2024

In-Kind Timber Bridge Replacement Program

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

IN-KIND TIMBER BRIDGE PROGRAM DESIGN GUIDELINES

CONTENTS

CHAPTER 1

GENERAL

1.1 PURPOSE

The In-Kind Timber Bridge Design Guidelines establishes the controlling design elements for new and reconstructed timber bridges on the North Carolina Highway System designated as secondary no-outlet roads. Engineering judgement must be applied during project development, while incorporating the site-specific conditions, to achieve the level of service and safety of the traveling public. Each bridge shall provide a safe and economical design, while either maintaining or improving the operating conditions at the site.

Bridge projects designated as "In-Kind Timber Bridge Replacements" designed to the standards set forth in these guidelines require no formal design exception approval.

Approval of a formal design exception is required for bridge projects that are not designed to the standards set forth in these guidelines. Project files shall justify and document the need for a design exception from the standards. Any design exceptions required for a project shall be listed in the environmental document.

1.2 BACKGROUND

The North Carolina bridge inventory is aging at a rate which exceeds the bridge replacement rate. Timber bridges on no-outlet roads in Divisions 11, 13 and 14 make up almost a quarter of the bridges listed in poor condition in those Divisions. These structures are located on local no-outlet roads, that are often gravel State Road Maintenance Right-of-Way (back of ditch to back of ditch) roadways, providing property access to a dozen homeowners or less. These guidelines establish minimum values for bridge replacement design criteria that maintains current operating conditions and allows engineering judgement to be applied to achieve desirable levels of traffic service and safety appropriate to the social, economic, and environmental controls applicable to the specific project. These guidelines allow planners and designers to minimize changes in the vertical grade, structure length and width, approach roadway limits and right of way for each bridge site.

1.3 PROCEDURE

The Environmental Analysis Branch will prepare a Minimum Criteria Design Checklist (MCDC) planning document that includes appropriate considerations for safety, social, economic and environmental impacts. On-site field reviews and scoping meetings must be held during the planning and design process. At a minimum, representatives from

Structures, Work Zone Traffic Control, EAU, Technical Services (as appropriate for the project site) and the Division should attend these meetings.

1.4 PLANNING

Through the use of ETRACS, the Environmental Analysis Unit will coordinate with the Division Bridge Program Manager and Traffic Engineering Staff to provide, in the environmental document, decisions reached regarding applicable design criteria such as bridge approach travel speed, design speed, bridge width, lane and shoulder widths. These decisions will be based off the current site conditions and past safety data. Consideration shall be given to the use of accelerated construction techniques. Surveys such as bat surveys have limitations for being completed from May through August, which requires consideration for project letting dates when developing project schedules.

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CHAPTER 2

ROADWAY DESIGN CRITERIA

The following roadway geometric design criteria will be used for the In-Kind Timber Bridge replacements. In-Kind Timber Bridge replacements should involve minimal roadway impacts and should be based on the current roadway geometric conditions and past evidence of crash history. For additional guidance on establishing roadway geometric design criteria, refer to Chapter 4 of the *AASHTO Guidelines for Geometric Designs of Low Volume Roads (2019).*

2.1 DESIGN SPEED

The proposed design speed should meet the design guidance for the posted speed plus 5mph. The Division, Roadway Design and Traffic Safety representatives will determine the appropriate design speed for roads not posted. The proposed speed should be informed by a speed study evaluation report. The design speed selected for the project shall be identified and recorded in the environmental document. Once the design speed is identified, all pertinent highway features should be based on this speed to obtain a balanced design.

2.2 LANE AND SHOULDER WIDTHS

Lane and shoulder widths on approach roadways are to remain as close as possible to the current conditions to minimize impact. If additional width is required for stage construction, do not use lane or shoulder widths on the bridge narrower than those of the approach roadway typical section.

2.3 BRIDGE WIDTHS

Final bridge widths should remain the same as the current bridge width unless site conditions require minor improvements such as sight distance or turning radii for the proposed design speed.

2.4 HORIZONTAL ALIGNMENT

The existing horizontal curve should be retained as much as possible. If the existing curvature is not able to be retained, apply engineering judgement to achieve desirable levels of traffic service and safety, considering site-specific conditions.

2.5 VERTICAL ALIGNMENT

The existing vertical curve may be retained unless there is evidence of a site-specific crash pattern attributable to inadequate sight distance. If a site-specific crash pattern is identified, apply engineering judgement to achieve desirable levels of traffic service and safety, considering site-specific conditions.

2.6 STOPPING SIGHT DISTANCE

The existing stopping sight distance may be retained unless there is evidence of a site-specific crash pattern attributable to inadequate sight distance. If a site-specific crash pattern is identified, apply engineering judgement to achieve desirable levels of traffic service and safety, considering site-specific conditions.

2.7 CROSS SLOPE

The existing pavement cross slope should be adequate to provide proper drainage. If not, normal cross slopes should be 2 percent for asphalt pavements.

2.8 SUPERELEVATION

The superelevation of the bridge should match the existing approach roadways, unless the existing roadway is gravel, in which case the bridge can be normal crown or reverse crown, and grading may be required on the approaches for an adequate tie. It is desirable to provide superelevation for curves on paved roadways. If minimum superelevation rates cannot be provided, coordinate with the Division Traffic engineer and the Signing and Delineation Engineer to determine whether to identify the permissible speed with speed limit signs.

2.9 GRADES

The existing roadway grade may be retained. An appropriate minimum grade is typically 0.5%. For any grades that are flatter than 0.5%, coordinate with the hydraulic engineer to confirm the grade is acceptable.

2.10 GUARDRAIL

For In-Kind Timber Bridge replacements, match existing conditions as much as possible. Roadside clear zones and traffic barriers are not generally cost effective and need not generally be provided, except in situations where a site-specific crash pattern is present or the engineering judgement of the designer identifies a need for the provision of a roadside clear zone or a guardrail.

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CHAPTER 3
HYDRAULIC DESIGN

The following hydraulic design criteria will be used for the In-Kind Timber Bridge replacements. In-Kind Timber Bridge replacements should involve minimal hydraulic impacts and shall be based on the current hydraulic conditions.

3.1 FEMA

Identify project site locations that are with-in Special Flood Hazard Areas (SFHA), as shown on the Flood Risk Information System (FRIS) website (http://fris.nc.gov/fris/). Design for compliance by ensuring the in-kind replacement bridge has the same dimensions (including but not limited to bridge width and length, low chord elevation, bents, etc.) and location of the existing bridge. To ensure compliance Submit the following to the Hydraulic Unit's Highway Floodplain Program:

- FEMA Coordination Form (submit as Excel form)
- Effective Model
- Duplicate Effective/Corrected Effective/(Existing Conditions if needed)/Revised Model package
- Bridge Survey Report
- CADD file (name file: "yyyymmdd_TIP_SFC.dgn") Include: existing and proposed roadway alignment, existing and proposed bridge, slope stakes, TOPO (w/any buildings, etc.), contours, stream alignment, and HEC RAS cross-section locations (with sections labeled).
- Hydraulic Model Narrative that describes model changes as progression takes place from the Duplicate Effective Model to the Corrective Effective Model (to the Existing Conditions Model if needed) to the Revised Model.
- Project .tin file
- Output Comparison Table (Excel format)

If in-kind replacement design deviates from existing dimensions or existing location or if there is an increase in the Base Flood Elevation then the project must obtain State Floodplain Compliance (SFC) or CLOMR approval if any portion of a project is in a FEMA Special Flood Hazard Zone. Follow the currently applicable technical guidance posted on the Hydraulics Unit website, Coordination and Compliance Plan for Department of Transportation and Emergency Management (CCP).

3.2 NON-FEMA

Consult with Division Office to establish Level of Service needs if the existing roadway is overtopped by the 25-year frequency storm or an event with lower return period.

The minimum return period for design shall maintain the existing level of service.

The maximum return period of design is the 25-year frequency storm.

Where design frequency is less than the 25-year storm, the engineer will assess the property upstream and downstream of the highway right of way for impacts to private property.

Submit the following to the Hydraulics Unit:

- Existing and Proposed HEC-RAS Model package
- Bridge Survey Report
- CADD file (name file: "yyyymmdd_TIP_SFC.dgn") Include: existing and proposed roadway alignment, existing and proposed bridge, slope stakes, TOPO (w/any buildings, etc.), contours, stream alignment, and HEC RAS cross-section locations (with sections labeled).
- Hydraulic Model Narrative that describes model changes as progression takes place from the Existing Model to the Proposed Model.
- Project .tin file

3.3 HYDRAULICS

The recommended structure at a minimum shall match the existing structure hydraulic opening to maintain existing level of service.

3.4 DECK DRAINAGE

Deck drainage shall be provided through the use of slots under the guiderail of the structure barrier rail.

3.5 GUTTER SPREAD

Avoid spread into the travel lane for a 4 inches/hour rainfall intensity. Investigate steeper gutter slope, increase deck cross slope, eliminate super elevation, coordinate rail and deck drain details with Structures Management Unit, etc. to reduce gutter spread when necessary.

3.6 BRIDGE SCOUR

The Hydraulics Engineer shall analyze scour for the 100-year or overtopping flood. Cone of influence for total scour to be shown as 1.4H: 1V on the bridge profile drawing.

3.7 DEBRIS ASSESSMENT

Identify debris transport potential at the site. Where debris transport potential is low, the use of battered piles may be appropriate and should be noted under “Additional Information” on the Bridge Survey Report.

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CHAPTER 4

GEOTECHNICAL

The following geotechnical design criteria will be used for the In-Kind Timber Bridge replacements. In-Kind Timber Bridge replacements should involve replacing timber bulkheads on concrete or timber sills with concrete abutments on spread footings. The geotechnical guidelines below are intended for use by in-house forces or their designated contractors and is not applicable to projects outside this scope of this program.

4.1 AASHTO LRFD SPECIFICATIONS

Design foundations according to the latest version of the ASSHTO Use higher resistance factors when substructure conditions are appropriate. Use Importance Factor, $\eta = 0.95$, for load factor.

4.2 SCOUR

For this program, the design scour will be based on the Q_{100} event as determined by the Hydraulics Engineer.

4.3 END BENTS

Spread footings for end bents should be designed to support the vertical and lateral loads applied to the structure. The foundation elevation will vary based on site and subsurface conditions. Design abutments to resist future scour. Where possible, extend the bottom of footing elevation to the weathered rock or rock horizon and key in the footing a minimum of 6”. Where the rock line is too deep, locate the top of footing at the historical scour elevation, as determined in the field investigation, or a minimum of 2 feet below the existing stream bed. The Scour Critical elevation will be equal to the bottom of footing elevation.

4.4 INTERIOR BENTS

Spread footings for interior bents should be designed to support the vertical and lateral loads applied to the structure. The foundation elevation will vary based on site and subsurface conditions. Design bents to resist future scour. Where possible, extend the bottom of footing elevation to the weathered rock or rock horizon and key in the footing a minimum of 6”. Where the rock line is too deep and locate the top of footing at the historical scour elevation, as determined in the field investigation, or a minimum of 3 feet below the existing stream bed. The Scour Critical elevation will be equal to the top of footing elevation.

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CHAPTER 5
STRUCTURES

Use the following structure design criteria for the in-kind timber bridge replacements. The objective is to replace poor condition timber joist or rolled beam, timber deck bridges on low volume (ADT ≤ 500), low speed (< 45 mph) roads with minimal change to the footprint. In-kind timber bridge replacements should involve minimal site impacts and shall be tailored to the current site conditions.

In general, the replacement bridge shall consist of a durable (75-year design life) substructure supporting a superstructure that consists of steel rolled beams, timber deck and asphalt wearing surface. Whenever possible, utilize the existing substructure.

5.1 PLAN PREPARATION

Use the guidance in Chapter 1 of the *NCDOT Structures Management Unit Design Manual* to prepare and assemble in-kind timber bridge plans.

5.2 DESIGN DATA

5.2.1 General

In-kind timber bridges shall be designed in accordance with *AASHTO LRFD Bridge Design Specifications*. Use Importance Factor, $\eta = 0.95$.

5.2.2 Permanent Loads

5.2.2.1 Dead Loads

For timber deck planks with timber nailers use 26 lbs/ft^2.

Concentrated line loads, such as rails and any other permanent loads, should be distributed to the beams they are attached to.

The weight of standard timber barrier rails is as follows:

- 42” Timber Rail: 45 lbs/ft.

5.2.2.2 Wearing Surfaces and Utilities

Assume a 2” asphalt overlay (40 lbs/ft^2) on top of timber plank decks for the finished roadway riding surface.

Include an additional 30 lbs/ft^2 for future asphalt wearing surface on all timber bridge decks.

5.2.2.3 Lateral Earth Pressure

See Section 2.1.2.2 of the *NCDOT Structures Management Unit Design Manual*.

5.2.2.4 Vehicular Live Loads

For timber structures, the minimum vehicular live load shall be HL-93 in accordance with the *AASHTO LRFD Bridge Design Specifications*.

5.2.3 Material Design Properties

5.2.3.1 Concrete

For reinforced concrete members use the following design strengths:

- 3,000 psi (Class A) concrete.

5.2.3.2 Timber

Design timber members, using No. 1 Dense Southern Pine that meets the requirements of Section 1082 of the *NCDOT Standard Specifications*.

For 2"- 4" thick by 8" wide timber deck planks, use the following design values in accordance with the 2018 NDS Design Supplement:

- F_{bo} = 1350 psi.
- F_v = 175 psi.

For other allowable design values, refer to the *AASHTO LRFD Bridge Design Specifications* or the recent edition of the *AWC National Design Specification* (NDS) *for Wood Construction*.

5.2.3.3 Steel

In general, use:

- Grade 50 steel for beams and other structural members.
- Grade 36 steel for bearing assemblies (sole and/or masonry plates) is acceptable.

5.2.3.4 Elastomeric Bearings

Design plain elastomeric pads using Method A in accordance with Article 14.7.6 of the LRFD specifications. Specify the shear modulus required for the design; do not specify the durometer hardness.

5.2.4 Variations from and Interpretations of the AASHTO LRFD Specifications

For most variations and interpretation from AASHTO LRFD Specifications, see Chapter 2 of the *NCDOT Structures Management Unit Design Manual*.

5.2.4.1 Article 3.4.1 Load Factors and Load Combinations

For timber deck design, the Strength I limit state live load factor may be reduced from 1.75 to 1.30.

5.2.4.2 Incising Factor Specified in Article 8.4.4.7

It is considered to be 1.0 for pressure treated non-incised No.1 Dense Southern Pine timber.

5.3 PRELIMINARY DRAWINGS

For requirements of preliminary general drawings refer to Chapter 4 of the *NCDOT Structures Management Unit Design Manual*.

5.4 GENERAL DRAWINGS

For requirements of general drawings see Chapter 5 of the *NCDOT Structures Management Unit Design Manual*. Add the following standard notes, as applicable, to the applicable notes listed in Chapter 5:

5.4.1 Timber Members

For bridges with timber members, place the following applicable notes on the plans:

For timber members, all timber and lumber shall be treated No. 1 Southern Pine and conform to Section 1082 of the Standard Specifications.

All timber dimensions shown on the plans are nominal dimensions.

When field cutting timber members, treat newly exposed surfaces with either a bituminous asphalt-based roofing cement, copper naphthenate paste, or approved preservative system before installing.

Treat all drilled or newly exposed holes in timber members by pumping with bituminous asphalt-based roofing cement, or approved preservative system before installing hardware.

Pre-drill holes in timber and lumber members accepting bolts to reduce splitting.

Prior to installing timber nailers, place a self-adhering high-density polyethylene rubberized asphalt adhesive flashing membrane on the top flange of the steel beams.

Prior to installing timber decking members, place a self-adhering high-density polyethylene rubberized asphalt adhesive flashing membrane to the top side of the timber nailers.

Screw or torque lag/structural screws; do not drive them with a hammer.

Screws shall have sufficient length so that screw threads and shank will penetrate receiving members.

5.4.2 Steel Members

For bridges with non-weathering steel, place the following notes on the plans:

Salvaged beams shall be not used, unless otherwise noted on the plans.

All structural steel shall be AASHTO M270 Grade 50 and painted with system 1 or hot dipped galvanized in accordance with the Structural Steel Coatings Program and Section 442-8 of the Standard Specifications, unless otherwise noted on the plans.

All structural steel field connections shall use 7/8" dia. galvanized high strength bolts unless otherwise noted.

All structural steel hardware shall be galvanized in accordance with Section 1076 of the Standard Specifications, unless otherwise noted on the plans.

5.5 SUPERSTRUCTURE

5.5.1 General

Coordinate with the Hydraulics Unit to determine if the structure is over a FEMA stream and the proposed structure is required to match the existing geometric features.

Match the existing bridge widths and crown drops as close as possible. Use the actual number of travel lanes on the existing structure for design of superstructure elements, in lieu of the number of design lanes that can be accommodated by the clear roadway.

5.5.1.1 Span Layout

In general, the use of timber bridges should only be considered for bridges on low volume roads. If the Average Daily Traffic (ADT) on the bridge exceeds 500 and the Tractor Trailer Semi-Truck (TTST) volume exceeds 10, use an alternate bridge type, such as a cored slab or box beam bridge.

Timber bridges are typically single span structures. For bridges with more than two spans, do not use timber bridges without collaborating with the Geotechnical Engineering and Hydraulic Design Units to determine a suitable and cost effective foundation for a bent.

Stage-construction is allowed for timber bridges. Staged construction or widening shall be phased to the downstream side of the bridge, unless otherwise directed by the Hydraulics Unit. Staged sections shall provide a minimum of 10ft clear roadway openings to provide access for emergency vehicles, unless otherwise directed by the Division.

5.5.2 Bridge Deck Design

The deck is designed for an estimated 30-year service life and is comprised of timber plank decks with solid sawn members classified as dimensional lumber. The planks are typically 4 inches in thickness and range from 8 to 16 inches wide. They are screwed, with structural screws, to nailers which are bolted to the top flange of steel beams.

Requirements for the design of timber decks and deck systems are described in Article 9.9 of the *AASHTO LRFD Bridge Design Specifications*.

Use the standard timber deck planks as shown in Figure 5-2. The planks are designed to carry HL93 live load for the specified top flange size and beam spacing. Limit the overhang widths from the centerline of the girder to the edge of the superstructure to the applicable maximum overhang shown in Figure 5-2.

The timber deck design for the flange sizes and beam spacing shown in Figure 5-2 accounts for a maximum bituminous wearing surface of 3.5” (2” asphalt overlay with 1.5” future wearing surface). If plan details are not consistent with these conditions, the designer must check to determine whether 4x timber plank decking is adequate.

When butt joints are required in a plank run, detail the butt joints over the centerline of the beam. Where timber planks runs contain butt joints across the width of the deck, detail staggered butt joints in the adjacent plank runs to be offset by 4 feet minimum as shown in the figure below in figure 5-1.

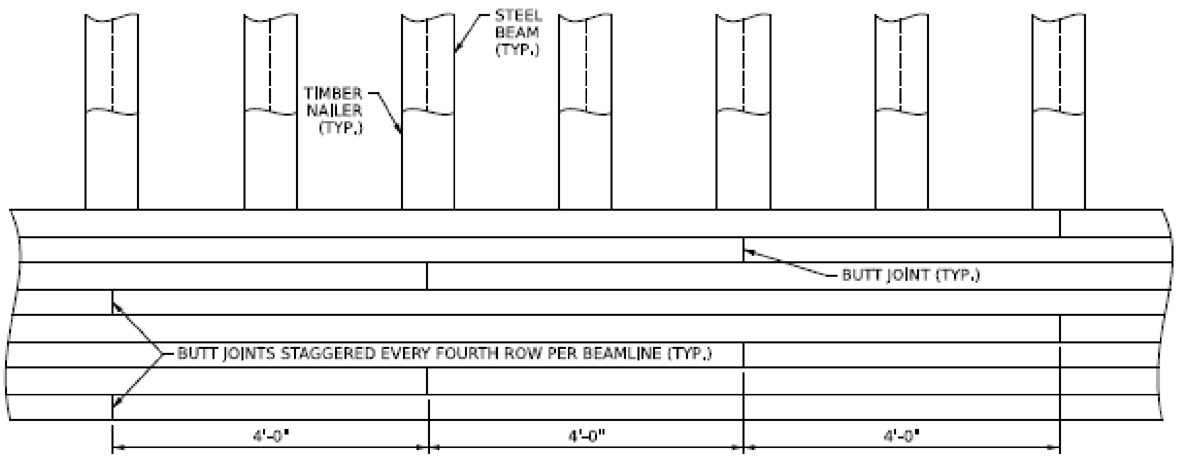

Figure 5-1

Position decking timber planks perpendicular to centerline of girders to provide optimal strength. Limit the overhang widths from the centerline of the exterior girder to edge of superstructure.

In general, timber bridge decks shall be sufficiently connected to the supporting beams. Use timber bolt connectors to attach timber nailers to the beams.

For all steel beams, detail 13/16 inch diameter holes in the top flange a minimum of 3 inches from the beam end, alternating on each side of the web at 30 inch maximum centers to allow for timber bolt connections to the nailers. The holes shall have a minimum 1½ inch clearance to the edge flange.

Overlays

Except for low water bridges, detail a minimum 2-inch asphalt overlay. Provide a waterproofing membrane on top of the timber deck prior to placing the asphalt overlay.

For low water bridges no overlay or waterproofing membrane is required.

5.5.2.1 Expansion Joints

Detail expansion joints at abutments to seal the gap between the timber deck and the backwall using the guidance below. To facilitate an even asphalt overlay transition from the roadway on to the bridge, the elevation of the top of the backwall and the top of timber deck board should be the same.

For timber bridges with more than one span, the timber nailers can be continuous across spans to provide a continuous nailing surface for a continuous deck.

Pourable Silicone Joint Seals

Provide pourable silicone joint seals at the abutments. The joint seal details are shown on the plan of span details sheet of timber bridge standard drawings.

Payment for the pourable silicone joint seals shall be at the linear foot price for "Pourable Silicone Joint Seals" pay item.

Place the following note on the plans:

For Pourable Silicone Joint Seals, see Special Provisions.

5.5.2.2 Bridge Rails

Utilize the standard 42" timber bridge rail to facilitate deck drainage and minimize bridge width, except when replacing in-kind timber bridges over a FEMA stream. Bridges rails on FEMA stream crossings shall match the existing rail height and length.

5.5.2.3 Deck Drains

The use of the standard 42" timber bridge rail provides drainage slots along the gutterline or bottom of the rail.

5.5.3 Structural Steel

5.5.3.1 Rolled Steel Beams

AASHTO M270 Grade 50 rolled steel beams shall be used for timber bridges. For corrosion protection, the steel structural steel shall be galvanized or painted. For structural steel material specifications, see Section 5.3.

5.5.3.2 Design

For the timber bridge design, use the fewest number of beams that is reasonable for the out-to-out roadway width and span. Figure 5-2 shows preferred rolled beams that satisfy the design requirements for various spans and maximum beam spacing. Standard overhang widths shall be 1ft.-3in., as shown in Figure 5-2.

Span (ft.)	Beam Size	Diaphragm Channel Size	Flange Width (in.)	Deck Plank Size	Nailer Size	Overhang (ft.)	Max. Beam Spacing (ft.)	Bearing Type
≤20	W10X45	C6X8.2	8.02	4X8	4X8	1.25	2.25	I
	W12X40	C9X15.3	8.01	4X8	4X8	1.25	2.25	I
	W14X34	C9X15.3	6.75	4X8	4X8	1.25	2.25	I
	W16X36	C12X20.7	7.00	4X8	4X8	1.25	2.25	I
	W18X50	C12X20.7	7.50	4X8	4X8	1.25	2.25	I
≤30	W10X68	C6X8.2	10.10	4X8	4X10	1.25	2.00	II
	W12X65	C9X15.3	12.00	4X8	4X12	1.25	2.25	II
	W14X61	C9X15.3	10.00	4X8	4X10	1.25	2.25	II
	W16X67	C12X20.7	10.25	4X8	4X10	1.25	2.25	II
	W18X55	C12X20.7	7.53	4X8	4X8	1.25	2.25	II
	W21X48	C12X20.7	8.14	4X8	4X8	1.25	2.25	II
≤40	W12X96	C9X15.3	12.10	4X8	4X12	1.25	2.25	III
	W14X90	C9X15.3	14.50	4X8	4X8 (2)	1.25	2.25	III
	W16X89	C12X20.7	10.38	4X8	4X10	1.25	2.25	II
	W18X76	C12X20.7	11.00	4X8	4X12	1.25	2.50	II
	W21X101	C12X20.7	12.25	4X8	4X12	1.25	2.50	III
	W24X76	C12X20.7	8.99	4X8	4X10	1.25	2.00	II
≤50	W14X145	C9X15.3	15.50	4X8	4X8 (2)	1.25	2.50	IV
	W18X130	C12X20.7	11.25	4X8	4X12	1.25	2.50	II
	W21X111	C12X20.7	12.38	4X8	4X12	1.25	2.50	III
	W24X104	C12X20.7	12.75	4X8	4X12	1.25	2.50	III

Figure 5-2

In Fig. 5-2, the rows highlighted in green and are bolded indicate beams that are detailed in the standard plans. If it is necessary to match the height of the existing bridge beams, which may be shallower or deeper sections than the bolded sections, use Fig. 5-2 to select an appropriate beam for the span.

For beams not listed in Fig. 5-2, a design will be required. When designing the beams, consider a few options and confirm availability of steel beam shapes prior to final selection. If the optimum steel beam is not readily available, then choose a readily available steel beam shape of similar depth and with a section modulus equal to or greater than the optimum beam. Design the beams for non-composite action, to not require bearing stiffeners, and do not use cover plates.

For constructability and to accommodate thermal movement, ensure a 3 in. minimum clearance between the end of the beam and the abutment backwall.

5.5.3.3 Diaphragms

Diaphragms shall be located 3 feet from the end of the beam and at the centerline of beam between bearings for spans greater than 30 feet. For spans equal to or less than 30 feet, use one intermediate diaphragm at the centerline of the beam between bearings. Diaphragms shall be bolted to connector plates with a minimum of two bolts per connection. Use channels sections shown Figure 5-2.

For economic and constructability reasons, consider uniformity in the diaphragm member sizes used throughout a project.

5.5.3.4 Connector Plates

When detailing connector plates, size the connector plate for the diaphragm, but do not show the width; the fabricator will determine the width.

Welded connections for connector plates to beam webs shall be in accordance with *NCDOT Structures Management Unit Design Manual* Figure 6-114.

5.5.3.5 Fabrication and Construction Details

For beams on a skew less than 60° or more than 120° detail clipped flanges to avoid conflicts with the backwall.

5.5.3.6 Charpy V-Notch

All structural steel furnished for primary members subject to tensile stresses shall meet the requirements of the longitudinal Charpy V-Notch Test.

Place the following note on the plans:

> ***A Charpy V-Notch Test is required on all beam sections, as shown on the plans and in accordance with Article 1072-7 of the Standard Specifications.***

5.5.3.7 Camber

In general, camber in beams for timber bridges is not necessary. Place the following note on the plans:

> ***No shop camber required, turn natural mill camber up.***

5.5.3.8 Constructability Guidelines

When environmental constraints, size, and/or complex geometry of the bridge favor prescribing a constructability plan, detail a proposed construction sequence in the plans. Describe the proposed construction sequence with plan notes and sketches of the various critical stages.

5.5.4 Elastomeric Bearings and Sole Plates

Bridge superstructures shall be supported on plain elastomeric bearing pads, which may be fixed or movable as required for the bridge design. The bearing pads shall be designed in accordance with the *AASHTO LRFD Bridge Design Specifications* – Method A.

50 durometer elastomeric bearings is preferred. For the bearing design, use the least favorable value from the range of shear modulii for the corresponding hardness. Place the following note on the plans:

Elastomeric in all bearings shall be 50 durometer hardness in accordance with the Standard Specifications

Provide a steel sole plate between the bottom flange of the steel beams and the elastomeric bearing.

5.5.4.1 Elastomeric Bearings

5.5.4.2 Sole Plate Details

Steel sole plates in accordance with the *Standard Specifications*, shall be AASHTO M270 Grade 36 (250) and all bearing plates, bolts, nuts and washers shall be galvanized. Place the following note on the plans:

All bearing plates shall be AASHTO M270 Grade 36.

At the fixed end of rolled beam spans, use 1-3/8" max ϕ holes in the sole plates and the elastomeric bearing pads.

At the expansion end of all beams, the slot size should be determined according to the amount of expansion and end rotation anticipated. See Figure 6-132 of the *NCDOT Structures Management Unit Design Manual* for the required slot size.

Show the weld size for the connection between the sole plate and the bottom flange.

Detail an optional bolted connection through the sole plate to bottom flange. Use the workable gage table shown below to determine the location of the bolts in relation to the bottom flange. Interpolate to determine the workable gage for flange widths falling between those specified in the workable gage table.

Workable Gages	
BF (IN.)	G (IN.)
14	8
12	7
10	6
8	5
7	4
6	3 ½

For the expansion ends of steel beams on elastomeric bearings, detail a field weld between the sole plates and the flanges. Place the following note on the plans:

When field welding the sole plate to the beam flange, use temperature indicating wax pens, or other suitable means, to ensure that the temperature of the sole plate does not exceed 300°F (149°C). Temperatures above this may damage the elastomer.

5.5.5 Anchorage

For rolled beams detail plain elastomeric bearings, use 1¼" ϕ anchor bolts. The anchor bolt gage for elastomeric bearings shall be shown on the Timber Bridge Bearing standard drawing.

For Contractor built structures, set anchor bolts 12 inches into the concrete cap.

5.5.6 Bridge Load Rating

All girders shall be designed in accordance with the *AASHTO LRFD Bridge Design Specifications* and load rated in accordance with the *AASHTO Manual for Bridge Evaluation*.

The load and resistance factor rating (LRFR) requirements for new bridges is summarized in the *NCDOT Structures Management Unit Design Manual* Figure 6-133. The LRFR limit states and load factors shall be as shown in *NCDOT Structures Management Unit Design Manual* Figure 6-134. See Section 5.2.4 for variances from the *AASHTO LRFD Bridge Design Specifications*. Where applicable, the allowable stress limits shall be as required for design. See *NCDOT Structures Management Unit Design Manual* Figure 6-134.

LRFR shall be performed for all applicable strength and service limit states. Perform and inventory and operating rating for the HL-93 design live load and HS-20 truck, and a legal load rating for all of North Carolina's national legal loads. For a list of NC legal loads configurations for Interstate and Non-Interstate structures, see *NCDOT Structures Management Unit Design Manual* Figure 6-146 and Figure 6-147, respectively.

The initial rating for exterior and interior beams shall be archived in the design folder. Acceptable rating factors (RF) shall be at least 1.00. Include a LRFR summary in the contract plans in the Plan Assembly Outline, *NCDOT Structures Management Unit Design Manual* Figure 1.1.

5.6 SUBSTRUCTURE

5.6.1 General

Whenever possible, timber substructures should be replaced with reinforced concrete abutments and bents. This will increase the substructure's life cycle and reduce maintenance.

Collaborate with the Geotechnical Engineering Unit and Hydraulic Design Unit to determine a suitable foundation type, which will be conveyed in the *Foundation Recommendations*. Substructures shall be designed in accordance with the *AASHTO LRFD Bridge Design Specifications* and the *NCDOT Structures Management Unit Design Manual*.

Substructures may need to be rebuilt in the same footprint as the existing substructure to satisfy permit requirements or match existing hydraulic openings, coordinate with the Hydraulic Design Unit.

5.6.2 Abutments

Abutments function as a foundation for the bridge superstructure and as an earth retaining structure for the roadway approaches and should be sized to ensure stability against overturning and sliding while resisting structural and soil bearing failure.

Whenever possible, abutments shall consist of reinforced concrete founded on reinforced concrete spread footings. When site conditions do not permit use of spread footings, deep foundation types, such as steel H-piles, micropiles, and helical piers may be considered.

5.6.2.1 Layout and Detailing

Dimensions

The typical abutment cap size shall be 2’-6” wide at the top of cap and uniform in width throughout the stem wall connected to the spread footing. Note that depending on the bridge skew, beam flange, sole plate, bearing, anchor bolt and reinforcement clearances outside of the standards, the cap width may need to be increased.

Detail the abutment cap length 3’-0” wider each side of the superstructure width to retain roadway approach fill and account for roadway shoulders.

Staged construction may require substructure members to be constructed larger than existing to accommodate staging and future staging for superstructure replacements.

Layout

In the plans, show plan and elevation views of the abutment. In the framing plan layout, show the following:

- Control line (fill face), and survey or control line,
- Work point and workline,
- Centerline of piles and centerline bearing

Provide all abutment dimensions as measured from the fill face, work point or workline. In the elevation layout, show all substructure elevations to two decimal places.

Bridge Seats and Top of Cap

In general the top of cap should be detailed level transversely, with a longitudinal 1% slope from the backwall to the front face for drainage. Do not detail stepped up or individual bearing areas for bridge seats.

To account for the roadway grade, it might be necessary to increase the longitudinal slope of the top of the cap from the backwall to the front face to match the roadway grade. Show the cap slope rate (%) on the plans.

Construction Joints

At the top of the footing, detail a construction joint with a shear key.

For staged construction, detail a shear key in the cap at the construction joint. Detail main cap reinforcement and skin reinforcement with lap splices when possible. Use of reinforcing steel mechanical couplers is permitted when lap splices are not feasible.

For stage-constructed abutment caps on skews, since the construction joint in the cap and backwall between stages is detailed normal to the cap, verify the staged length of cap and backwall will adequately support the approach backfill for the stage.

Acute Corners

For bridges with skews ≤ 60° or ≥ 120°, chamfer the abutment cap and wing corners in accordance with *NCDOT Structures Management Unit Design Manual* Figure 7-10, and ensure all minimum clearances and edge distances are maintained.

5.6.2.2 Clearances

For bearing assembly cap clearance requirements, see Section 7.2.2.3 of the *NCDOT Structures Management Unit Design Manual*.

5.6.2.3 Reinforcement

Design the cap to resist structural failure at the strength limit.

Main Reinforcement

The minimum number and size of main reinforcement bars for the top of the stem wall shall be 4- #7 bars for cap widths less than 3’-0”. For each additional 1’-0” of stem wall width, increase the reinforcement by one additional #7 bar.

Stem Reinforcement

Detail #7 vertical ‘M’ bars in the abutment at a maximum spacing of 12 inches, with lap splices to allow for field adjustments when there are variances in the height of the rock line from foundation recommendations. For the ‘M’ bars, do not detail bars smaller than #7.

Skin Reinforcement

The minimum size of reinforcement shall be #4 ‘U’ shaped stirrups along the top of the stem wall as shown in Timber Bridge Abutment standard drawing.

Provide minimum #4 skin reinforcement along both side faces of all abutment stems, as shown in the Timber Bridge Abutment standard drawing. See Section 2.3 for variations from the LRFD specifications.

5.6.2.4 Backwalls

Detail 1’-0” wide backwalls for all timber bridges. Design the backwall to retain the bridge approach fill. The elevation at the top of the back wall shall match the elevation of the timber plank decking. Compute the height of the backwall on this basis.

Detail a permitted horizontal construction joint between the backwall and the top of abutment cap. Extend the construction joint through the wings level with the cap. Detail the “K” bars for the entire length of the backwall. Match the “H” bars in the wing to the “K” bars in the backwall as applicable.

5.6.2.5 Wing-walls

Detail turned-back wing-walls thirty degrees from the front face of the abutment, where possible, with sufficient length and height to retain the approach roadway embankment and provide protection against erosion. Detail the bottom of the wingwalls level with the top of the spread footings and top of wingwalls tapering with the roadway embankment.

5.6.2.6 Spread Footings

Use of spread footings requires firm bearing conditions; competent material must be near the ground surface. Spread footings should not be used in scour critical locations. Spread footings should be utilized when the rock line is within 15ft of the roadway grade.

Design spread footings to resist structural failure, including flexure, shear, and punching shear. Provide sufficient thickness to resist shear in lieu of providing shear reinforcement. The footing should also be adequately proportioned to resist bearing, sliding, or overturning.

Anchor footings by detailing them keyed into rock 1’-0” with an option to be doweled into the rock on which it is bearing on with #6 bars at 3’-0” centers staggered along in both the length and width of the footing to resisting sliding.

The Geotechnical Engineering Unit will convey the allowable soil bearing pressure in the *Foundation Recommendations*.

Detail the bottom of the spread footing a minimum of 3ft below the lowest elevation (thalweg) of the existing streambed.

The minimum length and width for spread footings shall be 20% of the overall distance from the bottom of the footing to the crown of the roadway, rounded up to the next 6 inches. The maximum width should be approximately 10ft to minimize the amount of excavation and shoring required, and the minimum footing thickness shall be 2’-0”.

The minimum reinforcement shall be #6 bars at 1’-0” centers located 2 inches from the top and 3 inches off the bottom of the footing.

Design the abutment stem for an additional 3 feet of height to allow for the bottom of footing elevation to be lowered if the foundation material at the plan elevation does not meet the design bearing resistance. Detail the reinforcing steel accordingly.

Detail the spread footing to extend from under the abutment to under the wingwalls.

5.6.2.7 Piles/Micropiles/Helical Piers

The Geotechnical Engineering Unit will convey the foundation type and size (pile, micropile, or helical pier) in the *Foundation Recommendations*. Coordinate with the Geotechnical Engineering Unit to optimize the number of piles and pile tonnage. Discuss with the Geotechnical Engineering Unit whether it is more economical to use low tonnage piles based on the bridge location, the pile driving conditions, and the size of the crane required to drive piles.

Micropiles are commonly utilized if the rock line is beyond 15ft from the groundline and material present above the rock line is boulders/cobbles. The installation process of micropiles involves drilling through the existing material versus the driving of piles or auguring of helical piles.

For additional guidance on piles to support abutments, see Section 7.2.5 of the *NCDOT Structures Management Unit Design Manual*.

5.6.3 Bents

Bents function as a foundation for multi-span superstructure bridges and should be sized to structurally resist the applicable permanent and transient loads. Bents shall be designed to preclude soil bearing failure and to ensure deflections are with acceptable tolerances.

Bents for timber bridges typically consist of a reinforced concrete cap founded on:

- Piles (Steel H-Piles, Pipe Piles, or Micropiles),
- Walls/columns on spread footings.

Bent caps shall typically be constructed with cast-in-place concrete, precast cap may be considered for accelerated construction.

For constructability purposes, concrete pier walls are preferred.

Columns on spread footings may be used when competent material is near the ground line.

Pile bents capable of being constructed with smaller equipment may be used when feasible.

Bents with drilled shafts may be used when other bent types are not feasible.

The Geotechnical Engineering Unit will convey the foundation type and size in the *Foundation Recommendations*.

Design bents as per Section 7.4 of the *NCDOT Structures Management Unit Design Manual*.

5.6.3.1 Concrete Pier Walls

Concrete pier walls are used where foundation conditions allow, and the potential for drift accumulation is a concern.

Dimensions

The typical wall pier shall have a uniform 2'-9" width from the to the top of the spread footing, and located at least 6 inches from the edges of the footing. Note that depending on the bridge skew, beam flange, sole plate, bearing, anchor bolt and reinforcement clearances the cap width may need to be increased.

Provide all pier wall dimensions as measured from the fill face, work point or workline. In the elevation layout, show all substructure elevations to two decimal places. For debris deflection, detail tapered ends of the upstream end of the spread footing as well as the wall pier.

Layout

In the plans, show plan and elevation views of the pier wall. In the plan layout, provide the following information:

- Control line (fill face), and survey or control line,
- Work point and workline,
- Centerline of piles and centerline bearing

Bridge Seats and Top of Cap

In general, the top of cap shall be level; do not provide stepped or individual bearing areas for bridge seats.

To accommodate the grade of the bridge, it may be necessary to slope the top of the cap longitudinally. When necessary, show the cap slope rate (%) on the plans.

Construction Joints

Detail a construction joint with shear key in the at the construction joint at the top of the footing.

For staged construction, detail a shear key in the wall pier at the construction joint. Detail all reinforcement with lap splices when possible, and provide continuity across the stages. Use of reinforcing steel mechanical couplers is permitted when lap splices are not feasible.

Acute Corners

For bridges with skews ≤ 60° or ≥ 120°, chamfer the abutment cap and wing corners in accordance with *NCDOT Structures Management Unit Design Manual* Figure 7-10, and ensure all minimum clearances and edge distances are maintained.

Footings

Use of spread footings requires firm bearing conditions; competent material must be near the ground surface. Spread footings should not be used in scour prone locations. Spread footings should be utilized when the rock line is within 15ft of the roadway grade.

Design spread footings to resist structural failure, including flexure, shear, and punching shear. Provide sufficient thickness to resist shear in lieu of providing shear reinforcement. The footing should also be adequately proportioned to resist bearing, sliding, or overturning.

Anchor footings by detailing them keyed into rock 1'-0" with an option to be doweled into the rock on which it is bearing on with #6 bars at 3'-0" centers staggered along in both the length and width of the footing to resisting sliding.

The Geotechnical Engineering Unit will convey the allowable soil bearing pressure in the *Foundation Recommendations*.

Detail the bottom of the spread footing a minimum of 3ft below the lowest elevation (thalweg) of the existing streambed.

The minimum length and width for spread footings shall be 20% of the overall distance from the bottom of the footing to the crown of the roadway, rounded up to the next 6 inches. The maximum width should be approximately 10ft to minimize the amount of excavation and shoring required, and the minimum footing thickness shall be 2'-0".

The minimum reinforcement shall be #6 bars at 1'-0" centers located 2 inches from the top and 3 inches off the bottom of the footing.

Design the stem for an additional 3 feet of height to allow for the bottom of footing elevation to be lowered if the foundation material at the plan elevation does not meet the design bearing resistance. Detail the reinforcing steel accordingly.

Design the cap to resist structural failure at the strength limit.

Stem Reinforcement

Detail #7 vertical 'M' bars in the abutment at a maximum spacing of 12 inches, with lap splices to allow for field adjustments when there are variances in the height of the rock line from foundation recommendations. For the 'M' bars, do not detail bars smaller than #7.

The minimum size of reinforcement shall be #4 'U' shaped stirrups along the top of the stem matched with the 'M' bars.

Provide minimum #4 skin reinforcement along both side faces of all abutment stems, at 12 inch maximum spacing. See Section 2.3 for variations from the LRFD specifications.

5.6.4 Epoxy Protective Coating

Abutment and bent caps shall receive an epoxy protective coating in accordance with the *Standard Specifications*. The epoxy protective coating shall not be applied to the area under the elastomeric bearings.

When an epoxy protective coating is required, place the following notes on the abutment and bent plan sheets as they apply:

> ***The top surface areas of the caps shall be cured in accordance with the Standard Specifications, except the Membrane Curing Compound Method shall not be used.***
>
> ***Backwall shall be constructed before applying the Epoxy Protective Coating.***

Epoxy protective coating should be applied to the top of the backwall.

5.6.5 Scour

The *Foundation Recommendations* consider scour potential of the site and will provide scour critical elevations. The bottoms of spread footings or pile tip elevations should be determined such that scour will not compromise stability of the structure.

The Geotechnical Engineering Unit will determine when footings shall be protected against scour.

5.7 APPROACH SLABS

In-kind timber bridge replacements shall match current conditions. If the existing structure has approach slabs, or the site requires them, detail the approach slabs similar to those for cored slab bridges as the replacement approach slabs.

5.8 BRIDGE LAYOUT

5.8.1 General

Ensure timber bridge lengths, widths, and clearances conform to the Hydraulics Unit's recommendations.

Whenever possible, keep the overall bridge geometry close to the existing bridge geometry.

Standard plans provide general details. Modifications or adjustments will be necessary to suit the layout of each particular bridge site.

When laying out substructure and wing walls, look at the existing structure layout and consider factors such as the angle and direction of the stream flow. The layout of the substructure and wing walls shall adequately retain the roadway approach fills and provide protection from erosion.

5.8.1.1 Stream Crossings

FEMA Stream Crossings

The Hydraulics Unit will determine if the stream is a FEMA stream or not, which will determine if the hydraulic opening (span lengths and minimum clearance required between the abutment faces and the bottom of beams) is compliant with FEMA regulations. Do not change the grade, span arrangement, or superstructure depth that would affect the waterway opening beneath the structure, unless discussed with and approved by the Hydraulics Unit.

Non-FEMA Stream Crossings

The Hydraulics Unit will determine the span lengths and minimum clearance required between the abutment faces and the bottom of beam elevations can change. In general, do not change the grade. If the Bridge Maintenance Engineer requests a wider bridge, coordinate with the Hydraulics Unit to determine if the bridge can be widened.

5.9 WALLS

5.9.1 Retaining Walls

5.9.1.1 Reinforced Concrete Retaining Walls

For reinforced concrete retaining wall requirements, see Section 12-1 of the *NCDOT Structures Management Unit Design Manual*.

5.9.1.2 Geosynthetic Reinforced Soil Abutment Structures

Proprietary geosynthetic reinforced soil abutment structures (i.e., Gravity Stone Modular Block, Allen Block, Recon Wall Systems, etc.) may be used for replacing timber abutment bulkheads.

Detail the bottom of the wall footings a minimum of 3ft below the lowest elevation of the existing streambed.

Provide a sheet in the plans showing the plan and elevations of the proposed retaining walls.

After the letting, the Geotechnical Engineering Unit or Private Engineering Firm (PEF) responsible for the geotechnical design receives proprietary wall plans from the wall manufacturer. The Geotechnical Engineering Unit or PEF responsible for the geotechnical design will check the wall for bearing capacity, sliding, overturning and other items pertaining to soil mechanics. The Project Engineer from the Structures Management Unit or PEF responsible for the structure design will receive this package from the Geotechnical Engineering Unit or PEF to review the structural elements of the wall.

Place the following note on the plans:

For GRS Retaining Walls, see Special Provisions.

Show a sketch on the plans indicating the structure excavation limits for the installation of the walls.

5.10 CORROSION AND DECAY PROTECTION

5.10.1 Corrosion Protection

Durability of the bridge superstructure is dependent on corrosion protection of the steel beams. It is anticipated the timber deck can be replaced a few (2-3) times prior to replacing the steel beams.

Corrosion protection is achieved by providing:

- A waterproofing membrane on top of the bridge deck planking.
- A waterproofing flashing membrane on the top of the timber nailer to seal the punctures from the structural screws securing the timber deck planking to the nailer.
- A flashing membrane on the top flange of the beam to prevent corrosion from contact with the pressure treatment chemicals infused in the timber nailers.
- Elastomeric bearing pads to lift the steel beam off the top of the cap.

Place the following note on the plans:

Prior to placing timber beam nailer and edge nailer members, place a self-adhering high density polyethylene rubberized asphalt flashing membrane on the top side of the steel beams.

5.10.2 Steel Coatings

Steel beams and other structural steel members shall be either painted with System 1 or galvanized in accordance with the *NCDOT Structural Steel Coatings Program*.

Place the following note on the plans:

All structural steel shall be grade 50 and painted with System 1 or Galvanized in accordance with the Structural Steel Coatings Program and Section 442-8 of the Standard Specifications, unless otherwise noted on the plans.

5.10.3 Decay Protection

All timber and lumber members shall be treated as per Section 1082 of the *NCDOT Standard Specifications.*

To protect the timber plank decking, detail a waterproofing membrane on the top of the timber plank decking below the asphalt wearing surface.

To prevent decay of the timber plank decking ends, detail drip edge flashing.

To prevent water migration into nail/screw holes and causing decay, detail a flashing membrane on the top of all timber nailers below the timber plank decking.

Specify all freshly cut and drilled surfaces shall receive a coating of preservative system to prevent decay.

Place the following note on the plans:

> ***When field cutting timber members, treat newly exposed surfaces with either a bituminous asphalt-based roofing cement, copper naphthenate paste, or approved preservative system before installing.***
>
> ***Treat all drilled or freshly exposed holes in timber members by pumping with bituminous asphalt-based roofing cement, or approved preservative system before installing hardware.***

5.11 MISCELLANEOUS

5.11.1 Title Sheet

For title sheet requirements, see Section 12-1 of the *NCDOT Structures Management Unit Design Manual*.

5.11.2 Adhesively Anchored Anchor Bolts

For adhesively anchored anchor bolt requirements, see Section 12-3 of the *NCDOT Structures Management Unit Design Manual*.

5.11.3 Rip Rap

Rip rap is typically not needed. For requirements for when it is needed, see Section 12-4 of the *NCDOT Structures Management Unit Design Manual*.

5.11.4 Temporary Structures

For temporary structure requirements, see Section 12-7 of the *NCDOT Structures Management Unit Design Manual*.

5.11.5 Shoring Adjacent to Existing Bridges

For shoring adjacent to existing bridges requirements, see Section 12-9 of the *NCDOT Structures Management Unit Design Manual*.