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Forest Service

Forest
Products
Laboratory

U.S. DOT
Federal Highway
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Report
FPL-GTR-108

Plans for Crash-Tested Wood Bridge Railings for Concrete Decks

Michael A. Ritter
Ronald K. Faller
Paula D. Hilbrich Lee
Barry T. Rosson
Sheila Rimal Duwadi

Abstract

As part of a continuing cooperative research between the Midwest Roadside Safety Facility (MwRSF); the USDA Forest Service, Forest Products Laboratory (FPL); and the Federal Highway Administration (FHWA), several crashworthy wood bridge railings and approach railing transitions have been adapted for use on concrete bridge decks. These railings meet testing and evaluation criteria outlined in National Cooperative Research Program (NCHRP) Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features*, and include a glued-laminated timber (glulam) rail, with and without a curb, at Test Level- 2 (TL-2), a glulam rail with curb at TL-4, and a glulam curb rail for low-volume roads at TL-1. In adapting the railings from a wood deck to a concrete deck, the critical consideration was railing attachment to the deck. A comparable connection was obtained by an analysis of maximum loads measured by field instrumentation during crash testing or by equating the ultimate capacity of connections used on the wood deck to those required for a concrete deck. For the convenience of the user, full drawing sets are provided in customary U.S. and S.I. units.

August 1998

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Plans for Crash-Tested Wood Bridge Railings for Concrete Decks

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Introduction

Cooperative research between the Midwest Roadside Safety Facility (MwRSF); the USDA Forest Service, Forest Products Laboratory (FPL); and the Federal Highway Administration (FHWA) has resulted in the development of several crashworthy bridge railings for wood bridge decks (Faller et al. 1992). These railings involve both wood and steel systems and include crashworthy approach railing transitions. Criteria for evaluation and testing of these railings were originally based on requirements given in National Cooperative Research Program (NCHRP) Report 230, *Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances* (NCHRP 1981). Starting in 1993, criteria were based on NCHRP Report 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features* (Ross et al. 1993). In accordance with FHWA policy, those railings found acceptable under the NCHRP 230 criteria are also considered as meeting the requirements of NCHRP Report 350 without further testing. Given the success of the wood bridge railing development and crash testing, interest was expressed at the national level to adapt several of the wood bridge railings to concrete decks. These drawings include four railings that meet NCHRP 350 requirements and were adapted for concrete deck use. They include a glued-laminated timber (glulam) rail, with and without a curb, at Test Level 2 (TL-2), a glulam rail with curb at TL-4, and a glulam curb rail for low-volume roads at TL-1. In adapting the railings from a wood deck to a concrete deck, the critical consideration was railing attachment to the deck. A comparable connection was obtained by an analysis of maximum loads measured by field instrumentation during crash testing or by equating the ultimate capacity of connections used on the wood deck to those required for a concrete deck. For the convenience of the user, full drawing sets are provided in customary U.S. and S.I. units.

Acknowledgments

We express sincere appreciation to Brent Prauner, Keith Robertson, and Eric Keller of the Midwest Roadside Safety Facility, University of Nebraska-Lincoln, and the FPL Information Services Team for assistance in preparing this publication.

Specifications

AASHTO. 1989. Guide Specifications for Bridge Railings. Washington, DC: American Association of State Highway and Transportation Officials.

AASHTO. 1995. Standard Specifications for Transportation Materials and Methods of Sampling and Testing. Vol. 1: Specifications. Washington, DC: American Association of State Highway and Transportation Officials.

M111 Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
M133 Preservatives and Pressure Treatment Process for Timber
M168 Wood Products
M180 Corrugated Sheet Steel Beams for Highway Guardrail
M232 Zinc Coating (Hot-Dip) on Iron and Steel Hardware

ANSI/AASHTO/AWS D1.5-88. Bridge Welding Code. Washington, DC: American Association of State Highway and Transportation Officials.

ASTM. 1998. Annual Book of ASTM Standards. Philadelphia, PA: American Society for Testing and Materials.
A36 Standard Specification for Structural Steel
A47 Standard Specification for Ferritic Malleable Iron Castings
A307 Standard Specification for Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength

SAE 1989. J412. General Characteristics and Heat Treatment of Steels. Warrendale, PA. Society of Automotive Engineers.

References

Faller, R.K.; Ritter, M.A.; Holloway, J.C.; [and others]. 1992. Performance level 1 bridge railings for timber decks. In: Transportation Research Record 1419. Washington, DC: Transportation Research Board, National Research Council: 21-34.

NCHRP. 1981. Recommended procedures for the safety performance evaluation of highway appurtenances. NCHRP Rep. 230. Washington, DC: National Research Council, Transportation Research Board, National Cooperative Highway Research Program.

Ritter, M.; Faller, R. 1994. Crashworthy bridge railing for longitudinal wood decks. In: PTEC 94 Timber shaping the future: Proceedings of Pacific Timber Engineering conference; 1994 July 11-15; Gold Coast, Australia. Queensland, Australia: Fortitude Valley MAC; 2: 298-307.

Ritter, M.A.; Faller, R.K.; Lee, P.D.H., [and others]. 1995. Plans for crash-tested bridge railings for longitudinal wood decks. Gen. Tech. Rep. FPL-GTR-87. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

Ritter, M.A.; Faller, R.K.; Bunnell, S.; [and others]. 1998. Plans for crash-tested bridge railings for longitudinal wood decks on low-volume roads. Gen. Tech. Rep. FPL-GTR-**. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory.

Ross, H.E., Jr.; Sicking, D.L.; Zimmer, R.A.; Michie, J.D. 1993. Recommended procedures for the safety performance evaluation of highway features, NCHRP Rep. 350. Washington, DC: National Research Council, Transportation Research Board, National Cooperative Highway Research Program.

Rosson, B.T.; Faller, R.K.; Ritter, M.A. 1995. Performance level 2 and test level 4 bridge railings for timber decks. In: Transportation Research Record 1500. Washington, DC:, Transportation Research Board, National Research Council: 102-111.

Comments

Address comments on these drawings to the Wood Transportation Structures Team, Forest Products Laboratory, One Gifford Pinchot Drive, Madison, WI 53705-2398. http://www.fpl.fs.fed.us/wit/

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Rail Drawings in Customary U.S. Units

University of Nebraska Lincoln

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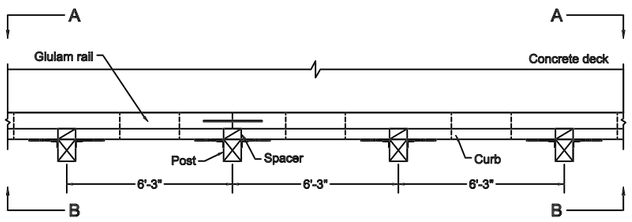
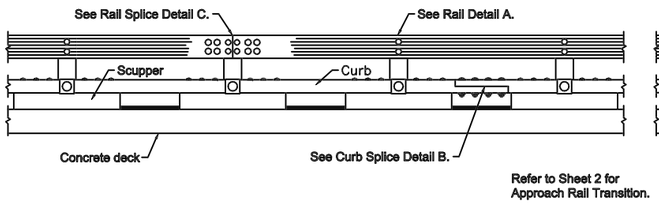


Plan



Refer to Sheet 2 for Approach Rail Transition.

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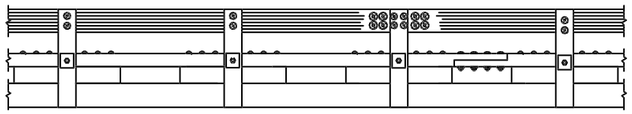
Section B-B



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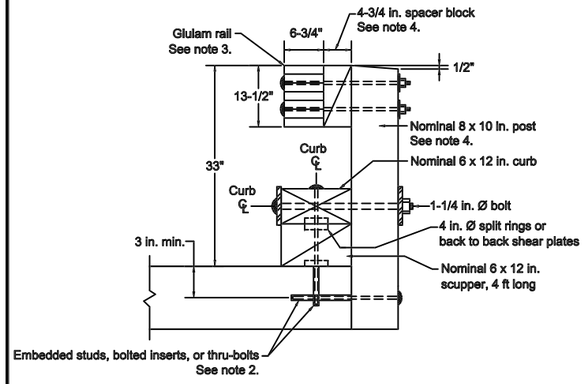
A Railing Details



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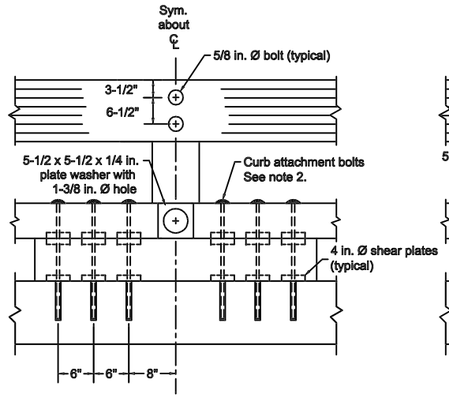

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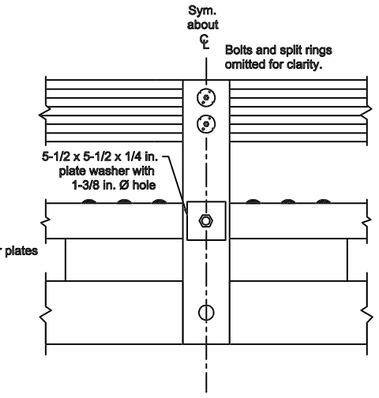
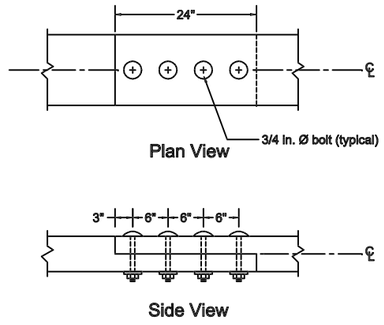


Back View

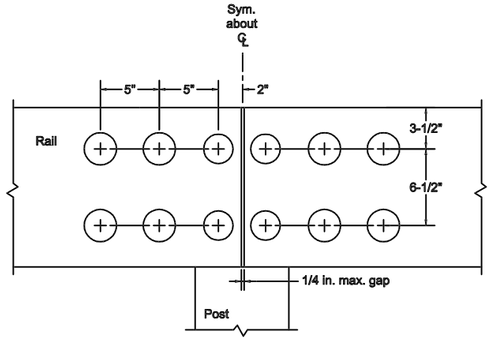
B Curb Splice Detail



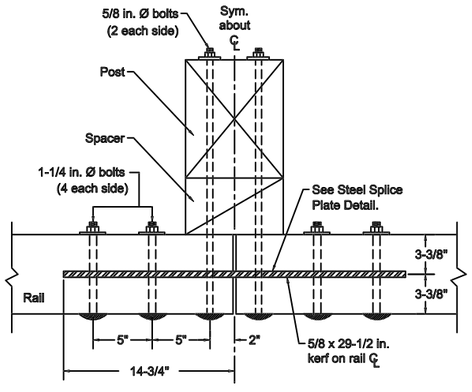
Plan View

Side View

C Rail Splice Details

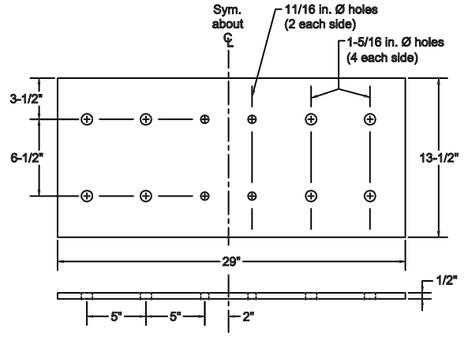


Front View



Plan View

Steel Splice Plate



Design

1. This bridge railing was sucessfully crash tested on a longitudinal wood deck to the requirements for Test Level 4 (TL-4), as outlined in NCHRP Report 350. Adaptation of this railing from a longitudinal wood deck to a concrete deck is based on test measurements and the ultimate capacity of deck attachment hardware.

2. Curb and post connections, such as attachment to the concrete deck, shall be with connections, such as embedded studs, bolted inserts, or thru-bolts. The minimum ultimate shear capacity of each connection shall not be less than 16,000 lb. Internal reinforcement of the concrete shall be designed accordingly to resist these ultimate loads.

3. Dimensions given for glued-laminated (glulam) timber rails are actual dimensions. The depth of the glulam may be increased to a maximum of 13-3/4 in. to allow for other standard glulam sizes. In such cases, detail dimensions shall be verified and modified accordingly.

4. Dimensions for wood posts, curbs, and scuppers are given as nominal dimensions. Actual dimensions may be a maximum of 1/2 in. less than the stated nominal dimensions, depending on material surfacing. Dimensions for spacer block depth are actual dimensions.

5. Curb and rail splices shall be located so that curb and rail members are continuous over not less than two posts. Curb splices shall be located a minimum of 1.5 post spacings away from rail splices. It is recommended that glulam rails be continuous over the length of the bridge.

Materials

6. Sawn lumber and glulam shall comply with the requirements of AASHTO M168 and shall be pressure treated with wood preservative in accordance with AASHTO M133.

7. Bridge rail shall be horizontally laminated glulam, visually graded western species Combination No. 2, or visually graded Southern Pine Combination No. 48. Other species and grades of glulam may be used, provided the minimum tabulated values are not less than the following:
$F_{b,y}$ = 1,800 lb/in^2 E = 1,800,000 lb/in^2

8. Posts, curbs, scuppers, and spacer blocks may be sawn lumber or glulam. When sawn lumber is used, material shall be visually graded No. 1 Southern Pine or visually graded No. 1 Douglas Fir-Larch. Glulam and other species and grades of sawn lumber may be used, provided the minimum tabulated values are not less than the following:
F_b = 1,350 lb/in^2 E = 1,500,000 lb/in^2

9. Steel plates and shapes shall comply with the requirements of ASTM A36.

10. Bolts shall comply with ASTM A307 requirements, Grade 2, and should preferably be dome-head timber bolts. Bolts on the rail traffic face shall be dome head.

11. Split rings shall be manufactured from SAE 1010 hot-rolled carbon steel (SAE J412). Shear plates shall be malleable iron manufactured according to ASTM A47, Grade 32510.

12. All steel components and fasteners shall be galvanized in accordance with AASHTO M111 or M232 or shall otherwise be provided with adequate corrosion protection. Galvanizing of high-strength steel bars shall follow the recommendations of the bar manufacturer so as not to adversely affect the mechanical properties of the steel.

Fabrication and Construction

13. To the extent possible, all wood shall be cut, drilled, and completely fabricated prior to pressure treatment with preservatives. When field fabrication of wood is required or if wood is damaged, all cuts, bore holes, and damage shall be immediately field treated with wood preservative in accordance with AASHTO M133.

14. Unless noted, malleable iron washers shall be provided under bolt heads and under nuts that are in contact with wood. When the size and strength of the head are sufficient to develop connection strength without wood crushing, washers may be omitted under heads of dome-head timber bolts.

15. Tops of rail posts and top of the rail splice plate shall be sealed with roofing cement or otherwise protected from direct exposure to weather.

The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

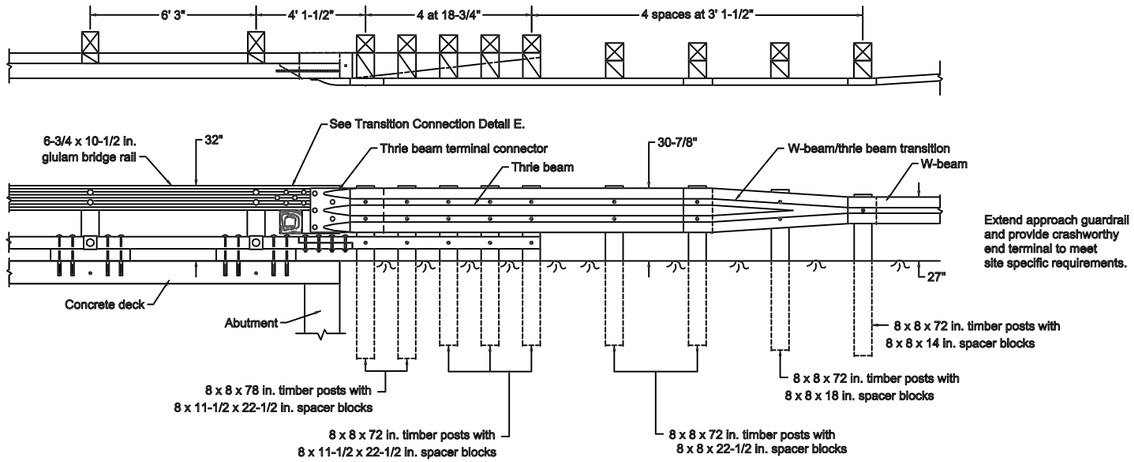
University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

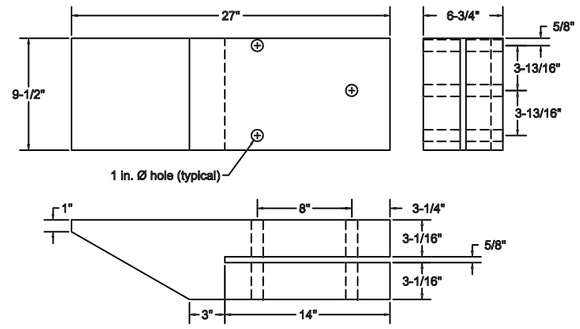
Glulam Timber Rail with Curb
NCHRP 350 Test Level 4 (TL-4)

August 1998

Approach Rail Transition General Configuration



D Transition Block



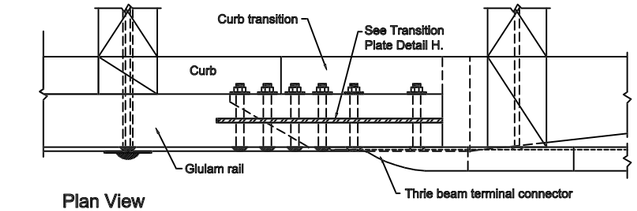
Depth of the transition block is based on a rail depth of 10-1/2 in. and surfaced curbs and scuppers (both 5-1/2 in. in height). If dimensions of any components increase, the depth of the transition block must be verified and reduced as necessary.

In addition to the notes on Sheet 1, the following apply to the approach rail transition:

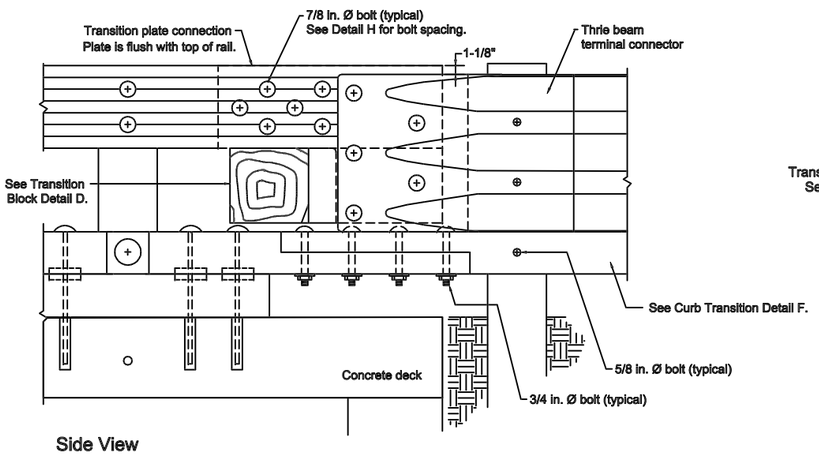
16. Thrie beam and thrie beam terminal connector shall be 10 gage. W-beam/thrie beam transition and W-beam shall be 12 gage. All shall comply with requirements of AASHTO M180.

17. W-beam and thrie beam rail splice bolts and post bolts shall comply with AASHTO M180.

E Transition Connection Details

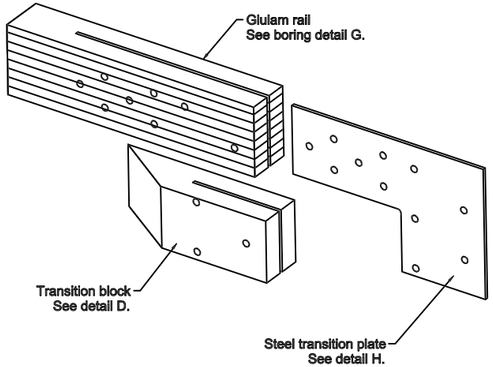


Plan View

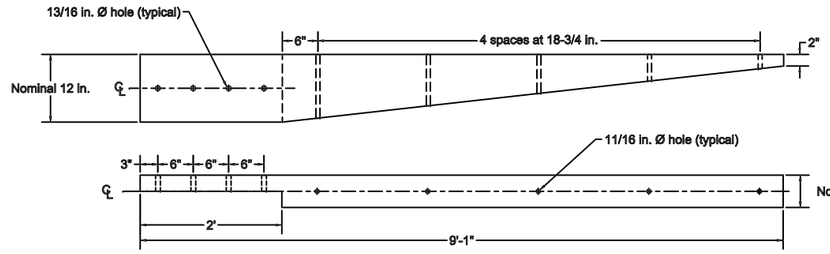


Side View

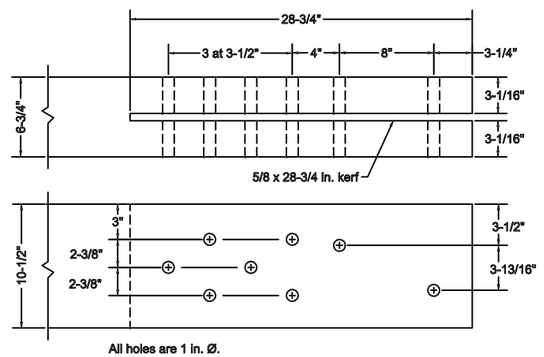
3 Dimensional View of Transition Connection



F Curb Transition

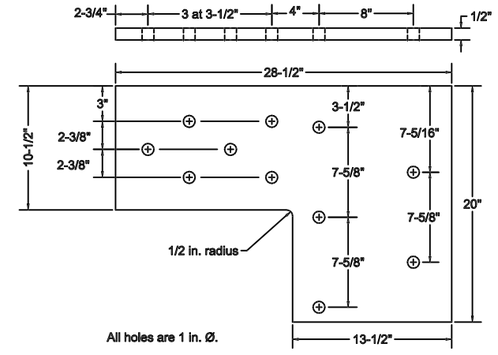


G Transition Glulam Rail Boring Detail



All holes are 1 in. Ø.

H Steel Transition Plate



The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

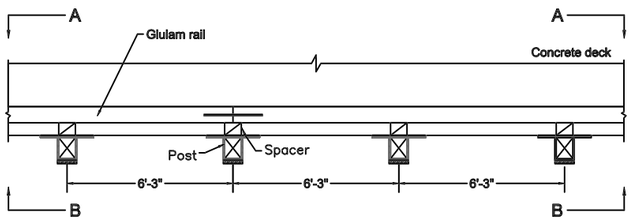
University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

Glulam Timber Rail with Curb
NCHRP 350 Test Level 2 (TL-2)

August 1998

General Configuration



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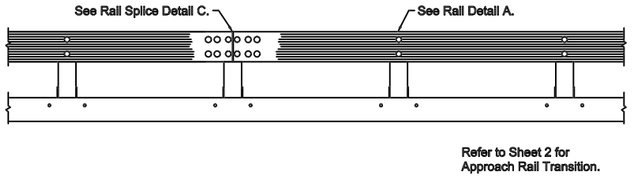
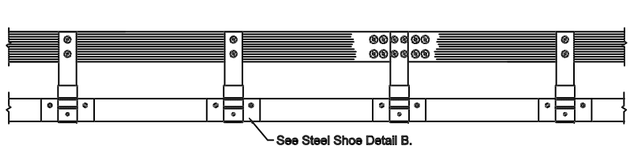
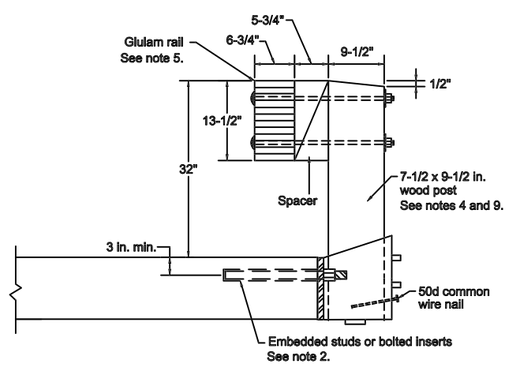


Front Elevation

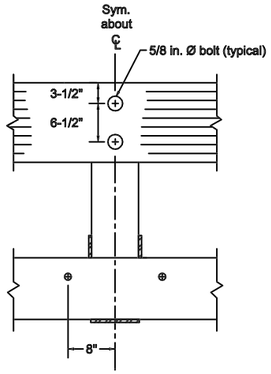


Back Elevation

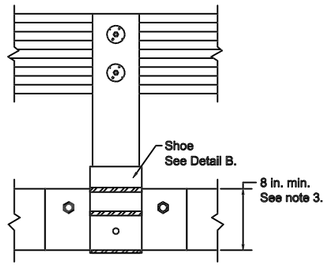
A Railing Details



End View

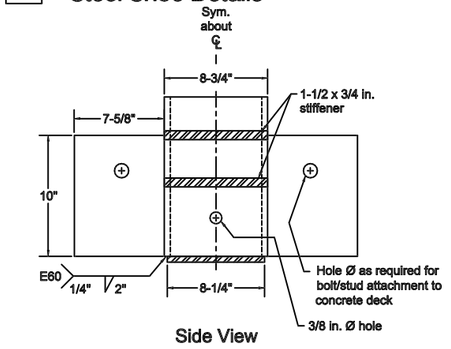


Front View



Back View

B Steel Shoe Details



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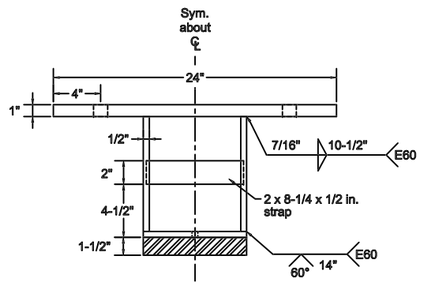

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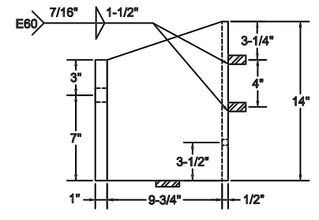

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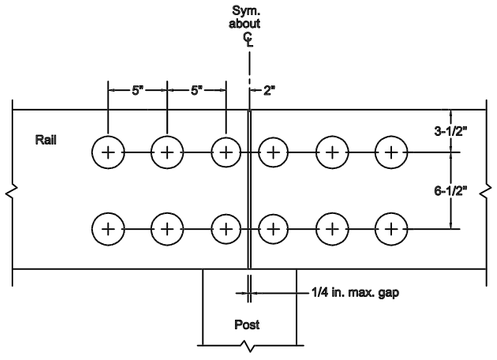
C Rail Splice Details



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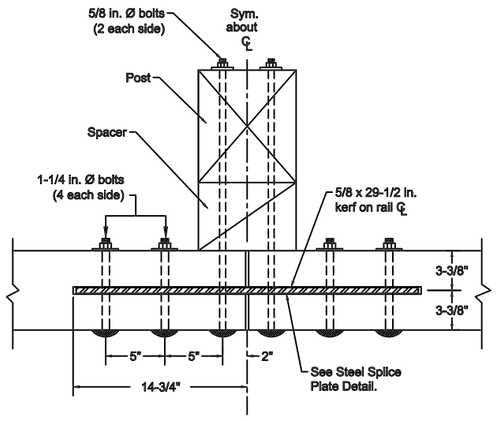
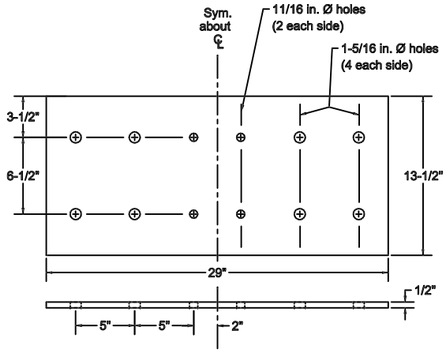


Plan View

Steel Splice Plate



Design

1. This bridge railing was successfully crash tested on a longitudinal wood deck to the requirements for Performance Level 1 (PL-1), as outlined in the AASHTO (1989) Guide Specifications for Bridge Railings. This railing has also been certified by the FHWA to meet requirements for Test Level 2 (TL-2) in accordance with NCHRP Report 350. Adaptation of this railing from a longitudinal wood deck to a concrete deck is based on test measurements and the ultimate capacity of deck attachment hardware.

2. Steel shoe for each post shall be attached to the concrete deck with two connections, such as bolted inserts or embedded studs. Each connection shall provide a minimum ultimate capacity of 50,000 lb. in tension. Internal reinforcement of the concrete deck shall be designed accordingly to resist these ultimate loads.

3. Concrete deck edge thickness shall be a minimum of 8 in. to provide bearing for the steel shoe plate.

4. Dimensions for the wood rail, post, and spacer are actual dimensions. Post dimensions correspond to the standard dressed dimensions for a nominal 8- by 10-in. member that is surfaced on four sides (S4S 1989).

5. Depth of the glued-laminated (glulam) timber rail may be increased to a maximum of 13-3/4 in. to allow for standard glulam timber sizes. In such cases, detail dimensions shall be verified and modified accordingly.

6. Rail splices shall be located so that rail members are continuous over not less than four posts. It is recommended that the rail be continuous over the length of the bridge.

Materials

7. Sawn lumber and glulam shall comply with the requirements of AASHTO M168 and shall be pressure treated with wood preservative in accordance with AASHTO M133.

8. Bridge rail shall be horizontally laminated glulam, visually graded western species Combination No. 2, or visually graded Southern Pine Combination No. 48. Other species and grades of glulam may be used, provided the minimum tabulated values are not less than the following:
$F_{b_{yy}} = 1{,}800$ lb/in^2 $E = 1{,}800{,}000$ lb/in^2

9. Posts and spacer blocks may be sawn lumber or glulam. When sawn lumber is used, material shall be visually graded No. 1 Southern Pine or visually graded No. 1 Douglas Fir-Larch. Glulam and other species and grades of sawn lumber may be used, provided the minimum tabulated values are not less than the following:
$F_b = 1{,}350$ lb/in^2 $E = 1{,}500{,}000$ lb/in^2

10. Steel plates and shapes shall comply with the requirements of ASTM A36.

11. Bolts shall comply with ASTM A307 requirements, Grade 2, and should preferably be dome-head timber bolts. Bolts on the rail traffic face shall be dome head.

12. All steel components and fasteners shall be galvanized in accordance with AASHTO M111 or M232 or shall otherwise be provided with adequate corrosion protection.

Fabrication and Construction

13. Welding shall be completed in accordance with the requirements of ANSI/AASHTO/AWS D1.5 Bridge Welding Code.

14. To the extent possible, all wood shall be cut, drilled, and completely fabricated prior to pressure treatment with preservatives. When field fabrication of wood is required or if wood is damaged, all cuts, bore holes, and damage shall be immediately field treated with wood preservative in accordance with AASHTO M133.

15. Unless noted, malleable iron washers shall be provided under bolt heads and under nuts that are in contact with wood. When the size and strength of the head are sufficient to develop connection strength without wood crushing, washers may be omitted under heads of dome-head timber bolts.

16. Tops of rail posts and top of the rail splice plate kerf shall be sealed with roofing cement or otherwise protected from direct exposure to weather.

The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

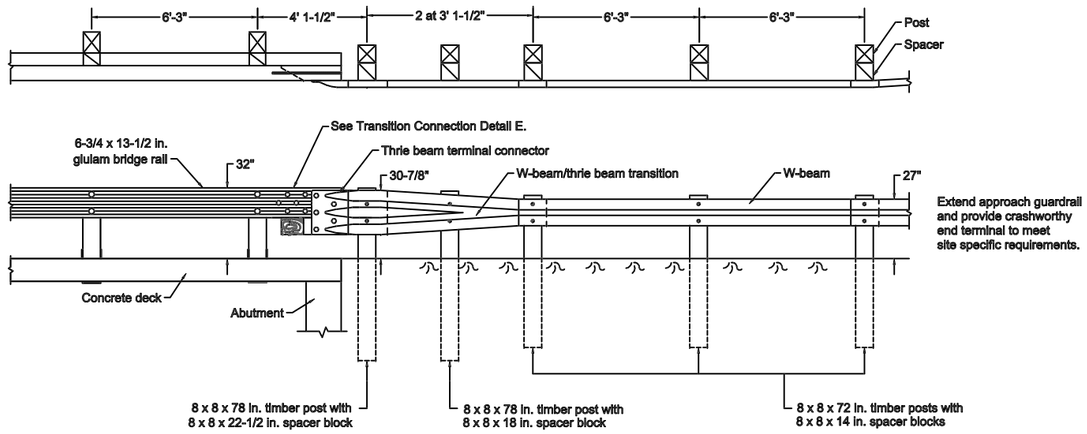
University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

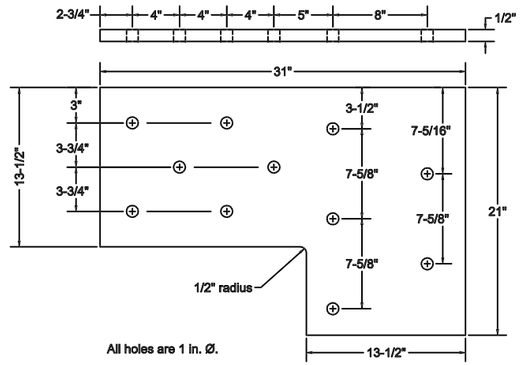
Glulam Timber Rail without Curb
NCHRP 350 Test Level 2 (TL-2)

August 1998

Approach Rail Transition General Configuration



D Steel Transition Plate

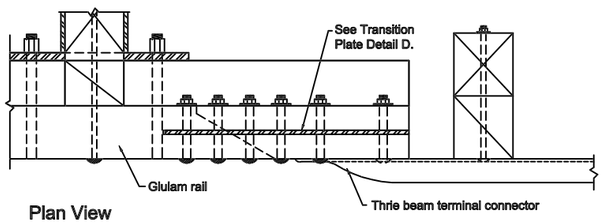


In addition to the notes on Sheet 1, the following apply to the approach rail transition:

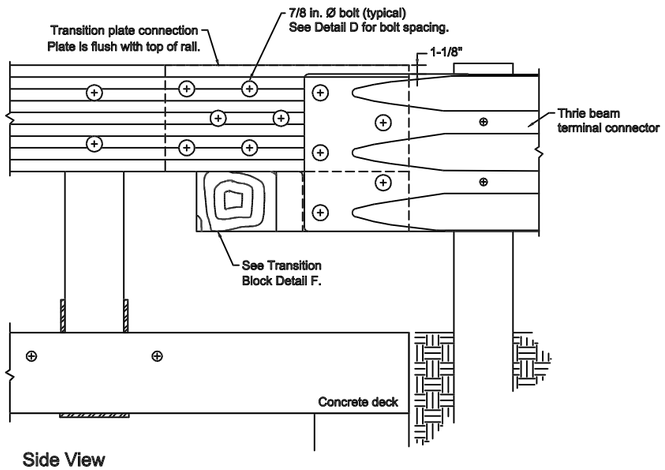
17. Thrie beam terminal connector shall be 10 gage. W-beam/thrie beam transition and w-beam shall be 12 gage. All shall comply with the requirements AASHTO M180.

18. W-beam and thrie beam rail splice bolts and post bolts shall comply with AASHTO M180.

E Transition Connection Details

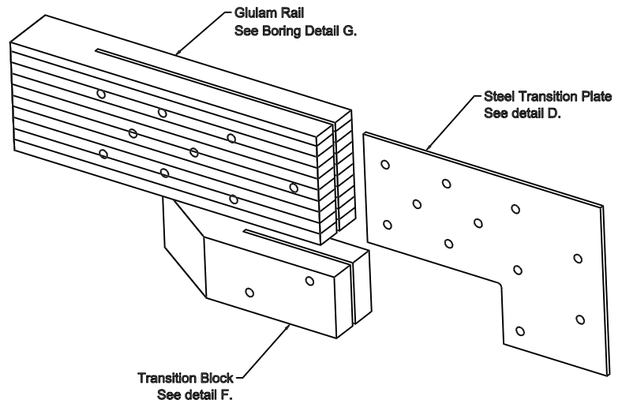


Plan View

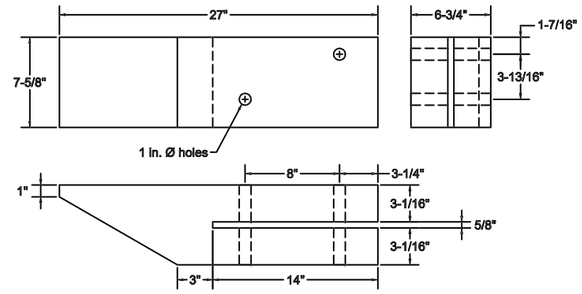


Side View

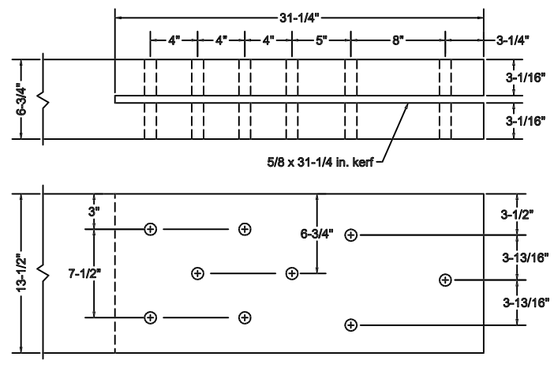
3 Dimensional View of Transition Connection



F Transition Block



G Transition Glulam Rail Boring Detail



All holes are 1 in. Ø.

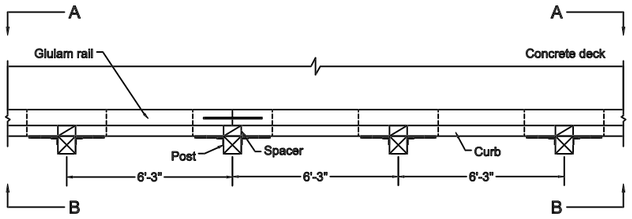
The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

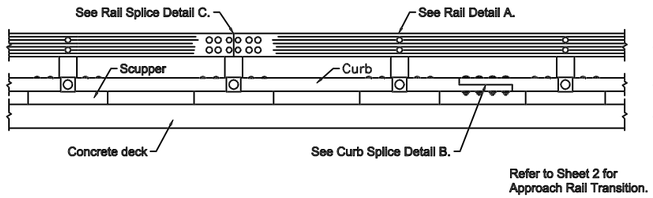
Glulam Timber Rail without Curb NCHRP 350 Test Level 2 (TL-2)	August 1998	Sheet 2 of 2

General Configuration



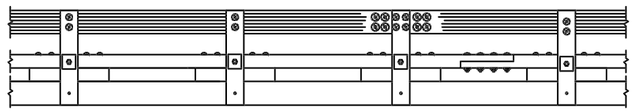
Plan

Section A-A



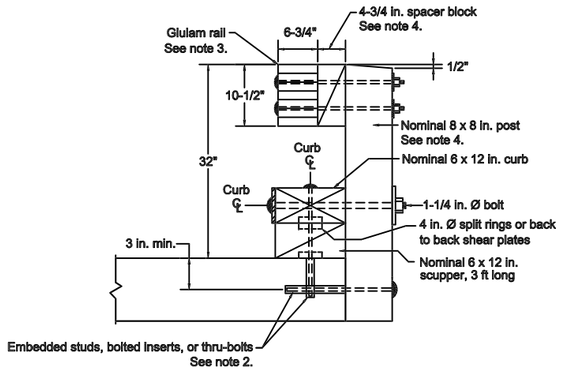
Front Elevation

Section B-B

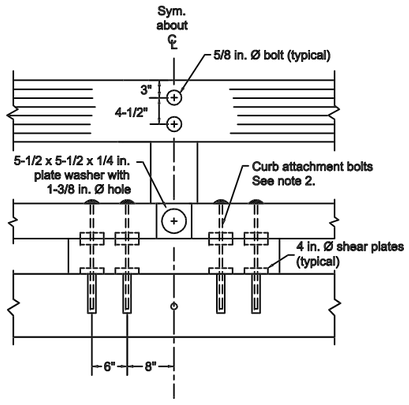


Back Elevation

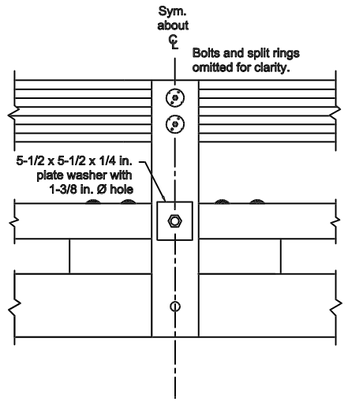
A Railing Details



End View

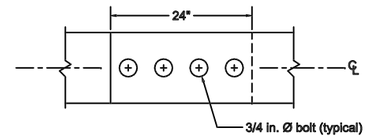


Front View

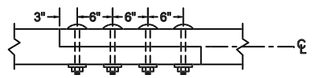


Back View

B Curb Splice Detail

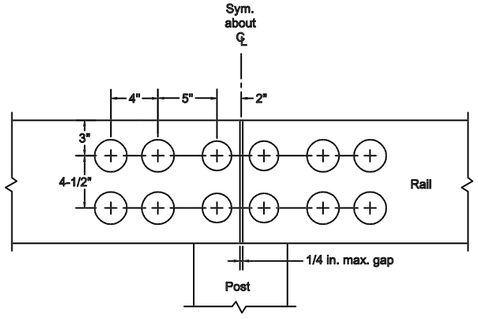


Plan View

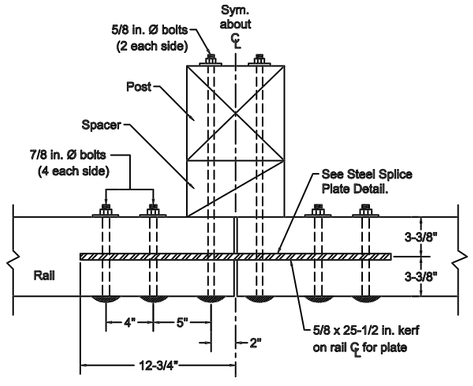


Side View

C Rail Splice Details

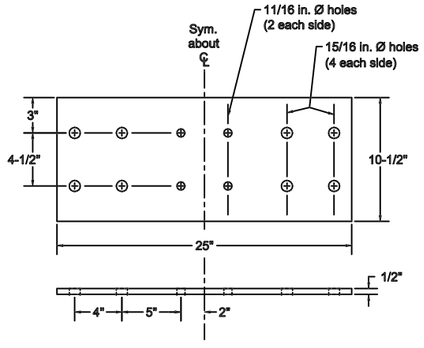


Front View



Plan View

Steel Splice Plate



Design

1. This bridge railing was successfully crash tested on a longitudinal wood deck to the requirements for Performance Level 1 (PL-1), as outlined in the AASHTO (1989) Guide Specifications for Bridge Railings. This railing has also been certified by the FHWA to meet requirements for Test Level 2 (TL-2) in accordance with NCHRP Report 350. Adaptation of this railing from a longitudinal wood deck to a concrete deck is based on test measurements and the ultimate capacity of deck attachment hardware.

2. Curb and post connections, such as attachment to the concrete deck, shall be with connections, such as embedded studs, bolted inserts, or through-bolts. The minimum ultimate shear capacity of each connection shall not be less than 16,000 lb. Internal reinforcement of the concrete shall be designed accordingly to resist these ultimate loads.

3. Dimensions given for glued-laminated (glulam) timber rails are actual dimensions. The depth of the glulam timber rail may be increased to a maximum of 10-3/4 in. to allow for other standard glulam sizes. In such cases, detail dimensions shall be modified accordingly.

4. Dimensions for wood posts, curbs, and scuppers are given as nominal dimensions. Actual dimensions may be a maximum of 1/2 in. less than the stated nominal dimensions. Dimension for spacer block depth are actual dimensions.

5. Curb and rail splices shall be located so that curb and rail members are continuous over not less than two posts. Curb splices shall be located a minimum of 1.5 post spacings away from rail splices. It is recommended that glulam rails be continuous over the length of the bridge.

Materials

6. Sawn lumber and glulam shall comply with the requirements of AASHTO M168 and shall be pressure treated with wood preservative in accordance with AASHTO M133.

7. Bridge rail shall be horizontally laminated glulam, visually graded western species Combination No. 2, or visually graded Southern Pine Combination No. 48. Other species and grades of glulam may be used, provided the minimum tabulated values are not less than the following:
F_{by} = 1,800 lb/in^2 E = 1,800,000 lb/in^2

8. Posts, curbs, scuppers, and spacer blocks may be sawn lumber or glulam. When sawn lumber is used, material shall be visually graded No. 1 Southern Pine or visually graded No. 1 Douglas Fir-Larch. Glulam and other species and grades of sawn lumber may be used, provided the minimum tabulated values are no less than the following:
F_b = 1,350 lb/in^2 E = 1,500,000 lb/in^2

9. Steel plates and shapes shall comply with the requirements of ASTM A36.

10. Bolts shall comply with ASTM A307 requirements, Grade 2, and should preferably be dome-head timber bolts. Bolts on the rail traffic face shall be dome head.

11. Split rings shall be manufactured from SAE 1010 hot-rolled carbon steel (SAE J412). Shear plates shall be malleable iron manufactured according to ASTM A47, Grade 32510.

12. All steel components and fasteners shall be galvanized in accordance with AASHTO M111 or M232 or shall otherwise be provided with adequate corrosion protection.

Fabrication and Construction

13. To the extent possible, all wood shall be cut, drilled, and completely fabricated prior to pressure treatment with preservatives. When field fabrication of wood is required or if wood is damaged, all cuts, bore holes, and damage shall be immediately treated with wood preservative in accordance with AASHTO M133.

14. Unless noted, malleable iron washers shall be provided under bolt heads and under nuts that are in contact with wood. When the size and strength of the head are sufficient to develop connection strength without wood crushing, washers may be omitted under heads of dome-head timber bolts.

15. Tops of rail posts and top of the rail splice plate kerf shall be sealed with roofing cement or otherwise protected from direct exposure to weather.

The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

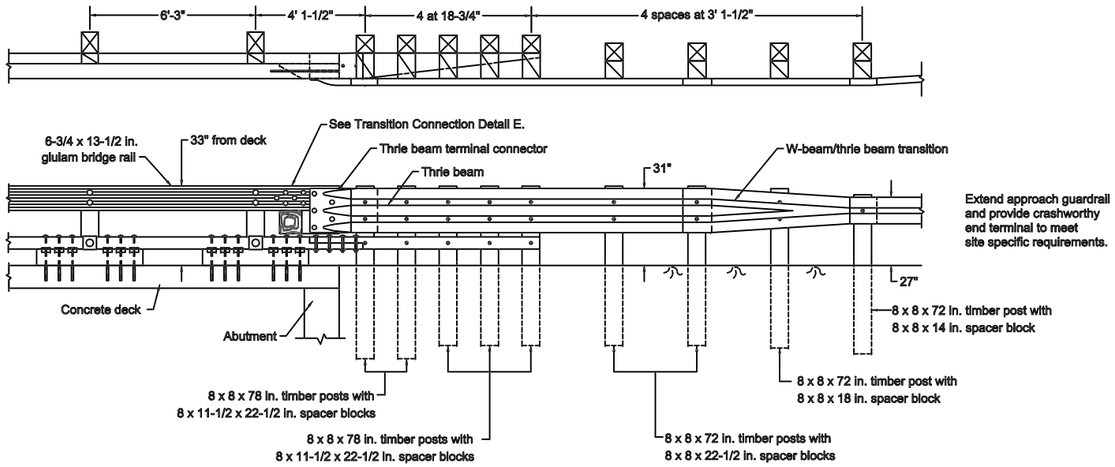
University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

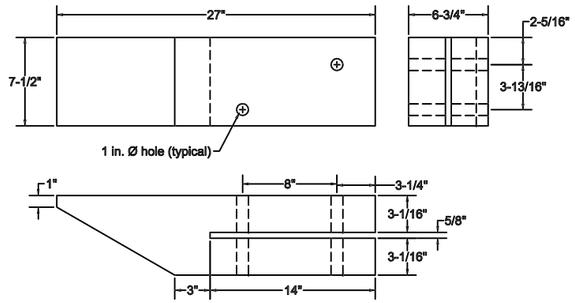
Glulam Timber Rail with Curb
NCHRP 350 Test Level 2 (TL-2)

August 1998

Approach Rail Transition General Configuration



D Curb Transition Block



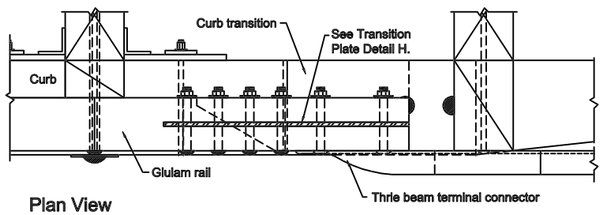
Depth of the transition block is based on a rail depth of 13-1/2 in. and surfaced curbs and scuppers (5-1/2 and 7-1/2 in. in height, respectively). If dimensions of any components increase, the depth of the transition block must be verified and reduced as necessary.

In addition to the notes on Sheet 1, the following apply to the approach rail transition:

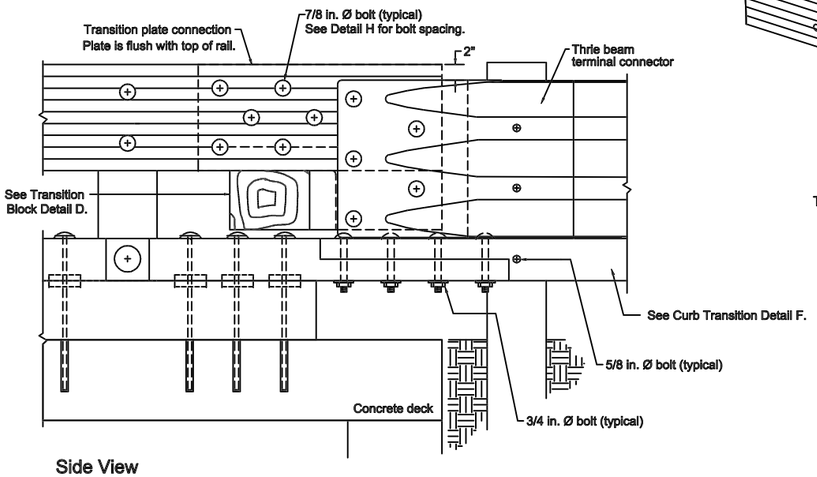
16. Thrie beam and thrie beam terminal connector shall be 10 gage. W-beam/thrie beam transition and W-beam shall be 12 gage. All shall comply with requirements AASHTO M180.

17. W-beam and thrie beam rail splice bolts and post bolts shall comply with AASHTO M180.

E Transition Connection Details

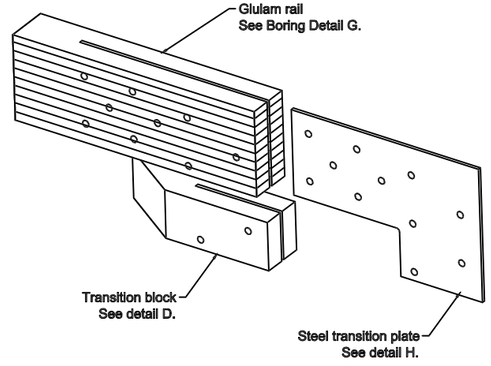


Plan View

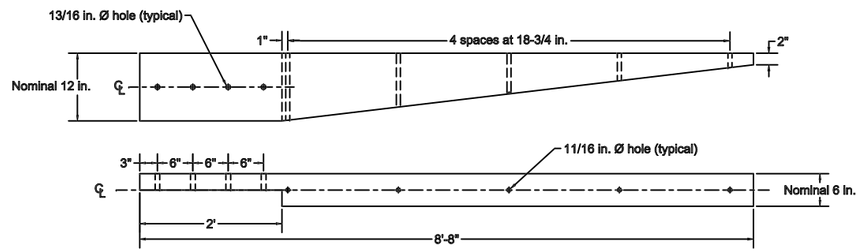


Side View

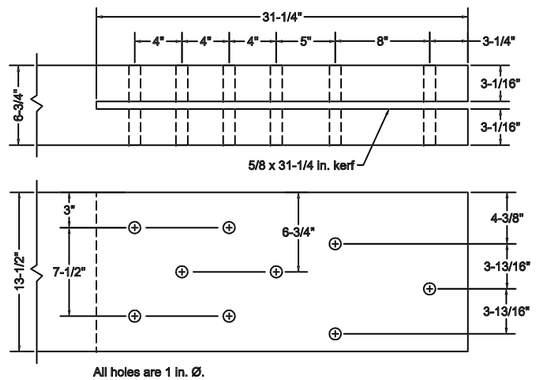
3 Dimensional View of Transition Connection



F Curb Transition

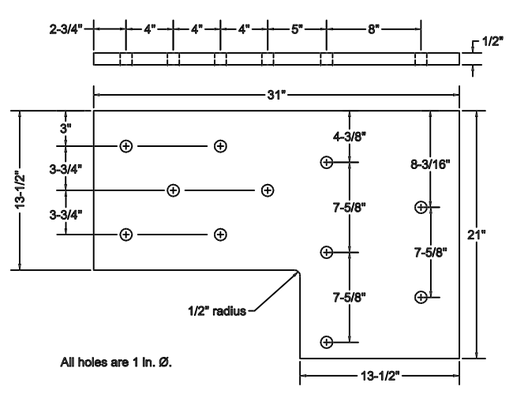


G Transition Glulam Rail Boring Detail



All holes are 1 in. Ø.

H Transition Plate



All holes are 1 in. Ø.

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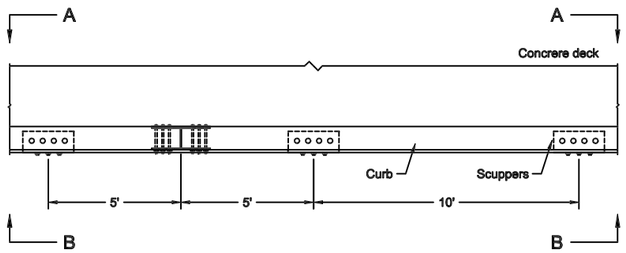
University of Nebraska Lincoln

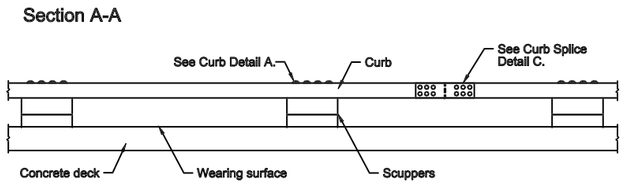
Crash-Tested Wood Bridge Railings for Concrete Decks

Glulam Timber Rail with Curb NCHRP 350 Test Level 4 (TL-4)	August 1998	Sheet 2 of 2

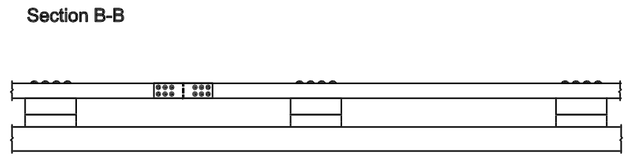
General Configuration



Plan View

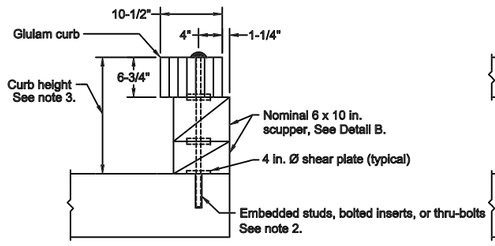


Front Elevation

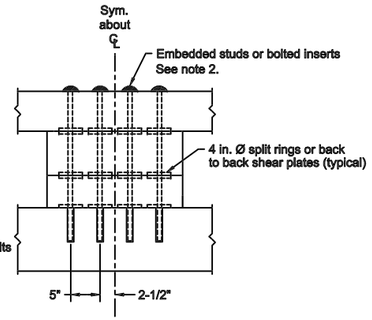


Back Elevation

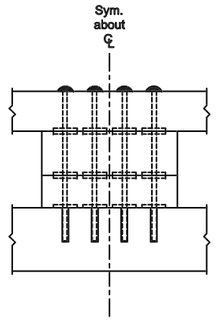
A Curb Details



End View

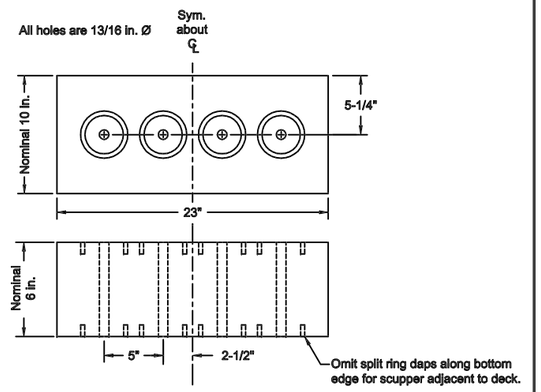


Front View

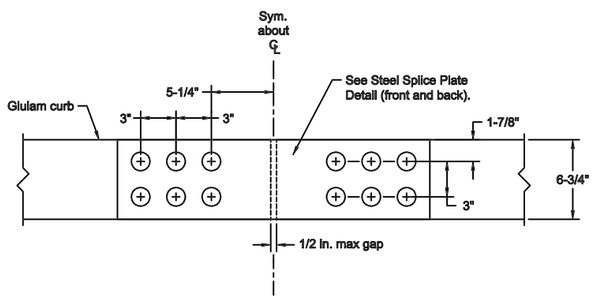


Back View

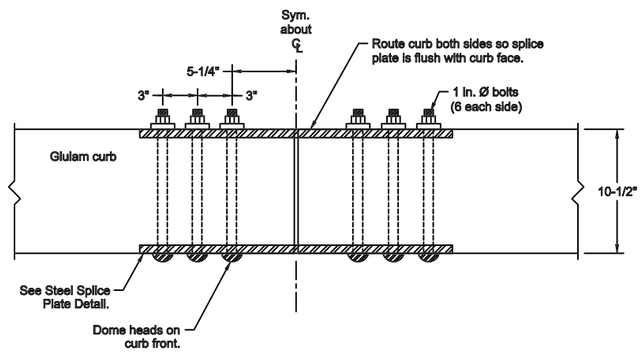
B Scupper Detail



C Curb Splice Details

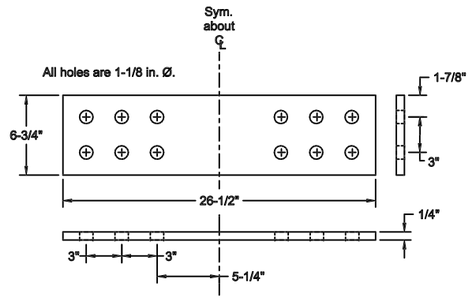


Front View



Plan View

Steel Splice Plate



Design

1. This curb railing was successfully crash tested on a longitudinal wood deck to the requirements for Test Level 1 (TL-1), as outlined in NCHRP Report 350. Adaptation of this railing from a longitudinal wood deck to a concrete deck is based on test measurements and the ultimate capacity of deck attachment hardware.

2. Curb and post connections, such as attachment to the concrete deck, shall be with connections, such as embedded studs, bolted inserts, or thru-bolts. The minimum ultimate shear capacity of each connection shall not be less than 16,000 lb. Internal reinforcement of the concrete shall be designed accordingly to resist these ultimate loads.

3. Actual height of the curb railing rail shall be 17-3/4 to 18-3/4 in. above the traveled way.

4. Dimensions for glued-laminated (glulam) timber components are actual dimensions. Dimensions for sawn lumber components are nominal dimensions. Actual sawn lumber dimensions may be up to a maximum of 1/2 in. less than nominal dimensions to permit the use of surfaced or rough-sawn material.

5. Curb railing splices are midway between scuppers and shall be located so that curb is continuous over not less than two scuppers. It is recommended that the glulam curbs be continuous over the length of the bridge.

Materials

6. Sawn lumber and glulam shall comply with the requirements of AASHTO M168 and shall be pressure treated with wood preservative in accordance with AASHTO M133. Glulam shall be manufactured using wet use adhesives to an industrial appearance grade.

7. Curb railing shall be visually graded glulam, western species Combination No. 2, or Southern Pine Combination No. 48. Other species and grades of glulam may be used, provided the minimum tabulated values are not less than the following:
F_b = 1,800 lb/in^2 E = 1,800,000 lb/in^2

8. Scuppers may be sawn lumber or glulam. When sawn lumber is used, material shall be visually graded No. 1 Southern Pine or visually graded No. 1 Douglas Fir-Larch. Glulam and other species and grades of sawn lumber may be used, provided the minimum tabulated values are no less than the following:
F_b = 1,350 lb/in^2 E = 1,500,000 lb/in^2

9. Steel plates and shapes shall comply with the requirements of ASTM A36.

10. Bolts shall comply with ASTM A307 requirements, Grade 2, and should preferably be dome-head timber bolts. Bolts on traffic face of rail shall be dome head.

11. Split rings shall be manufactured from SAE 1010 hot-rolled carbon steel (SAE J412). Shear plates shall be malleable iron manufactured according to ASTM A47, Grade 32510.

12. All steel components and fasteners shall be galvanized in accordance with AASHTO M111 or M232 or shall otherwise be provided with adequate corrosion protection.

Fabrication and Construction

13. To the extent possible, all wood shall be cut, drilled, and completely fabricated prior to pressure treatment with preservatives. When field fabrication of wood is required or if wood is damaged, all cuts, bore holes, and damage shall be immediately treated with wood preservative in accordance with AASHTO M133.

14. Unless noted, malleable iron washers shall be provided under bolt heads and under nuts that are in contact with wood. When the size and strength of the head are sufficient to develop connection strength without wood crushing, washers may be omitted under heads of dome-head timber bolts.

15. Tops of rail posts shall be sealed with roofing cement or otherwise protected from direct exposure to weather.

The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

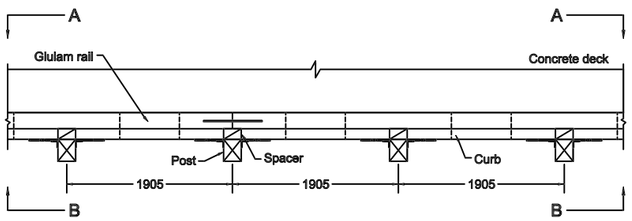
Curb Railing NCHRP 350 Test Level 1 (TL-1)	August 1998	Sheet 1 of 1

Rail Drawings in S.I. Units

University of Nebraska Lincoln

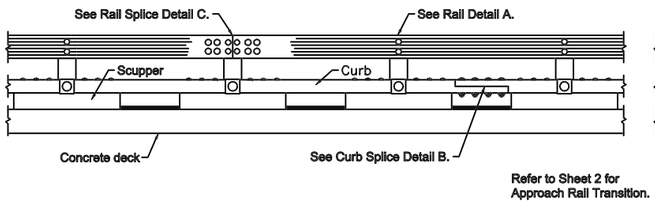
General Configuration

All units are in millimeters based on a soft conversion from customary U.S. units.



Plan

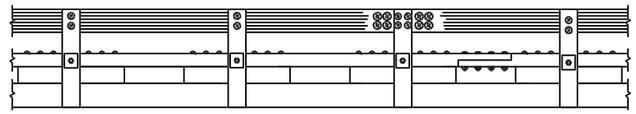
Section A-A



Refer to Sheet 2 for Approach Rail Transition.

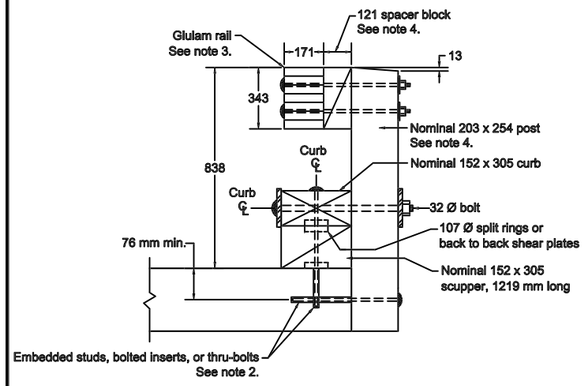
Front Elevation

Section B-B

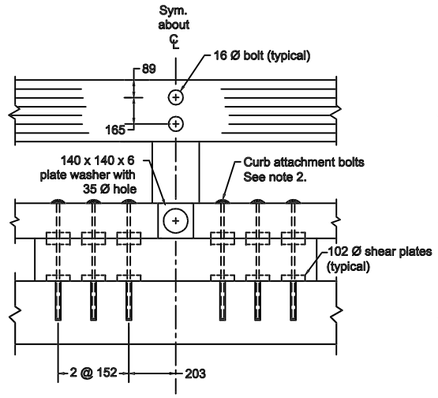


Back Elevation

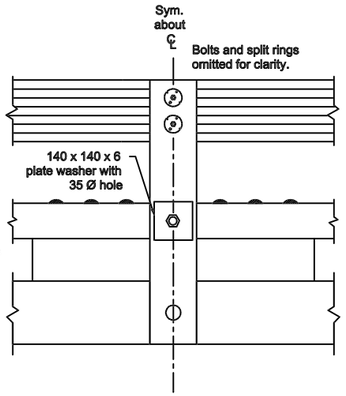
A Railing Details



End View

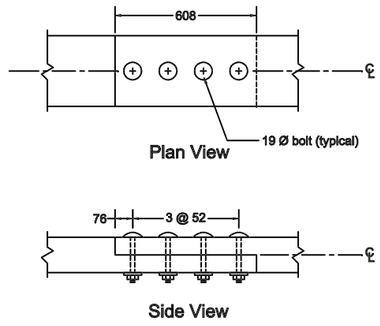


Front View



Back View

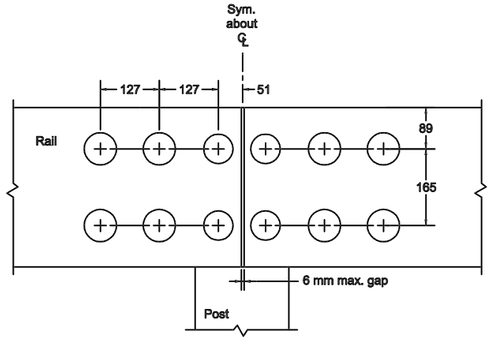
B Curb Splice Detail



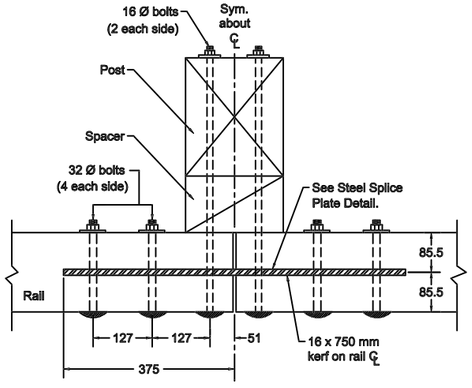
Plan View

Side View

C Rail Splice Details

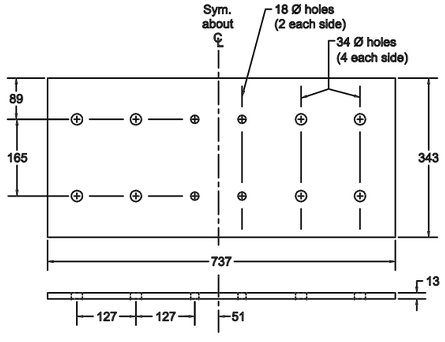


Front View



Plan View

Steel Splice Plate



Design

1. This bridge railing was sucessfully crash tested on a longitudinal wood deck to the requirements for Test Level 4 (TL-4), as outlined in NCHRP Report 350. Adaptation of this railing from a longitudinal wood deck to a concrete deck is based on test measurements and the ultimate capacity of deck attachment hardware.

2. Curb and post connections, such as attachment to the concrete deck, shall be with connections, such as embedded studs, bolted inserts, or through-bolts. The minimum ultimate shear capacity of each connection shall not be less than 71.2 kN. Internal reinforcement of the concrete shall be designed accordingly to resist these ultimate loads.

3. Dimensions given for glued-laminated (glulam) timber rails are actual dimensions. The depth of the glulam may be increased to a maximum of 349 mm to allow for other standard glulam sizes. In such cases, detail dimensions shall be verified and modified accordingly.

4. Dimensions for wood posts, curbs, and scuppers are given as nominal dimensions. Actual dimensions may be a maximum of 13 mm less than the stated nominal dimensions, depending on material surfacing. Dimensions for spacer block depth are actual dimensions.

5. Curb and rail splices shall be located so that curb and rail members are continuous over not less than two posts. Curb splices shall be located a minimum of 1.5 post spacings away from rail splices. It is recommended that glulam rails be continuous over the length of the bridge.

Materials

6. Sawn lumber and glulam shall comply with the requirements of AASHTO M168 and shall be pressure treated with wood preservative in accordance with AASHTO M133.

7. Bridge rail shall be horizontally laminated glulam, visually graded western species Combination No. 2, or visually graded Southern Pine Combination No. 48. Other species and grades of glulam may be used, provided the minimum tabulated values are not less than the following:
$F_{b,y}$ = 12.4 MPa E = 12,410 MPa

8. Posts, curbs, scuppers, and spacer blocks may be sawn lumber or glulam. When sawn lumber is used, material shall be visually graded No. 1 Southern Pine or visually graded No. 1 Douglas Fir-Larch. Glulam and other species and grades of sawn lumber may be used, provided the minimum tabulated values are not less than the following:
F_b = 9.3 MPa E = 10,342 MPa

9. Steel plates and shapes shall comply with the requirements of ASTM A36.

10. Bolts shall comply with ASTM A307 requirements, Grade 2, and should preferably be dome-head timber bolts. Bolts on the rail traffic face shall be dome head.

11. Split rings shall be manufactured from SAE 1010 hot-rolled carbon steel (SAE J412). Shear plates shall be malleable iron manufactured according to ASTM A47, Grade 32510.

12. All steel components and fasteners shall be galvanized in accordance with AASHTO M111 or M232 or shall otherwise be provided with adequate corrosion protection. Galvanizing of high-strength steel bars shall follow the recommendations of the bar manufacturer so as not to adversely affect the mechanical properties of the steel.

Fabrication and Construction

13. To the extent possible, all wood shall be cut, drilled, and completely fabricated prior to pressure treatment with preservatives. When field fabrication of wood is required or if wood is damaged, all cuts, bore holes, and damage shall be immediately field treated with wood preservative in accordance with AASHTO M133.

14. Unless noted, malleable iron washers shall be provided under bolt heads and under nuts that are in contact with wood. When the size and strength of the head are sufficient to develop connection strength without wood crushing, washers may be omitted under heads of dome-head timber bolts.

15. Tops of rail posts and top of the rail splice plate shall be sealed with roofing cement or otherwise protected from direct exposure to weather.

The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

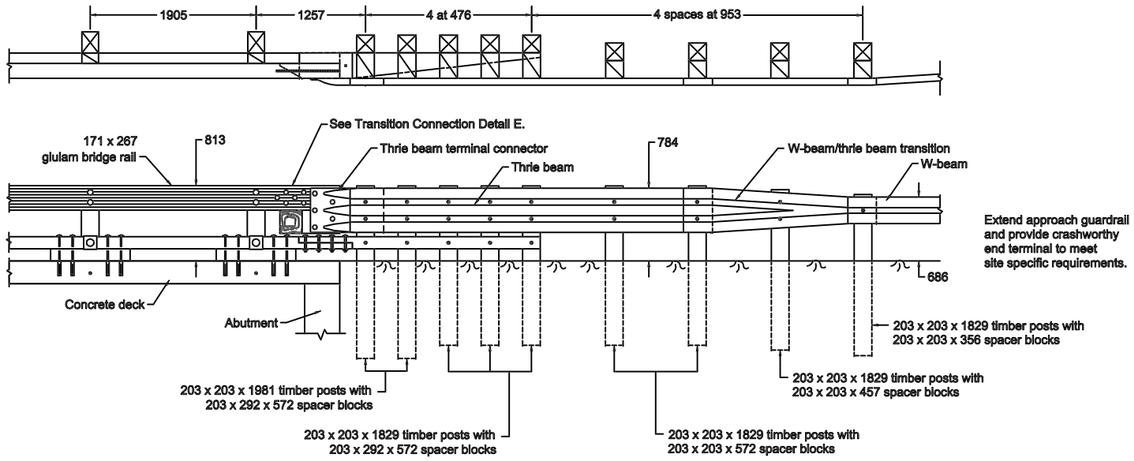
University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

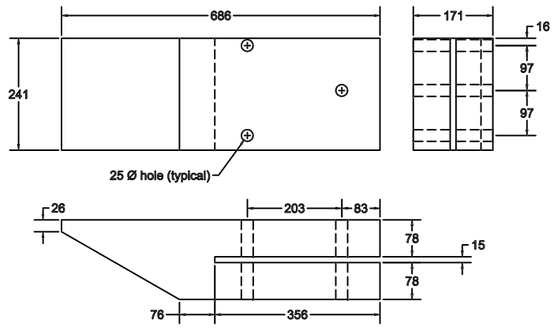
Glulam Timber Rail with Curb
NCHRP 350 Test Level 4 (TL-4)

August 1998

Approach Rail Transition General Configuration



D Transition Block



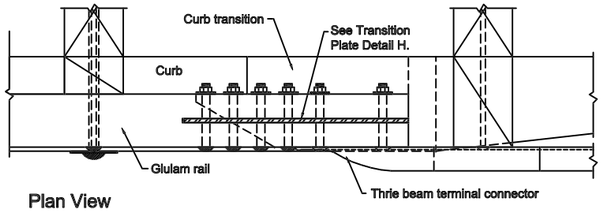
Depth of the transition block is based on a rail depth of 267 mm and surfaced curbs and scuppers (both 140 mm in height). If dimensions of any components increase, the depth of the transition block must be verified and reduced as necessary.

In addition to the notes on Sheet 1, the following apply to the approach rail transition:

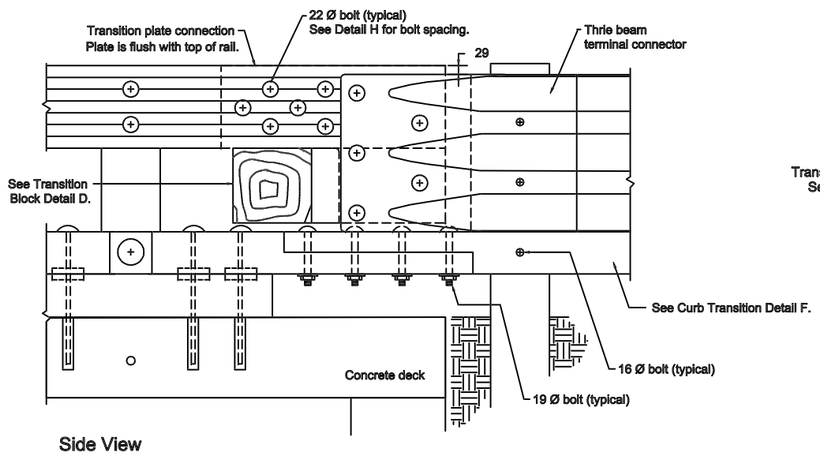
16. Thrie beam and thrie beam terminal connector shall be 10 gage. W-beam/thrie beam transition and W-beam shall be 12 gage. All shall comply with requirements of AASHTO M180.

17. W-beam and thrie beam rail splice bolts and post bolts shall comply with AASHTO M180.

E Transition Connection Details

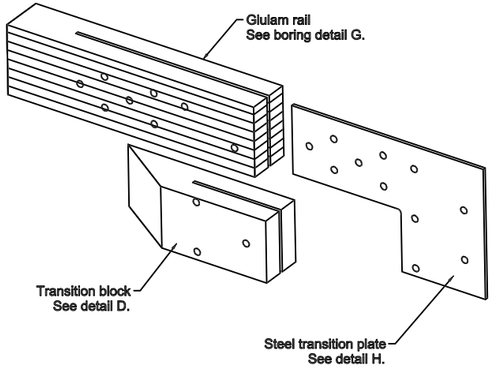


Plan View

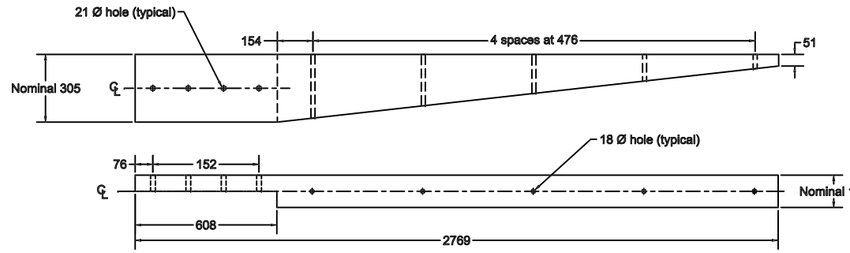


Side View

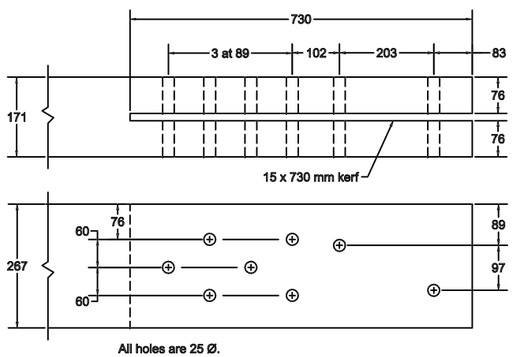
3 Dimensional View of Transition Connection



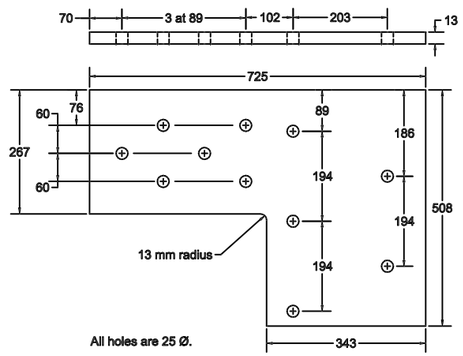
F Curb Transition



G Transition Glulam Rail Boring Detail



H Steel Transition Plate



The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

University of Nebraska Lincoln

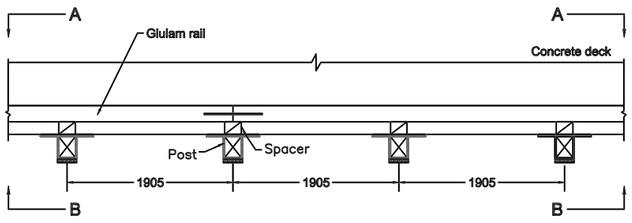
Crash-Tested Wood Bridge Railings for Concrete Decks

Glulam Timber Rail with Curb
NCHRP 350 Test Level 2 (TL-2)

August 1998

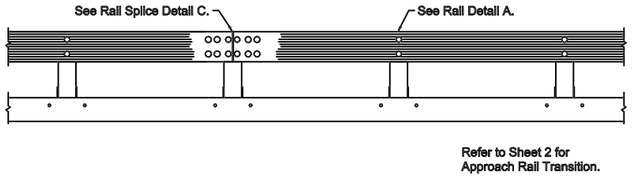
General Configuration

All units are in millimeters based on a soft conversion from customary U.S. units.



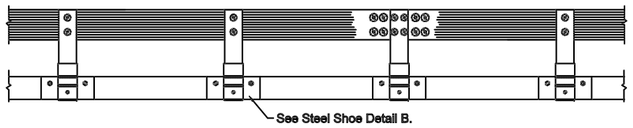
Plan View

Section A-A



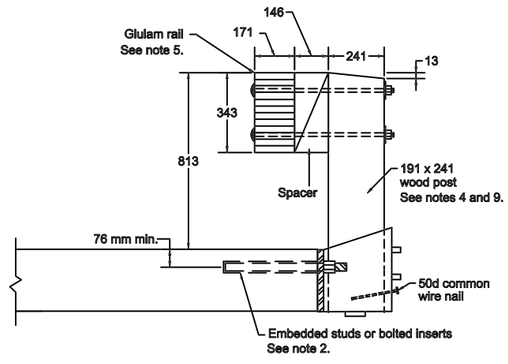
Front Elevation

Section B-B

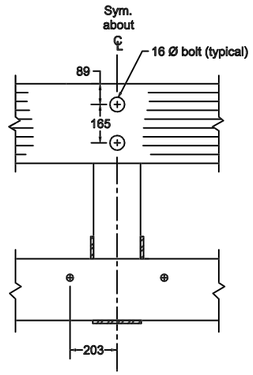


Back Elevation

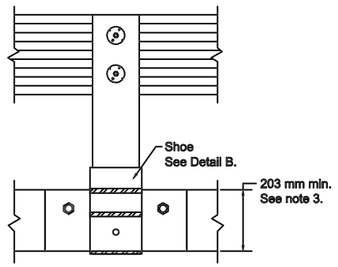
A Railing Details



End View

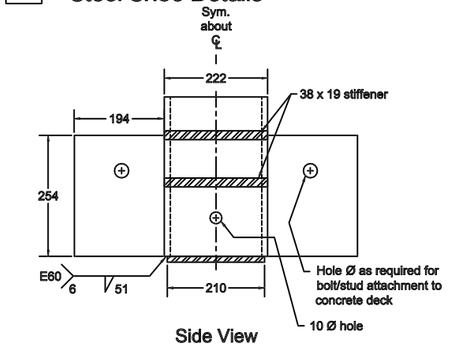


Front View

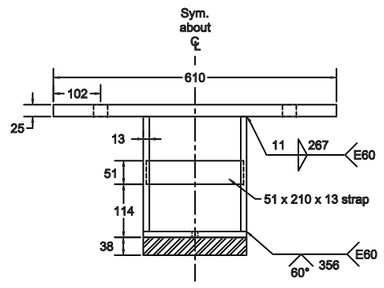


Back View

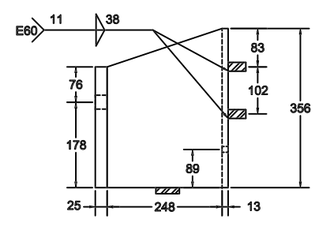
B Steel Shoe Details



Side View

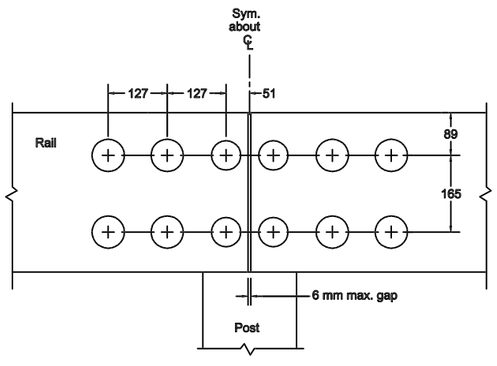


Plan View

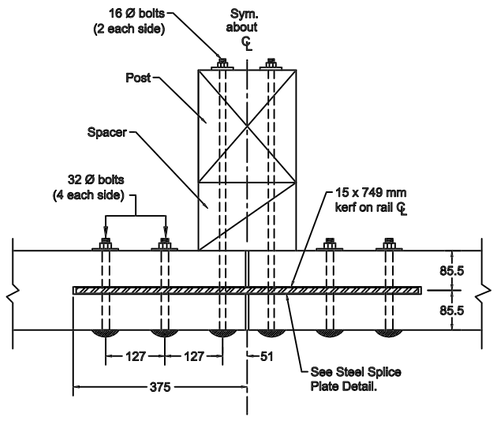


End View

C Rail Splice Details

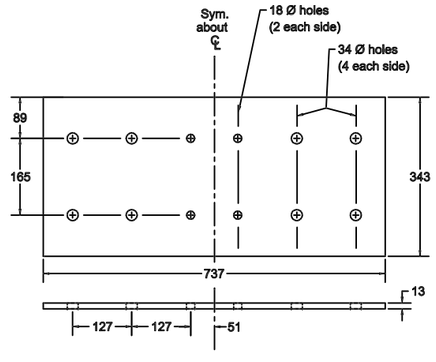


Side View



Plan View

Steel Splice Plate



Design

1. This bridge railing was successfully crash tested on a longitudinal wood deck to the requirements for Performance Level 1 (PL-1), as outlined in the AASHTO (1989) Guide Specifications for Bridge Railings. This railing has also been certified by the FHWA to meet requirements for Test Level 2 (TL-2) in accordance with NCHRP Report 350. Adaptation of this railing from a longitudinal wood deck to a concrete deck is based on test measurements and the ultimate capacity of deck attachment hardware.

2. Steel shoe for each post shall be attached to the concrete deck with two connections, such as bolted inserts or embedded studs. Each connection shall provide a minimum ultimate capacity of 222.4 kN in tension. Internal reinforcement of the concrete deck shall be designed accordingly to resist these ultimate loads.

3. Concrete deck edge thickness shall be a minimum of 203 mm to provide bearing for the steel shoe plate.

4. Dimensions for the wood rail, post, and spacer are actual dimensions. Post dimensions correspond to the standard dressed dimensions for a nominal 203- by 254-mm member that is surfaced on four sides (S4S 1989).

5. Depth of the glued-laminated (glulam) timber rail may be increased to a maximum of 349 mm to allow for standard glulam timber sizes. In such cases, detail dimensions shall be verified and modified accordingly.

6. Rail splices shall be located so that rail members are continuous over not less than four posts. It is recommended that the rail be continuous over the length of the bridge.

Materials

7. Sawn lumber and glulam shall comply with the requirements of AASHTO M168 and shall be pressure treated with wood preservative in accordance with AASHTO M133.

8. Bridge rail shall be horizontally laminated glulam, visually graded western species Combination No. 2, or visually graded Southern Pine Combination No. 48. Other species and grades of glulam may be used, provided the minimum tabulated values are not less than the following:
F_{bv} = 12.4 MPa E = 12,410 MPa

9. Posts and spacer blocks may be sawn lumber or glulam. When sawn lumber is used, material shall be visually graded No. 1 Southern Pine or visually graded No. 1 Douglas Fir-Larch. Glulam and other species and grades of sawn lumber may be used, provided the minimum tabulated values are not less than the following:
F_b = 9.3 MPa E = 10,342 MPa

10. Steel plates and shapes shall comply with the requirements of ASTM A36.

11. Bolts shall comply with ASTM A307 requirements, Grade 2, and should preferably be dome-head timber bolts. Bolts on the rail traffic face shall be dome head.

12. All steel components and fasteners shall be galvanized in accordance with AASHTO M111 or M232 or shall otherwise be provided with adequate corrosion protection.

Fabrication and Construction

13. Welding shall be completed in accordance with the requirements of ANSI/AASHTO/AWS D1.5 Bridge Welding Code.

14. To the extent possible, all wood shall be cut, drilled, and completely fabricated prior to pressure treatment with preservatives. When field fabrication of wood is required or if wood is damaged, all cuts, bore holes, and damage shall be immediately field treated with wood preservative in accordance with AASHTO M133.

15. Unless noted, malleable iron washers shall be provided under bolt heads and under nuts that are in contact with wood. When the size and strength of the head are sufficient to develop connection strength without wood crushing, washers may be omitted under heads of dome-head timber bolts.

16. Tops of rail posts and top of the rail splice plate kerf shall be sealed with roofing cement or otherwise protected from direct exposure to weather.

The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

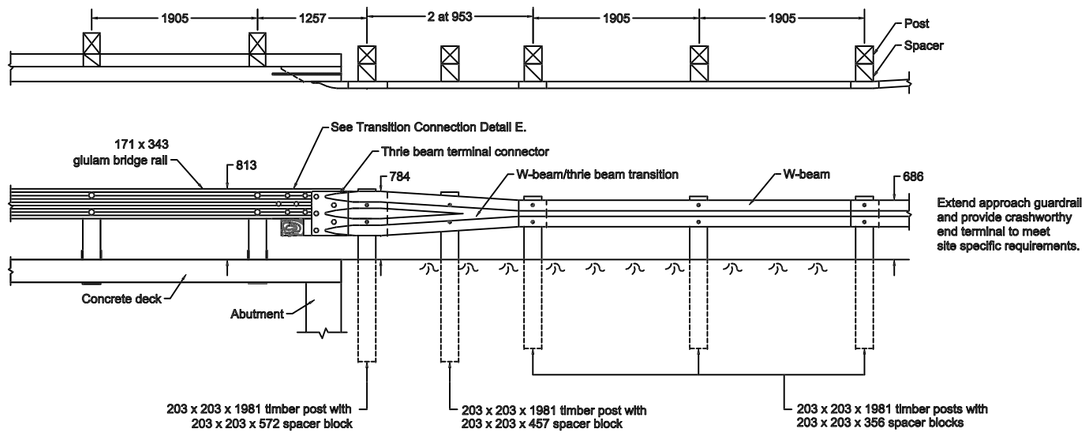
University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

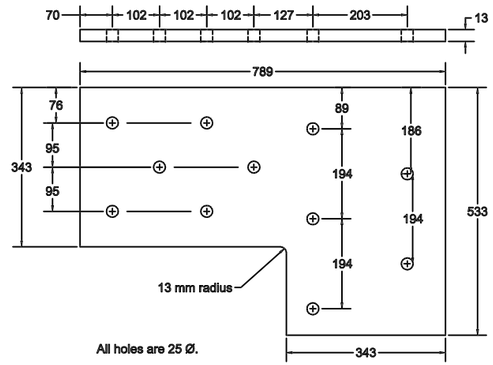
Glulam Timber Rail without Curb
NCHRP 350 Test Level 2 (TL-2)

August 1998

Approach Rail Transition General Configuration



D Steel Transition Plate

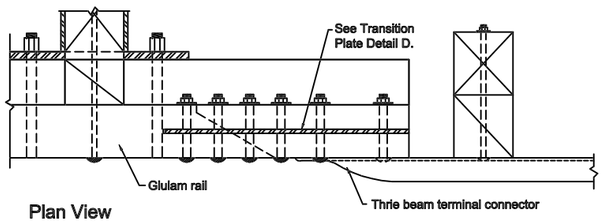


In addition to the notes on Sheet 1, the following apply to the approach rail transition:

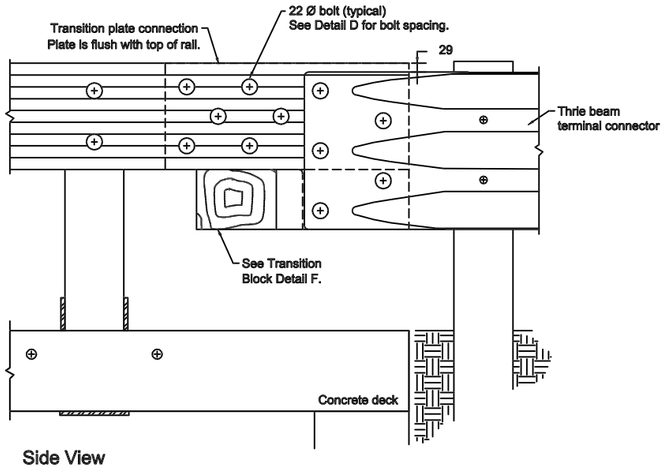
17. Thrie beam terminal connector shall be 10 gage. W-beam/thrie beam transition and w-beam shall be 12 gage. All shall comply with the requirements AASHTO M180.

18. W-beam and thrie beam rail splice bolts and post bolts shall comply with AASHTO M180.

E Transition Connection Details

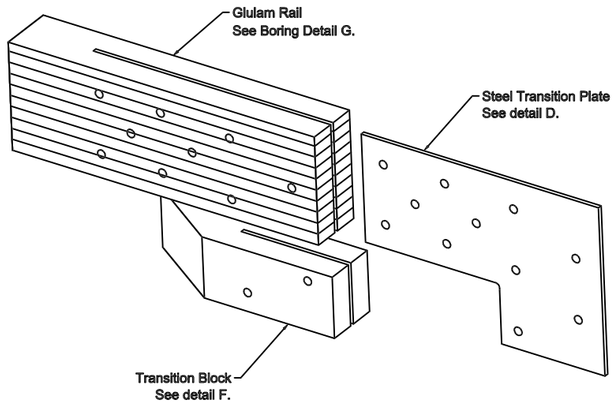


Plan View

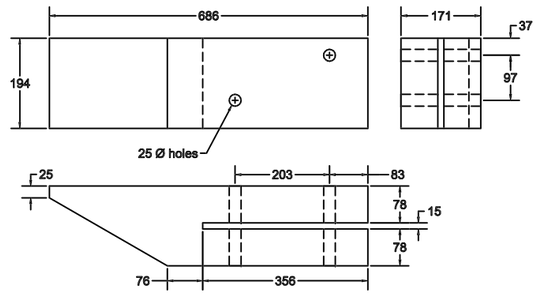


Side View

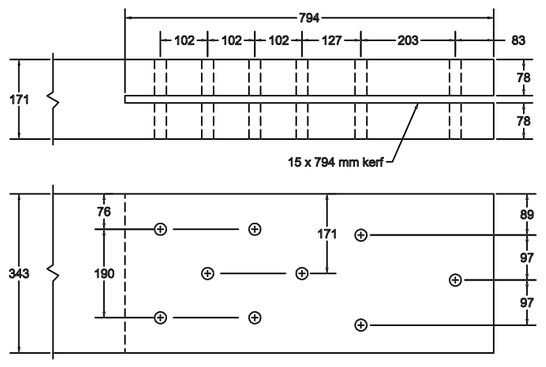
3 Dimensional View of Transition Connection



F Transition Block



G Transition Glulam Rail Boring Detail



The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

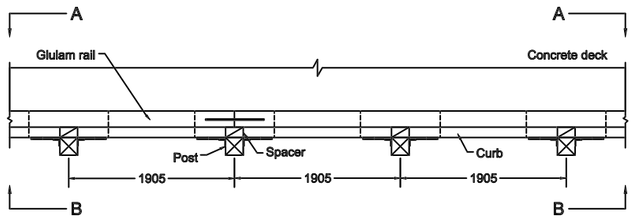
University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

Glulam Timber Rail without Curb NCHRP 350 Test Level 2 (TL-2)	August 1998	Sheet 2 of 2

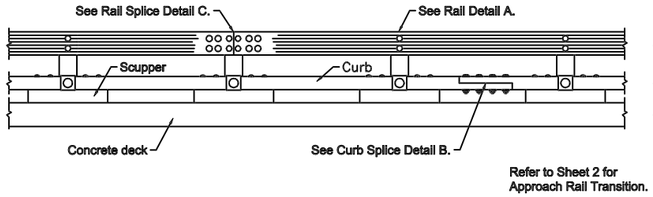
General Configuration

All units are in millimeters based on a soft conversion from customary U.S. units.



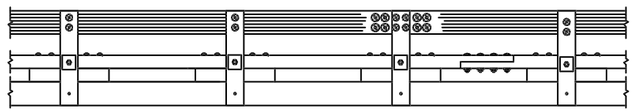
Plan

Section A-A



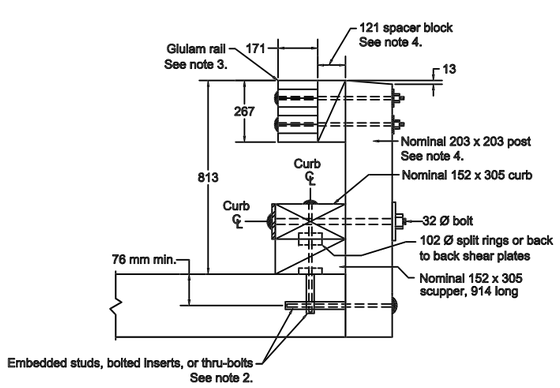
Front Elevation

Section B-B

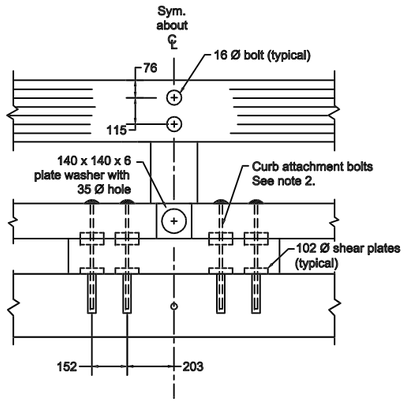


Back Elevation

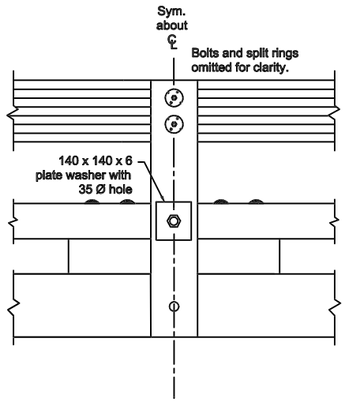
A Railing Details



End View

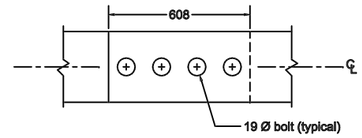


Front View

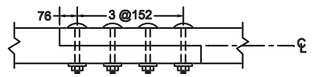


Back View

B Curb Splice Detail

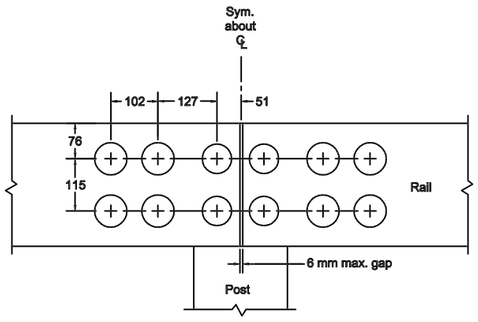


Plan View

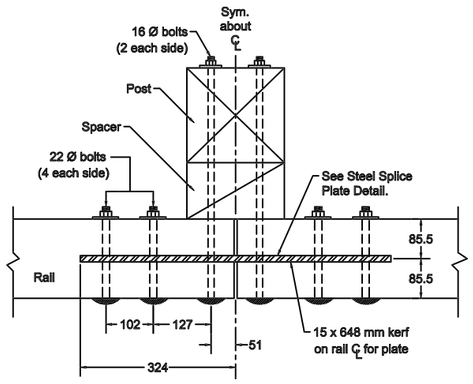


Side View

C Rail Splice Details

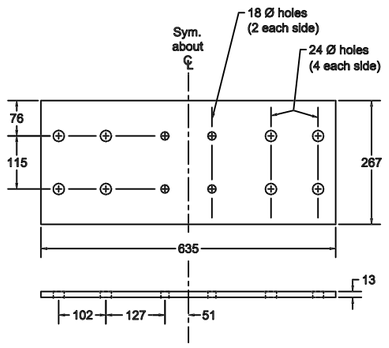


Front View



Plan View

Steel Splice Plate



Design

1. This bridge railing was successfully crash tested on a longitudinal wood deck to the requirements for Performance Level 1 (PL-1), as outlined in the AASHTO (1989) Guide Specifications for Bridge Railings. This railing has also been certified by the FHWA to meet requirements for Test Level 2 (TL-2) in accordance with NCHRP Report 350. Adaptation of this railing from a longitudinal wood deck to a concrete deck is based on test measurements and the ultimate capacity of deck attachment hardware.

2. Curb and post connections, such as attachment to the concrete deck, shall be with connections, such as embedded studs, bolted inserts, or through-bolts. The minimum ultimate shear capacity of each connection shall not be less than 71.2 kN. Internal reinforcement of the concrete shall be designed accordingly to resist these ultimate loads.

3. Dimensions given for glued-laminated (glulam) timber rails are actual dimensions. The depth of the glulam timber rail may be increased to a maximum of 273 mm to allow for other standard glulam sizes. In such cases, detail dimensions shall be modified accordingly.

4. Dimensions for wood posts, curbs, and scuppers are given as nominal dimensions. Actual dimensions may be a maximum of 13 mm less than the stated nominal dimensions. Dimension for spacer block depth are actual dimensions.

5. Curb and rail splices shall be located so that curb and rail members are continuous over not less than two posts. Curb splices shall be located a minimum of 1.5 post spacings away from rail splices. It is recommended that glulam rails be continuous over the length of the bridge.

Materials

6. Sawn lumber and glulam shall comply with the requirements of AASHTO M168 and shall be pressure treated with wood preservative in accordance with AASHTO M133.

7. Bridge rail shall be horizontally laminated glulam, visually graded western species Combination No. 2, or visually graded Southern Pine Combination No. 48. Other species and grades of glulam may be used, provided the minimum tabulated values are not less than the following:
F_{by} = 12.4 MPa E = 12,410 MPa

8. Posts, curbs, scuppers, and spacer blocks may be sawn lumber or glulam. When sawn lumber is used, material shall be visually graded No. 1 Southern Pine or visually graded No. 1 Douglas Fir-Larch. Glulam and other species and grades of sawn lumber may be used, provided the minimum tabulated values are no less than the following:
F_b = 9.5 MPa E = 10,342 MPa

9. Steel plates and shapes shall comply with the requirements of ASTM A36.

10. Bolts shall comply with ASTM A307 requirements, Grade 2, and should preferably be dome-head timber bolts. Bolts on the rail traffic face shall be dome head.

11. Split rings shall be manufactured from SAE 1010 hot-rolled carbon steel (SAE J412). Shear plates shall be malleable iron manufactured according to ASTM A47, Grade 32510.

12. All steel components and fasteners shall be galvanized in accordance with AASHTO M111 or M232 or shall otherwise be provided with adequate corrosion protection.

Fabrication and Construction

13. To the extent possible, all wood shall be cut, drilled, and completely fabricated prior to pressure treatment with preservatives. When field fabrication of wood is required or if wood is damaged, all cuts, bore holes, and damage shall be immediately treated with wood preservative in accordance with AASHTO M133.

14. Unless noted, malleable iron washers shall be provided under bolt heads and under nuts that are in contact with wood. When the size and strength of the head are sufficient to develop connection strength without wood crushing, washers may be omitted under heads of dome-head timber bolts.

15. Tops of rail posts and top of the rail splice plate kerf shall be sealed with roofing cement or otherwise protected from direct exposure to weather.

The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

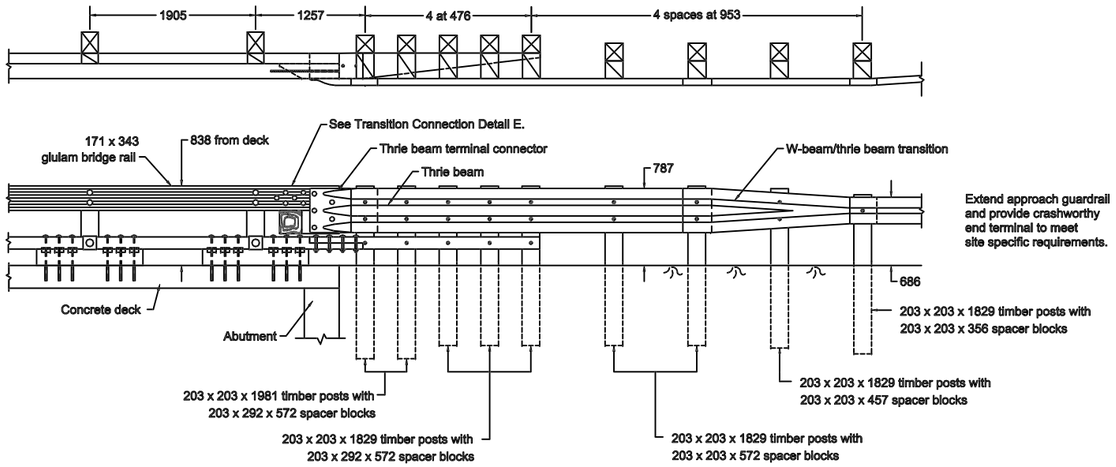
University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

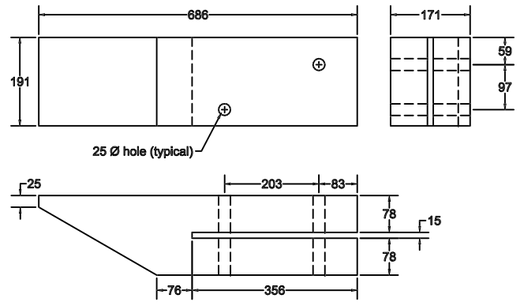
Glulam Timber Rail with Curb
NCHRP 350 Test Level 2 (TL-2)

August 1998

Approach Rail Transition General Configuration



D Curb Transition Block



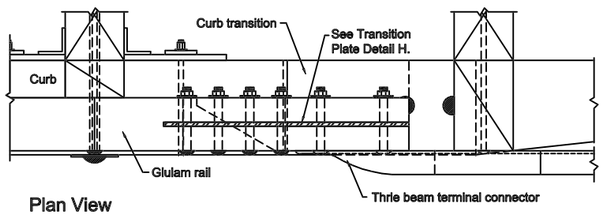
Depth of the transition block is based on a rail depth of 267 mm and surfaced curbs and scuppers (140 and 191 mm in height, respectively). If dimensions of any components increase, the depth of the transition block must be verified and reduced as necessary.

In addition to the notes on Sheet 1, the following apply to the approach rail transition:

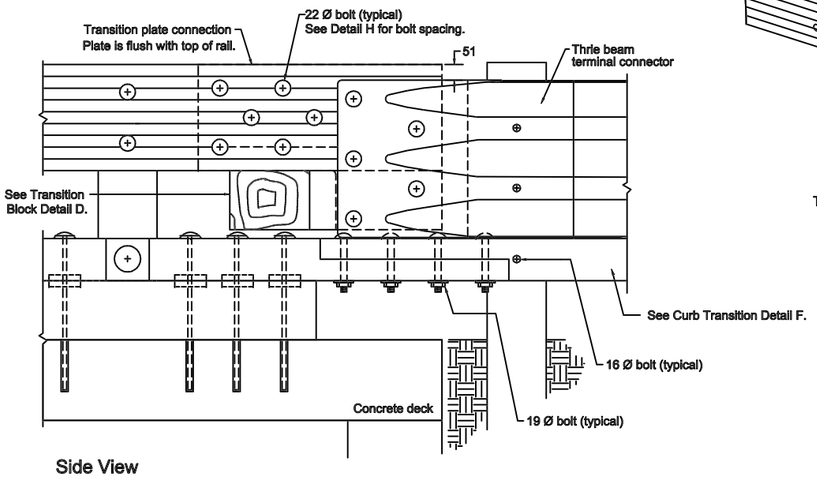
16. Thrie beam and thrie beam terminal connector shall be 10 gage. W-beam/thrie beam transition and W-beam shall be 12 gage. All shall comply with requirements AASHTO M180.

17. W-beam and thrie beam rail splice bolts and post bolts shall comply with AASHTO M180.

E Transition Connection Details

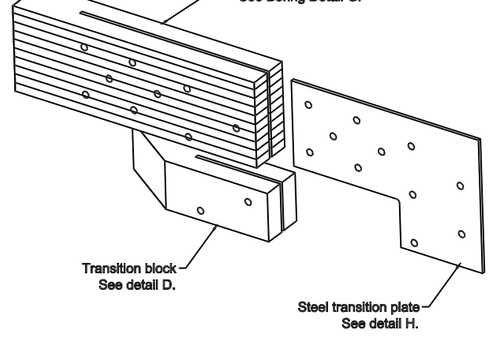


Plan View

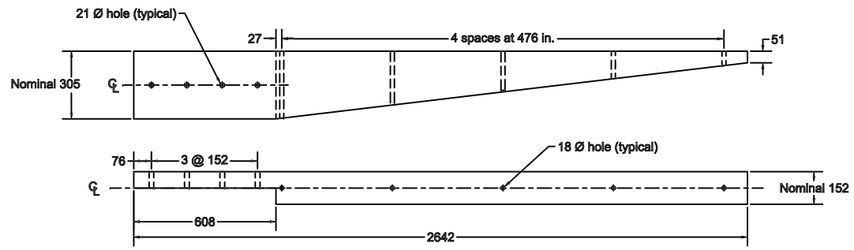


Side View

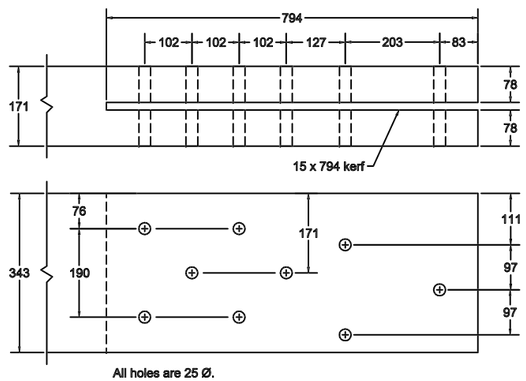
3 Dimensional View of Transition Connection



F Curb Transition

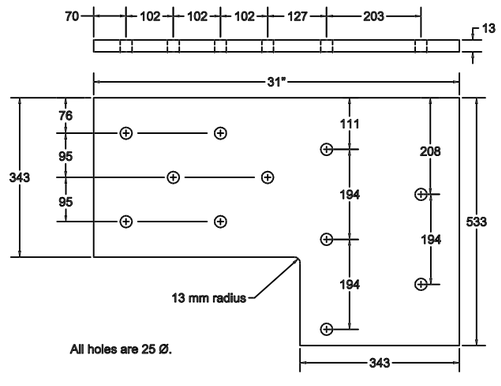


G Transition Glulam Rail Boring Detail



All holes are 25 Ø.

H Transition Plate



All holes are 25 Ø.

343

The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

University of Nebraska Lincoln

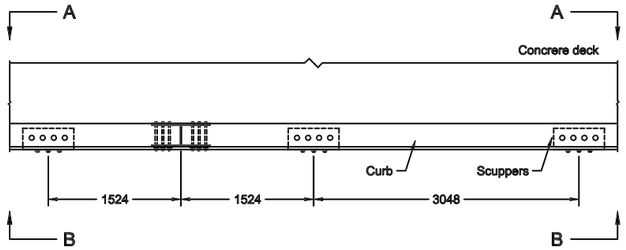
Crash-Tested Wood Bridge Railings for Concrete Decks

Glulam Timber Rail with Curb
NCHRP 350 Test Level 4 (TL-4)

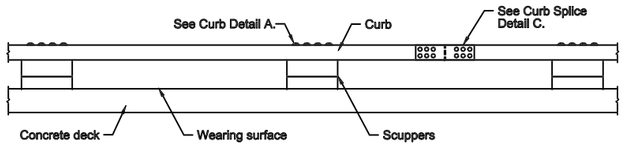
August 1998

General Configuration

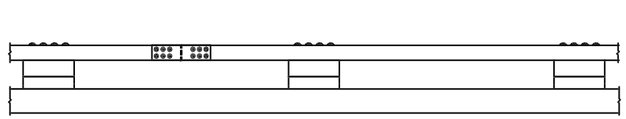
All units are in millimeters based on a soft conversion from customary U.S. units.



Plan View

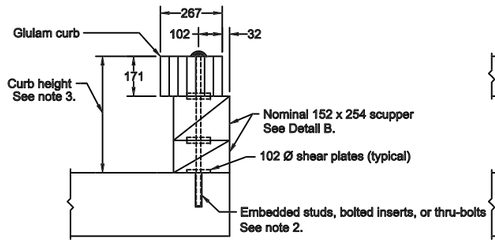


Front Elevation

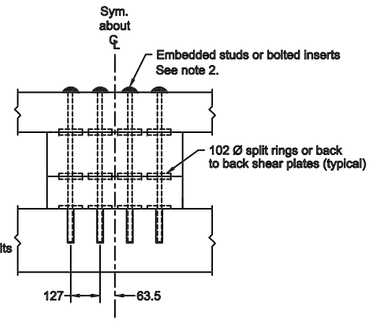


Back Elevation

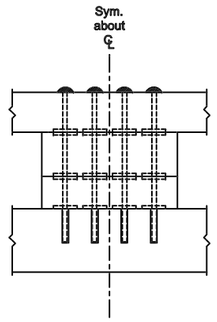
A Curb Details



End View

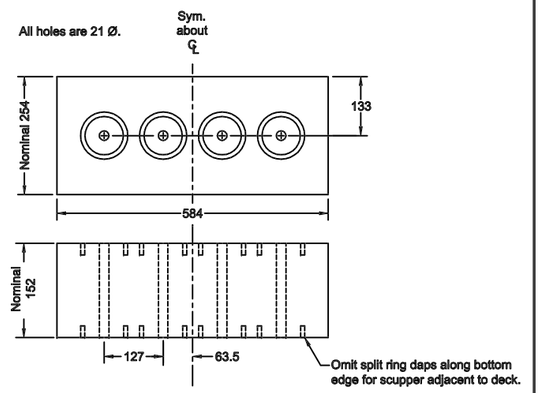


Front View

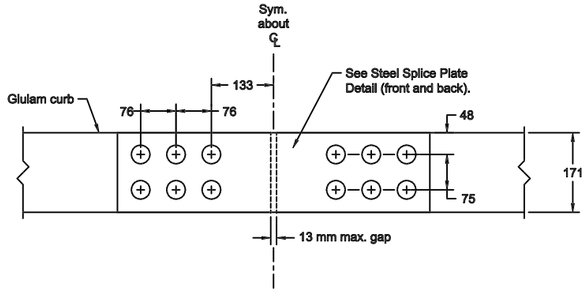


Back View

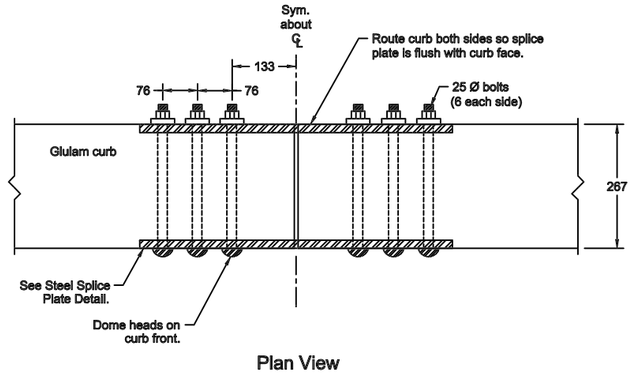
B Scupper Detail



C Curb Splice Details

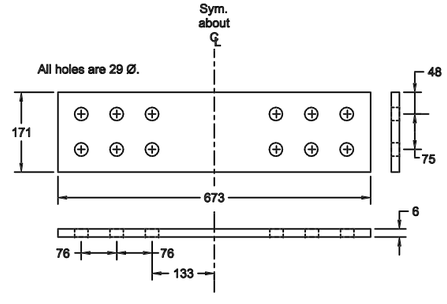


Front View



Plan View

Steel Splice Plate



Design

1. This curb railing was successfully crash tested on a longitudinal wood deck to the requirements for Test Level 1 (TL-1), as outlined in NCHRP Report 350. Adaptation of this railing from a longitudinal wood deck to a concrete deck is based on test measurements and the ultimate capacity of deck attachment hardware.

2. Curb and post connections, such as attachment to the concrete deck, shall be with connections, such as embedded studs, bolted inserts, or thru-bolts. The minimum ultimate shear capacity of each connection shall not be less than 71.2 kN. Internal reinforcement of the concrete shall be designed accordingly to resist these ultimate loads.

3. Actual height of the curb railing rail shall be 451 to 476 mm above the traveled way.

4. Dimensions for glued-laminated (glulam) timber components are actual dimensions. Dimensions for sawn lumber components are nominal dimensions. Actual sawn lumber dimensions may be up to a maximum of 13 mm less than nominal dimensions to permit the use of surfaced or rough-sawn material.

5. Curb railing splices are midway between scuppers and shall be located so that curb is continuous over not less than two scuppers. It is recommended that the glulam curbs be continuous over the length of the bridge.

Materials

6. Sawn lumber and glulam shall comply with the requirements of AASHTO M168 and shall be pressure treated with wood preservative in accordance with AASHTO M133. Glulam shall be manufactured using wet use adhesives to an industrial appearance grade.

7. Curb railing shall be visually graded glulam, western species Combination No. 2, or Southern Pine Combination No. 48. Other species and grades of glulam may be used, provided the minimum tabulated values are not less than the following:
F_b = 12.4 MPa E = 12,140 MPa

8. Scuppers may be sawn lumber or glulam. When sawn lumber is used, material shall be visually graded No. 1 Southern Pine or visually graded No. 1 Douglas Fir-Larch. Glulam and other species and grades of sawn lumber may be used, provided the minimum tabulated values are no less than the following:
F_b = 9.3 MPa E = 10,342 MPa

9. Steel plates and shapes shall comply with the requirements of ASTM A36.

10. Bolts shall comply with ASTM A307 requirements, Grade 2, and should preferably be dome-head timber bolts. Bolts on traffic face of rail shall be dome head.

11. Split rings shall be manufactured from SAE 1010 hot-rolled carbon steel (SAE J412). Shear plates shall be malleable iron manufactured according to ASTM A47, Grade 32510.

12. All steel components and fasteners shall be galvanized in accordance with AASHTO M111 or M232 or shall otherwise be provided with adequate corrosion protection.

Fabrication and Construction

13. To the extent possible, all wood shall be cut, drilled, and completely fabricated prior to pressure treatment with preservatives. When field fabrication of wood is required or if wood is damaged, all cuts, bore holes, and damage shall be immediately treated with wood preservative in accordance with AASHTO M133.

14. Unless noted, malleable iron washers shall be provided under bolt heads and under nuts that are in contact with wood. When the size and strength of the head are sufficient to develop connection strength without wood crushing, washers may be omitted under heads of dome-head timber bolts.

15. Tops of rail posts shall be sealed with roofing cement or otherwise protected from direct exposure to weather.

The bridge railings depicted on these drawings were developed and crash tested under a cooperative research agreement between the Midwest Roadside Safety Facility of the University of Nebraska-Lincoln, the USDA Forest Service, Forest Products Laboratory, and the U.S. DOT Federal Highway Administration.

University of Nebraska Lincoln

Crash-Tested Wood Bridge Railings for Concrete Decks

Curb Railing NCHRP 350 Test Level 1 (TL-1)	August 1998	Sheet 1 of 1