

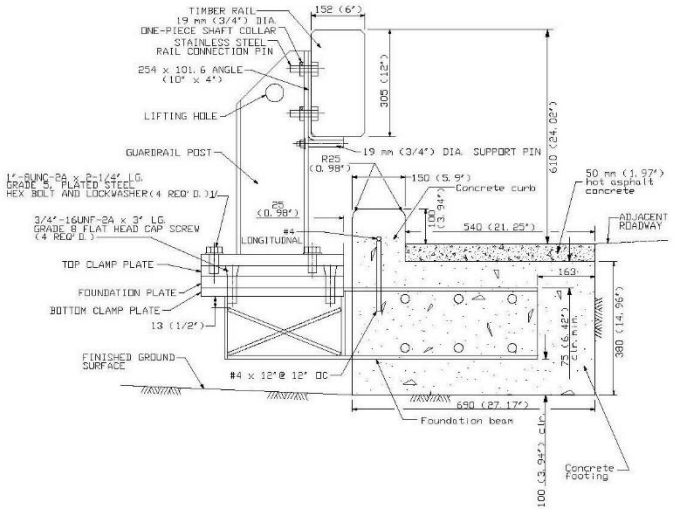


Figure 41. Schematic of Glacier Removable Rail

Figure 42. Glacier Removable Rail

3.25 Glacier Log Removable Rail [41]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-1

Test Details: 1,808-lb car, 31.6 mph, 20.9 degrees; 4,519-lb pickup truck, 31.7 mph, 26.1 degrees

Deck Type: Concrete Deck

System Material: Timber Rail with Steel Posts

Research Sponsor: USDOT – FHWA – Office of Safety and Traffic Operations

Research/Test Agency: TTI

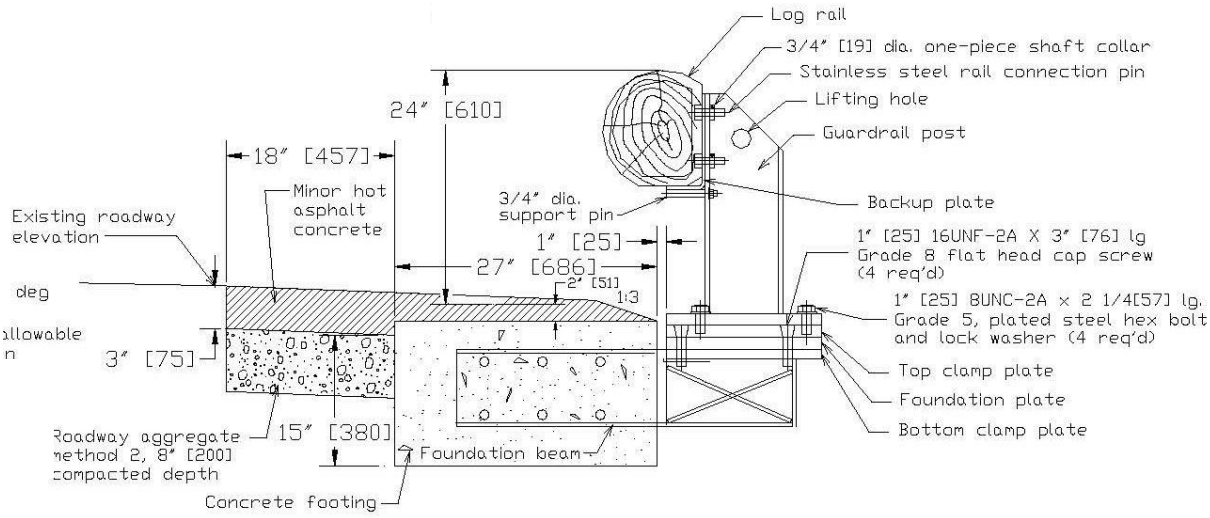


Figure 43. Schematic of Glacier Log Removable Rail

Figure 44. Glacier Log Removable Rail

3.26 Tubular Steel-Backed Timber Bridge Rail [41]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-3

Test Details: 4,597-lb pickup truck, 61.9 mph, 25.5 degrees

Deck Type: Concrete Deck

System Material: Timber Rail with Steel Posts

Research Sponsor: USDOT – FHWA – Office of Safety and Traffic Operations

Research/Test Agency: TTI

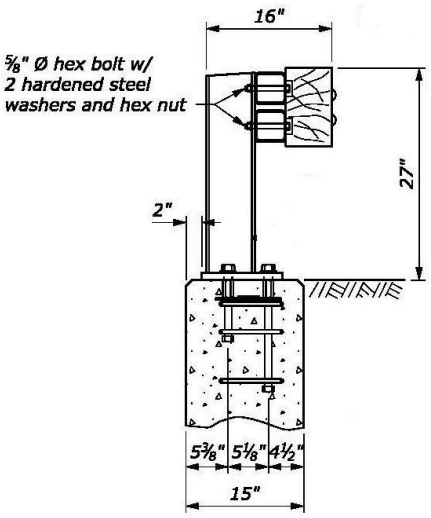


Figure 45. Schematic of Tubular Steel-Backer Timber Bridge Rail

Figure 46. Tubular Steel-Backed Timber Bridge Rail

Note: This bridge railing was developed for use with the Tubular Steel-Backed Timber Bridge Rail Transition found in Section 4.15 of this report.

4 GUARDRAIL TO BRIDGE RAILING TRANSITIONS AND END TREATMENTS

4.1 Introduction

Section 4 contains an overview of 14 approach guardrail transitions or end treatments for use with some bridge railings previously depicted in Section 3.

4.2 Low-Height, Curb-Type, Glulam Bridge Railing End Treatment [14, 15]

Test Specification: AASHTO MASH 2009 [3]

Test Level: TL-1

Test Details: Not Tested

Deck Type: Transverse, Nail-Laminated Timber Deck

System Materials: Glulam Timber Rail with Sawn Timber Scuppers

Research Sponsor: WVDOT

Research/Test Agency: MwRSF – UNL

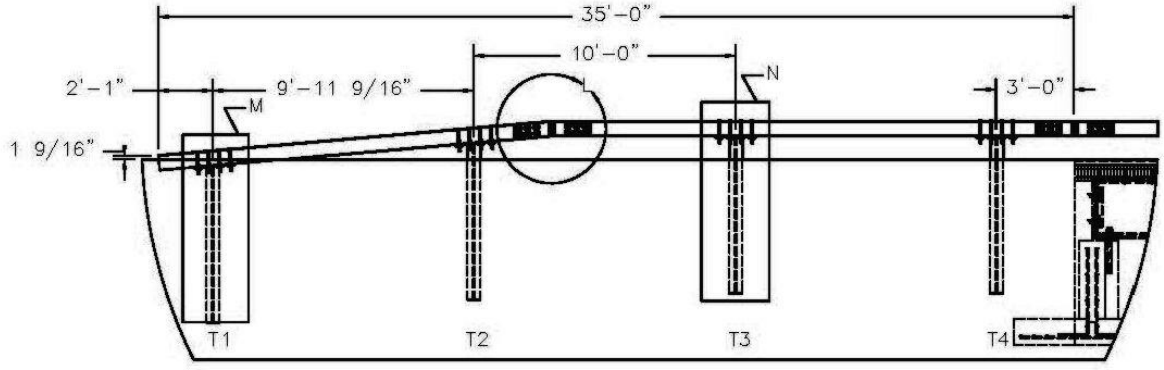


Figure 47. Schematic of Low-Height, Curb-Type, Glulam Bridge Railing End Treatment

Figure 48. Low-Height, Curb-Type, Glulam Bridge Railing End Treatment

Note: This transition was developed for use with the Low-Height, Curb-Type, Glulam Bridge Railing found in Section 3.4 of this report. No crash testing was performed on this end treatment. Crash testing would need to be performed under AASHTO MASH TL-1 criteria in order to receive an FHWA eligibility letter.

4.3 "Shoe Box System" Transition [18, 22]

Test Specification: NCHRP Report No. 230 [42]

Test Level: Multiple Service Level 1 (MSL-1)

Test Details: 4,430-lb sedan, 60.2 mph, 15.0 degrees

Deck Type: Longitudinal, Glulam Timber Deck

System Material: Steel Rail to Timber Rail Transition

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

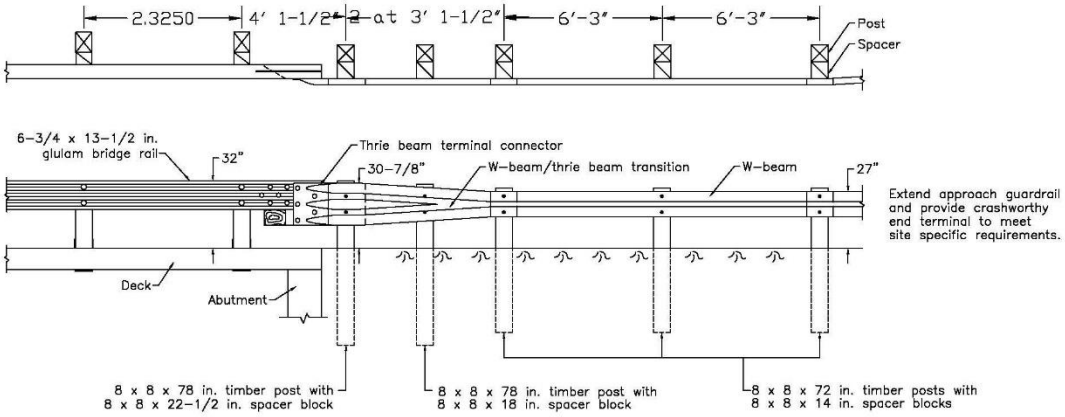


Figure 49. Schematic of "Shoe Box System" Transition

Figure 50. "Shoe Box System" Transition

Note: This transition was developed for use with the "Shoe Box System" Bridge Railing found in Section 3.5 of this report.

4.4 Timber Bridge Rail System I Transition [23, 24]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-1

Test Details: Not Tested

Deck Type: Transverse, Glulam Timber Deck

System Material: Continuous Timber Rail Transition

Research Sponsor: USDOT – FHWA – Office of Engineering and Highway Operations

Research/Test Agency: CFC – WVU and TTI

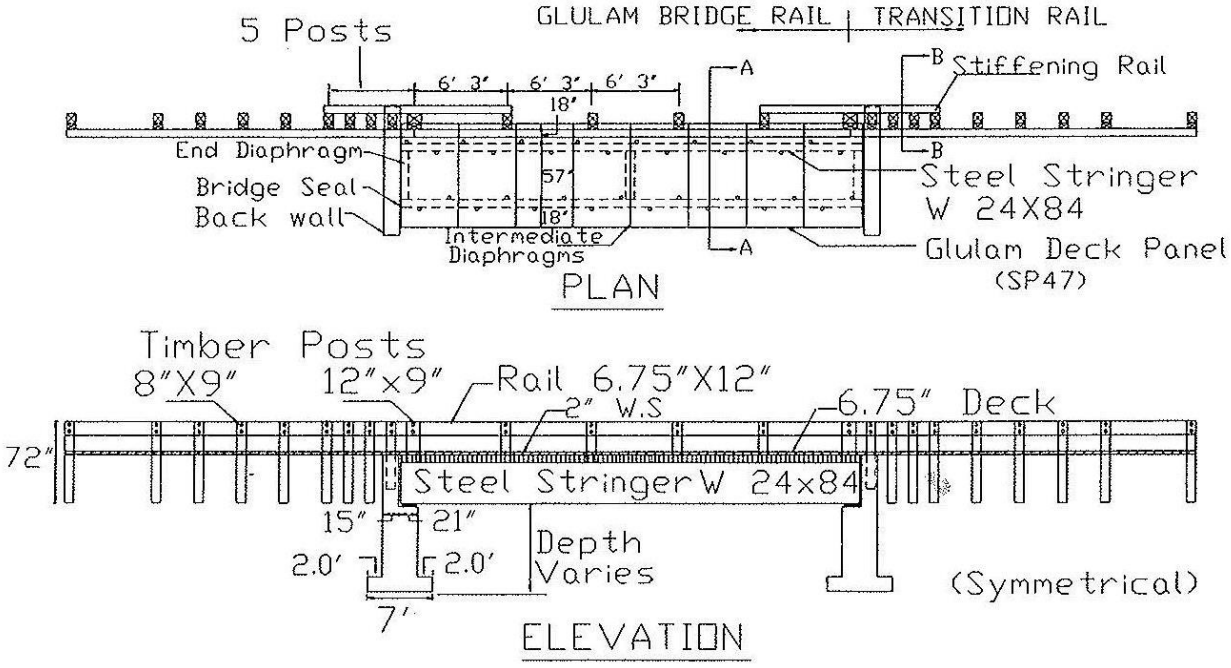


Figure 51. Schematic of Timber Bridge Rail System I Transition (No Photographs Available)

Note: This transition was developed for use with the Timber Bridge Rail System I found in Section 3.6 of this report. No crash testing was performed on this transition.

4.5 Glulam Timber Bridge Railing/Nested W-Beam Guardrail Transition [25, 26]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-2

Test Details: 4,433-lb pickup truck, 44.5 mph, 26.3 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Steel Rail to Timber Rail Transition

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

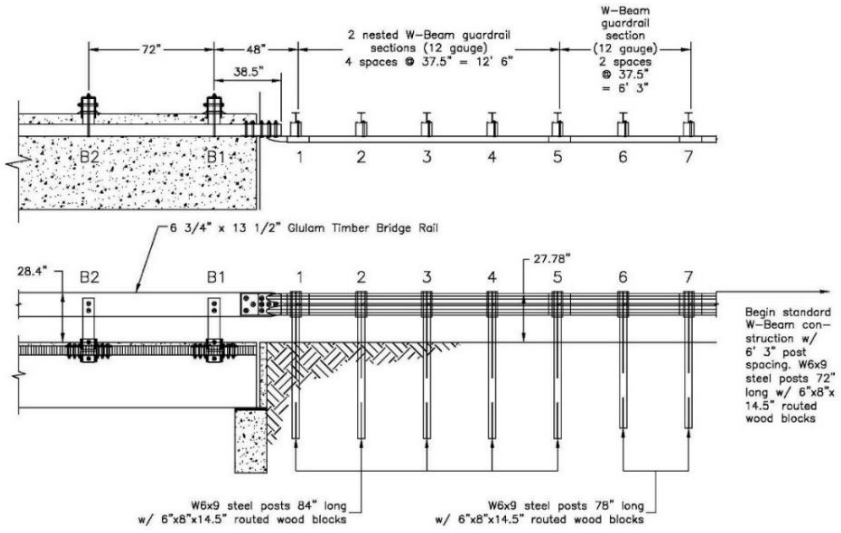


Figure 52. Schematic of Glulam Timber Bridge Railing/Nested W-Beam Guardrail Transition

Figure 53. Glulam Timber Bridge Railing/Nested W-Beam Guardrail Transition

Note: This transition was developed for use with the Glulam Timber Bridge Railing found in Section 3.7 of this report.

4.6 "Curb System" Transition [18, 22]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Test Level: PL-1

Test Details: Not Tested

Deck Type: Longitudinal, Glulam Timber Deck

System Material: Steel Rail to Timber Rail Transition

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

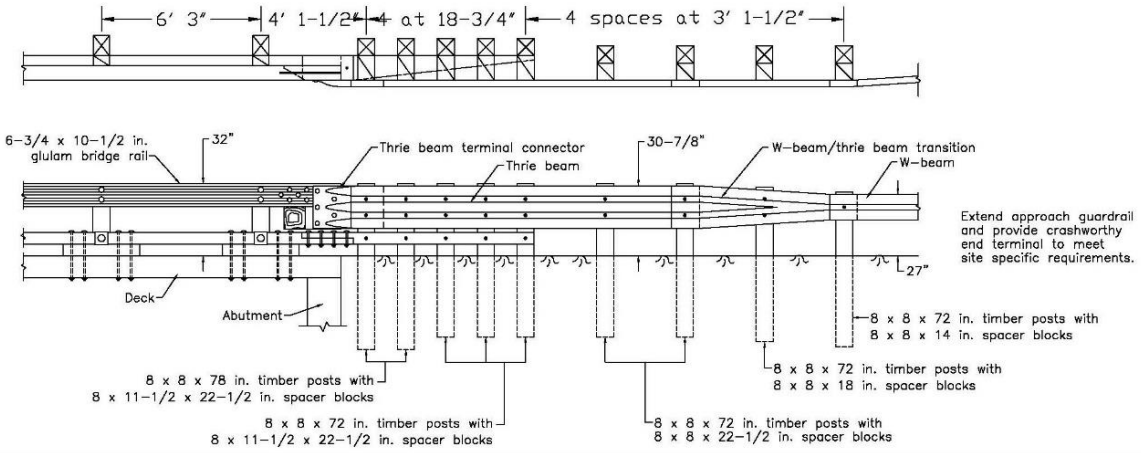


Figure 54. Schematic of "Curb System" Transition

Figure 55. "Curb System" Transition

Note: This transition was configured for anchoring the "Curb System" Bridge Railing found in Section 3.10 of this report. No crash testing was performed on this transition. The schematic shown was developed after testing to be similar to the GC-8000 Bridge Railing/Standard W-Beam Guardrail Transition (Section 4.8).

4.7 Timber Bridge Rail System II Transition [23, 24]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-1

Test Details: 5,400-lb pickup truck, 44.8 mph, 18.0 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Continuous Timber Rail Transition

Research Sponsor: USDOT – FHWA – Office of Engineering and Highway Operations

Research/Test Agency: CFC – WVU and TTI

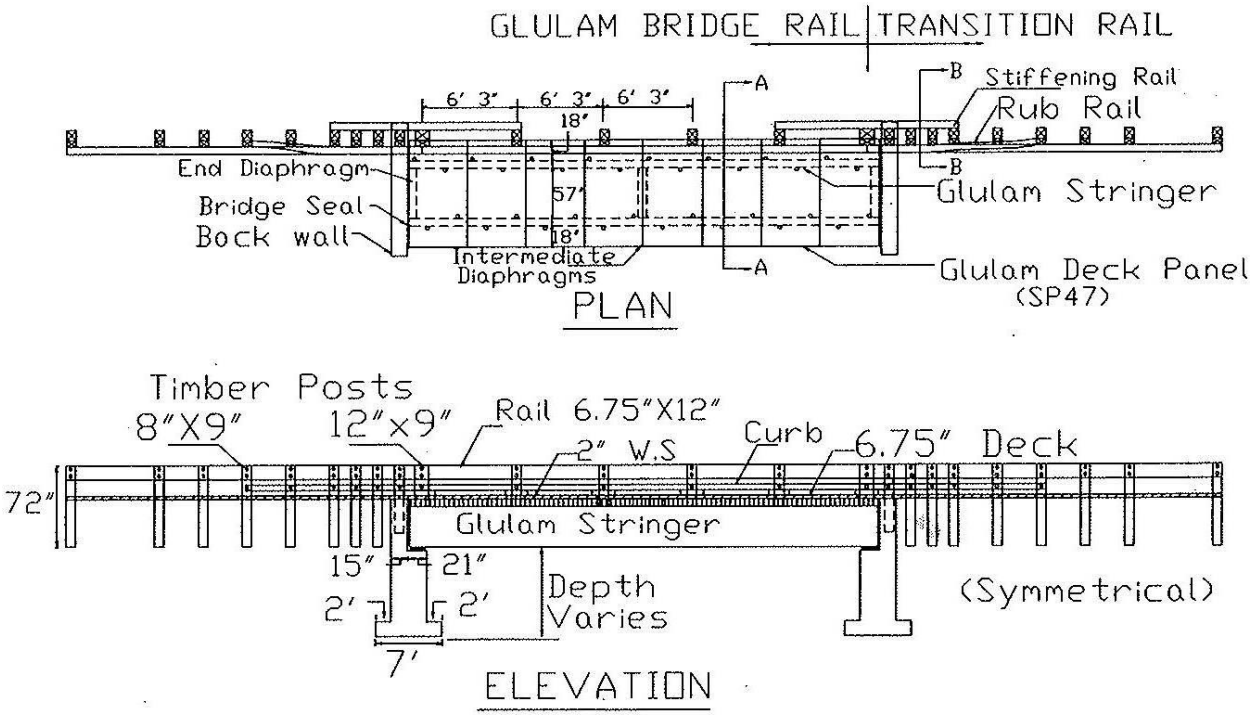


Figure 56. Schematic of Timber Bridge Rail System II Transition (No Photographs Available)

Note: This transition was developed for use with the Timber Bridge Rail System II found in Section 3.11 of this report.

4.8 GC-8000 Bridge Railing/Standard W-Beam Guardrail Transition [22, 30, 31]

Test Specification: NCHRP Report No. 230 [42]

Test Level: Multiple Service Level 2 (MSL-2)

Test Details: 4,506-lb sedan, 62.4 mph, 24.8 degrees

Deck Type: Longitudinal, Glulam Timber Deck

System Material: Steel Rail to Timber Rail Transition

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

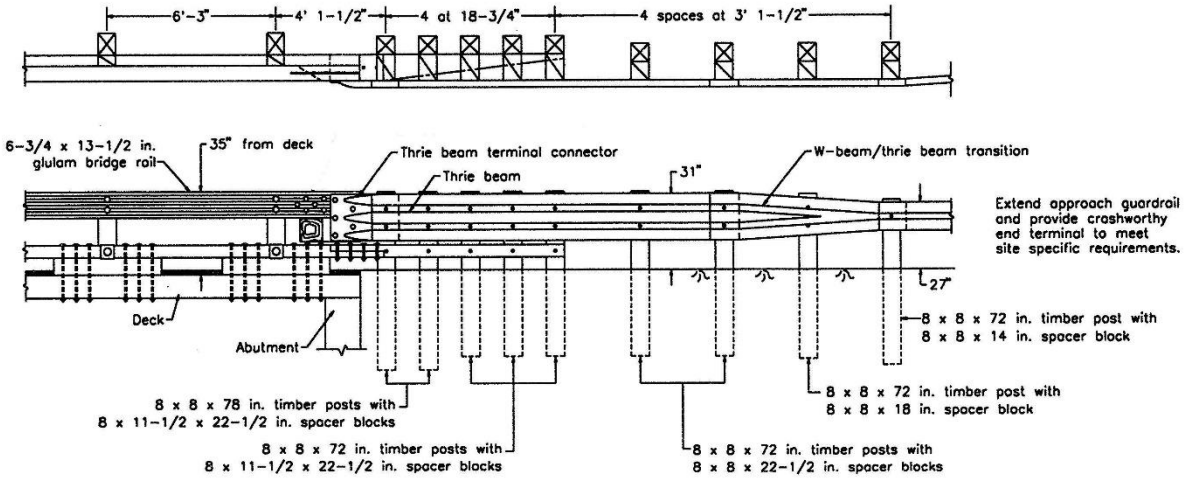


Figure 57. Schematic of GC-8000 Bridge Railing/Standard W-Beam Guardrail Transition

Figure 58. GC-8000 Bridge Railing/Standard W-Beam Guardrail Transition

Note: This transition was developed for use with the Glulam Timber Rail with Curb Bridge Railing (GC-8000) found in Section 3.12 of this report.

4.9 Glulam Timber Rail with Curb Bridge Railing/Standard W-Beam Guardrail Transition [32, 33]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-4

Test Details: 4,473-lb pickup truck, 65.2 mph, 26.4 degrees; 17,644-lb single-unit truck, 51.3 mph, 13.7 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Steel Rail to Timber Rail Transition

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

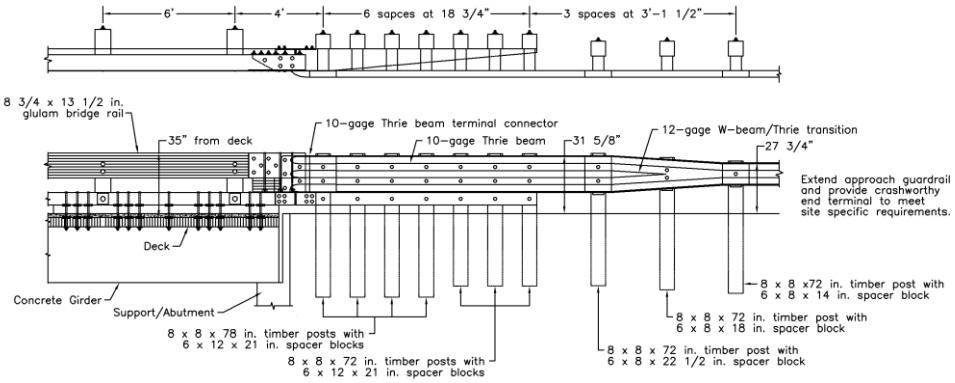


Figure 59. Schematic of Glulam Timber Rail with Curb Bridge Railing/Standard W-Beam Guardrail Transition

Figure 60. Glulam Timber Rail with Curb Bridge Railing/Standard W-Beam Guardrail Transition

Note: This transition was developed for use with the Glulam Timber Rail with Curb Bridge Railing found in Section 3.13 of this report.

4.10 Timber Bridge Rail System III Transition [23, 24]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-1

Test Details: Not Tested

Deck Type: Transverse, Glulam Timber Deck

System Material: Continuous Steel Rail Transition

Research Sponsor: USDOT – FHWA – Office of Engineering and Highway Operations

Research/Test Agency: CFC – WVU and TTI

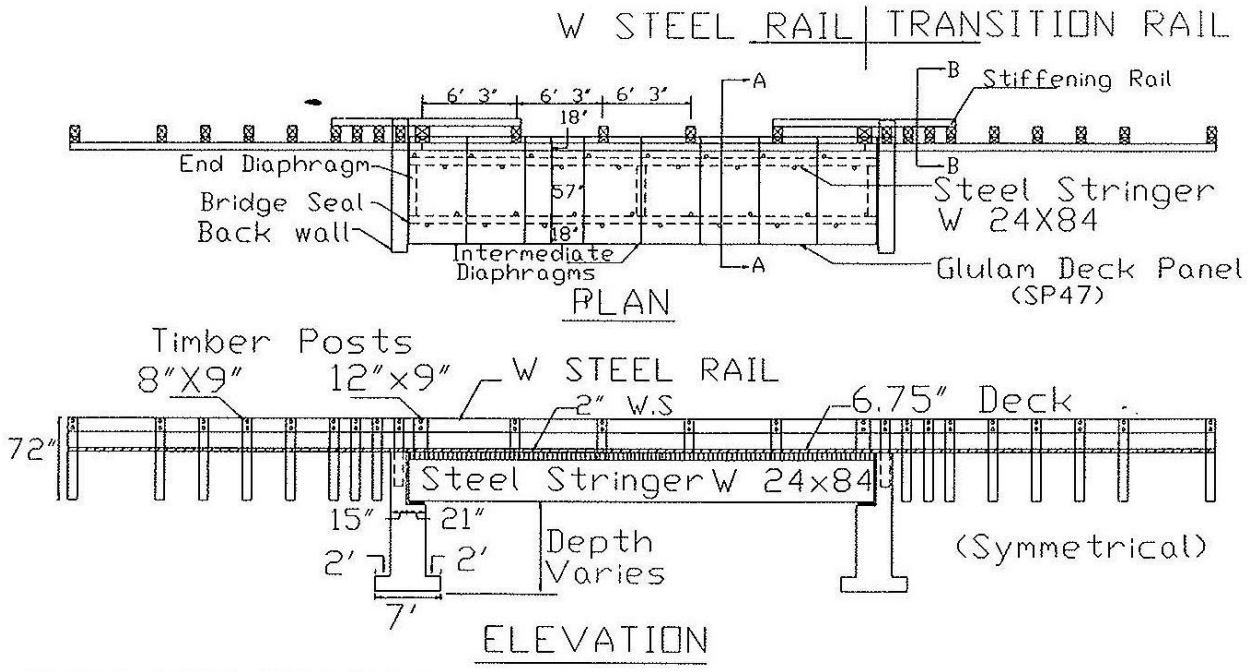


Figure 61. Schematic of Timber Bridge Rail System III Transition (No Photographs Available)

Note: This transition was developed for use with the Timber Bridge Rail System III found in Section 3.18 of this report. No crash testing was performed on this transition.

4.11 "Steel System" Transition [18, 22]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Test Level: PL-1

Test Details: Not Tested

Deck Type: Longitudinal, Glulam Timber Deck

System Material: Continuous Steel Rail Transition

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

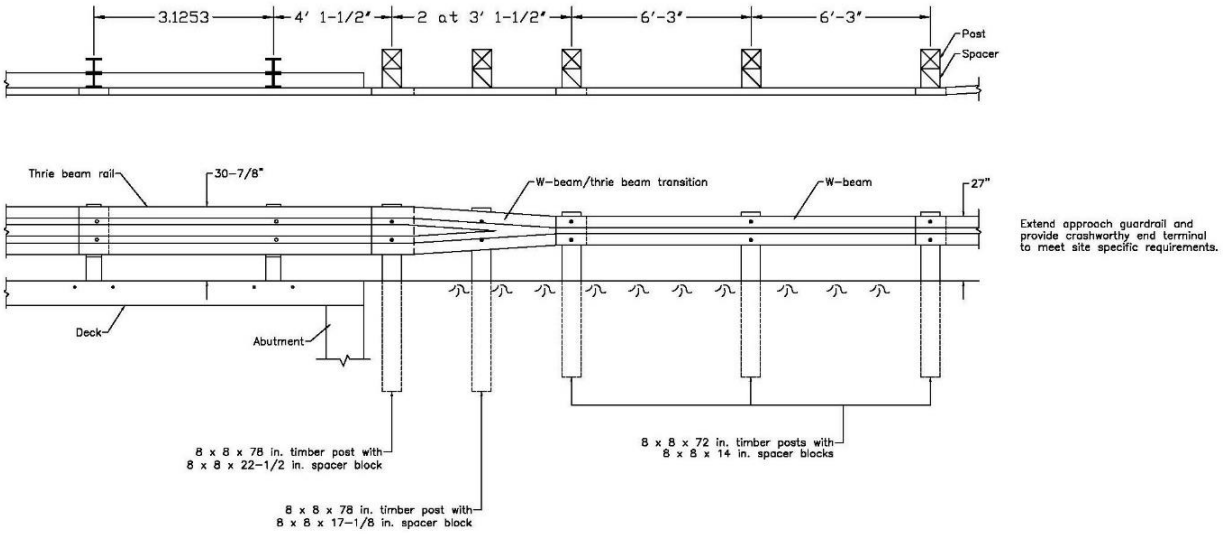


Figure 62. Schematic of "Steel System" Transition (No Photographs Available)

Note: This transition was configured for anchoring the "Steel System" Bridge Railing found in Section 3.19 of this report. No crash testing was performed on this transition.

4.12 TBC-8000 Bridge Railing/Standard W-Beam Guardrail Transition [22, 30, 37]

Test Specification: AASHTO Guide Specifications for Bridge Railings (1989) [2]

Performance Level: PL-2

Test Details: Not Tested

Deck Type: Longitudinal, Glulam Timber Deck

System Material: Continuous Steel Rail Transition

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

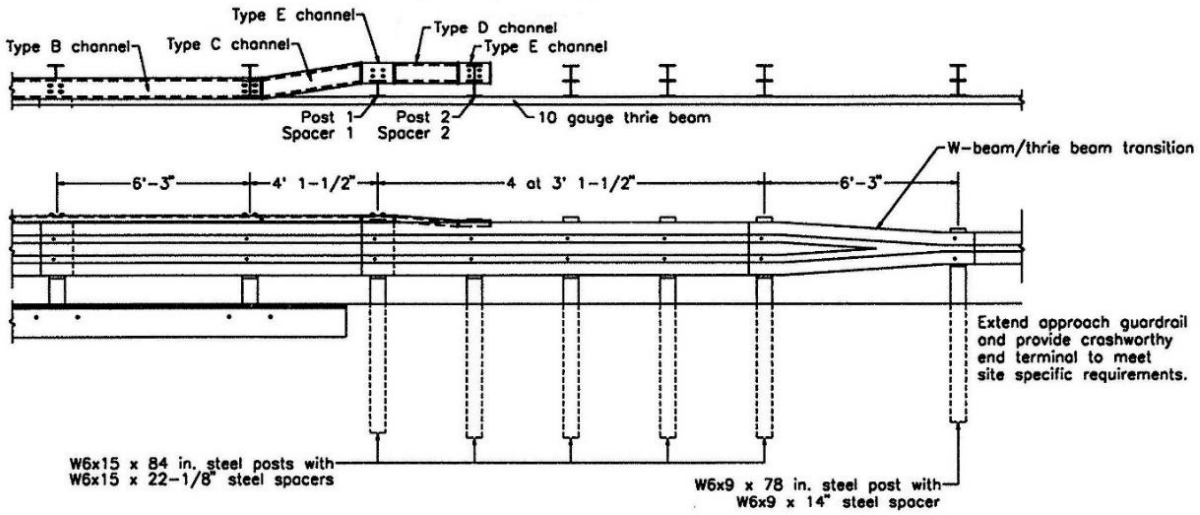


Figure 63. Schematic of TBC-8000 Bridge Railing/Standard W-Beam Guardrail Transition

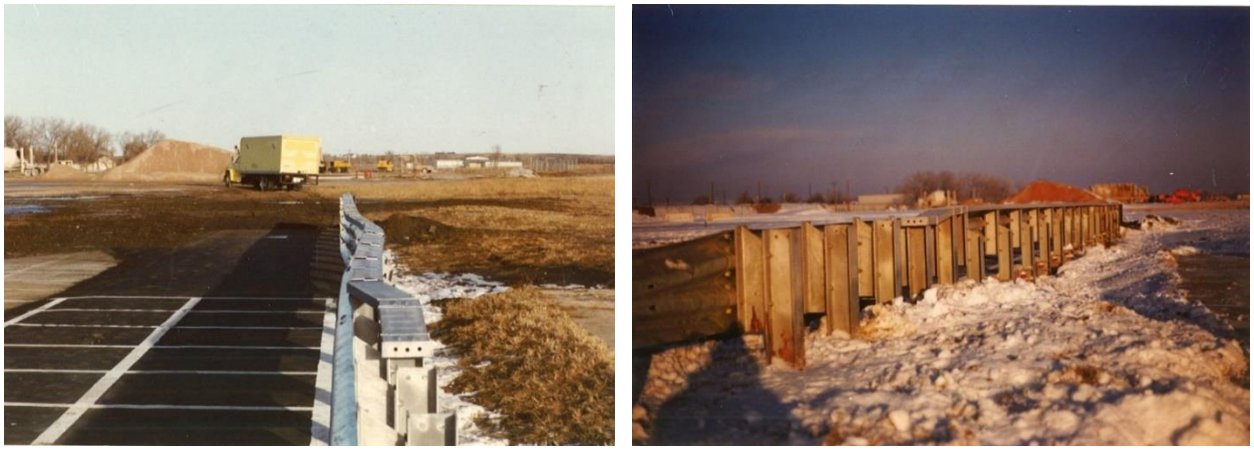


Figure 64. TBC-8000 Bridge Railing/Standard W-Beam Guardrail Transition

Note: This transition was developed for use with the Steel Thrie Beam with Structural Channel Bridge Railing (TBC-8000) found in Section 3.20 of this report. No crash testing was performed on this transition.

4.13 Steel Thrie Beam with Structural Channel Bridge Railing/Standard W-Beam Guardrail Transition [25, 26, 38]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-2

Test Details: 4,486-lb pickup truck, 43.4 mph, 25.8 degrees

Deck Type: Transverse, Glulam Timber Deck or Transverse, Nail-Laminated Timber Deck

System Material: Continuous Steel Rail Transition

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

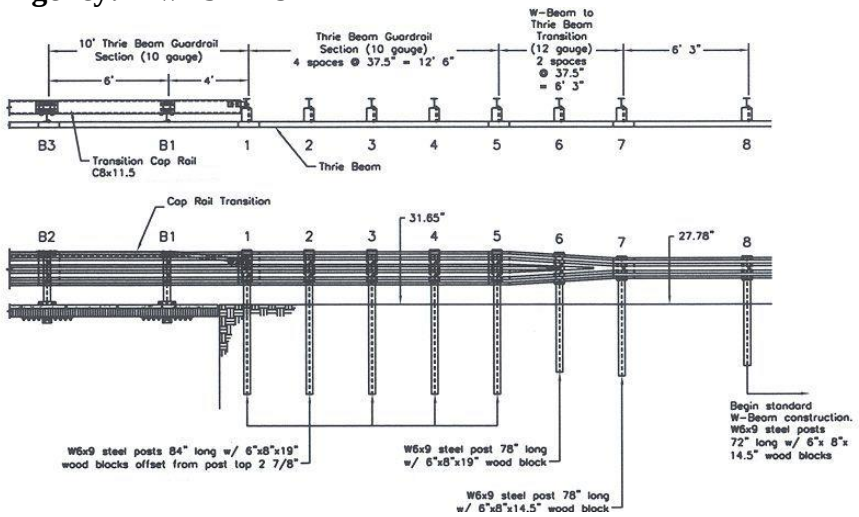


Figure 65. Schematic of Steel Thrie Beam with Structural Channel Bridge Railing/Standard W-Beam Guardrail Transition

Figure 66. Steel Thrie Beam with Structural Channel Bridge Railing/Standard W-Beam Guardrail Transition

Note: This transition was developed for use with the Steel Thrie Beam with Structural Channel Bridge Railing found in Sections 3.21 and 3.22 of this report.

4.14 Steel Thrie Beam with Structural Tube Bridge Railing/Standard W-Beam Guardrail Transition [32, 33]

Test/Performance Level: NCHRP Report No. 350 [1]

Test Level: TL-4

Test Details: 4,403-lb pickup truck, 62.8 mph, 25.6 degrees; 17,650-lb single-unit truck, 50.8 mph, 15.2 degrees

Deck Type: Transverse, Glulam Timber Deck

System Material: Continuous Steel Rail Transition

Research Sponsor: USDA – FS – FPL

Research/Test Agency: MwRSF – UNL

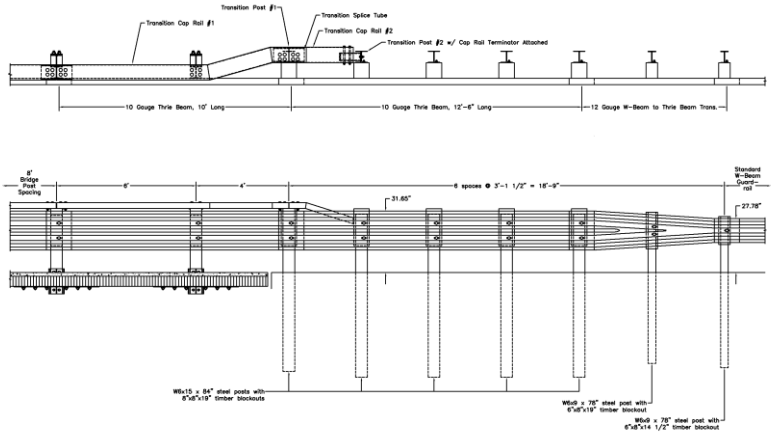


Figure 67. Schematic of Steel Thrie Beam with Structural Tube Bridge Railing/Standard W-Beam Guardrail Transition

Figure 68. Steel Thrie Beam with Structural Tube Bridge Railing/Standard W-Beam Guardrail Transition

Note: This transition was developed for use with the Steel Thrie Beam with Structural Tube Bridge Railing found in Section 3.23 of this report.

4.15 Tubular Steel-Backed Timber Bridge Rail Transition [41]

Test Specification: NCHRP Report No. 350 [1]

Test Level: TL-3

Test Details: 4,572-lb pickup truck, 61.8 mph, 24.7 degrees

Deck Type: Concrete Bridge Deck

System Material: Continuous Steel-Backed Timber Rail Transition

Research Sponsor: USDOT – FHWA – Office of Safety and Traffic Operations

Research/Test Agency: TTI

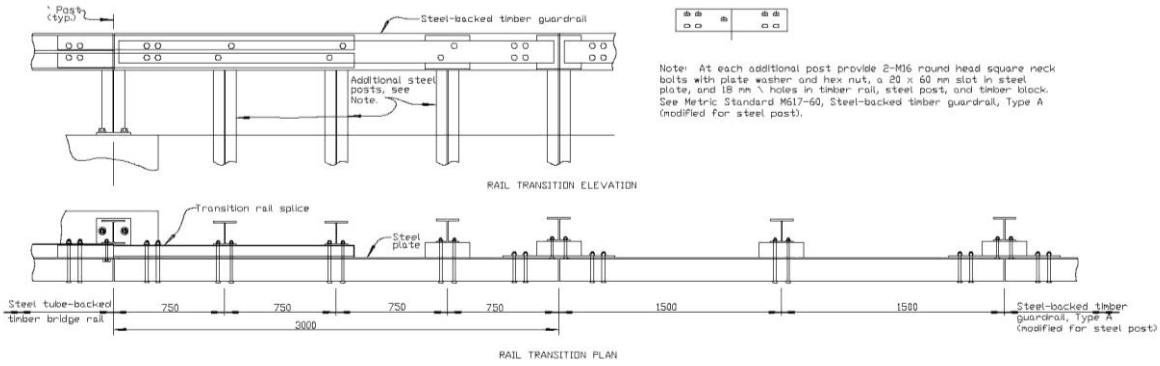


Figure 69. Schematic of Tubular Steel-Backed Timber Bridge Rail Transition

Figure 70. Tubular Steel-Backed Timber Bridge Rail Transition

Note: This transition was developed for use with the Tubular Steel-Backed Timber Bridge Rail found in Section 3.26 of this report

5 EXAMPLES OF BRIDGE RAILING SYSTEMS FOR WOOD BRIDGES

5.1 Introduction

The following sections provide visual, real-world examples of pertinent timber bridge railings and/or railing for timber deck bridges that are used across the United States.

5.2 Alamco Wood Products, LLC

Figure 71. Bridge Railing from Alamco Wood Products, LLC

5.3 Laminated Concepts Inc.

Figure 72. Bridge Railings from Laminated Concepts Inc.

Figure 73. Bridge Railings from Laminated Concepts Inc.

Figure 74. Bridge Railings from Laminated Concepts Inc.

5.4 Western Wood Structures

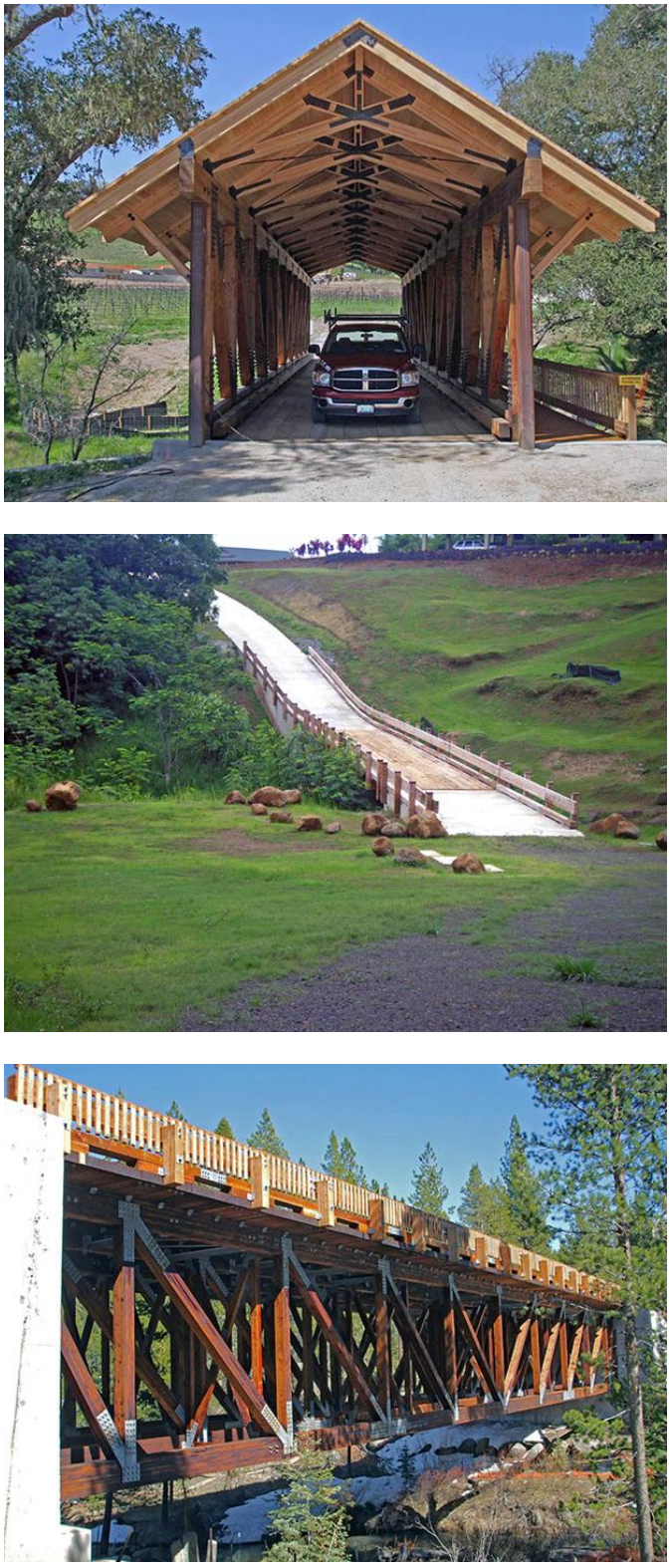


Figure 75. Bridge Railings from Western Wood Structures

5.5 Wheeler Lumber, LLC

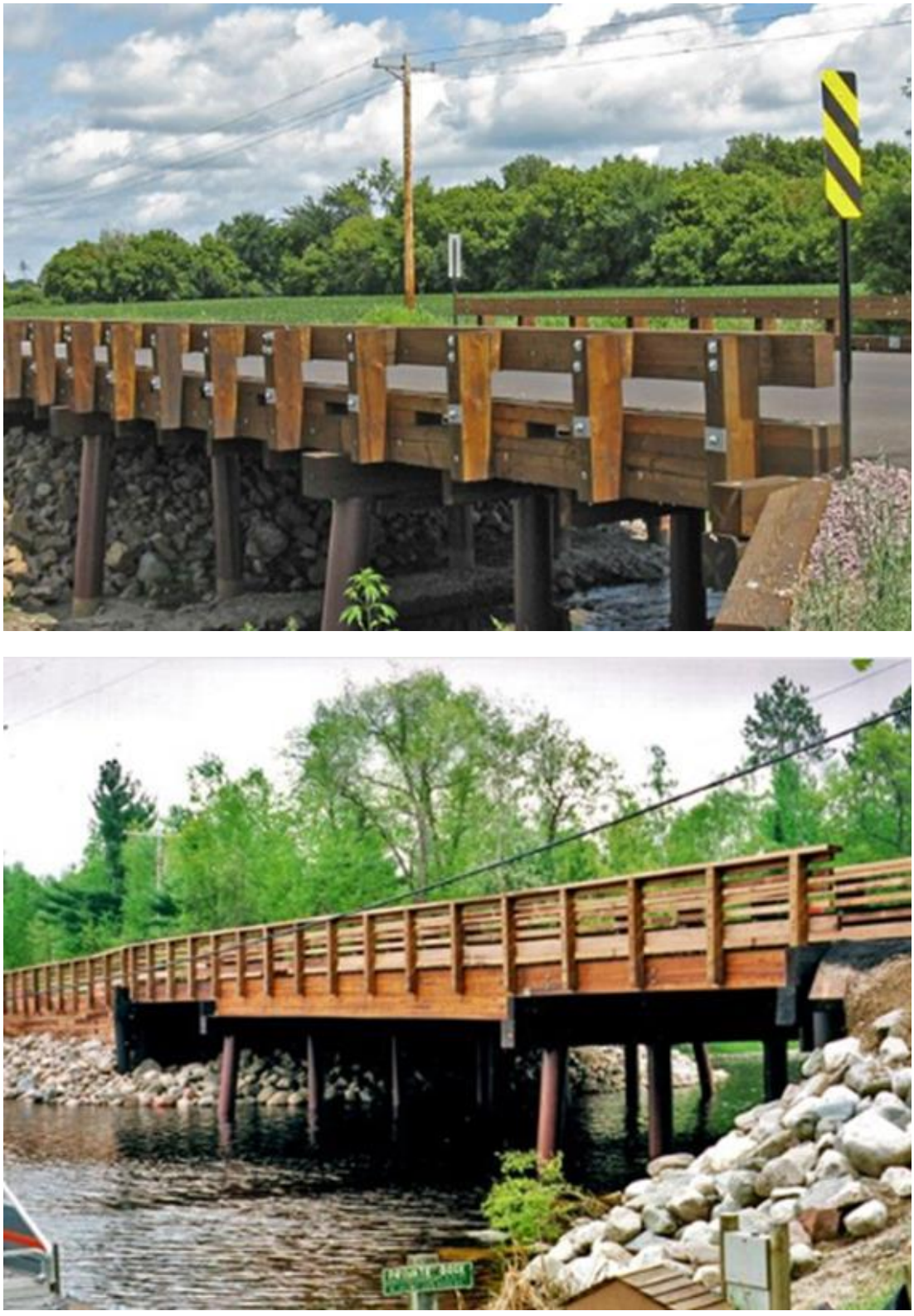


Figure 76. Bridge Railings from Wheeler Lumber, LLC

5.6 Sweden

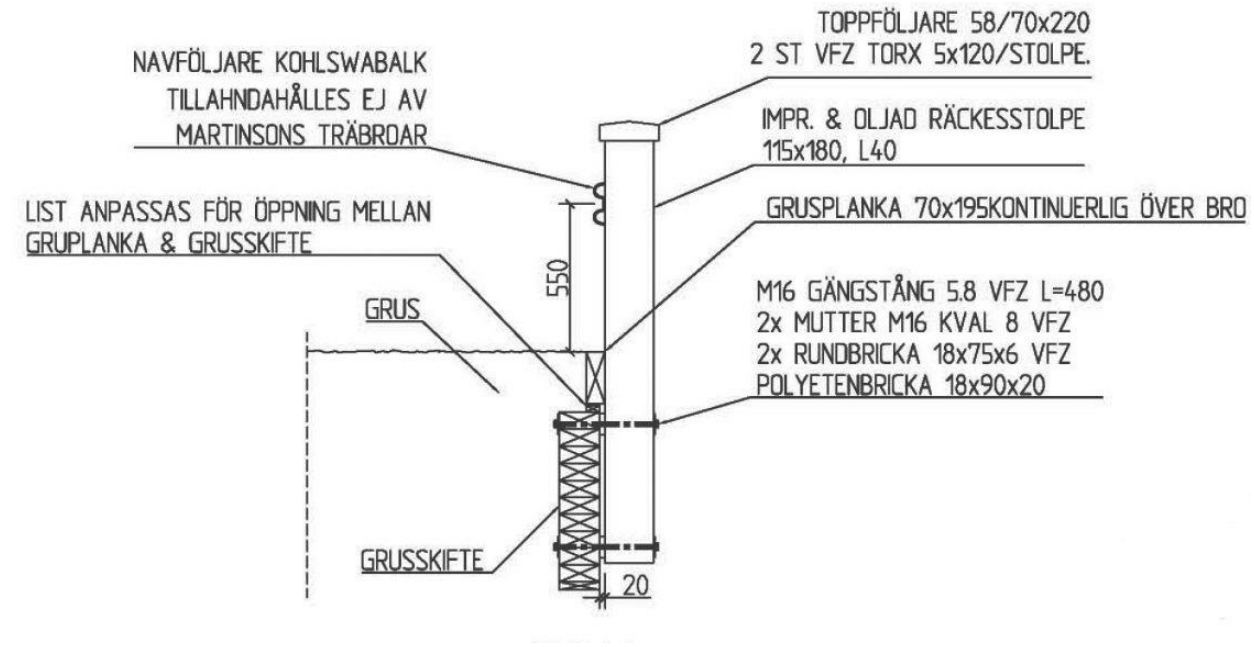


Figure 77. Bridge Railing from Sweden [43]

5.7 Other Implemented Bridge Railings

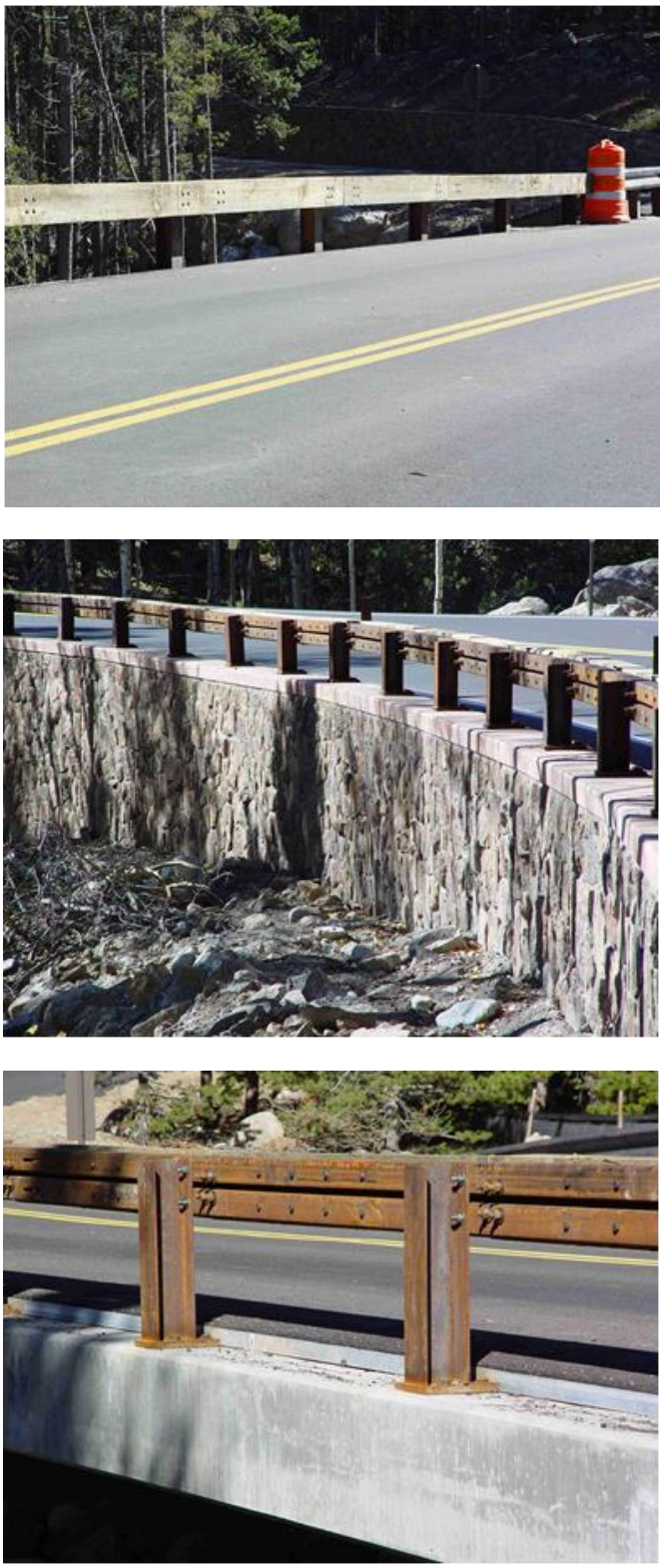


Figure 78. Other Implemented Bridge Railings

Figure 79. Other Implemented Bridge Railings

Figure 80. Other Implemented Bridge Railings

Figure 81. Other Implemented Bridge Railings

6 SURVEY

6.1 Overview

The survey was utilized to: (1) identify commonly-used bridge railing systems for wood bridges; (2) uncover any other ideas for bridge railing systems to be developed to meet current AASHTO MASH impact safety criteria; (3) identify any special conditions for consideration when developing approach guardrail transitions or bridge rail terminations to accompany these bridge railings; and (4) help researchers and government agencies select systems for future development, testing, and evaluation under current AASHTO MASH impact safety criteria [4].

The successful completion of the survey was expected to benefit participating groups and organizations by allowing their bridge railing systems and needs to be considered within the Phase I project. Further, the noted systems may potentially be selected for further research, development, testing, and evaluation under the MASH safety performance guidelines, thus possibly lowering the research and development costs for other groups and stakeholders.

In total, the survey was sent to 78 different groups or organizations. Of the 78 groups, two were technical committees from AASHTO, six were offices and teams from FHWA, and one was a group within the United States Bureau of Reclamation (USBR). Another ten groups were from the USDA-FS, nine of which were engineering departments from distinct regions across the country. The next eight groups were the consulting groups mentioned in Section 2 of this report, and the last 51 groups were State Departments of Transportation, including the Washington, D.C. DOT. The two AASHTO technical committees also comprised representatives from many of the state DOTs.

A copy of the survey can be found in Appendix A. The survey consisted of five main questions. After giving instructions and asking the user to enter their contact information, the first question asked the user to provide information on bridge railing systems that are currently installed on wood bridges. Consultants were asked to include bridge railing systems that they had designed, constructed, or recommended for use in the field. Government agencies were to include bridge railing systems that they own or manage. The question specifically requested the system name, a brief description, the deck types on which it had been installed, and whether or not it had been previously crash-tested. At the end of the question, the respondent was also asked to estimate the percentage of installed systems for each type. The second question asked the user whether they would like any of the bridge railing systems entered in the first question to be updated to current MASH standards. If they would like a system to be updated, the question asked which test level or levels were desired. For the third question, an attached document presented general schematics and photographs of the six different families of bridge rail systems that were identified and proposed for updating, as obtained from the initial literature review. This attachment is provided in Appendix A, immediately following the survey. With the attachment, the user was asked if they would like to have an updated version of each of these families of bridge railings to be developed. If they responded yes to a certain system type, they were then asked to provide the desired bridge deck types and test level or levels. The fourth question asked for any information regarding new systems that could be developed, or deviations or modifications that the user would like to see implemented when updating previous designs. The final question provided space for the user to enter any special site conditions, transitions, or termination features that they would like to have considered in new or updated systems.

6.2 Analysis of Survey Response

The research team received and compiled data from 36 completed survey responses out of a total of 78 distributed surveys. More specifically, the research team received: (1) 2 responses out of 2 surveys sent to AASHTO technical committees; (2) 1 response out of 6 surveys sent to FHWA offices and teams; (3) 1 response from the single survey sent to the USBR group; (4) 1 response out of 10 surveys sent to USDA-FS groups; (5) 4 responses out of 8 surveys sent to consulting groups; and (6) 29 responses out of 51 surveys sent to state DOTs. It should be noted that although two responses were recorded for the AASHTO groups, the respondents from these groups responded in relation to the state DOT in which they were employed. For this reason, their responses were counted both as an AASHTO response and a state DOT response above, leading to a sum of 38 responding groups but only 36 completed surveys.

The data from all 36 completed surveys were combined and analyzed to help the research team better understand the types of bridge railing systems that are currently used, as well as those systems that were desired to be updated. The provided information was examined on a question by question basis and compiled into tables.

Overall, 9 of the 36 respondents indicated that their group or agency does not currently use any bridge railing systems for wood bridges and that they do not desire to develop bridge railing systems for wood bridges. Another 2 of the 36 respondents provided information on systems that are currently used, but they did not request any systems to be updated or developed to meet current MASH standards. The last 25 responses all either provided information about bridge railings that are currently used and requested some system types to be updated or newly developed, or they simply requested systems to be developed through Question 3 of the survey. From the 25 survey respondents that requested updates or new developments, 9 requested a Low-Height, Curb-Type Bridge Railing, 10 requested a Timber Railing without Curb Bridge Railing, 18 requested a Timber Railing with Curb Bridge Railing, 12 requested a W-Beam Bridge Railing, 11 requested a Thrie Beam Bridge Railing, 9 requested a Steel-Backed Timber Bridge Railing, and 1 requested updates to a system that did not fall into any of the noted bridge railing families. As shown in Table 1, this data was further separated by the number of groups requesting each system type to be (1) updated in response to Question 2 or (2) newly developed in response to Question 3.

Table 1. Summary of Respondent Requests

Requests by Bridge Railing Type							
Category	Low-Height, Curb-Type Rail	Timber Railing without Curb	Timber Railing with Curb	W-Beam Rail	Thrie Beam Rail	Steel-Backed Timber Rail	Other Rail
Number of Requesting Groups	9	10	18	12	11	9	1
Requests to Update*	2 of 9	0 of 10	13 of 18	2 of 12	1 of 11	0 of 9	1 of 1
Requests to Develop**	9 of 9	10 of 10	18 of 18	12 of 12	11 of 11	9 of 9	NA

* – Requests to update a system type were gathered in response to Question 2 of survey.
** – Requests to develop a system type were gathered in response to Question 3 of survey.
NA – Not Applicable

From the collected surveys, information on 52 currently-used systems was acquired in response to Question 1. Of these 52 systems, 29 systems were also requested to be updated through Question 2. The information about each of these systems can be found in Tables B-1 through B-10 of Appendix B. For the 29 systems that were requested to be updated, two groups requested three Low-Height, Curb-Type Bridge Railing Systems, 13 groups requested 21 Timber Railing with Curb Bridge Railing Systems, two groups requested two W-Beam Bridge Railing System, one group requested two Thrie Beam Bridge Railing Systems, and one group requested a system that comprised box beam members that did not fit into any of the other bridge railing families. As shown in Table B-7, the USBR responded to Question 1 of the survey stating that they are a decentralized agency that does not keep an inventory of the railing systems on their bridges. The USBR, which maintains or owns nearly 1,500 public and private bridges across the United States, uses a wide variety of systems with differing materials, characteristics, and dimensions. Most of the bridge railing systems that are in use on their bridges have not been evaluated or crash-tested to meet a crashworthiness standard. The USBR expressed great support for the development of bridge railing systems that could be used on their bridges going forward, specifically those systems that will meet AASHTO MASH TL-1 and TL-2 impact safety standards [4].

Respondents also had the opportunity to request the development of new systems within the 6 families of bridge railings that were presented in the document attached to the third question of the survey. This question further clarified the wants and needs of the groups and organizations that completed the survey by allowing them to express interest in a certain system type, even if it was not currently used. As shown in Table 1, 9 groups requested development of a Low-Height, Curb-Type System, 10 groups requested development of a Timber Railing without Curb System, 18 groups requested development of a Timber Railing with Curb System, 12 groups requested development of a W-Beam System, 11 groups requested development of a Thrie Beam System,

and 9 groups requested development of a Steel-Backed Timber System. The information provided with these requests is provided in greater detail in Tables B-11 through B-16 of Appendix B.

Through the process of collecting and compiling the data from Questions 1 and 2, follow-up contact was made with the Delaware DOT to clarify an answer provided about a bridge railing system that is currently used. From the information provided in the survey, it was unclear if the railing was part of the Timber Railing without Curb or Timber Railing with Curb System family. In order to accurately account for this railing system in the data, follow-up contact was made, and the research team was provided with an explanation and a drawing set. The drawing set is provided in Figures C-1 through C-3 of Appendix C. This drawing set has been included herein to serve as an example of the modifications that different groups have made to bridge railing systems for wood bridges. The State of Delaware has implemented a Timber Railing with Curb System similar to what was tested in the past, but they added their own modifications to allow its use with a steel-backed timber transition and guardrail system. These modifications include special transition features that allow for the bridge railing and guardrail systems to connect to one another even with a height difference, as well as a termination feature for the curb portion of the system, and a termination feature for the transition/guardrail system. This drawing set provided the research team with valuable information that will be key in making decisions for future system development in the subsequent research stages of the research project.

The data from Questions 1 and 2 was further analyzed to collect information on the test levels and deck types that are often used and which were requested for updating and development for each railing system. Tables 2 through 13 show this information.

Tables 2 and 3 show the data collected in relation to Low-Height, Curb-Type Systems. It is evident that not many groups currently use systems from this family, but there is enough support to make the development of a Low-Height, Curb-Type System a priority, specifically to meet AASHTO MASH TL-1 or TL-2 standards. In terms of the deck types for which a Low-Height, Curb-Type System should be developed, the requests varied greatly.

Table 2. Test Level Requests for a Low-Height, Curb-Type System

Test Level	***Requests***		
	Update*	***Develop***	***Total***
TL-1	2	3	5
TL-2	1	5	6
TL-3	0	2	2
TL-4	0	1	1

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.

Table 3. Deck Type Requests for a Low-Height, Curb-Type System

Deck Type	***Requests***		
	Update*	***Develop*****	***Total***
LG	1	4	5
LN	1	3	4
LSp	1	4	5
LSt	0	3	3
TG	1	4	5
TN	2	4	6
Concrete	0	1	1
Other	1	1	2

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Tables 4 and 5 show the data collected in relation to Timber Railing without Curb Systems. Similar to the data shown in Tables 2 and 3 for Low-Height, Curb-Type Systems, Timber Railing without Curb Systems are currently not well represented in the field, but many groups would like an option to install. For this reason, the research team has identified priorities to develop such a system at TL-2, TL-3, and TL-4. Again, the number of requests for each deck type were relatively similar.

Table 4. Test Level Requests for a Timber Railing without Curb System

Test Level	***Requests***		
	Update*	***Develop*****	***Total***
TL-1	0	4	4
TL-2	0	4	4
TL-3	0	4	4
TL-4	0	3	3

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.

Table 5. Deck Type Requests for a Timber Railing without Curb System

Deck Type	***Requests***		
	Update*	***Develop*****	***Total***
LG	0	6	6
LN	0	4	4
LSp	0	5	5
LSt	0	5	5
TG	0	6	6
TN	0	5	5
Concrete	0	2	2
Other	0	1	1

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Tables 6 and 7 show the data gathered in regards to Timber Railing with Curb Systems. This type of bridge railing system was the most commonly-used system, and it was also widely requested for further development. Because of the number of requests, this system was selected as a top priority for development going forward. There were a significant number of requests for systems at TL-2, TL-3, and TL-4. Consideration for each test level will be given in the Phase I priority list. Transverse and longitudinal glulam timber decks were the two most-requested deck types for this type of railing system.

Table 6. Test Level Requests for a Timber Railing with Curb System

Test Level	***Requests***		
	Update*	***Develop*****	***Total***
TL-1	2	2	4
TL-2	9	10	19
TL-3	6	6	12
TL-4	12	6	18

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.

Table 7. Deck Type Requests for a Timber Railing with Curb System

Deck Type	***Requests***		
	Update*	***Develop*****	***Total***
LG	7	9	16
LN	2	6	8
LSp	5	7	12
LSt	2	6	8
TG	9	9	18
TN	5	6	11
Concrete	6	5	11
Other	1	3	4

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Tables 8 and 9 show the data collected in relation to W-Beam Systems. Much like the first two families of bridge railing systems that were discussed, W-Beam Bridge Railing Systems have not been widely used. However, there was significant interest in the development of a W-Beam Bridge Railing System, especially due to the wide use of W-Beam Guardrail Systems. Consistent with many guardrail systems, TL-2 and TL-3 configurations were most commonly requested for development. This railing system was most often requested for use on longitudinal, glue-laminated or transverse, nail-laminated timber decks.

Table 8. Test Level Requests for a W-Beam System

Test Level	***Requests***		
	Update*	***Develop*****	***Total***
TL-1	1	1	2
TL-2	2	6	8
TL-3	0	8	8
TL-4	1	0	1

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.

Table 9. Deck Type Requests for a W-Beam System

Deck Type	***Requests***		
	Update*	***Develop*****	***Total***
LG	2	4	6
LN	1	3	4
LSp	1	3	4
LSt	0	4	4
TG	1	4	5
TN	2	5	7
Concrete	0	4	4
Other	1	1	2

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Tables 10 and 11 show the data collected in relation to Thrie Beam Railing Systems. In the past, multiple variations within this family of bridge railings have been developed, but they are not widely used. There were multiple requests for a new system to be developed using a thrie beam rail, especially to meet the AASHTO MASH TL-2 and TL-3 criteria. Respondents requested use of this type of railing system on transverse, nail-laminated timber, or reinforced concrete decks.

Table 10. Test Level Requests for a Thrie Beam System

Test Level	***Requests***		
	Update*	***Develop*****	***Total***
TL-1	0	3	3
TL-2	2	7	9
TL-3	2	5	7
TL-4	0	4	4

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.

Table 11. Deck Type Requests for a Thrie Beam System

Deck Type	***Requests***		
	Update*	***Develop*****	***Total***
LG	0	5	5
LN	0	4	4
LSp	0	3	3
LSt	0	3	3
TG	0	5	5
TN	0	7	7
Concrete	2	5	7
Other	1	0	1

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Tables 12 and 13 show the data gathered in relation to Steel-Backed Timber Systems. No responding groups denoted that this type of system is currently used, but many groups would like to have this railing system developed. There was significant interest in having a Steel-Backed Timber System for use at AASHTO MASH TL-2, TL-3, and TL-4. Longitudinal and transverse glulam timber decks were the two most commonly-requested deck types for consideration in future research and development.

Table 12. Test Level Requests for a Steel-Backed Timber System

Test Level	***Requests***		
	Update*	***Develop*****	***Total***
TL-1	0	0	0
TL-2	0	4	4
TL-3	0	4	4
TL-4	0	5	5

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.

Table 13. Deck Type Requests for a Steel-Backed Timber System

Deck Type	***Requests***		
	Update*	***Develop*****	***Total***
LG	0	7	7
LN	0	4	4
LSp	0	4	4
LSt	0	4	4
TG	0	6	6
TN	0	4	4
Concrete	0	2	2
Other	0	1	1

* – Requests to update a system type were gathered in response to Question 2 of the survey.
** – Requests to develop a system type were gathered in response to Question 3 of the survey.
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

After inquiring about currently-used bridge railing systems as well as their desire to update currently-used systems in Questions 1 through 3, Question 4 of the survey asked respondents to provide details for any new bridge railing systems that could be developed for use on wood bridges, or to provide information on any modifications or deviations that should be considered with current railing systems. From this question, only one group responded with information for a new bridge railing system. The exact response is provided in Table 14. The respondent desired a railing system that is tested to meet MASH TL-3 criteria instead of MASH TL-4 criteria in order to reduce total system cost since timber systems are most commonly installed on roads with relatively low traffic volumes. These roads typically do not carry much large truck traffic, which is the main consideration in using a MASH TL-4 bridge railing instead of a MASH TL-3 bridge railing.

Table 14. Question 4-1 Summary: New Bridge Railing System Responses

Respondent Type	***Respondent Group***	***System #***	***System Description***	***Deck Type(s)***	***Test Level***
Industry Consultant	Wheeler Lumber, LLC	1	TL-3 instead of TL-4 as there are currently no TL-3 systems	LSp, TG, TN, and Concrete	TL-3

LSp – Longitudinal, Spike-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Four other groups offered deviations or modifications to existing railing systems, each of which can be seen in Table B-17 of Appendix B. The biggest concern gathered from this portion of the survey was that industry/consultants preferred that all timber components be standardized to use glulam timber instead of having a mixed use of glulam and sawn timber. Other concerns

included developing Timber Railing with Curb Systems to be compatible with all deck types, making connections simpler and more field friendly, and incorporating pedestrian rail options into commonly-used systems. Many of the railing systems that have been installed across the United States, as shown in Section 5 of this report, already contain an additional pedestrian rail, even though such elements have not actually been crash tested.

The fifth and final survey question asked if there were any special site conditions, approach transitions, or terminations that should be considered when approach guardrail transitions or bridge rail end terminations are developed for use with any new bridge railing systems. Ten respondents offered recommendations for this question, and their responses are provided in Tables B-18 and B-19 of Appendix B. From the information provided for this question, the most important aspect appeared to be steep slopes located behind transition regions. Furthermore, multiple groups requested an approach transition that utilizes a timber rail in order to maintain the bridge rail's aesthetic appearance beyond the end of the bridge rail. In contrast to a timber rail transition, it was also important to develop a transition to the 31-in. tall, Midwest Guardrail System (MGS) due to its significant use as a guardrail system across the United States.

Two state DOTs, Alaska and South Carolina, offered considerations that required further clarification by the research team. Thus, follow-up contact was made by researchers. Alaska DOT asked the research team to take into account "considerations for snow removal and dirt accumulation," as well as "durability." In response to the follow-up contact, it was clarified that Alaska DOT preferred the use of open rail systems, such as box-beam guardrails and transitions, instead of closed systems, such as W-Beam or Thrie Beam systems. The use of open rail systems allow for snow to more easily be plowed off of the road and behind such barriers as well as reduced snow drifting on roadways. It was also noted that snow plow damage was prevalent in many areas throughout Alaska. When snow plow drivers clear as much roadway as possible, they can also brush against barriers, thus damaging the guardrail and/or bridge railing systems. In terms of durability, the Alaska respondent noted that new preservatives used for pressure-treating wood do not seem to be as effective as older preservatives, such as creosote. Further, high winds often blast sand into timber railing and post elements, thus causing severe wood deterioration over time. Figure 82 shows typical wood deterioration under sand blasting conditions due to high winds in the State of Alaska.

Figure 82. Sand-Blasted Timber Posts in Alaska

In response to Question 5, the South Carolina DOT response noted a desire to transition from a "timber curb to concrete curb on [a] roadway." Once again, the research team sought further clarification on this response. Thus, follow-up communication was initiated. In response, it was determined that occasionally a concrete curb was cast at the bridge ends and beyond to align with the lower curb portion of a Timber Railing with Curb System. It was believed by South Carolina personnel that this curb helped to reduce vehicle snag at the end of the bridge railing system as well as provided a way to direct water off of the bridge and toward a drainage flume instead of eroding the soil near the bridge abutments. The South Carolina DOT respondent provided a Roadway Standard Drawing of such a curbed system, which is shown in Figure C-4 of Appendix C and in Figure 83. Within Figure 83, an added pedestrian rail is also depicted on the right side railing system of the bridge, which was also requested in survey Question 4 pertaining to desired modifications and deviations.

Figure 83. Concrete Curb to Timber Curb Transition Feature in South Carolina

Using the literature review results in combination with the information and considerations offered by the survey respondents, the research team sought to determine which bridge railing systems should be developed, tested, and evaluated under MASH 2016 and whether an approach transition should also be developed. The final determinations are outlined in the next section of this report.

6.3 Future Research Priorities for Bridge Railing and Transition Systems

Following the completion of the survey and analysis of the data, a priority list was created to guide future research and development of bridge railing and approach guardrail transition systems. The priority list is provided in Table 15. Each system in the table is ranked from 1 to 15, followed by the type of system. The test level and deck types that were commonly requested at that test level were also noted. The deck types are followed by a number in parentheses, indicating the number of requests for that deck type at that test level. Many of the systems were requested for development at a certain test level, such as TL-4, but they may also have received a similar number of requests at a test level either one step higher or lower, such as TL-3. For some of these systems, it was determined that the most effective method of development would be to develop the system at one test level and then offer alterations that could be made to the system to be acceptable at the second test level. These systems have entries in the "Other Considerations" column of Table 15.

Table 15. Future Research and Development Priority List

Priority	Bridge Railing System Type	Bridge Railing Test Level	Deck Type(s)	Other Considerations	Responses	Transition Needs	Transition Test Level	Section 3 Bridge Railing Reference	Section 4 Transition Reference
1	TR w/ Curb	TL-4	TG (13), LG (8), Conc (6)	TL-3	18/12	Yes	TL-3	3.13, 3.12	4.9, 4.8
2	TR w/ Curb	TL-2	Conc (8), LSp (7), TN (8)	-	19	Yes	TL-2	3.13, 3.12	4.9, 4.8
3	Thrie Beam	TL-2	Conc (7), TN (4)	-	9	Yes	TL-2	3.22, 3.21	4.13
4	W-Beam	TL-3	TN (4), Conc (3)	-	8	No	TBD[1]	3.17, 3.16	NA
5	W-Beam	TL-2	LG (6)	-	8	No	TBD[1]	3.17, 3.16	NA
6	Thrie Beam	TL-3	Conc (6), TN (3)	-	7	Yes	TL-3	3.22, 3.21	4.13
7	LHCT	TL-2	LSp (3), TN (3)	-	6	Yes - End Treatment	TL-2	3.4	4.2
8	Steel-Backed	TL-4	LG (4), TG (4)	TL-3	5/4	Yes	TL-3	3.26, 3.24	4.15
9	LHCT	TL-1	TN (5)	-	5	Yes - End Treatment	TL-1	3.4	4.2
10	TR w/o Curb	TL-3	LSp (3), LSt (3)	-	4	Yes	TL-3	3.7, 3.5	4.5, 4.3
11	Steel-Backed	TL-2	Conc (2), LG (2)	-	4	Yes	TL-2	3.26, 3.24	4.15
12	TR w/o Curb	TL-2	Any	-	4	Yes	TL-2	3.7, 3.5	4.5, 4.3
13	Thrie Beam	TL-4	TG (4)	-	4	Yes	TL-3	3.23, 3.21	4.14, 4.13
14	TR w/o Curb	TL-4	LG (3), TG (3)	-	3	Yes	TL-3	3.7, 3.5	4.5, 4.3
15	Other (Type 10T)	TL-3	Steel w/ Conc (1), LN (1)	TL-4	1/1	Yes	TL-3	Figure C-2	Figure C-2

[1] – A stiffness transition may not be needed.
LHCT – Low-Height, Curb-Type
LG – Longitudinal, Glulam Timber
LSp – Longitudinal, Spike-Laminated Timber
TG – Transverse, Glulam Timber
TR w/ Curb – Timber Railing with Curb
TR w/o Curb – Timber Railing without Curb
LN – Longitudinal, Nail-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TN – Transverse, Nail-Laminated Timber

Following these entries, the table contains the number of requests for the specified system type at the specified test level, an indication of the need for a transition to be developed with the system, and if so, the test level for the transition. The final information found in the table are references to systems and transitions noted in Sections 3 and 4, respectively, that have been previously developed and similar to what will be developed in the future.

In order to create the tabulated list of priorities, the number of requests for each system at each test level were determined and generally placed in order from greatest to least. After organizing the railing systems into the priority list, the data for each system was reviewed again to determine the most commonly-requested deck types at the specified test level. This information has been compiled within Tables B-20 through B-26 of Appendix B. Through discussions amongst the research team, a question was raised as to whether a transition should be developed for each system on the priority list, and if so, to which test level it should be tested. To help make this determination, the information gathered from Question 5 of the survey was reviewed. With all of this information compiled, a reference was found to link both the bridge railing and the approach guardrail transition systems to be developed to the closest existing system found in Sections 3 or 4, respectively, of this report.

The highest priority system to be developed to meet MASH TL-4 standards was a Timber Railing with Curb System. There were 18 requests to develop this type of railing system at TL-4, but there were also 12 requests to develop it to meet TL-3. It was determined that due to cost considerations and the similarity in the TL-3 and TL-4 test matrices, it would not be necessary to develop a completely new system and conduct crash tests again. Therefore, the system is recommended to be designed for use at MASH TL-4 and then used in TL-3 situations as well. The most requested deck type for this system at TL-4 was a transverse, glulam timber deck. There was also significant interest for its use on longitudinal glulam timber or reinforced concrete decks. Because this system was requested so frequently, a transition that meets MASH TL-3 standards will be developed for use with it as well.

The second highest priority system was a Timber Railing with Curb System, but this system will only be developed to meet MASH TL-2 standards. This system was requested 19 times, and the three most common deck types were reinforced concrete decks, longitudinal spike-laminated timber decks, and transverse, nail-laminated timber decks. Again, a transition will be developed for use with this bridge railing system. The approach guardrail transition will be designed and tested to meet MASH TL-2 standards.

The third highest priority system was a Thrie Beam System to be developed to meet MASH TL-2 criteria. This system was most commonly requested for development on concrete or transverse, nail-laminated timber decks. An approach guardrail transition will be developed to meet MASH TL-2 standards.

The next system, fourth on the priority list, was a W-Beam System developed to meet MASH TL-3 standards. This system was most commonly requested for use on transverse, nail-laminated timber or concrete decks. At this time, it is unclear if a new stiffness transition is required between the bridge rail and guardrail systems. Further analysis will have to be performed after the bridge railing system has been developed.

The fifth highest priority system was a W-Beam System. This system will be designed to meet MASH TL-2 standards. It was requested for use on longitudinal, glulam timber decks. It is again unclear at this time if a stiffness transition will be necessary, however, this will be determined once bridge railing development has begun.

The sixth highest priority system was a Thrie Beam System. There were seven requests for this system to be developed to meet MASH TL-3 standards. This system was most commonly requested for use on concrete or transverse, nail-laminated timber decks. An approach guardrail transition will be developed with this bridge railing system to the respective test level as well.

The seventh highest priority system was a Low-Height, Curb-Type System to be designed to meet MASH TL-2 standards. This system was requested for use on longitudinal, spike-laminated or transverse, nail-laminated timber decks. For Low-Height, Curb-Type Systems, transitions are not typically used. Thus, a bridge railing end termination will be developed with this bridge railing system to meet MASH TL-2 standards.

The eighth highest priority system was a Steel-Backed Timber System which was to meet MASH TL-4 standards. Similar to the first priority system, which was a Timber Railing with Curb System to meet TL-4 criteria with considerations for TL-3 as well, this system will be developed to meet TL-4 criteria but will be able to be used in TL-3 situations. This Steel-Backed Timber System was requested for use on longitudinal or transverse glulam timber bridge decks. A transition will be developed with this bridge railing system to meet the MASH TL-3 standards as well.

The ninth highest priority system was a Low-Height, Curb-Type System. This system was requested to meet MASH TL-1 criteria and be used on transverse, nail-laminated timber decks. As planned with the TL-2 Low-Height, Curb-Type System (seventh highest priority), an end treatment will be developed to meet MASH TL-1 criteria.

The tenth highest priority system was a Timber Railing without Curb System, which was to meet MASH TL-3 impact safety standards. This system was requested for use on longitudinal, spike-laminated or longitudinal, stress-laminated timber decks. An approach guardrail transition will be developed to meet MASH TL-3 criteria.

The eleventh highest priority system was a Steel-Backed Timber System to meet MASH TL-2 criteria and developed for use on longitudinal, glulam timber or reinforced concrete decks. An approach guardrail transition will also be developed to meet MASH TL-2 impact safety standards.

The twelfth highest priority system was a Timber Railing without Curb System to meet MASH TL-2 impact safety criteria. The number of requests for each deck type were all very close. Thus, a deck type will be determined in the future. An approach guardrail transition will be developed to meet MASH TL-2 impact safety standards.

The thirteenth highest priority system was a Thrie Beam System to meet the MASH TL-4 criteria and for use on a transverse, glulam timber deck. An approach guardrail transition will be designed to meet MASH TL-3 safety criteria.

The fourteenth highest priority system was a Timber Railing without Curb System to meet MASH TL-4 criteria and for use on longitudinal and transverse glulam timber decks. An approach guardrail transition to meet MASH TL-3 criteria will also be developed.

The final system on the priority list was the Type 10T System offered for updates by the Colorado DOT. An example drawing of this system is provided in Figure C-5 of Appendix C. This system is composed of box beams supported by steel posts. A search through the Colorado DOT website revealed that other variations of this bridge railing system have been used with other deck types, including reinforced concrete decks where a concrete curb replaces the box-beam curb. It is believed that the characteristics for these other design variations may be considered when updating the Type 10T railing system in the future. According to the survey, this railing system was desired to meet MASH TL-3 and TL-4 criteria. At this time, the research team has prioritized the system development to meet MASH TL-3 while considering the additional aspects of the MASH TL-4 test matrix. It was requested to have this railing system be used on longitudinal, nail-laminated timber decks and steel corrugated decking with concrete or asphalt topping. An approach guardrail transition to meet MASH TL-3 criteria will also be developed.

7 RESEARCH PLANS

7.1 Future Research Plans

The 15 bridge railing systems and associated approach guardrail transitions identified within this study were compiled using survey results and findings from the literature review. For these bridge railing and transition systems, substantial project funding would be needed to perform the necessary research, development, construction, testing, and evaluation under the MASH 2016 criteria. Under this study, detailed research budgets were not created for the barrier systems. Instead and for all 15 systems, the research team created global tasks with sub-tasks and cost estimates for the global tasks using the priorities determined in Section 6. The research costs for each bridge railing and transition system is provided in Tables 16 through 23, with the total cost for all 15 systems provided in Table 24.

For each system, the first project task includes general project planning and documentation, client correspondence, progress reports and meetings, literature review as needed, development of computer-aided design details for the selected system, and documentation of mill certifications, material specifications, and certificates of conformity/compliance.

The second project task consists of the development, analysis, and design of the bridge railing and transition systems. The sub-tasks would include modifications to previous railing designs, selection and design of the bridge deck and surfacing, development of the post-to-deck anchorage systems, determination and selection of critical impact points, computer simulation of MASH impacts into barriers, and documentation of the analysis, design, and simulation efforts with findings.

The third project task includes dynamic component testing, which consists of the construction of test articles, conducting component and/or sub-system dynamic testing with electronic sensor instrumentation and video footage, field measurements, analysis of test results, and documentation of tests with findings.

The fourth through seventh project tasks included site preparations for construction and testing; acquisition of construction materials for the bridge railing and transition systems; conducting the MASH 2016 full-scale vehicle crash tests; removal and/or repair of damaged barriers, bridge deck, and soil regions between tests; test documentation; and removal of each system at the project conclusion.

The final project task includes the preparation of a summary report for each system with discussion of test results, presentation of findings, as well as conclusions and recommendations. This tasks also includes obtaining an FHWA eligibility letter and submitting drawings of the bridge railing and transition systems to the Task Force 13 database. Further, the research team envisions the preparation of journal articles, assisting with dissemination of research findings, and providing thoughts on implementation.

It should be noted that the estimated project costs presented in Tables 16 to 23 were based on the research for each system being performed separately. These costs do not take into consideration that the simultaneous funding of other research projects may provide material savings. For example, some components may be used on multiple projects. However, all design

details would need to be known for multiple projects on the onset in order to realize such cost savings as fabricated components would need to accommodate multiple connections. As such, the estimated project costs for all 15 systems depicted in Table 24 could decrease.

Note that the estimated costs shown in Tables 16 through 23 also represent testing being performed on the most critical deck type for each system, which would need to be determined through other research and analysis, such as bogie testing. If the most critical deck type cannot be determined, MASH testing may need to be performed on two or more deck types. This outcome would increase the cost for any system shown in the presented tables.

Table 16. Estimated Global Cost Per System

Project Tasks and Sub-Tasks	*Priority #1*		*Priority #2*	
	TL-4 TR w/ Curb	**Transition**	**TL-2 TR w/ Curb**	**Transition**
1. Project Planning and Correspondence	$35,000	$25,000	$35,000	$25,000
General Planning and Documentation				
Client Correspondence				
Progress Updates				
Literature Review				
Development of CAD Details for Selected Design				
2. Design and Analysis of Bridge Railing and Transition Systems	$100,000	$75,000	$100,000	$75,000
Modifications to Preliminary/Previous Design				
Selection and Design of Bridge Deck and Wearing Surface				
Development and Analysis of Post-to-Deck Anchorage				
Selection of Critical Impact Points				
Analysis Using LS-DYNA Computer Simulation				
Documentation of Design Process with Findings				
3. Dynamic Component Testing	$50,000	$100,000	$50,000	$100,000
Construction of Test Articles				
Conducting Dynamic Impact Tests				
Component Testing Data Analysis				
Onboard Vehicle Accelerometers and Angular Rate Trans.				
High-Speed and Low-Speed Video				
Post-Test Field Measurements, Documentation, and Findings				
4. Site Preparation	$300,000	$75,000	$300,000	$75,000
Soil Excavation				
Acquisition of Bridge Railing/AGT Materials				
Construction of Simulated Bridge Deck				
Construction of Bridge Railing System/AGT				
Instrumentation Installations (String Pots, etc.)				
5. MASH Testing for Respective Test Level - Includes Data Analysis from Onboard Vehicle Accelerometers and Angular Rate Transducers, High-Speed Video, and Post-Test Field Measurements	-	-	-	-
Test No. X-10/20: 1100C Small Car	$65,000	$65,000	$65,000	$65,000
Test No. X-11/21: 2270P Pickup Truck	$75,000	$75,000	$75,000	$75,000
Test No. X-12: 10000S Single Unit Truck at 56 mph and 15 degrees	$85,000	-	-	-
Reverse Direction Impact with Pickup Truck	-	$75,000	-	-
6. System Removal/Repair to Damaged Sections/ Deck	$30,000	$20,000	$20,000	$20,000
Repairs After First Test				
Repairs After Second Test				
7. System Removal and Disposal	$50,000	$20,000	$50,000	$20,000
Removal of Bridge Deck/Bridge Rail/AGT				
Restoration of Site w/ Compacted Soil				
8. Reporting and Project Deliverables	$50,000	$35,000	$40,000	$30,000
Summary Report with CAD Details, Mat. Specs., Mill Certs., Crash Testing, and Recommendations				
Report Editing (Internal and Sponsor Review)				
FHWA Eligibility Letter Submittal and TF13 Drawings				
Printing, Dissemination, and Accounting				
Total Cost for System Part	$840,000	$565,000	$735,000	$485,000
Total Cost for Development on Only First (Critical) Deck Type	$1,405,000		$1,220,000	

Table 17. Estimated Global Cost Per System (continued)

Project Tasks and Sub-Tasks	*Priority #3*		*Priority #4*	
	TL-2 Thrie Beam	**Transition**	**TL-3 W-Beam**	**Transition**
1. Project Planning and Correspondence	$30,000	$15,000	$30,000	$15,000
General Planning and Documentation				
Client Correspondence				
Progress Updates				
Literature Review				
Development of CAD Details for Selected Design				
2. Design and Analysis of Bridge Railing and Transition Systems	$75,000	$50,000	$50,000	$30,000
Modifications to Preliminary/Previous Design				
Selection and Design of Bridge Deck and Wearing Suface				
Development and Analysis of Post-to-Deck Anchorage				
Selection of Critical Impact Points				
Analysis Using LS-DYNA Computer Simulation				
Documentation of Design Process with Findings				
3. Dynamic Component Testing	$50,000	$50,000	$20,000	$50,000
Construction of Test Articles				
Conducting Dynamic Impact Tests				
Component Testing Data Analysis				
Onboard Vehicle Accelerometers and Angular Rate Trans.				
High-Speed and Low-Speed Video				
Post-Test Field Measurements, Documentation, and Findings				
4. Site Preparation	$300,000	$75,000	$250,000	$50,000
Soil Excavation				
Acquisition of Bridge Railing/AGT Materials				
Construction of Simulated Bridge Deck				
Construction of Bridge Railing System/AGT				
Instrumentation Installations (String Pots, etc.)				
5. MASH Testing for Respective Test Level - Includes Data Analysis from Onboard Vehicle Accelerometers and Angular Rate Transducers, High-Speed Video, and Post-Test Field Measurements	-	-	-	-
Test No. X-10/20: 1100C Small Car	$65,000	$65,000	$65,000	$65,000
Test No. X-11/21: 2270P Pickup Truck	$75,000	$75,000	$75,000	$75,000
Test No. X-12: 10000S Single Unit Truck at 56 mph and 15 degrees	-	-	-	-
Reverse Direction Impact with Pickup Truck	-	-	-	-
6. System Removal/Repair to Damaged Sections/ Deck	$30,000	$20,000	$20,000	$20,000
Repairs After First Test				
Repairs After Second Test				
7. System Removal and Disposal	$50,000	$20,000	$50,000	$15,000
Removal of Bridge Deck/Bridge Rail/AGT				
Restoration of Site w/ Compacted Soil				
8. Reporting and Project Deliverables	$40,000	$30,000	$40,000	$30,000
Summary Report with CAD Details, Mat. Specs., Mill Certs., Crash Testing, and Recommendations				
Report Editing (Internal and Sponsor Review)				
FHWA Eligibility Letter Submittal and TF13 Drawings				
Printing, Dissemination, and Accounting				
Total Cost for System Part	$715,000	$400,000	$600,000	$350,000
Total Cost for Development on Only First (Critical) Deck Type	$1,115,000		$950,000	

Table 18. Estimated Global Cost Per System (continued)

Project Tasks and Sub-Tasks	*Priority #5*		*Priority #6*	
	TL-2 W-Beam	**Transition**	**TL-3 Thrie Beam**	**Transition**
1. Project Planning and Correspondence	$30,000	$15,000	$30,000	$15,000
General Planning and Documentation				
Client Correspondence				
Progress Updates				
Literature Review				
Development of CAD Details for Selected Design				
2. Design and Analysis of Bridge Railing and Transition Systems	$50,000	$30,000	$75,000	$50,000
Modifications to Preliminary/Previous Design				
Selection and Design of Bridge Deck and Wearing Surface				
Development and Analysis of Post-to-Deck Anchorage				
Selection of Critical Impact Points				
Analysis Using LS-DYNA Computer Simulation				
Documentation of Design Process with Findings				
3. Dynamic Component Testing	$20,000	$50,000	$50,000	$50,000
Construction of Test Articles				
Conducting Dynamic Impact Tests				
Component Testing Data Analysis				
Onboard Vehicle Accelerometers and Angular Rate Trans.				
High-Speed and Low-Speed Video				
Post-Test Field Measurements, Documentation, and Findings				
4. Site Preparation	$250,000	$50,000	$300,000	$75,000
Soil Excavation				
Acquisition of Bridge Railing/AGT Materials				
Construction of Simulated Bridge Deck				
Construction of Bridge Railing System/AGT				
Instrumentation Installations (String Pots, etc.)				
5. MASH Testing for Respective Test Level - Includes Data Analysis from Onboard Vehicle Accelerometers and Angular Rate Transducers, High-Speed Video, and Post-Test Field Measurements	-	-	-	-
Test No. X-10/20: 1100C Small Car	$65,000	$65,000	$65,000	$65,000
Test No. X-11/21: 2270P Pickup Truck	$75,000	$75,000	$75,000	$75,000
Test No. X-12: 10000S Single Unit Truck at 56 mph and 15 degrees	-	-	-	-
Reverse Direction Impact with Pickup Truck	-	-	-	-
6. System Removal/Repair to Damaged Sections/ Deck	$20,000	$20,000	$30,000	$20,000
Repairs After First Test				
Repairs After Second Test				
7. System Removal and Disposal	$50,000	$15,000	$50,000	$20,000
Removal of Bridge Deck/Bridge Rail/AGT				
Restoration of Site w/ Compacted Soil				
8. Reporting and Project Deliverables	$40,000	$30,000	$40,000	$30,000
Summary Report with CAD Details, Mat. Specs., Mill Certs., Crash Testing, and Recommendations				
Report Editing (Internal and Sponsor Review)				
FHWA Eligibility Letter Submittal and TF13 Drawings				
Printing, Dissemination, and Accounting				
Total Cost for System Part	$600,000	$350,000	$715,000	$400,000
Total Cost for Development on Only First (Critical) Deck Type	$950,000		$1,115,000	

Table 19. Estimated Global Cost Per System (continued)

Project Tasks and Sub-Tasks	*Priority #7*		*Priority #8*	
	TL-2 LHCT	**Transition**	**TL-4 Steel-Backed**	**Transition**
1. Project Planning and Correspondence	$30,000	$15,000	$35,000	$25,000
General Planning and Documentation				
Client Correspondence				
Progress Updates				
Literature Review				
Development of CAD Details for Selected Design				
2. Design and Analysis of Bridge Railing and Transition Systems	$75,000	$50,000	$75,000	$50,000
Modifications to Preliminary/Previous Design				
Selection and Design of Bridge Deck and Wearing Surface				
Development and Analysis of Post-to-Deck Anchorage				
Selection of Critical Impact Points				
Analysis Using LS-DYNA Computer Simulation				
Documentation of Design Process with Findings				
3. Dynamic Component Testing	$50,000	$30,000	$50,000	$50,000
Construction of Test Articles				
Conducting Dynamic Impact Tests				
Component Testing Data Analysis				
Onboard Vehicle Accelerometers and Angular Rate Trans.				
High-Speed and Low-Speed Video				
Post-Test Field Measurements, Documentation, and Findings				
4. Site Preparation	$250,000	$50,000	$250,000	$75,000
Soil Excavation				
Acquisition of Bridge Railing/AGT Materials				
Construction of Simulated Bridge Deck				
Construction of Bridge Railing System/AGT				
Instrumentation Installations (String Pots, etc.)				
5. MASH Testing for Respective Test Level - Includes Data Analysis from Onboard Vehicle Accelerometers and Angular Rate Transducers, High-Speed Video, and Post-Test Field Measurements	-	-	-	-
Test No. X-10/20: 1100C Small Car	$65,000	$65,000	$65,000	$65,000
Test No. X-11/21: 2270P Pickup Truck	$75,000	$75,000	$75,000	$75,000
Test No. X-12: 10000S Single Unit Truck at 56 mph and 15 degrees	-	-	$85,000	-
Reverse Direction Impact with Pickup Truck	-	-	-	$75,000
6. System Removal/Repair to Damaged Sections/ Deck	$15,000	$15,000	$40,000	$30,000
Repairs After First Test				
Repairs After Second Test				
7. System Removal and Disposal	$50,000	$15,000	$75,000	$20,000
Removal of Bridge Deck/Bridge Rail/AGT				
Restoration of Site w/ Compacted Soil				
8. Reporting and Project Deliverables	$40,000	$30,000	$50,000	$35,000
Summary Report with CAD Details, Mat. Specs., Mill Certs., Crash Testing, and Recommendations				
Report Editing (Internal and Sponsor Review)				
FHWA Eligibility Letter Submittal and TF13 Drawings				
Printing, Dissemination, and Accounting				
Total Cost for System Part	$650,000	$345,000	$800,000	$500,000
Total Cost for Development on Only First (Critical) Deck Type	$995,000		$1,300,000	

Table 20. Estimated Global Cost Per System (continued)

Project Tasks and Sub-Tasks	*Priority #9*		*Priority #10*	
	TL-1 LHCT	**Transition**	**TL-3 TR w/o Curb**	**Transition**
1. Project Planning and Correspondence	$25,000	$15,000	$35,000	$25,000
General Planning and Documentation				
Client Correspondence				
Progress Updates				
Literature Review				
Development of CAD Details for Selected Design				
2. Design and Analysis of Bridge Railing and Transition Systems	$25,000	$20,000	$100,000	$75,000
Modifications to Preliminary/Previous Design				
Selection and Design of Bridge Deck and Wearing Surface				
Development and Analysis of Post-to-Deck Anchorage				
Selection of Critical Impact Points				
Analysis Using LS-DYNA Computer Simulation				
Documentation of Design Process with Findings				
3. Dynamic Component Testing	$0	$0	$50,000	$100,000
Construction of Test Articles				
Conducting Dynamic Impact Tests				
Component Testing Data Analysis				
Onboard Vehicle Accelerometers and Angular Rate Trans.				
High-Speed and Low-Speed Video				
Post-Test Field Measurements, Documentation, and Findings				
4. Site Preparation	$225,000	$50,000	$275,000	$75,000
Soil Excavation				
Acquisition of Bridge Railing/AGT Materials				
Construction of Simulated Bridge Deck				
Construction of Bridge Railing System/AGT				
Instrumentation Installations (String Pots, etc.)				
5. MASH Testing for Respective Test Level - Includes Data Analysis from Onboard Vehicle Accelerometers and Angular Rate Transducers, High-Speed Video, and Post-Test Field Measurements	-	-	-	-
Test No. X-10/20: 1100C Small Car	$65,000	$65,000	$65,000	$65,000
Test No. X-11/21: 2270P Pickup Truck	-	$75,000	$75,000	$75,000
Test No. X-12: 10000S Single Unit Truck at 56 mph and 15 degrees	-	-	-	-
Reverse Direction Impact with Pickup Truck	-	-	-	$75,000
6. System Removal/Repair to Damaged Sections/ Deck	$0	$15,000	$30,000	$20,000
Repairs After First Test				
Repairs After Second Test				
7. System Removal and Disposal	$50,000	$15,000	$50,000	$20,000
Removal of Bridge Deck/Bridge Rail/AGT				
Restoration of Site w/ Compacted Soil				
8. Reporting and Project Deliverables	$30,000	$30,000	$40,000	$35,000
Summary Report with CAD Details, Mat. Specs., Mill Certs., Crash Testing, and Recommendations				
Report Editing (Internal and Sponsor Review)				
FHWA Eligibility Letter Submittal and TF13 Drawings				
Printing, Dissemination, and Accounting				
Total Cost for System Part	$420,000	$285,000	$720,000	$565,000
Total Cost for Development on Only First (Critical) Deck Type	$705,000		$1,285,000	

Table 21. Estimated Global Cost Per System (continued)

Project Tasks and Sub-Tasks	*Priority #11*		*Priority #12*	
	TL-2 Steel-Backed	**Transition**	**TL-2 TR w/o Curb**	**Transition**
1. Project Planning and Correspondence	$35,000	$25,000	$35,000	$25,000
General Planning and Documentation				
Client Correspondence				
Progress Updates				
Literature Review				
Development of CAD Details for Selected Design				
2. Design and Analysis of Bridge Railing and Transition Systems	$75,000	$50,000	$100,000	$75,000
Modifications to Preliminary/Previous Design				
Selection and Design of Bridge Deck and Wearing Surface				
Development and Analysis of Post-to-Deck Anchorage				
Selection of Critical Impact Points				
Analysis Using LS-DYNA Computer Simulation				
Documentation of Design Process with Findings				
3. Dynamic Component Testing	$50,000	$50,000	$50,000	$100,000
Construction of Test Articles				
Conducting Dynamic Impact Tests				
Component Testing Data Analysis				
Onboard Vehicle Accelerometers and Angular Rate Trans.				
High-Speed and Low-Speed Video				
Post-Test Field Measurements, Documentation, and Findings				
4. Site Preparation	$250,000	$75,000	$275,000	$75,000
Soil Excavation				
Acquisition of Bridge Railing/AGT Materials				
Construction of Simulated Bridge Deck				
Construction of Bridge Railing System/AGT				
Instrumentation Installations (String Pots, etc.)				
5. MASH Testing for Respective Test Level - Includes Data Analysis from Onboard Vehicle Accelerometers and Angular Rate Transducers, High-Speed Video, and Post-Test Field Measurements	-	-	-	-
Test No. X-10/20: 1100C Small Car	$65,000	$65,000	$65,000	$65,000
Test No. X-11/21: 2270P Pickup Truck	$75,000	$75,000	$75,000	$75,000
Test No. X-12: 10000S Single Unit Truck at 56 mph and 15 degrees	-	-	-	-
Reverse Direction Impact with Pickup Truck	-	$75,000	-	-
6. System Removal/Repair to Damaged Sections/ Deck	$30,000	$20,000	$30,000	$20,000
Repairs After First Test				
Repairs After Second Test				
7. System Removal and Disposal	$65,000	$20,000	$50,000	$20,000
Removal of Bridge Deck/Bridge Rail/AGT				
Restoration of Site w/ Compacted Soil				
8. Reporting and Project Deliverables	$40,000	$35,000	$40,000	$30,000
Summary Report with CAD Details, Mat. Specs., Mill Certs., Crash Testing, and Recommendations				
Report Editing (Internal and Sponsor Review)				
FHWA Eligibility Letter Submittal and TF13 Drawings				
Printing, Dissemination, and Accounting				
Total Cost for System Part	$685,000	$490,000	$720,000	$485,000
Total Cost for Development on Only First (Critical) Deck Type	$1,175,000		$1,205,000	

Table 22. Estimated Global Cost Per System (continued)

Project Tasks and Sub-Tasks	*Priority #13*		*Priority #14*	
	TL-4 Thrie Beam	**Transition**	**TL-4 TR w/o Curb**	**Transition**
1. Project Planning and Correspondence	$35,000	$25,000	$35,000	$25,000
General Planning and Documentation				
Client Correspondence				
Progress Updates				
Literature Review				
Development of CAD Details for Selected Design				
2. Design and Analysis of Bridge Railing and Transition Systems	$100,000	$75,000	$125,000	$75,000
Modifications to Preliminary/Previous Design				
Selection and Design of Bridge Deck and Wearing Surface				
Development and Analysis of Post-to-Deck Anchorage				
Selection of Critical Impact Points				
Analysis Using LS-DYNA Computer Simulation				
Documentation of Design Process with Findings				
3. Dynamic Component Testing	$50,000	$50,000	$75,000	$100,000
Construction of Test Articles				
Conducting Dynamic Impact Tests				
Component Testing Data Analysis				
Onboard Vehicle Accelerometers and Angular Rate Trans.				
High-Speed and Low-Speed Video				
Post-Test Field Measurements, Documentation, and Findings				
4. Site Preparation	$300,000	$75,000	$300,000	$75,000
Soil Excavation				
Acquisition of Bridge Railing/AGT Materials				
Construction of Simulated Bridge Deck				
Construction of Bridge Railing System/AGT				
Instrumentation Installations (String Pots, etc.)				
5. MASH Testing for Respective Test Level - Includes Data Analysis from Onboard Vehicle Accelerometers and Angular Rate Transducers, High-Speed Video, and Post-Test Field Measurements	-	-	-	-
Test No. X-10/20: 1100C Small Car	$65,000	$65,000	$65,000	$65,000
Test No. X-11/21: 2270P Pickup Truck	$75,000	$75,000	$75,000	$75,000
Test No. X-12: 10000S Single Unit Truck at 56 mph and 15 degrees	$85,000	-	$85,000	-
Reverse Direction Impact with Pickup Truck	-	-	-	$75,000
6. System Removal/Repair to Damaged Sections/ Deck	$40,000	$30,000	$40,000	$30,000
Repairs After First Test				
Repairs After Second Test				
7. System Removal and Disposal	$50,000	$20,000	$65,000	$20,000
Removal of Bridge Deck/Bridge Rail/AGT				
Restoration of Site w/ Compacted Soil				
8. Reporting and Project Deliverables	$50,000	$30,000	$50,000	$35,000
Summary Report with CAD Details, Mat. Specs., Mill Certs., Crash Testing, and Recommendations				
Report Editing (Internal and Sponsor Review)				
FHWA Eligibility Letter Submittal and TF13 Drawings				
Printing, Dissemination, and Accounting				
Total Cost for System Part	$850,000	$445,000	$915,000	$575,000
Total Cost for Development on Only First (Critical) Deck Type	$1,295,000		$1,490,000	

Table 23. Estimated Global Cost Per System (continued)

Project Tasks and Sub-Tasks	*Priority #15*	
	TL-3 Type 10T	**Transition**
1. Project Planning and Correspondence	$30,000	$25,000
General Planning and Documentation		
Client Correspondence		
Progress Updates		
Literature Review		
Development of CAD Details for Selected Design		
2. Design and Analysis of Bridge Railing and Transition Systems	$75,000	$75,000
Modifications to Preliminary/Previous Design		
Selection and Design of Bridge Deck and Wearing Surface		
Development and Analysis of Post-to-Deck Anchorage		
Selection of Critical Impact Points		
Analysis Using LS-DYNA Computer Simulation		
Documentation of Design Process with Findings		
3. Dynamic Component Testing	$75,000	$75,000
Construction of Test Articles		
Conducting Dynamic Impact Tests		
Component Testing Data Analysis		
Onboard Vehicle Accelerometers and Angular Rate Trans.		
High-Speed and Low-Speed Video		
Post-Test Field Measurements, Documentation, and Findings		
4. Site Preparation	$325,000	$75,000
Soil Excavation		
Acquisition of Bridge Railing/AGT Materials		
Construction of Simulated Bridge Deck		
Construction of Bridge Railing System/AGT		
Instrumentation Installations (String Pots, etc.)		
5. MASH Testing for Respective Test Level - Includes Data Analysis from Onboard Vehicle Accelerometers and Angular Rate Transducers, High-Speed Video, and Post-Test Field Measurements	-	-
Test No. X-10/20: 1100C Small Car	$65,000	$65,000
Test No. X-11/21: 2270P Pickup Truck	$75,000	$75,000
Test No. X-12: 10000S Single Unit Truck at 56 mph and 15 degrees	-	-
Reverse Direction Impact with Pickup Truck	-	$75,000
6. System Removal/Repair to Damaged Sections/ Deck	$30,000	$25,000
Repairs After First Test		
Repairs After Second Test		
7. System Removal and Disposal	$50,000	$20,000
Removal of Bridge Deck/Bridge Rail/AGT		
Restoration of Site w/ Compacted Soil		
8. Reporting and Project Deliverables	$40,000	$35,000
Summary Report with CAD Details, Mat. Specs., Mill Certs., Crash Testing, and Recommendations		
Report Editing (Internal and Sponsor Review)		
FHWA Eligibility Letter Submittal and TF13 Drawings		
Printing, Dissemination, and Accounting		
Total Cost for System Part	$765,000	$545,000
Total Cost for Development on Only First (Critical) Deck Type	$1,310,000	

Table 24. Estimated Global Cost for All Systems

System	*Cost*
Priority #1 **TL-4 TR w/ Curb**	$1,405,000
Priority #2 **TL-2 TR w/ Curb**	$1,220,000
Priority #3 **TL-2 Thrie Beam**	$1,115,000
Priority #4 **TL-3 W-Beam**	$950,000
Priority #5 **TL-2 W-Beam**	$950,000
Priority #6 **TL-3 Thrie Beam**	$1,115,000
Priority #7 **TL-2 LHCT**	$995,000
Priority #8 **TL-4 Steel-Backed**	$1,300,000
Priority #9 **TL-1 LHCT**	$705,000
Priority #10 **TL-3 TR w/o Curb**	$1,285,000
Priority #11 **TL-2 Steel-Backed**	$1,175,000
Priority #12 **TL-2 TR w/o Curb**	$1,205,000
Priority #13 **TL-4 Thrie Beam**	$1,295,000
Priority #14 **TL-4 TR w/o Curb**	$1,490,000
Priority #15 **TL-3 Type 10T**	$1,310,000
All Systems	$17,515,000

8 REFERENCES

1. Ross, H.E., Sicking, D.L., Zimmer, R.A., and Michie, J.D., *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, National Cooperative Highway Research Program (NCHRP) Report 350, Transportation Research Board, Washington, D.C., 1993.

2. *Guide Specifications for Bridge Railings*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 1989.

3. *Manual for Assessing Safety Hardware (MASH)*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2009.

4. *Manual for Assessing Safety Hardware (MASH), Second Edition*, American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 2016.

5. Ritter, M.A., Faller, R.K., Sicking, D.L., and Bunnell, S., *Development of Low-Volume Curb-Type Bridge Railings for Timber Bridge Decks*, Draft Report to the United Sates Department of Agriculture-Forest Service-Forest Products Laboratory, Transportation Report No. TRP-03-31-93, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, December 1993.

6. Faller, R.K., Rosson, B.T., Ritter, M.A., Sicking, D.L., and Bunnell, S., *Design and Evaluation of Two Low-Volume Bridge Railings*, Sixth International Conference on Low-Volume Roads, Volume 2, Conference Proceedings 6, University of Minnesota, Minneapolis, Minnesota, June 25-29, 1995, Transportation Research Board, Washington, D.C.

7. Faller, R.K., Rosson, B.T., Ritter, M.A., Lee, P.D.H., and Duwadi, S.R., *Railing Systems for Longitudinal Timber Deck Bridges*, National Conference on Wood Transportation Structures, Madison, Wisconsin, October 23-25, 1996, General Technical Report No. FPL-GTR-94, United States Department of Agriculture - Forest Service - Forest Products Laboratory and Federal Highway Administration, October 1996.

8. Ritter, M.A., Faller, R.K., Bunnell, S., Lee, P.D.H., and Rosson, B.T., *Plans for Crash-Tested Bridge Railings for Longitudinal Wood Decks on Low-Volume Roads*, General Technical Report No. FPL-GTR-107, United States Department of Agriculture - Forest Service - Forest Products Laboratory and Federal Highway Administration, August 1998.

9. Faller, R.K., and Rosson, B.T., *Crashworthy Barriers for Timber Deck Bridges*, 18th Annual Structural Conference - Engineered Wood Systems, Sponsored by the University of Nebraska-Lincoln and the American Society of Civil Engineers Nebraska Section, Kiewit Conference Center, Omaha, Nebraska, October 2, 1998.

10. Ritter, M.A., Faller, R.K., and Duwadi, S.R., *Crashworthy Railing for Timber Bridges*, Proceedings of the 1999 Pacific Timber Engineering Conference (PTEC), Rotorua, New Zealand, March 14-18, 1999, New Zealand Forest Research Institute, Forest Service Research Bulletin No. 212, Volume 3: 325-332.

11. Faller, R.K., Rosson, B.T., Ritter, M.A., and Duwadi, S.R., *Railing Systems for Use on Timber Deck Bridges*, Transportation Research Record No. 1656, Journal of the Transportation Research Board, Transportation Research Board, Washington, D.C., July 1999, 110-119.

12. Faller, R.K., Soyland, K., Rosson, B.T., and Stutzman, T.M., *TL-1 Curb-Type Bridge Railing for Longitudinal Glulam Timber Decks Located on Low-Volume Roads*, Draft Report to the United Sates Department of Agriculture-Forest Service-Forest Products Laboratory, Transportation Report No. TRP-03-54-96, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, April 1996.

13. Ritter, M.A., Faller, R.K., Lee, P.D.H., Rosson, B.T., and Duwadi, S.R., *Plans for Crash-Tested Wood Bridge Railings for Concrete Decks*, General Technical Report No. FPL-GTR-108, United States Department of Agriculture - Forest Service - Forest Products Laboratory and Federal Highway Administration, August 1998.

14. Rosenbaugh, S.K., Benner, C.D., Faller, R.K., Bielenberg, R.W., Reid, J.D., and Sicking, D.L., *Development of a TL-1 Timber, Curb-Type, Bridge Railing for Use on Transverse, Nail-Laminated, Timber Bridges*, Final Report to the West Virginia Department of Transportation, Transportation Research Report No. TRP-03-211-09, Project No.: WV-09-2007-B1, Sponsor Agency Code: SPR-3(017) Supplement #53, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, May 6, 2009.

15. Mongiardini, M, Rosenbaugh, S.K., Faller, R.K., Reid, J.D., Bielenberg, R.W., and Sicking, D.L., *Design and Testing of Two Bridge Railings for Transverse, Nail-Laminated, Timber Deck Bridges*, Paper No. 11-2936, Transportation Research Record No. 2262, Journal of the Transportation Research Board, TRB AFB20 Committee on Roadside Safety Design, Transportation Research Board, Washington D.C., January 2011.

16. Ritter, M.A., Post, E.R., and Faller, R.K., *Vehicular Railing Systems for Timber Bridges: A Program Overview*, COMPONENTS, Wood Design Focus - A Journal of Contemporary Wood Engineering, Volume 1, Number 4, Winter 1990.

17. Ritter, M.A., Post, E.R., and Faller, R.K., *Crashworthy Railing Systems for Timber Bridge Decks*, Structures Congress 1991, Compact Papers, 9th Structures Congress Proceedings, 1991 April 29 - May 1, Indianapolis, IN, American Society of Civil Engineers, Pages 540-543, 1991.

18. Ritter, M.A., Faller, R.K., Holloway, J.C., Pfeifer, B.G., and Rosson, B.T., *Development and Testing of Bridge Railings for Longitudinal Timber Decks by Full-Scale Crash Testing*, Draft Report to the U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Transportation Research Report No. TRP-03-29-94, Civil Engineering Department, University of Nebraska-Lincoln, August 1992.

19. Faller, R.K., Ritter, M.A., Holloway, J.C., Pfeifer, B.G., and Rosson, B.T., *Performance Level 1 Bridge Railings for Timber Decks*, Transportation Research Record No. 1419, Best Paper Award - TRB A2A04 Committee on Roadside Safety Appurtenances, Transportation Research Board, Washington, D.C., October 1993.

20. Ritter, M.A. and Faller, R.K., *Crashworthy Bridge Railings for Longitudinal Wood Decks*, Proceedings of the 1994 Pacific Timber Engineering Conference (PTEC) - Timber Shaping the Future, Gold Coast, Australia, Fortitude Valley MAC, Queensland, Australia, July 11-15, 1994, Timber Research and Advisory Council, Volume 2: 298-307.

21. Ritter, M.A., Faller, R.K., and Duwadi, S.R., *Crash-Tested Bridge Railings for Timber Bridges*, Fourth International Bridge Engineering Conference, Volume 2, Conference Proceedings 7, San Francisco, California, August 28-30, 1995, Transportation Research Board, Washington, D.C.

22. Ritter, M.A., Faller, R.K., Lee, P.D.H., Rosson, B.T., and S.R. Duwadi, *Plans for Crash Tested Bridge Railings for Longitudinal Wood Decks*, General Technical Report No. FPL-GTR-87, United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, September 1995.

23. Raju, P.R. and GangaRao, H.V.S., *Timber Bridge Rail Testing and Evaluation*. Report 186187188. Constructed Facilities Center, West Virginia University, Morgantown, Submitted for Publication, 1994.

24. Raju, P.R., GangaRao, H.V.S., Duwadi, S.R., and Thippeswamy, H.K., *Development and Testing of Timber Bridge and Transition Rails for Transverse Glued-Laminated Bridge Decks*. Transportation Research Record: Journal of the Transportation Research Board, 1994. 1460: 8-18.

25. Faller, R.K., Ritter, M.A., Rosson, B.T., Keller, E.A., and Duwadi, S.R., *Development of Two TL-2 Bridge Railings and Transitions for Use on Transverse Glue-Laminated Deck Bridges*, Paper No. 01-0378, Transportation Research Record No. 1743, Journal of the Transportation Research Board, Transportation Research Board, Washington, D.C., January 2001.

26. Polivka, K.A., Faller, R.K., Ritter, M.A., Rosson, B.T., Rohde, J.R., and Keller, E.A., *Two Test Level 2 Bridge Railing and Transition Systems for Transverse Glue-Laminated Timber Decks*, Draft Report to the U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Report No. TRP-03-125-03, Midwest Roadside Safety Facility, Civil Engineering Department, University of Nebraska-Lincoln, March 11, 2003.

27. Hancock, K.L., Hansen, A.G., and Mayer, J.B., *Aesthetic Bridge Rails, Transitions, and Terminals For Park Roads and Parkways*, Report No. FHWA-RD-90-052, FHWA, U.S. Department of Transportation, May 1990.

28. Hale, C.Y., *Static Load Test of Weyerhaeuser Bridge Rail Systems*, Weyerhaeuser Company, Report No. RDR 045-1609-1, Tacoma, Washington, April 1977.

29. *AASHTO Interim 1975 to Standard Specifications for Highway Bridges, 11th ed*. American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C., 1973.

30. Rosson, B.T., Faller, R.K., and Ritter, M.A., *Performance Level 2 and Test Level 4 Bridge Railings for Timber Decks*, Transportation Research Record No. 1500, Transportation Research Board, Washington, D.C., July 1995.

31. Hitz, R.A., Polivka, K.A., Faller, R.K., Ritter, M.A., Rosson, B.T., and Holloway, J.C., *Development of the GC-8000 Bridge Railing and Transition*, Draft Report to the U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Report No. TRP-03-161-06, Midwest Roadside Safety Facility, Civil Engineering Department, University of Nebraska-Lincoln, May 2, 2006.

32. Faller, R.K., Ritter, M.A., Rosson, B.T., Fowler, M.D., and Duwadi, S.R., *Two Test Level 4 Bridge Railing and Transition Systems for Transverse Timber Deck Bridges*, Paper No. 5B0110, Transportation Research Record No. 1696, Journal of the Transportation Research Board, Volume 1, Fifth International Bridge Engineering Conference, Tampa, Florida, April 3-5, 2000, Transportation Research Board, Washington, D.C., 334-351.

33. Polivka, K.A., Faller, R.K., Ritter, M.A., Rosson, B.T., Fowler, M.D., and Keller, E.A., *Two Test Level 4 Bridge Railing and Transition Systems for Transverse Glue-Laminated Timber Decks*, Draft Report to the U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Report No. TRP-03-71-01, Midwest Roadside Safety Facility, Civil Engineering Department, University of Nebraska-Lincoln, January 30, 2002.

34. Faller, R.K., and Rosson, B.T., *Development of a Flexible Bridge Railing for Longitudinal Timber Decks*, Draft Report to the United Sates Department of Agriculture-Forest Service-Forest Products Laboratory, Transportation Report No. TRP-03-62-96, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, June 1997.

35. Faller, R.K., Rosson, B.T., and Fowler, M.D., *Top-Mounted W-Beam Bridge Railing for Longitudinal Glulam Timber Decks Located on Low-Volume Roads*, Draft Report to the United Sates Department of Agriculture-Forest Service-Forest Products Laboratory, Transportation Report No. TRP-03-61-96, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, September 1996.

36. Williams, W.F., *W-Beam Bridge Rail for Temporary Timber Deck Bridge Installations*, Memorandum, TM-405160-40, Texas A&M Transportation Institute, College Station, TX. August 2013.

37. Polivka, K.A., Faller, R.K., Ritter, M.A., and Rosson, B.T., *Development of the TBC-8000 Bridge Railing*, Draft Report to the U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Report No. TRP-03-30-93, Midwest Roadside Safety Facility, Civil Engineering Department, University of Nebraska-Lincoln, September 5, 2000.

38. Terpsma, R.J., Faller, R.K., Reid, J.D., Sicking, D.L., Bielenberg, R.W., Rosenbaugh, S.K., Lechtenberg, K.A., and Holloway, J.C., *Development of a TL-2 Steel Bridge Railing and Transition for Use on Transverse, Nail-Laminated, Timber Bridges*, Final Report to the West Virginia Department of Transportation, Transportation Research Report No. TRP-03-212-09, Project No.: WV-09-2007-B2, Sponsor Agency Code: SPR-3(017) Supplement #52, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, August 13, 2009.

39. Mongiardini, M, Rosenbaugh, S.K., Faller, R.K., Reid, J.D., Bielenberg, R.W., and Sicking, D.L., *Design and Testing of Two Bridge Railings for Transverse, Nail-Laminated, Timber Deck Bridges*, Paper No. 11-2936, Transportation Research Record No. 2262, Journal of the Transportation Research Board, TRB AFB20 Committee on Roadside Safety Design, Transportation Research Board, Washington D.C., January 2011.

40. Reid, J.D., Faller, R.K., and Hascall, J.A., *Deck-Mounted Steel Post Barrier System*, Manuscript No. BE 23205, Journal of Bridge Engineering, Volume 12, Number 4, American Society of Civil Engineering (ASCE), July/August 2007, 449-455.

41. Bullard, D.L. Jr., Menges, W.L., Buth, C.E. and Haug, R.R., *Guardrail Testing Program IV, Volume I: Technical Report*, Report No. FHWA-RD-04-086, FHWA, U.S. Department of Transportation, September 2004.

42. *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances*, National Cooperative Highway Research Program Report No. 230, Transportation Research Board, Washington, D.C., March 1981.

43. Pousette, A. and Fjellström, P.A., *Experiences from timber bridge inspections in Sweden – examples of influence of moisture*, SP Technical Research Institute of Sweden, SP Report No. 2016:45, 2016.

9 APPENDICES

Appendix A. Blank Survey Content

MwRSF-UNL and USDA-FS-FPL Survey

Introduction

This survey pertains to FPL Project No. 18-JV-11111107-037, *Evaluation of Crash Tested Bridge Railing for Wood Bridges*. Your participation is vital to the research team and advisory panel.

The survey will:

- identify commonly-used bridge railing systems for wood bridges;
- help researchers and panel members select currently-implemented systems for future evaluation under the AASHTO MASH impact safety criteria;
- uncover any other ideas for bridge railing systems to be developed to current AASHTO MASH impact safety criteria; and
- identify any special conditions to take into consideration when developing approach guardrail transitions or bridge rail terminations to accompany these bridge railings.

The successful completion of this survey will allow your organization's bridge railings and needs to be considered within the project planning and potentially selected for further research, development, testing, and evaluation under MASH safety performance guidelines.

The study is focused on identifying commonly-used, non-proprietary systems in need of testing under MASH.

Instructions

This survey consists of **five questions**, each of which pertain to bridge railing systems for use on wood bridges, as well as their approach guardrail transitions or end terminations. For the purpose of this survey, we are defining a wood bridge as a bridge that has a wood deck, wood railing system, or both. For example, a relevant system could include a steel thrie beam bridge railing attached to a wood bridge deck, or a wood bridge railing attached to a concrete bridge deck. The survey may require 15 minutes to complete.

Throughout the survey, when entering information into a single-line response box, text can continuously scroll to the right. When entering information into a

multi-line response box, drag the bottom right corner with your cursor to expand the box for better viewing. Also, questions with circular check boxes can only have one answer (Yes/No), while questions with square check boxes can have multiple answers.

To save your progress and finish the survey at a later time, enter your email address using the **"Save and continue later"** button visible at the top of the screen. This process will provide you with a unique link that you can click on to re-enter the survey where you left off. The email with the link may be sent to your email's spam folder, so if your email does not arrive within a few minutes, **please check your spam**. This unique link may be shared with others to allow multiple people to answer and save questions in the same survey.

Portions of this survey are not compatible with mobile devices, so please complete the survey on a desktop computer or laptop. To go back and forth between pages, do not use your browser's back button. Instead, use the "Back" and "Next" buttons at the bottom of each page.

The primary survey participant shall complete the following information:

If another person provides survey content or should be contacted later, please add their name(s), phone number(s), and email address(es) at the end of the survey to aid with follow-up communications.

	Response:
First Name:	
Last Name:	
Position/Title:	
Organization:	
Department/Division:	
Street Address:	
Building:	
Room Number:	

City:	
State:	
Zip Code:	
Telephone Number:	
Fax Number:	
Email Address:	

Example Bridge Railing Systems

Question 1 of 5: Bridge Railing Systems Currently In Use

1) What types of bridge railing systems are ***currently*** installed on wood bridges? **If you are a consultant, please denote any bridge railing systems that you have designed, constructed, or recommended for use in the field. If you are a representative of a government agency, please denote any bridge railing systems that your agency owns or manages.** For each system, please indicate the deck type(s) on which the system has been installed and indicate whether or not the system has been deemed crashworthy by previous crash testing. If yes, please indicate to which test or performance level the system has been tested and evaluated. Finally, estimate the percentage of systems in place for each type. Be sure to check that percentages sum to 100% in the end.

Number of Systems:*

If you have more than ten systems, please contact the survey distributor to provide additional information.

- 0
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10

System 1:*

System Name:*:

System Description:*

Deck Type:*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*:

Crash-Tested:*

- ○ Yes
- ○ No

Test or Performance Level:*:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

1

2

3

4

5

6

7

8

9

10

System 2:*

System Name:*:

System Description:*

Deck Type:*

- Longitudinal, Glulam Timber
- Longitudinal, Nail-Laminated Timber
- Longitudinal, Spike-Laminated Timber
- Longitudinal, Stress-Laminated Timber
- Transverse, Glulam Timber
- Transverse, Nail-Laminated Timber
- Other Deck Type(s)

Other Deck Type(s):*:

Crash-Tested:*

Yes

No

Test or Performance Level:*:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

1

2

3

4

5

6

7

8

9

10

System 3:*

System Name:*:

System Description:*

Deck Type:*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*:

Crash-Tested:*

- ○ Yes
- ○ No

Test or Performance Level:*:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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System 4:*

System Name:*:

System Description:*

Deck Type:*

- Longitudinal, Glulam Timber
- Longitudinal, Nail-Laminated Timber
- Longitudinal, Spike-Laminated Timber
- Longitudinal, Stress-Laminated Timber
- Transverse, Glulam Timber
- Transverse, Nail-Laminated Timber
- Other Deck Type(s)

Other Deck Type(s):*:

Crash-Tested:*

- Yes
- No

Test or Performance Level:*:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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System 5:*

System Name:*:

System Description:*

Deck Type:*

- Longitudinal, Glulam Timber
- Longitudinal, Nail-Laminated Timber
- Longitudinal, Spike-Laminated Timber

- [ ] Longitudinal, Stress-Laminated Timber
- [ ] Transverse, Glulam Timber
- [ ] Transverse, Nail-Laminated Timber
- [ ] Other Deck Type(s)

Other Deck Type(s):*:

Crash-Tested:*

- ( ) Yes
- ( ) No

Test or Performance Level:*:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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System 6:*

System Name:*:

System Description:*

Deck Type:*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*:

Crash-Tested:*

- ○ Yes
- ○ No

Test or Performance Level:*:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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System 7:*

System Name:*:

System Description:*

Deck Type:*

- Longitudinal, Glulam Timber
- Longitudinal, Nail-Laminated Timber
- Longitudinal, Spike-Laminated Timber
- Longitudinal, Stress-Laminated Timber
- Transverse, Glulam Timber
- Transverse, Nail-Laminated Timber
- Other Deck Type(s)

Other Deck Type(s):*:

Crash-Tested:*

Yes

No

Test or Performance Level:*:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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System 8:*

System Name:*:

System Description:*

Deck Type:*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*:

Crash-Tested:*

- ○ Yes
- ○ No

Test or Performance Level:*:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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System 9:*

System Name:*:

System Description:*

Deck Type:*

- Longitudinal, Glulam Timber
- Longitudinal, Nail-Laminated Timber
- Longitudinal, Spike-Laminated Timber
- Longitudinal, Stress-Laminated Timber
- Transverse, Glulam Timber
- Transverse, Nail-Laminated Timber
- Other Deck Type(s)

Other Deck Type(s):*:

Crash-Tested:*

- Yes
- No

Test or Performance Level:*:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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System 10:*

System Name:*:

System Description:*

Deck Type:*

- Longitudinal, Glulam Timber
- Longitudinal, Nail-Laminated Timber
- Longitudinal, Spike-Laminated Timber

- [ ] Longitudinal, Stress-Laminated Timber
- [ ] Transverse, Glulam Timber
- [ ] Transverse, Nail-Laminated Timber
- [ ] Other Deck Type(s)

Other Deck Type(s):*:

Crash-Tested:*

- ○ Yes
- ○ No

Test or Performance Level:*:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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For each system, please estimate the percentage of systems installed. The total MUST add up to 100%.*

_____ System 1

_____ System 2

_____ System 3

_____ System 4

_____ System 5

_____ System 6

_____ System 7

_____ System 8

_____ System 9

_____ System 10

Question 2 of 5: Updates to Current Bridge Railing Systems

2) Is it desirable to update any of the bridge railing systems listed in Question 1 to current AASHTO MASH impact safety criteria? If so, please indicate which test level(s) is/are desired.*

System 1*

○ Yes

○ No

System 1 - Test Level(s) Desired:*

☐ TL-1

☐ TL-2

☐ TL-3

☐ TL-4

System 2*

- Yes
- No

System 2 - Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

System 3*

- Yes
- No

System 3 - Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

System 4*

- Yes
- No

System 4 - Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

System 5*

- Yes
- No

System 5 - Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

System 6*

- Yes
- No

System 6 - Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

System 7*

- Yes
- No

System 7 - Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

System 8*

- Yes
- No

System 8 - Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

System 9*

- Yes
- No

System 9 - Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

System 10*

- Yes
- No

System 10 - Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

Due to your answer to Question 1, you do not need to answer Question 2. Please click "Next" below to continue to the next question.

Question 3 of 5: Past Bridge Railing System Developments

3) An attached document depicts schematics and photographs of bridge railing systems for wood bridges that have been developed and crash tested in the past. Each new page is representative of a family of systems, and there are **6 families** in total. The family name can be found at the top of each page, which corresponds to the options given below. Please indicate whether it is desirable to develop a crashworthy system for each respective family according to the AASHTO MASH impact safety criteria. If a certain system type is desired, please indicate the desired deck type(s) and test level(s).

Schematics and Photographs for Each Bridge Railing System Family

Clicking the link above will open the document in another tab of your browser. Keep the document open while completing this question. *

3-1. Low-Height, Curb-Type Bridge Railing*

(Vertical Connection between Timber Curb Rail and Scupper Blocks)

- ○ Yes
- ○ No

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*: _____

Test Level(s) Desired:*

- ☐ TL-1
- ☐ TL-2
- ☐ TL-3
- ☐ TL-4

3-2. Timber Railing without Curb*

(Horizontal Connection between Timber Rail and Posts)

- ○ Yes
- ○ No

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- ☐ TL-1
- ☐ TL-2
- ☐ TL-3
- ☐ TL-4

3-3. Timber Railing with Curb*

(Vertical Connection between Timber Curb Rail and Scupper Blocks with Horizontal Connection between Timber Rail and Posts)

- ○ Yes
- ○ No

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- ☐ TL-1
- ☐ TL-2
- ☐ TL-3
- ☐ TL-4

3-4. W-Beam Railing*

- ○ Yes
- ○ No

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber

- [ ] Longitudinal, Stress-Laminated Timber
- [ ] Transverse, Glulam Timber
- [ ] Transverse, Nail-Laminated Timber
- [ ] Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- [ ] TL-1
- [ ] TL-2
- [ ] TL-3
- [ ] TL-4

3-5. Thrie Beam Railing*

- ( ) Yes
- ( ) No

Deck Type(s):*

- [ ] Longitudinal, Glulam Timber
- [ ] Longitudinal, Nail-Laminated Timber
- [ ] Longitudinal, Spike-Laminated Timber
- [ ] Longitudinal, Stress-Laminated Timber
- [ ] Transverse, Glulam Timber
- [ ] Transverse, Nail-Laminated Timber
- [ ] Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- [ ] TL-1
- [ ] TL-2

- [ ] TL-3
- [ ] TL-4

3-6. Steel-Backed Timber Railing*

- ( ) Yes
- ( ) No

Deck Type(s):*

- [ ] Longitudinal, Glulam Timber
- [ ] Longitudinal, Nail-Laminated Timber
- [ ] Longitudinal, Spike-Laminated Timber
- [ ] Longitudinal, Stress-Laminated Timber
- [ ] Transverse, Glulam Timber
- [ ] Transverse, Nail-Laminated Timber
- [ ] Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- [ ] TL-1
- [ ] TL-2
- [ ] TL-3
- [ ] TL-4

Question 4 of 5: Additional Bridge Railing System Information

4) Please provide any available details for bridge railing systems that are desirable for development that **have not been** previously mentioned in this survey. This information would include general system details, along with deck type(s) and test level(s) for each system.

In this section, please provide any available details for suggested deviations or

modifications to any systems that **have been** previously mentioned in this survey. This information could include any tolerance, constructability, or maintenance considerations, as well as any special attachment locations or hardware that should be used or is desired.

Providing Details For:*

- ○ New Bridge Railing Systems
- ○ Deviations/Modifications to Existing Bridge Railing Systems
- ○ Both
- ○ Neither

Number of New Systems:*

If you have more than ten systems, please contact the survey distributor to provide additional information.

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9
- ○ 10

New System 1:*

General Details:

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- ☐ TL-1
- ☐ TL-2
- ☐ TL-3
- ☐ TL-4

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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New System 2:*

General Details:

Deck Type(s):*

- Longitudinal, Glulam Timber
- Longitudinal, Nail-Laminated Timber
- Longitudinal, Spike-Laminated Timber
- Longitudinal, Stress-Laminated Timber
- Transverse, Glulam Timber
- Transverse, Nail-Laminated Timber
- Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- ☐ TL-1
- ☐ TL-2
- ☐ TL-3
- ☐ TL-4

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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New System 3:*

General Details:

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*: ____

Test Level(s) Desired:*

- ☐ TL-1
- ☐ TL-2
- ☐ TL-3
- ☐ TL-4

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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New System 4:*

General Details:

Deck Type(s):*

- Longitudinal, Glulam Timber
- Longitudinal, Nail-Laminated Timber
- Longitudinal, Spike-Laminated Timber
- Longitudinal, Stress-Laminated Timber
- Transverse, Glulam Timber
- Transverse, Nail-Laminated Timber
- Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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New System 5:*

General Details:

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber

- [ ] Transverse, Glulam Timber
- [ ] Transverse, Nail-Laminated Timber
- [ ] Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- [ ] TL-1
- [ ] TL-2
- [ ] TL-3
- [ ] TL-4

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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New System 6:*

General Details:

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- ☐ TL-1
- ☐ TL-2
- ☐ TL-3
- ☐ TL-4

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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New System 7:*

General Details:

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- ☐ TL-1
- ☐ TL-2
- ☐ TL-3
- ☐ TL-4

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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New System 8:*

General Details:

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber
- ☐ Transverse, Glulam Timber
- ☐ Transverse, Nail-Laminated Timber
- ☐ Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- ☐ TL-1
- ☐ TL-2
- ☐ TL-3
- ☐ TL-4

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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New System 9:*

General Details:

Deck Type(s):*

- Longitudinal, Glulam Timber
- Longitudinal, Nail-Laminated Timber
- Longitudinal, Spike-Laminated Timber
- Longitudinal, Stress-Laminated Timber
- Transverse, Glulam Timber
- Transverse, Nail-Laminated Timber
- Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- TL-1
- TL-2
- TL-3
- TL-4

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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New System 10:*

General Details:

Deck Type(s):*

- ☐ Longitudinal, Glulam Timber
- ☐ Longitudinal, Nail-Laminated Timber
- ☐ Longitudinal, Spike-Laminated Timber
- ☐ Longitudinal, Stress-Laminated Timber

- [ ] Transverse, Glulam Timber
- [ ] Transverse, Nail-Laminated Timber
- [ ] Other Deck Type(s)

Other Deck Type(s):*:

Test Level(s) Desired:*

- [ ] TL-1
- [ ] TL-2
- [ ] TL-3
- [ ] TL-4

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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Deviations or Modifications to Existing Bridge Railing Systems:*

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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Question 5 of 5: Approach Guardrail Transition Information

5) When either connecting guardrail to bridge rail ends or terminating a bridge rail, are there any special site conditions or features that should be considered in the approach guardrail transition or bridge rail termination? For example, these

considerations could include a desired post spacing, a specific material to be used, compatibility with certain roadside slopes, etc.

Special Site Conditions:

Special Transition or Termination Features:

Additional information can be provided using the electronic document upload link.

Accepted file types: png, gif, jpg, jpeg, doc, xls, docx, xlsx, pdf, txt, mov, mp3, mp4. Upload maximum 10 files, 50 megabytes per file, for each question.

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Additional Contact Information

If other personnel should be contacted regarding the information provided in this survey, please list their contact information below. This list can include individuals who helped to provide content for this survey or could provide further information that would be helpful with project planning.

	Name:	**Organization:**	**Phone Number:**	**Email Address:**
Additional Contact 1:				
Additional Contact 2:				
Additional Contact 3:				
Additional Contact 4:				
Additional Contact 5:				

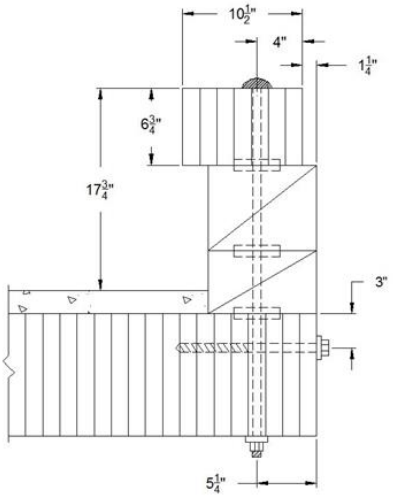
Thank You!

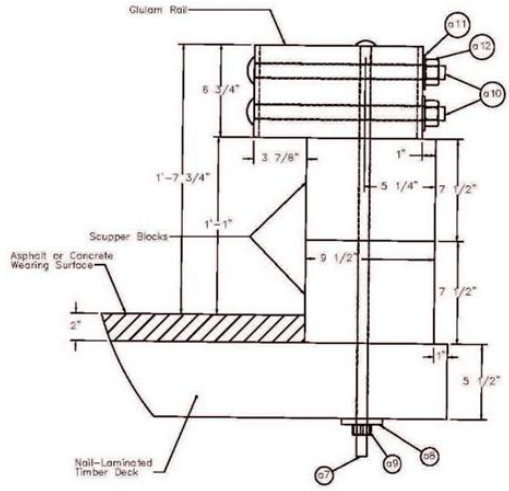
Thank you for taking our survey. An email confirming your response submission has been sent to your account. If you do not receive an email within a few minutes, please check your spam folder.

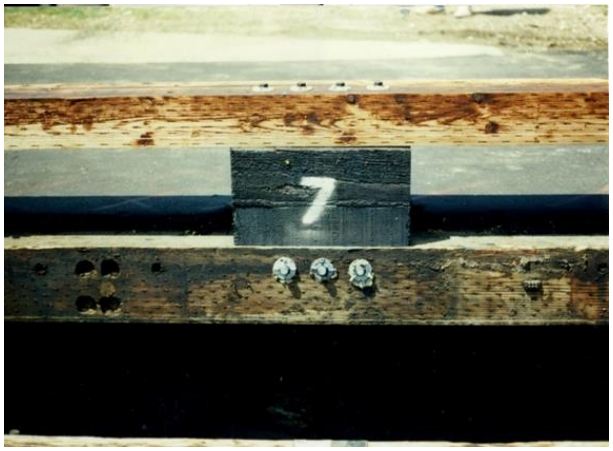
Survey Question 3 Attachment: Schematics and Photographs for Each Bridge Railing System Family

Question 3-1. Low-Height, Curb-Type Bridge Railing

(Vertical Connection between Timber Curb Rail and Scupper Blocks)

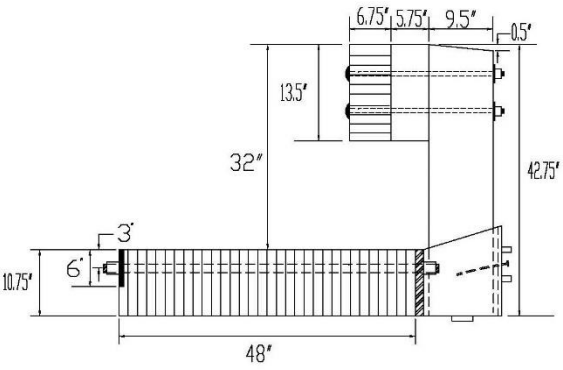


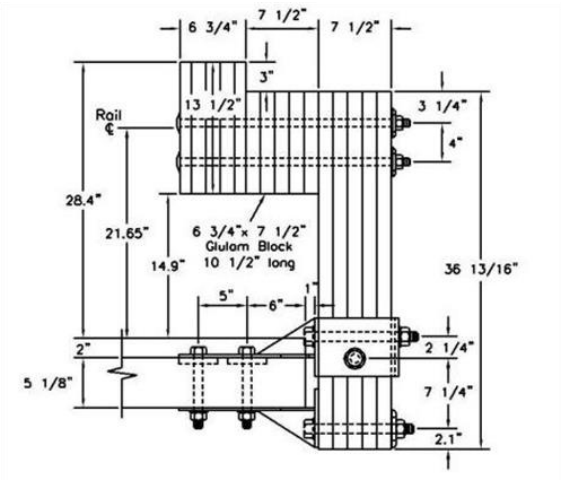


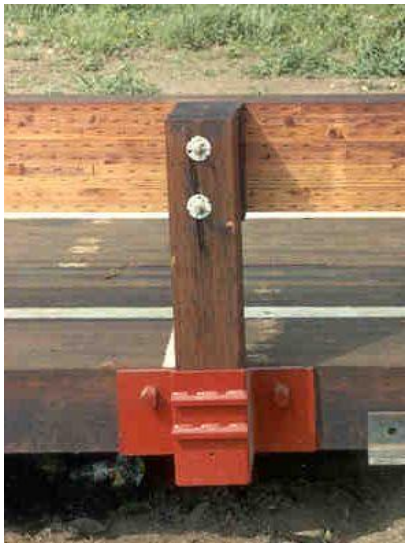


Question 3-2. Timber Railing without Curb

(Horizontal Connection between Timber Rail and Posts)

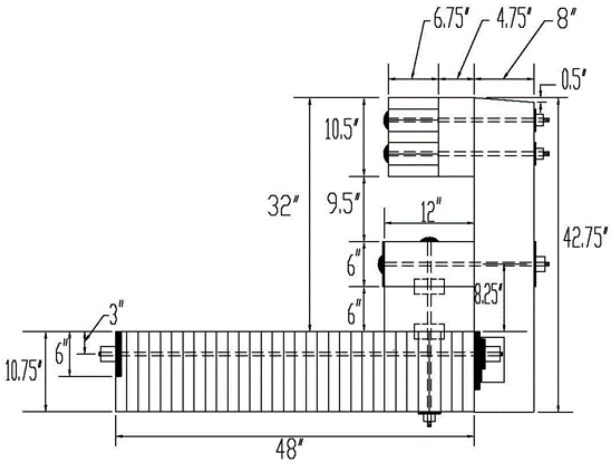


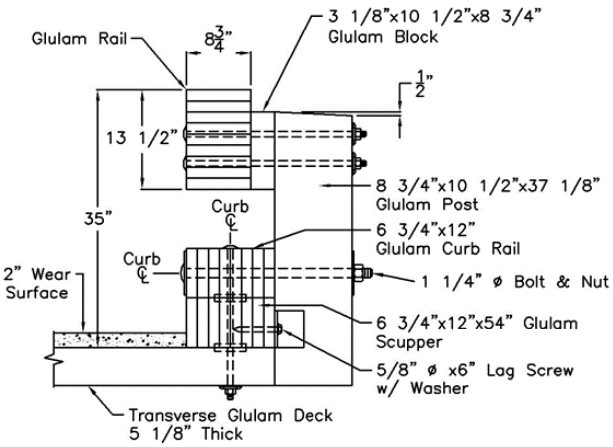




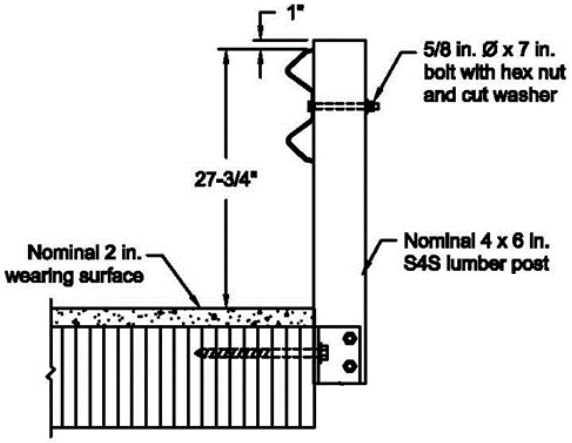
Question 3-3. Timber Railing with Curb

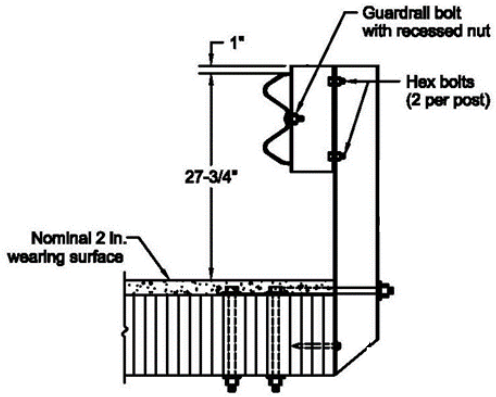
(Vertical Connection between Timber Curb Rail and Scupper Blocks with Horizontal Connection between Timber Rail and Posts)



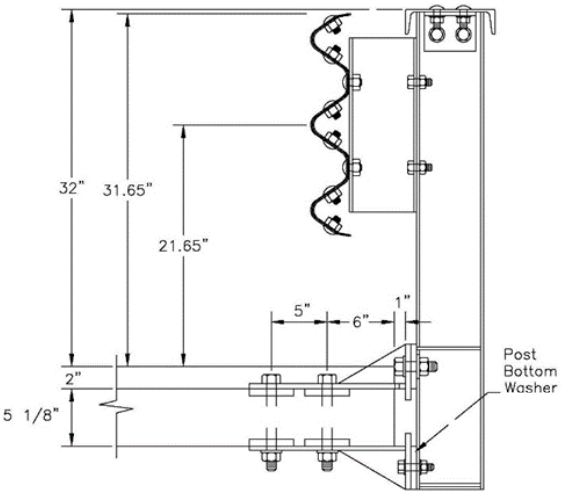


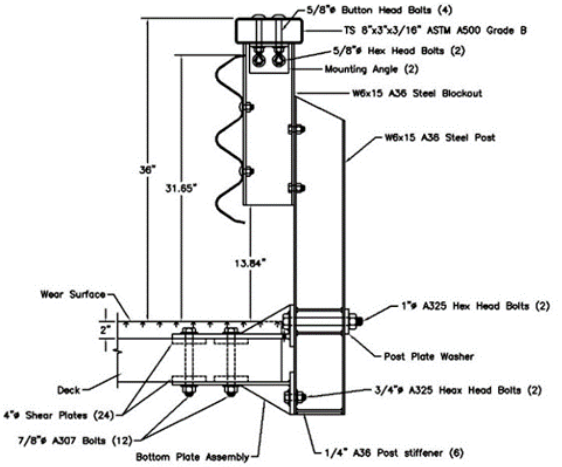
Question 3-4. W-Beam Railing



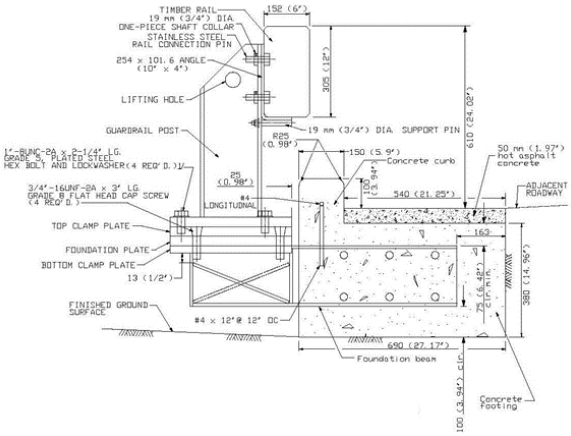


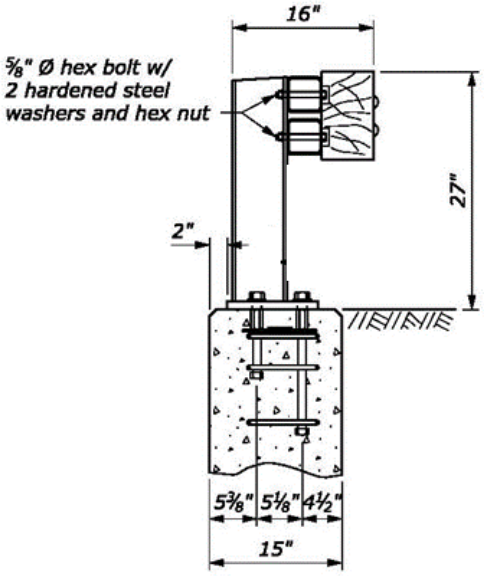
Question 3-5. Thrie Beam Railing





Question 3-6. Steel-Backed Timber Railing





Appendix B. Survey Data

Table B-1. Questions 1 and 2 Summary: Currently Used Systems and Update Requests

Respondent Type	*Respondent Group*	*System #*	*System Name*	*Brief System Description*	*Deck Types Installed On*	*Previously Crash-Tested*	*Test/Performance Level*	*Percent Usage by Respective Group*	*Update*	*Test Level*
State Government	Alabama	NA	-	-	-	-	-	-	-	-
	Alaska	1	TL-4 Glulam Timber Bridge Railing	Glulam Rail and Curb	TG	Yes	NCHRP 350 TL-4	100%	Yes	TL-4
	Arkansas	NA	-	-	-	-	-	-	-	-
	Colorado	1	Timber Rail	Existing Timber Post and Rail	LN	No	-	3%	No	-
		2	Type 10T	Two Steel Tube System with Steel Posts	LN, Steel Corrugated Decking with Concrete or Asphalt Topping	Yes	NCHRP 350 TL-4	49%	Yes	TL-3, TL-4
		3	Type 3 Wood Post	Tube or Metal Backed W-Beam on Wood Posts	LN, Steel Corrugated Decking with Concrete or Asphalt Topping	No	-	38%	No	-
		4	Type 3 Metal Post	Tube or Metal Backed W-Beam on Metal Posts	LN, Steel Corrugated Decking with Concrete or Asphalt Topping	No	-	10%	No	-

NA – Not Applicable
TG – Transverse, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber

Table B-2. Questions 1 and 2 Summary: Currently Used Systems and Update Requests (continued)

Respondent Type	*Respondent Group*	*System #*	*System Name*	*Brief System Description*	*Deck Types Installed On*	*Previously Crash-Tested*	*Test/Performance Level*	*Percent Usage by Respective Group*	*Update*	*Test Level*
State Government	Deleware	1	Timber Bridge Rail	Glulam Rail and Curb Attached to Sawn Lumber Posts	LG, LN, LSp, LSt, Concrete	Yes	NCHRP 350 TL-2	90%	Yes	TL-2, TL-3
		2	Steel Beam Bridge Mounted Guardrail	W-Beam Mounted on Bridge	LG, LN, LSp, LSt	Yes	NCHRP 350 TL-2	10%	No	-
	Florida	NA	-	-	-	-	-	-	-	-
	Illinois	NA	-	-	-	-	-	-	-	-
	Indiana	NA	-	-	-	-	-	-	-	-
	Kansas	NA	-	-	-	-	-	-	-	-
	Louisiana	1	Side Mounted Guard Rail	Thrie Beam with Side Mounted Steel Posts	Concrete with Timber Stringers	No	-	25%	Yes	TL-2, TL-3
		2	Bridge Rail Rehab	Thrie Beam with Side Mounted Timber Posts	Timber, Concrete	No	-	75%	Yes	TL-2, TL-3
	Maryland	NA	-	-	-	-	-	-	-	-
	Minnesota	1	TL-2 Glulam Rail with Curb	Glulam Rail and Curb with Sawn Lumber Posts	LSp, Concrete Slab Spans, Concrete Decks	Yes	NCHRP 350 TL-2	70%	Yes	TL-2

NA – Not Applicable
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Spike-Laminated Timber

Table B-3. Questions 1 and 2 Summary: Currently Used Systems and Update Requests (continued)

Respondent Type	*Respondent Group*	*System #*	*System Name*	*Brief System Description*	*Deck Types Installed On*	*Previously Crash-Tested*	*Test/Performance Level*	*Percent Usage by Respective Group*	*Update*	*Test Level*
State Government	Minnesota	2	TL-4 Glulam Rail with Curb	Glulam Rail and Curb with Sawn Lumber Posts	LSp, Concrete Slab Spans, Concrete Decks	Yes	NCHRP 350 TL-4	30%	Yes	TL-4
	Mississippi	NA	-	-	-	-	-	-	-	-
	Missouri	1	Unknown	8"x12"x4'-6" Lumber Posts with a 6"x10.75" Glulam Rail	LG	No	-	100%	No	-
	Montana	1	Wood Rail on Wood Deck	Sawn Lumber Rail Attached to Sawn Lumber Posts	TN	No	-	50%	No	-
		2	W-Beam Rail on Wood Deck	W-Beam Rail Attached to Steel Posts	TN	No	-	44%	No	-
		3	Thrie Beam on Wood Deck	Thrie Beam Rail Attached to Steel Posts	TN	No	-	1%	No	-
		4	Box Beam on Wood Deck	Box Beam Attached to Steel Posts	TN	No	-	5%	No	-

NA – Not Applicable
LSp – Longitudinal, Spike-Laminated Timber
LG – Longitudinal, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-4. Questions 1 and 2 Summary: Currently Used Systems and Update Requests (continued)

Respondent Type	*Respondent Group*	*System #*	*System Name*	*Brief System Description*	*Deck Types Installed On*	*Previously Crash-Tested*	*Test/Performance Level*	*Percent Usage by Respective Group*	*Update*	*Test Level*
State Government	Nevada	NA	-	-	-	-	-	-	-	-
	New Hampshire	1	T101	Texas Bridge Rail	LG, TN	Yes	NCHRP 350 TL-3	100%	Yes	TL-2
	New Jersey	1	GC-8000	Side Mounted Glulam Timber Rail with Curb	LG	Yes	NCHRP 350 TL-4	50%	Yes	TL-4
		2	Wood System	Top Mounted Glulam Timber Railing with Curb	TG	Yes	NCHRP 350 TL-4	50%	Yes	TL-4
	North Carolina	1	Timber Rub Rail	Low-Height, Curb-Type Bridge Railing	TN	No	-	40%	Yes	TL-1, TL-2
		2	Timber Rail	Timber Railing with Curb	TN	No	-	60%	Yes	TL-1, TL-2
	North Dakota	NA	-	-	-	-	-	-	-	-
	Ohio	1	TST-1-99	Steel Post and Steel Tube	TN	Yes	TL-4	25%	No	-
		2	Deep Beam Bridge Railing	Steel Post and Steel Tube	TN	Yes	TL-3	75%	No	-
	Oklahoma	NA	-	-	-	-	-	-	-	-

NA – Not Applicable
LG – Longitudinal, Glulam Timber
TN – Transverse, Nail-Laminated Timber
TG – Transverse, Glulam Timber

Table B-5. Questions 1 and 2 Summary: Currently Used Systems and Update Requests (continued)

Respondent Type	*Respondent Group*	*System #*	*System Name*	*Brief System Description*	*Deck Types Installed On*	*Previously Crash-Tested*	*Test/Performance Level*	*Percent Usage by Respective Group*	*Update*	*Test Level*
State Government	Rhode Island	1	Timber Rail with Curb	Solid Timber Posts and Rail with a Vertical Connection for Scupper Blocks and a Horizontal Connection Between the Posts and Rail	TG	No	-	100%	Yes	TL-4
	South Carolina	1	Glulam	Glulam Curb and Railing Mounted to Glulam Posts	LG, TG	No	-	100%	Yes	TL-3
	South Dakota	NA	-	-	-	-	-	-	-	-
	Texas	NA	-	-	-	-	-	-	-	-
	Virginia	1	GC-8000	Sawn Lumber Posts Attached to Glulam Timber Deck	LG	Yes	NCHRP 350 TL-4	80%	Yes	TL-3
		2	SBD01D	Sawn Lumber Posts Attached to Glulam Timber Deck	TG	Yes	NCHRP 350 TL-4	20%	Yes	TL-3
	Washington	1	Existing - As Built	Timber Posts Bolted into Timber Stringers	TN	No	-	3%	No	-
		2	Service Level 1	Steel Posts with Thrie Beam Guardrail, Breakaway Bolts to Steel Bracket	TN	Yes	SL-1	97%	No	-

NA – Not Applicable
LG – Longitudinal, Glulam Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-6. Questions 1 and 2 Summary: Currently Used Systems and Update Requests (continued)

Respondent Type	*Respondent Group*	*System #*	*System Name*	*Brief System Description*	*Deck Types Installed On*	*Previously Crash-Tested*	*Test/Performance Level*	*Percent Usage by Respective Group*	*Update*	*Test Level*
State Government	Wisconsin	1	Timber Railing Attached to Concrete Slab	Glulam Railing Attached to Timber Posts with Curb	Concrete	Yes	NCHRP 350 TL-2	100%	Yes	TL-2
Federal Government	FHWA	NA	-	-	-	-	-	-	-	-
	USFS	1	Sawn Timber Curb Only	Sawn Timber Curb on Sawn Timber Scupper Blocks; Top-Mounted	LG, LN, LSp, LSt, TG, TN, Planks Decks	No	-	45%	Yes	TL-1
		2	Sawn Bridge Railing with Sawn Timber Curb	Sawn Timber Bridge Railing with Sawn Timber Curb Attached to Sawn Timber Posts	LG, LN, LSp, LSt, TG, TN, Planks Decks	No	-	15%	Yes	TL-1, TL-2
		3	W-Beam Bridge Railing	W-Beam Bridge Railing Attached to Sawn Timber Posts or Steel Posts	TG, TN, Plank Decks, Corrugated Metal Deck	No	-	5%	Yes	TL-1, TL-2
		4	Glulam Curb Only	Glulam Timber Curb on Glulam Timber Scupper Blocks	LG, TG, TN	No	-	25%	Yes	TL-1

NA – Not Applicable
LN – Longitudinal, Nail-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TN – Transverse, Nail-Laminated Timber
LG – Longitudinal, Glulam Timber
LSp – Longitudinal, Spike-Laminated Timber
TG – Transverse, Glulam Timber

Table B-7. Questions 1 and 2 Summary: Currently Used Systems and Update Requests (continued)

Respondent Type	*Respondent Group*	*System #*	*System Name*	*Brief System Description*	*Deck Types Installed On*	*Previously Crash-Tested*	*Test/Performance Level*	*Percent Usage by Respective Group*	*Update*	*Test Level*
Federal Government	USFS	5	Glulam Bridge Railing with Glulam Curb	Glulam Timber Bridge Railing with Glulam Timber Curb Attached to Glulam Timber Posts	TG, TN	No	-	10%	Yes	TL-1
	Bureau of Reclamation	1	Wide Variety	Decentralized agency with no railing system inventory	Wide Variety	No	-	100%	Yes	TL-1
Industry Consultant	Alamco Wood Products, LLC	1	Glulam Beam Vehicular Bridge	Glulam Deck Panels, Posts, and Railing	LG, TG	Yes	NCHRP 350 TL-4	60%	No	-
		2	Glulam Beam Pedestrian Bridge	Glulam Deck Panels, Posts, and Railing	LG, TG	Yes	NCHRP 350 TL-5	40%	No	-
	Bridge Builders USA, Inc.	1	Timber Vehicular Bridge Guardrail	6x12 S4S SYP Rail attached to 8x10 S4S SYP Posts, Posts attached to 6x12 S4S SYP curb on 30" curb blocks	4x12 S4S SYP (Timber)	No	-	100%	Yes	TL-2

NA – Not Applicable
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-8. Questions 1 and 2 Summary: Currently Used Systems and Update Requests (continued)

Respondent Type	*Respondent Group*	*System #*	*System Name*	*Brief System Description*	*Deck Types Installed On*	*Previously Crash-Tested*	*Test/Performance Level*	*Percent Usage by Respective Group*	*Update*	*Test Level*
Industry Consultant	Laminated Concepts, LLC	1	Weyerhaeuser Rail System	Static Load Tested System with Glulam Posts, Wheel Guards, and Top Rails	LG, TG	No	-	3%	No	-
		2	FHA Longitudinal PL-1	Curb on Scupper Blocks with a Top Rail Attached to Posts	LG, LSt, Concrete	Yes	PL-1	28%	No	-
		3	FHA Longitudinal PL-1 Curbless	Post and Top Rails with Steel Post Shoe	LG, LSt, Concrete	Yes	PL-1	5%	No	-
		4	FHA Longitudinal TL-4	Curb on Scupper Blocks with a Top Rail Attached to Posts	LG, LSt, Concrete	Yes	TL-4	14%	Yes	TL-4
		5	FHA Transverse TL-2	Curb on Scupper Blocks with a Top Rail Attached to Posts	TG	Yes	TL-2	5%	No	-

* - Not counted as a system in reported number of systems in Section 6
LG – Longitudinal, Glulam Timber
TG – Transverse, Glulam Timber
LSt – Longitudinal, Stress-Laminated Timber

Table B-9. Questions 1 and 2 Summary: Currently Used Systems and Update Requests (continued)

Respondent Type	*Respondent Group*	*System #*	*System Name*	*Brief System Description*	*Deck Types Installed On*	*Previously Crash-Tested*	*Test/Performance Level*	*Percent Usage by Respective Group*	*Update*	*Test Level*
Industry Consultant	Laminated Concepts, LLC	6	FHA Transverse TL-4	Curb on Scupper Blocks with a Top Rail Attached to Posts	TG	Yes	TL-4	45%	Yes	TL-4
	Wheeler Lumber, LLC	1	4x10	Lightweight Timber Railing for Low Volume Roads; 8x8 Curbs on Scuppers with 8x8 Posts and a 4x10 Sawn Timber Rail	LSp, TN	No	-	10	No	-
		2	PL-1	6x12 Sawn Timber Curb on Scuppers, 8x10 Solid Sawn Posts, Glulam Rail	LSp, TN	Yes	NCHRP 230 PL-1/TL-2	35	Yes	TL-2
		3	TL-2 & TL-4 for Concrete Decks	Standard Issue from USDA FS, Sawn Curbs, Scuppers, Posts, and Blockouts with a Glulam Rail	Concrete	Yes	NCHRP 350 TL-2 & TL-4	10	Yes	TL-2, TL-3, TL-4
		4	TL-4	Sawn Curbs, Scuppers, Posts, and Blockouts with a Glulam Rail	LG, LSp, TG, TN	Yes	NCHRP 350 TL-4	35	Yes	TL-3, TL-4

TG – Transverse, Glulam Timber
LSp – Longitudinal, Spike-Laminated Timber
TN – Transverse, Nail-Laminated Timber
TG – Transverse, Glulam Timber

Table B-10. Questions 1 and 2 Summary: Currently Used Systems and Update Requests (continued)

Respondent Type	*Respondent Group*	*System #*	*System Name*	*Brief System Description*	*Deck Types Installed On*	*Previously Crash-Tested*	*Test/Performance Level*	*Percent Usage by Respective Group*	*Update*	*Test Level*
Industry Consultant	Wheeler Lumber, LLC	5	Railing for Transverse Deck Panels	Railings for Transverse Timber Panels	TG, TN	Yes	NCHRP 350 TL-2 & TL-4	5	Yes	TL-2, TL-3, TL-4
		6	Steel Plate Beam	Sawn Curbs, Scuppers, and Posts with a Steel W-Beam Rail	LSp, TN	No	-	2	No	-
		7	Curbs Only	Sawn Curb and Scuppers	LSp, TN	No	-	2	No	-
		8	Ornamental Log	Projects with Desire for Log Appearance	LSp, TN	No	-	1	No	-

TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber

Table B-11. Question 3-1 Summary: Low-Height, Curb-Type System Development Requests

Respondent Type	*Respondent Group*	*Update*	*Deck Type(s)*	*Test Level*
State Government	Alabama	No	-	-
	Alaska	No	-	-
	Arkansas	No	-	-
	Colorado	No	-	-
	Delaware	Yes	LG, LN, LSp, LSt, Concrete	TL-2, TL-3
	Florida	No	-	-
	Illinois	No	-	-
	Indiana	No	-	-
	Kansas	No	-	-
	Louisiana	No	-	-
	Maryland	No	-	-
	Minnesota	No	-	-
	Mississippi	No	-	-
	Missouri	No	-	-
	Montana	No	-	-
	Nevada	No	-	-
	New Hampshire	Yes	LSp, TG	TL-2
	New Jersey	No	-	-
	North Carolina*	Yes	TN	TL-1, TL-2
	North Dakota	Yes	Timber Planks	TL-2
	Ohio	No	-	-
	Oklahoma	No	-	-
	Rhode Island	Yes	LG, LN, LSp, LSt, TG, TN	TL-4
	South Carolina	No	-	-
	South Dakota	No	-	-
	Texas	No	-	-
	Virginia	Yes	LG	TL-3
	Washington	No	-	-
	Wisconsin	No	-	-
Federal Government	FHWA	Yes	LG, LN, LSp, LSt, TG, TN	TL-1, TL-2
	USDA-FS*	Yes	LG, LN, LSp, TG, TN, Plank Deck	TL-1
	USBR	Yes	TG, TN	TL-1
Industry Consultant	Alamco Wood Products, LLC	No	-	-
	Bridge Builders USA, Inc.	No	-	-
	Laminated Concepts, LLC	No	-	-
	Wheeler Lumber, LLC	No	-	-

* - Groups with an asterisk also requested updates to systems that are already used from this family.
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-12. Question 3-2 Summary: Timber Railing without Curb System Development Requests

Respondent Type	***Respondent Group***	***Update***	***Deck Type(s)***	***Test Level***
State Government	Alabama	No	-	-
	Alaska	No	-	-
	Arkansas	No	-	-
	Colorado	No	-	-
	Delaware	Yes	LG, LN, LSp, LSt, Concrete	TL-2, TL-3
	Florida	No	-	-
	Illinois	No	-	-
	Indiana	No	-	-
	Kansas	No	-	-
	Louisiana	No	-	-
	Maryland	Yes	LSp, LSt	TL-3
	Minnesota	No	-	-
	Mississippi	No	-	-
	Missouri	No	-	-
	Montana	No	-	-
	Nevada	No	-	-
	New Hampshire	No	-	-
	New Jersey	Yes	LG, LN, LSp, LSt, TG, TN	TL-3, TL-4
	North Carolina	Yes	TN	TL-1, TL-2
	North Dakota	Yes	Timber Planks	TL-3
	Ohio	No	-	-
	Oklahoma	No	-	-
	Rhode Island	No	-	-
	South Carolina	Yes	LG, TG	TL-4
	South Dakota	No	-	-
	Texas	No	-	-
	Virginia	No	-	-
	Washington	No	-	-
	Wisconsin	No	-	-
Federal Government	FHWA	Yes	LG, LN, LSp, LSt, TG, TN	TL-1, TL-2
	USDA-FS	Yes	LG, LN, LSp, TG, TN	TL-1, TL-2
	USBR	Yes	TG, TN	TL-1
Industry Consultant	Alamco Wood Products, LLC	No	-	-
	Bridge Builders USA, Inc.	No	-	-
	Laminated Concepts, LLC	Yes	LG, LSt, TG, Concrete	TL-4
	Wheeler Lumber, LLC	No	-	-

LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-13. Question 3-3 Summary: Timber Railing with Curb System Development Requests

Respondent Type	*Respondent Group*	*Update*	*Deck Type(s)*	*Test Level*
State Government	Alabama	No	-	-
	Alaska	Yes	LG, TG	TL-4
	Arkansas*	No	-	-
	Colorado	No	-	-
	Delaware*	Yes	LG, LN, LSp, LSt, Concrete	TL-2, TL-3
	Florida	No	-	-
	Illinois	No	-	-
	Indiana	Yes	Unsure	TL-2, TL-3
	Kansas	No	-	-
	Louisiana	No	-	-
	Maryland	Yes	LSp, LSt	TL-3
	Minnesota*	Yes	LSp, TG, TN, Concrete Slab Spans and Concrete Decks	TL-2, TL-4
	Mississippi	No	-	-
	Missouri	No	-	-
	Montana	No	-	-
	Nevada	No	-	-
	New Hampshire	Yes	LG, LN, TG	TL-2
	New Jersey*	Yes	LG, LN, LSp, LSt, TG, TN	TL-4
	North Carolina*	Yes	TN	TL-1, TL-2
	North Dakota	No	-	-
	Ohio	No	-	-
	Oklahoma	Yes	Details Vary by County/City	TL-1, TL-2
	Rhode Island*	Yes	LG, LN, LSp, LSt, TG, TN	TL-4
	South Carolina*	Yes	LG, TG	TL-4
	South Dakota	No	-	-
	Texas	No	-	-
	Virginia*	Yes	LG	TL-3
	Washington	No	-	-
	Wisconsin*	Yes	LN, Concrete	TL-2
Federal Government	FHWA	Yes	LG, LN, LSp, LSt, TG, TN	TL-2, TL-3
	USDA-FS*	Yes	LG, LN, TG, TN	TL-1, TL-2
	USBR	No	-	-
Industry Consultant	Alamco Wood Products, LLC	No	-	-
	Bridge Builders USA, Inc.*	Yes	4x12 S4S SYP (Timber)	TL-2
	Laminated Concepts, LLC*	Yes	LG, LSt, TG, Concrete	TL-4
	Wheeler Lumber, LLC*	Yes	LSp, TG, TN, Concrete	TL-2, TL-3, TL-4

* - Groups with an asterisk also requested updates to systems that are already used from this family.
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-14. Question 3-4 Summary: W-Beam System Development Requests

Respondent Type	*Respondent Group*	*Update*	*Deck Type(s)*	*Test Level*
State Government	Alabama	No	-	-
	Alaska	No	-	-
	Arkansas	No	-	-
	Colorado	No	-	-
	Delaware	Yes	LG, LN, LSp, LSt, Concrete	TL-2, TL-3
	Florida	No	-	-
	Illinois	No	-	-
	Indiana	No	-	-
	Kansas	No	-	-
	Louisiana	Yes	Concrete on Timber Stringers	TL-2, TL-3
	Maryland	Yes	LSp, LSt	TL-3
	Minnesota	No	-	-
	Mississippi	No	-	-
	Missouri	No	-	-
	Montana	Yes	TN	TL-3
	Nevada	No	-	-
	New Hampshire*	Yes	LG, LN, TG	TL-2
	New Jersey	No	-	-
	North Carolina	Yes	TN, Low Fill Culverts	TL-2, TL-3
	North Dakota	Yes	Timber Planks	TL-3
	Ohio	Yes	TN	TL-3
	Oklahoma	No	-	-
	Rhode Island	No	-	-
	South Carolina	No	-	-
	South Dakota	No	-	-
	Texas	No	-	-
	Virginia	No	-	-
	Washington	No	-	-
	Wisconsin	No	-	-
Federal Government	FHWA	Yes	LG, LN, LSp, LSt, TG, TN	TL-2, TL-3
	USDA-FS*	Yes	LG, LN, LSp, TG, TN, Plank Deck	TL-1, TL-2, TL-4
	USBR	Yes	TG, TN, Concrete	TL-1
Industry Consultant	Alamco Wood Products, LLC	No	-	-
	Bridge Builders USA, Inc.	No	-	-
	Laminated Concepts, LLC	Yes	LG, LSt, TG	TL-2
	Wheeler Lumber, LLC	No	-	-

* - Groups with an asterisk also requested updates to systems that are already used from this family.
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-15. Question 3-5 Summary: Thrie Beam System Development Requests

Respondent Type	*Respondent Group*	*Update*	*Deck Type(s)*	*Test Level*
State Government	Alabama	No	-	-
	Alaska	No	-	-
	Arkansas	No	-	-
	Colorado	No	-	-
	Delaware	Yes	LG, LN, LSp, LSt, Concrete	TL-2, TL-3
	Florida	No	-	-
	Illinois	No	-	-
	Indiana	No	-	-
	Kansas	No	-	-
	Louisiana*	Yes	Concrete on Timber Stringers	TL-2, TL-3
	Maryland	No	-	-
	Minnesota	Yes	TG, TN	TL-2, TL-4
	Mississippi	No	-	-
	Missouri	No	-	-
	Montana	Yes	TN	TL-3
	Nevada	No	-	-
	New Hampshire	No	-	-
	New Jersey	No	-	-
	North Carolina	Yes	TN, Low Fill Culverts, Concrete	TL-2, TL-3
	North Dakota	No	-	-
	Ohio	No	-	-
	Oklahoma	No	-	-
	Rhode Island	Yes	LG, LN, LSp, LSt, TG, TN	TL-4
	South Carolina	Yes	LG, TG	TL-4
	South Dakota	No	-	-
	Texas	No	-	-
	Virginia	No	-	-
	Washington	Yes	TN	TL-1
	Wisconsin	No	-	-
Federal Government	FHWA	Yes	LG, LN, LSp, LSt, TG, TN	TL-2, TL-3
	USDA-FS	Yes	LG, LN, TG, TN	TL-1, TL-2, TL-4
	USBR	Yes	Concrete	TL-1, TL-2
Industry Consultant	Alamco Wood Products, LLC	No	-	-
	Bridge Builders USA, Inc.	No	-	-
	Laminated Concepts, LLC	No	-	-
	Wheeler Lumber, LLC	No	-	-

* - Groups with an asterisk also requested updates to systems that are already used from this family.
LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-16. Question 3-6 Summary: Steel-Backed Timber System Development Requests

Respondent Type	*Respondent Group*	*Update*	*Deck Type(s)*	*Test Level*
State Government	Alabama	No	-	-
	Alaska	Yes	LG, TG	TL-4
	Arkansas	No	-	-
	Colorado	No	-	-
	Delaware	Yes	LG, LN, LSp, LSt, Concrete	TL-2, TL-3
	Florida	No	-	-
	Illinois	No	-	-
	Indiana	Yes	Unsure	TL-2
	Kansas	No	-	-
	Louisiana	No	-	-
	Maryland	No	-	-
	Minnesota	No	-	-
	Mississippi	No	-	-
	Missouri	No	-	-
	Montana	No	-	-
	Nevada	No	-	-
	New Hampshire	Yes	LG, TG	TL-2
	New Jersey	Yes	LG, LN, LSp, LSt, TG, TN	TL-3, TL-4
	North Carolina	Yes	TN, Concrete	TL-2, TL-3, TL-4
	North Dakota	No	-	-
	Ohio	No	-	-
	Oklahoma	No	-	-
	Rhode Island	Yes	LG, LN, LSp, LSt, TG, TN	TL-4
	South Carolina	Yes	LG, TG	TL-4
	South Dakota	No	-	-
	Texas	No	-	-
	Virginia	No	-	-
	Washington	No	-	-
	Wisconsin	No	-	-
Federal Government	FHWA	Yes	LG, LN, LSp, LSt, TG, TN	TL-3
	USDA-FS	No	-	-
	USBR	No	-	-
Industry Consultant	Alamco Wood Products, LLC	No	-	-
	Bridge Builders USA, Inc.	No	-	-
	Laminated Concepts, LLC	No	-	-
	Wheeler Lumber, LLC	No	-	-

LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-17. Question 4-2 Summary: Modifications/Deviations to Currently Used Bridge Railing Systems

Respondent Type	***Respondent Group***	***Modifications and Deviations***
Industry Consultant	Laminated Concepts, LLC	Curb-type systems for all decks.
		Eliminate or provide a more 'field friendly' connection for scupper to curb, curb to deck, mainly the split ring connections.
		Standardize all rail timber materials to be glued laminated to eliminate sizing confusion between glulam and solids.
	Wheeler Lumber, LLC	Often owners want to add pedestrian railing elements to the vehicle rail. Typically this is increasing the total height to 42" and adding safety rails to limit the rail spacing. TL-2 and TL-4 have been modified in this way.
	Alamco Wood Products, LLC	Acceptance of glulam timber in lieu of where solids are called out.
State Government	Louisiana	In lieu of thrie beam, I would consider steel tube railing and/or posts.

Table B-18. Question 5 Summary: Special Site Conditions or Transition/Terminations Features

Respondent Type	***Respondent Group***	***Special Site Conditions***	***Special Transition/Termination Features***
Industry Consultant	Laminated Concepts, LLC	-	Ability to carry the top timber rail of the guide rail system off the bridge to create a timber approach rail
	Wheeler Lumber, LLC	We are often asked for an all wood approach rail to match the bridge rail. Currently the most common systems are steel or steel backed systems.	-
State Government	Indiana	slopes 3:1 or steeper and whether such slopes may be acceptable at a specific test level or a lower test level	-
	Minnesota	-	MnDOT uses a Type 31 guardrail system. The Type 31 guardrail system was developed to meet the MASH TL-3. It's 31" in height with a Thrie-Beam connection at the bridge, and transitions to a W-Beam away from the bridge. MASH approved connection details for our type 31 guardrail to all MASH TL-2 & TL-4 timber rail systems will be needed.
	South Carolina	-	Timber curb to concrete curb on roadway
	Virginia	Timber bridge railings are usually used for timber bridges with low traffic volume	Need a transition to 31" MGS or a timber termination
	Alaska	Considerations for snow removal and dirt accumulation	Durability

Table B-19. Question 5 Summary: Special Site Conditions or Transition/Termination Features (continued)

Respondent Type	***Respondent Group***	***Special Site Conditions***	***Special Transition/Termination Features***
State Government	North Dakota	Low strength soils to frozen ground in the winter time at 1:1 to 4:1 inslopes	-
	Louisiana	Most of our timber bridges are in very rural areas with poor slope conditions (2:1 or even 1:1). While not a requirement, a transition that could be used with steep slide slopes would be beneficial.	Our standard guard rail to bridge rail transition uses thrie beam so having a thrie beam rail makes such a transition very easy and would be our preferred choice. That being said, LADOTD would be open to other options.
Federal Government	Bureau of Reclamation	Main thing Reclamation needs is better guidelines for when approach guardrail is needed.	-

Table B-20. Deck Type vs. Test Level Requests: Low-Height, Curb-Type System

Deck Type	***Requests***			
	TL-1	***TL-2***	***TL-3***	***TL-4***
LG	2	2	2	1
LN	2	2	1	1
LSp	2	3	1	1
LSt	1	2	1	1
TG	3	2	0	1
TN	5	3	0	1
Concrete	0	1	1	0
Other	1	1	0	0

LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-21. Deck Type vs. Test Level Requests: Timber Railing without Curb System

Deck Type	***Requests***			
	TL-1	***TL-2***	***TL-3***	***TL-4***
LG	2	3	2	3
LN	2	3	2	1
LSp	2	3	3	1
LSt	1	2	3	2
TG	3	2	1	3
TN	4	3	1	1
Concrete	0	1	1	1
Other	0	0	1	0

LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-22. Deck Type vs. Test Level Requests: Timber Railing with Curb System

Deck Type	***Requests***			
	TL-1	***TL-2***	***TL-3***	***TL-4***
LG	1	5	7	8
LN	1	6	3	2
LSp	0	7	6	6
LSt	0	3	4	4
TG	1	6	6	13
TN	3	8	4	6
Concrete	0	8	4	6
Other	1	4	1	0

LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-23. Deck Type vs. Test Level Requests: W-Beam System

Deck Type	***Requests***			
	TL-1	***TL-2***	***TL-3***	***TL-4***
LG	1	6	2	1
LN	1	4	2	1
LSp	1	3	3	1
LSt	0	3	3	0
TG	2	4	1	1
TN	2	4	4	1
Concrete	1	3	3	0
Other	1	1	1	1

LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-24. Deck Type vs. Test Level Requests: Thrie Beam System

Deck Type	***Requests***			
	TL-1	***TL-2***	***TL-3***	***TL-4***
LG	1	3	2	3
LN	1	3	2	2
LSp	0	2	2	1
LSt	0	2	2	1
TG	1	3	1	4
TN	2	4	3	3
Concrete	1	7	6	0
Other	0	1	1	0

LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-25. Deck Type vs. Test Level Requests: Steel-Backed Timber System

Deck Type	***Requests***			
	TL-1	***TL-2***	***TL-3***	***TL-4***
LG	0	2	3	4
LN	0	1	3	2
LSp	0	1	3	2
LSt	0	1	3	2
TG	0	1	2	4
TN	0	1	3	3
Concrete	0	2	2	1
Other	0	1	0	0

LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Table B-26. Deck Type vs. Test Level Requests: Other Systems

Deck Type	***Requests***			
	TL-1	***TL-2***	***TL-3***	***TL-4***
LG	0	0	0	0
LN	0	0	1	1
LSp	0	0	0	0
LSt	0	0	0	0
TG	0	0	0	0
TN	0	0	0	0
Concrete	0	0	1	1
Other	0	0	0	0

LG – Longitudinal, Glulam Timber
LN – Longitudinal, Nail-Laminated Timber
LSp – Longitudinal, Spike-Laminated Timber
LSt – Longitudinal, Stress-Laminated Timber
TG – Transverse, Glulam Timber
TN – Transverse, Nail-Laminated Timber

Appendix C. System Details

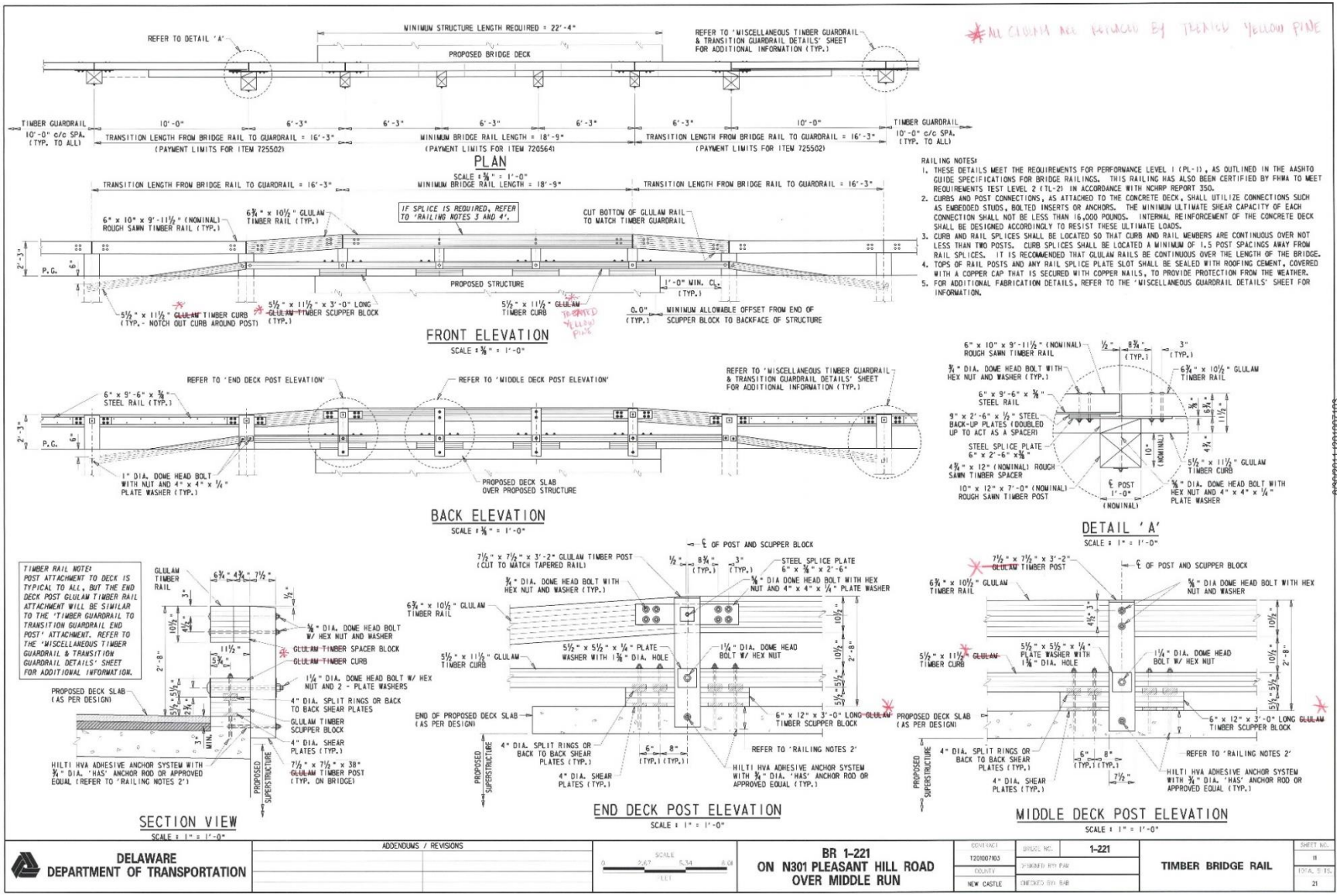


Figure C-1. Delaware DOT Drawing Set of Timber Railing with Curb System and Steel-Backed Timber Transition

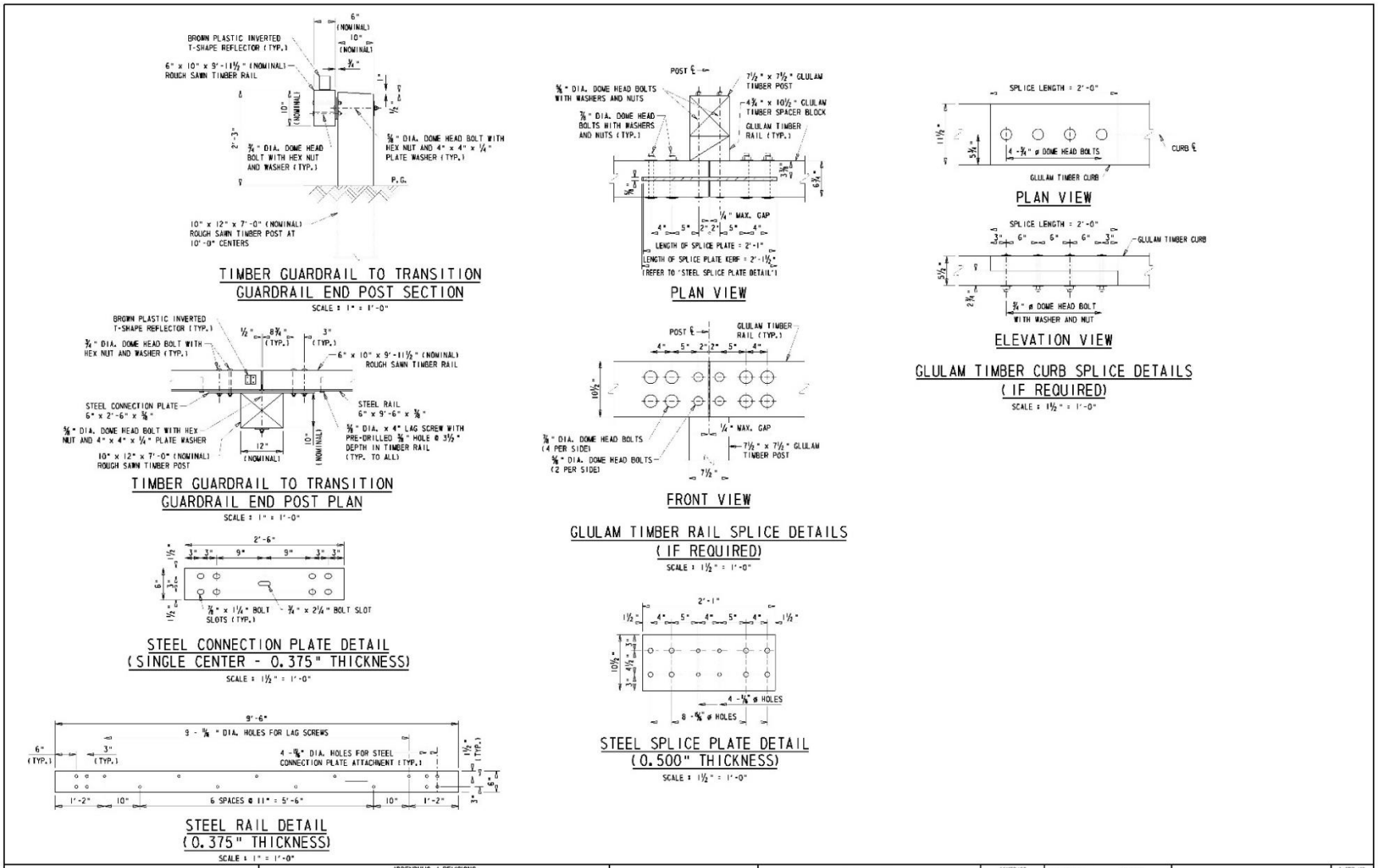


Figure C-2. Delaware DOT Drawing Set of Timber Railing with Curb System and Steel-Backed Timber Transition (continued)

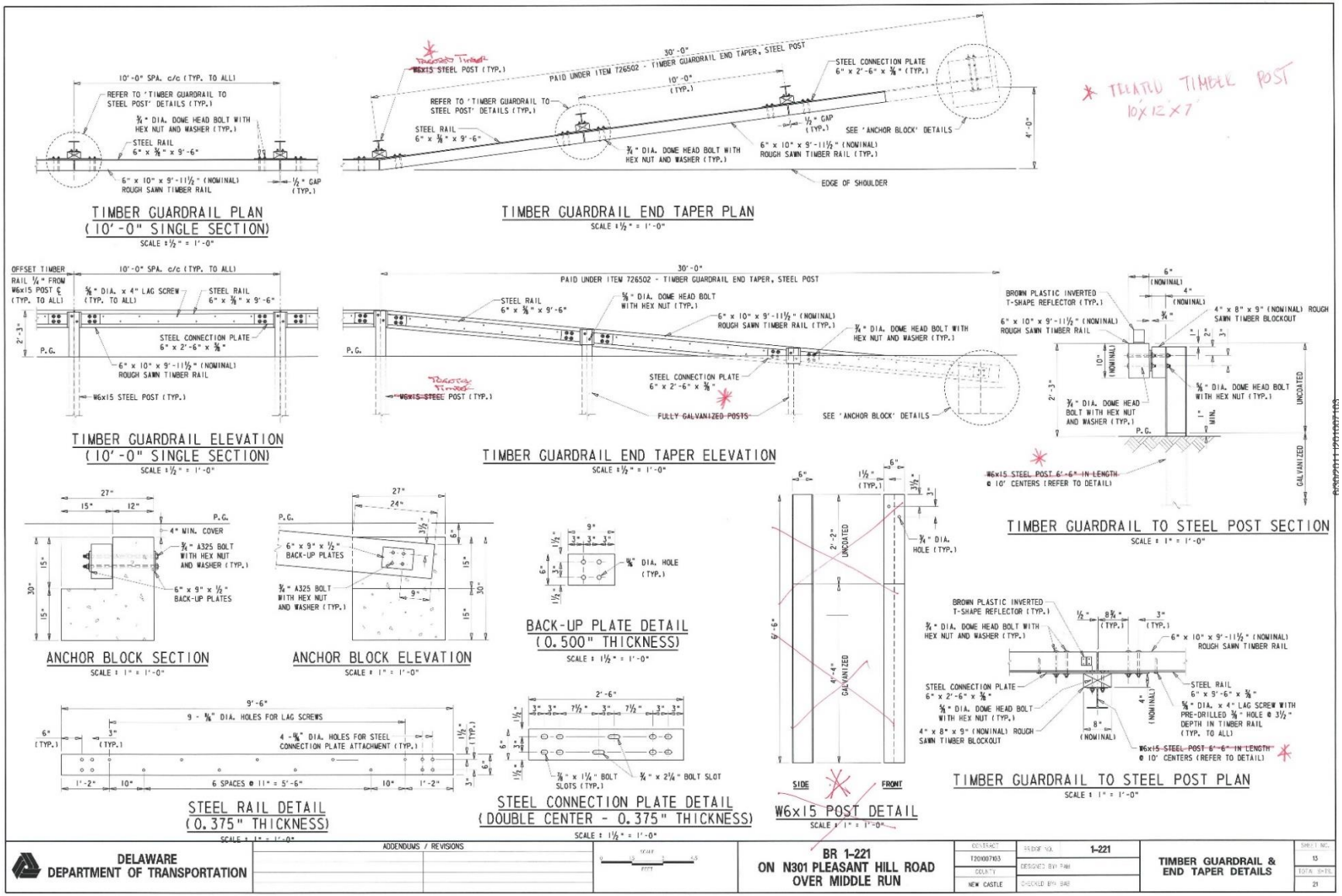


Figure C-3. Delaware DOT Drawing Set of Timber Railing with Curb System and Steel-Backed Timber Transition (continued)

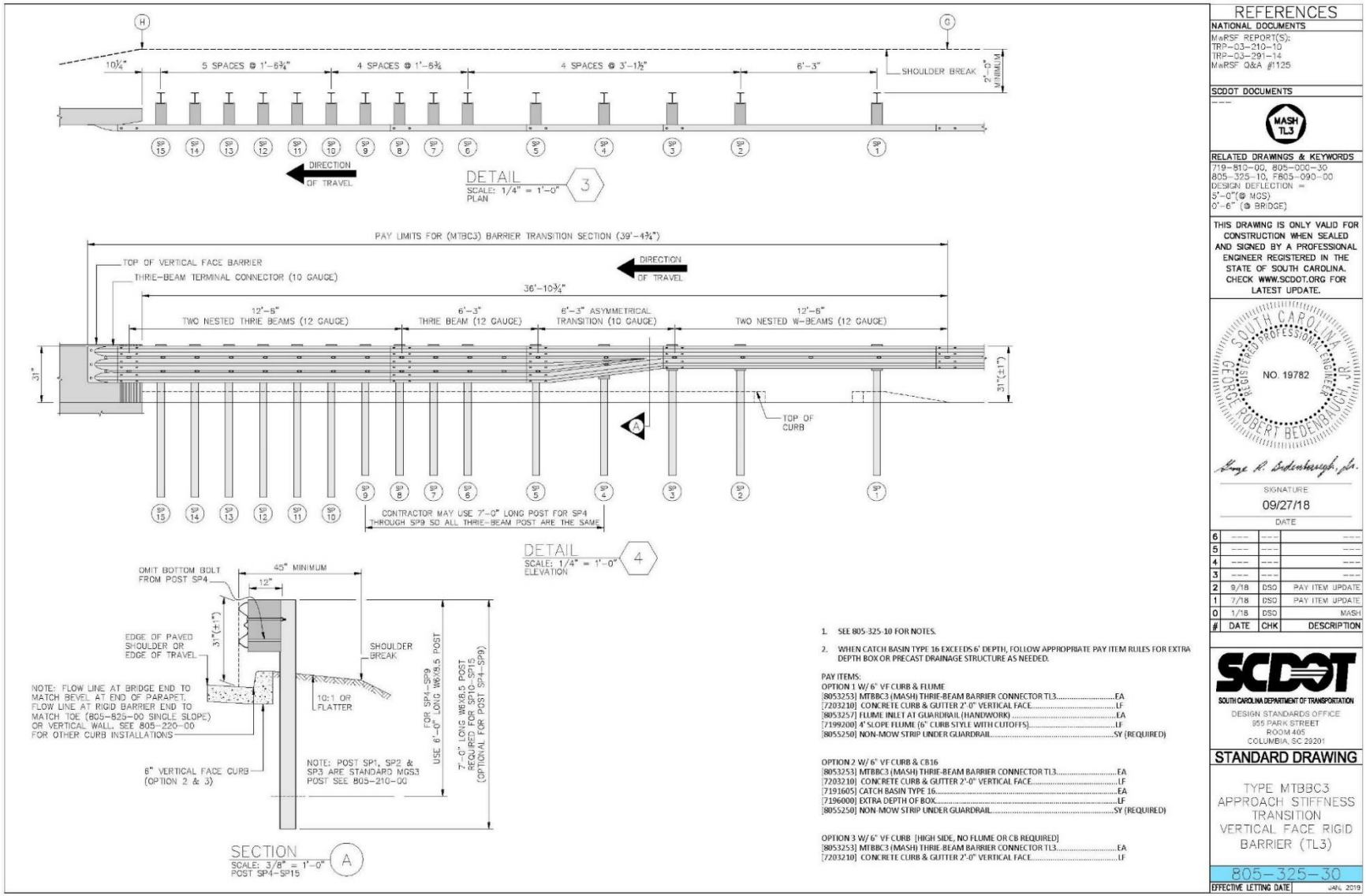


Figure C-4. South Carolina DOT Standard Drawing of Concrete Curb to Timber Curb Transition Feature

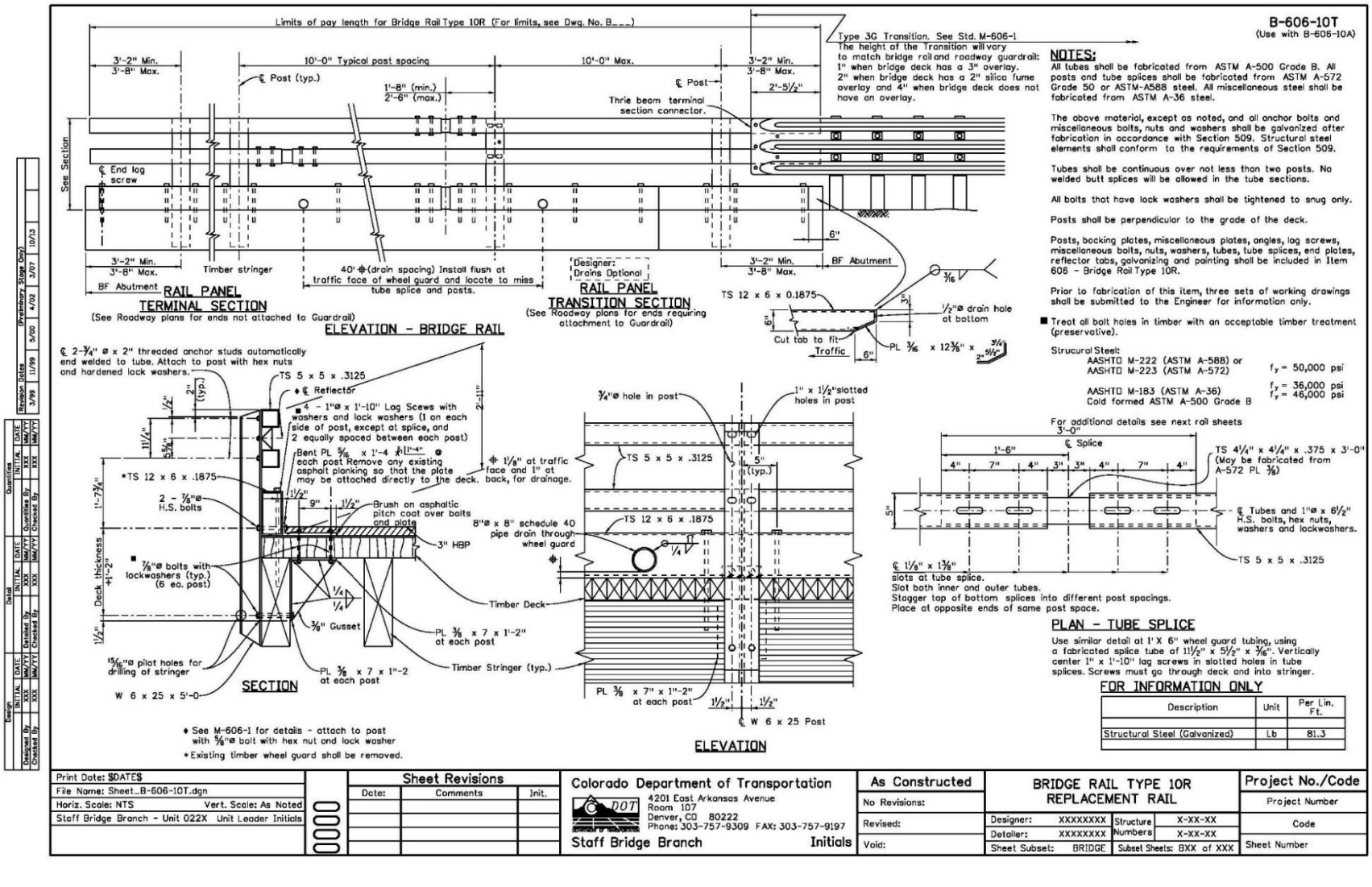


Figure C-5. Colorado DOT Drawing of Type 10T Bridge Railing System

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