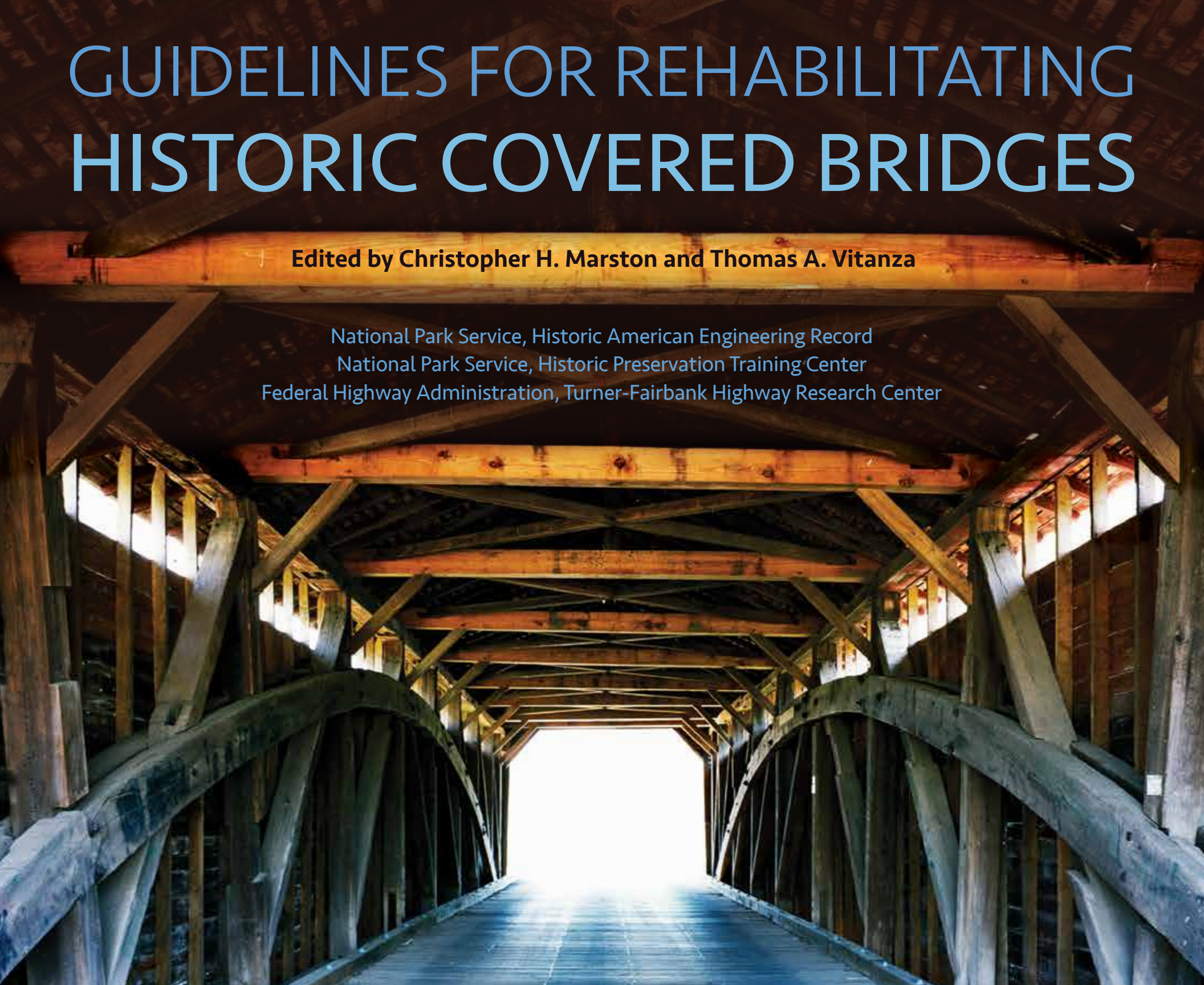


GUIDELINES FOR REHABILITATING HISTORIC COVERED BRIDGES

Edited by Christopher H. Marston and Thomas A. Vitanza

National Park Service, Historic American Engineering Record
National Park Service, Historic Preservation Training Center
Federal Highway Administration, Turner-Fairbank Highway Research Center



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U.S. Department
of Transportation

**Federal Highway
Administration**

This study is part of the Research, Technology and Education portion of the National Historic Covered Bridge Preservation (NHCBP) Program administered by the Federal Highway Administration. The NHCBP Program includes preservation, rehabilitation and restoration of covered bridges that are listed or are eligible for listing in the National Register of Historic Places; research for better means of restoring and protecting these bridges; development of educational aids; and technology transfer to disseminate information on covered bridges in order to preserve the Nation's cultural heritage.

This study is conducted under a joint agreement between the Federal Highway Administration–Turner Fairbank Highway Research Center, and the National Park Service–Historic American Engineering Record (HAER).

Federal Highway Administration Program Manager–Sheila Rimal Duwadi, P.E.
HAER National Covered Bridges Recording Project Leader–Christopher H. Marston.

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Carol M. Highsmith Archive, Library of Congress, Prints and Photographs Division, ca. 2000.

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These Guidelines are dedicated to the memory of the following individuals who helped lay the groundwork for the principles outlined in this publication:

H. Thomas McGrath

(1950-2018)

Superintendent, Historic Preservation Training Center

Eric N. DeLony

(1944-2018)

Chief, Historic American Engineering Record

Joseph D. Conwill

(1954-2017)

Editor, *Covered Bridge Topics*

David W. Wright

(1940-2013)

President, National Society for the Preservation of Covered Bridges

David C. Fischetti

(1946-2011)

President, DCF Engineering

Milton S. Graton

(1908-1994)

Covered bridge builder



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The First National Covered Bridge Conference was held in June 2003 in Burlington, Vermont, and chaired by Tom McGrath, Superintendent of the Historic Preservation Training Center (HPTC). Vermont Senator James Jeffords, who had first introduced and fought to pass the NHCBP legislation in 2000, was an honored guest. This inaugural gathering of over 200 professionals and covered bridge enthusiasts adopted the "Burlington Charter for the Preservation of Historic Covered Bridges" (see Appendix A). The charter created the mandate for this document, resolving to "develop guidelines that apply and adapt *The Secretary of the Interior's Standards for the Treatment of Historic Properties: with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings* to historic covered bridges in a manner consistent with these goals and objectives."

HPTC's Thomas A. Vitanza served as the Guidelines project leader and editor from 2003-2015. He supervised interns Roger Ciuffo and Holly Beach (now Ravesloot) in producing the first draft in 2004. A lapse in funding stalled further work on the publication until 2009. Vitanza coordinated the completion of the case study reports in 2013, edited by Justine Christianson. HPTC's Sharon Feeney completed the second draft in 2015 with assistance from Chris McGuigan. Christopher H. Marston completed the final edit (with several reviews by Timothy Andrews and James Barker) and selected the photographs in 2016-2018. This final publication is indebted to their work, the peer reviewers, and all the contributors to the case studies listed in Appendix III.

The editors thank FHWA's Sheila Duwadi, MaryAnn Naber, and Wendy McAbee for moving the project forward. Anne Grimmer of the National Park Service's (NPS) Technical Preservation Services (co-author of the original Secretary of the Interior's Standards for the Treatment of Historic Properties) was a stalwart reviewer at all steps in the process. Peer reviewers of the final draft include: Timothy Andrews (Barns & Bridges of New England), James Barker (VS Engineering), Tom Barrett (Ohio DOT), Laura Black (New Hampshire Division of Historical Resources), Rebecca Burrow (Oregon DOT), Justine Christianson (HAER), David Clarke (FHWA), Joseph Conwill (editor, Covered Bridge Topics), James Garvin (New Hampshire State Architectural Historian, retired), Michael Grayson (Quebec engineer), Sean James (Hoyle, Tanner & Associates), Mary Kennedy (Indiana SHPO), Robert McCullough (University of Vermont), Richard O'Connor (HAER), Kara Russell (Pennsylvania DOT), David Simmons (Ohio Historic Bridge Association), and Winston Sitton (Alabama DOT).

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Several photographs included in the Guidelines are from the HAER collection at the Library of Congress. Thanks go to those contributing additional rehabilitation photos, including: Doug Christian, Dean Fitzgerald, Matthew Kierstead, Earl Simmers, James Smedley, and Will Truax. A full list of image credits for pages 1-91 is on page 96.

Phillip Pierce should also be recognized as the principal author of the *Covered Bridge Manual*, published by FHWA in 2005. That NHCBP-sponsored publication is meant to be used in conjunction with these Guidelines.

Figure 0.2 Auxiliary guy wires with chained braces and timber crib towers were used to adjust and stabilize the Burr-arch truss during the rehabilitation of Gilpin's Falls Covered Bridge, MD. HAER MD-174-4, David Ames, 2009.



INTRODUCTION

Historic covered bridges represent an important part of the evolution of early American civil engineering and remain a significant symbol of our cultural heritage. They played an integral role in the development of the United States by helping expand transportation routes across the country, thereby facilitating both settlement and commercial activity. At the same time, covered bridges—perhaps more than other historic property types—are evocative of a bygone era and are highly prized by the communities in which they are located.

A covered bridge is a timber truss bridge with a housing to cover the truss and protect it from the elements, thus extending its service life. Throughout the nineteenth century, covered bridges were built across the United States, especially in the areas of early/mid-nineteenth century development of the Northeast, mid-Atlantic, upland South, Midwest, and West Coast. By 1870, there were more than 10,000 covered bridges. Though they fell out of favor with the introduction of wrought iron, inexpensive steel, and, eventually, concrete, covered bridges continued to be built in timber-rich Oregon through the early 1950s.¹ Now fewer than 700 historic covered bridges remain, the others lost due to floods, arson and deterioration from a lack of maintenance, or removed and replaced by modern structures. It is crucial that the extant historic covered bridges be retained and appropriate treatments be applied to ensure their preservation as American icons and for their significance to the field of civil engineering.

In 1998, Vermont Senator James Jeffords introduced the legislation for the National Historic Covered Bridge Preservation Program. Later that year, Congress authorized the NHCBP under Section 1224 of the Transportation Equity Act for the 21st Century (TEA21), and continued it through 2012 under the Safe, Accountable, Flexible, Efficient Transportation Equity Act—A

¹ Joseph D. Conwill, *Covered Bridges Across North America* (St. Paul: MBI Pub. Co., 2004), 77. Irish Bend Bridge (1954) in Benton County, Oregon, is generally considered to be the last covered bridge built during the historic era of covered bridge building. The structure was bypassed in the 1970s and moved to the Oregon State University campus at Corvallis in 1989.

Figure 0.3 Brown Bridge in Vermont is a designated National Historic Landmark. Among the character-defining features of this Town lattice truss is the utilization of the large boulder as the abutment. It was photographed after crew replaced deteriorated siding with a new layer of unpainted vertical wood siding. HAER VT-28-6, Jet Lowe, 2002.

Legacy for Users (SAFETEA-LU).² The NHCBP program, administered by the Federal Highway Administration, provided funding to assist states in their efforts to preserve, rehabilitate, or restore the nation’s historic covered bridges, and for research, education and technology transfer. Funding eligibility for rehabilitation was determined based on the bridges being listed in or eligible for listing in the National Register of Historic Places.

Legal Mandates for Retaining Historic Covered Bridges

Sections 106 and 110 of the National Historic Preservation Act (NHPA) are the basis for the regulatory requirements that affect the treatment of historic covered bridges whether directly under the ownership of a Federal agency or under the jurisdiction of state departments of transportation (DOTs), county or municipal authorities, or in private ownership and receiving Federal assistance. The guidance presented in the following pages has been developed specifically to assist those responsible for compliance and planning, and for carrying out this directive to ensure that “the best practices” are applied to the treatment of historic covered bridges. The information included here is equally useful for anyone charged with the maintenance and preservation of a historic covered bridge.

The Secretary of the Interior’s Standards for the Treatment of Historic Properties

As directed by the NHPA, the Secretary of the Interior is responsible for establishing professional standards and promulgating guidelines for Federal agencies to assist in fulfilling their obligations to preserve historic properties under their jurisdiction. Accordingly, *The Secretary of the Interior’s Standards for Historic Preservation Projects* were developed in 1976, revised in 1992, and in 1995 were retitled *The Secretary of the Interior’s Standards for the Treatment of Historic Properties: with Guidelines for Preserving, Rehabilitating, Restoring and Reconstructing Historic Buildings*. Anne Grimmer, co-author of the 1995 Standards, has recently completed the 2017 Revised Guidelines, consisting of four sets of Standards: treatments for Preservation, Rehabilitation,

²The Historic Covered Bridge Preservation Program was eliminated as a separate funding category in MAP-21 legislation in 2012 although unobligated funds remained available through 2017; however, historic covered bridges continue to be eligible for funding under the Transportation Alternatives Program of the Fixing America’s Surface Transportation (FAST) Act: http://www.fhwa.dot.gov/environment/transportation_alternatives/

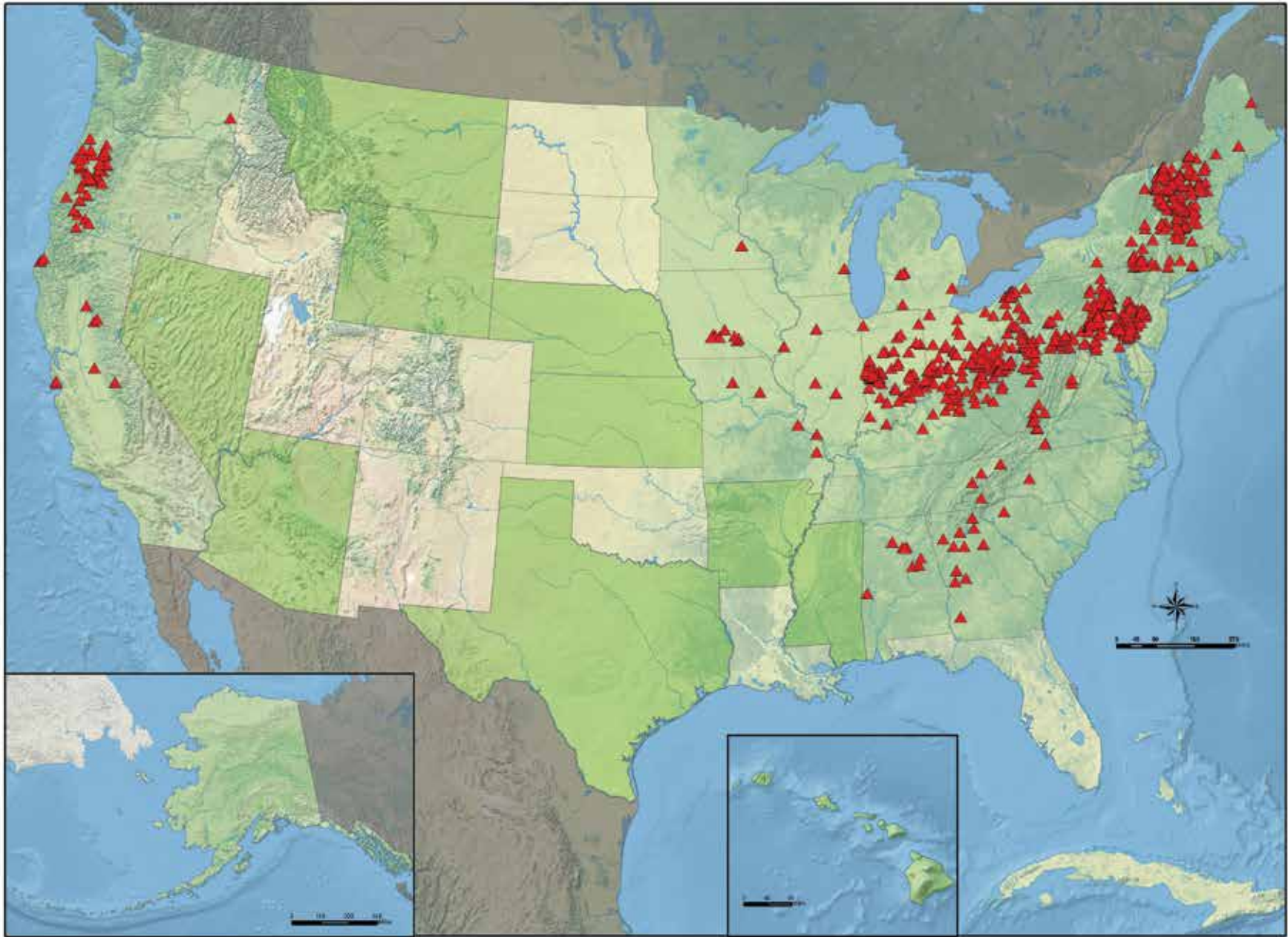


Figure 0.4 Map of extant historic covered bridges in the United States. James Stein and Matthew Stutts, NPS Cultural Resources Geographical Information System Facility, 2004, 2014.

Restoration, and Reconstruction. Of the four Standards, the Preservation Standards require retention of the greatest amount of historic fabric, including form, features, structures, and details of the property as they have evolved over time. The Rehabilitation Standards permit the most change and acknowledge the need to alter or add materials or features to meet continuing or new uses while retaining the historic character of the property. The Restoration Standards apply when the purpose of the treatment is to re-establish the character and appearance of a property at a particular time in history by preserving materials from the period of significance and removing materials from other periods. The Reconstruction Standards establish a framework for recreating a vanished or non-surviving historic property, primarily for interpretive purposes, with new materials.³

Best Practices: Selecting the Appropriate Treatment for a Historic Covered Bridge

Depending on the particular circumstances, any of the four Standards may be applied to a historic covered bridge. For example, the Preservation Standards apply when a bridge has retained its character-defining trusses, structural system, and sheathing materials and only minimal repair and general maintenance are required to keep the bridge in use for restricted or limited traffic as opposed to an extensive replacement and upgrade project. The Rehabilitation Standards are appropriate when a greater amount of repair and replacement of deteriorated materials and code-required alterations are necessary to allow the bridge to continue in service. The Restoration Standards apply when a historic covered bridge, because of its design and construction, is so significant for its appearance at a particular point in time that later features may be removed. The Reconstruction Standards provide a framework to be used in very limited instances when it is necessary to depict a no longer extant covered bridge that was of special significance for its design or role in history.

The majority of historic covered bridges that still carry vehicular traffic, whether on low volume roads or on more traveled secondary roads, are an integral part of our national transportation system. As such, they must be able to carry loads of a certain weight and width that may be more than

what the bridges were originally built to handle. These factors, as well as modern code and safety regulations, mean that historic covered bridges generally require certain adaptations to continue in service. There are various alternatives to replacement to preserve bridges that cannot be adapted to carry heavy vehicular traffic without destroying their historic integrity. An example of a successful alternative preservation use would be to close the bridge for vehicular traffic, rehabilitate the bridge in place, and allow limited pedestrian and bicycle use. If there is no other alternative, a historic covered bridge can be moved to a similar location, although it is always preferable to keep a structure in its original location.

Choosing the most appropriate treatment requires careful understanding of the bridge's historical significance as well as considering its relative importance in history, its physical condition, proposed use, public safety, and code requirements. In addition, although some states have their own requirements, generally all vehicular and pedestrian bridges serving the public conform to the appropriate American Association of State Highway and Transportation Officials (AASHTO) standards and codes. Note that there is flexibility inherent in the AASHTO Guidelines that can be negotiated during the decision making process.

Rehabilitation as a Treatment for Historic Covered Bridges

In most cases where Federal funding is being used in order to keep a historic covered bridge in use today, at least some alterations will likely have to be made. This work must be undertaken in a manner that retains the bridge's significant character-defining features that make it a distinctive example of covered bridge engineering. This treatment is Rehabilitation. Rehabilitation is defined as "the process of returning a property to a state of utility, through repair or alteration, which makes possible an efficient contemporary use while preserving those portions and features of the property which are significant to its historic, architectural, and cultural values." Accordingly, The Secretary of the Interior's Standards for Rehabilitation are the standards most often and most appropriately applied to historic covered bridges when work is undertaken to rehabilitate them to meet the purpose and need of the crossing. It can also be the most intrusive treatment given the potential for introduction of new materials, and therefore the most critical to be accomplished in a sensitive manner.

³ Kay D. Weeks, Kay D. and Anne E. Grimmer, *The Secretary of the Interior's Standards for the Treatment of Historic Properties: with Guidelines for Preserving, Rehabilitating, Restoring & Reconstructing Historic Buildings* (Washington, DC: U.S. Department of the Interior, National Park Service, 1995); and revised edition (Washington, DC: U.S. Department of the Interior, National Park Service, 2017).

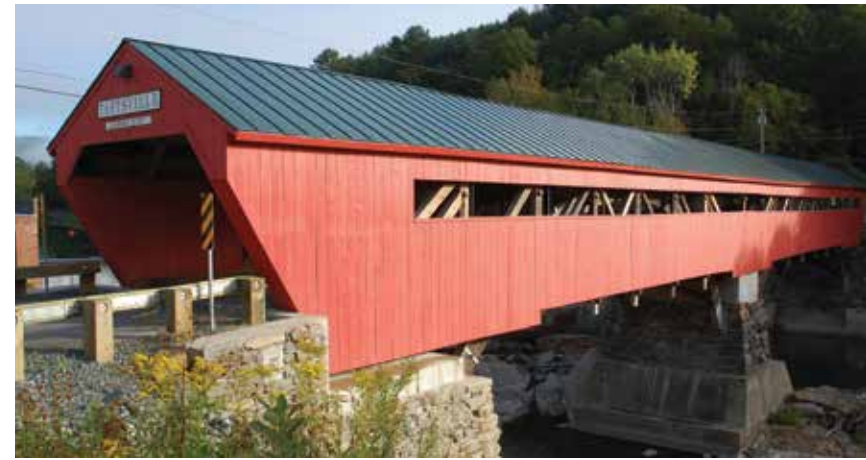


Figure 0.5a-b Vermont's Taftsville Bridge suffered major damage from Hurricane Irene in 2011. While one span needed to be completely rebuilt, a large percentage of the original hand-hewn truss members were salvaged and retained during the rehabilitation project.

Rehabilitation as a treatment for a covered bridge should be considered when repair and replacement of deteriorated features become necessary or when alterations or additions to the bridge or surrounding area are planned. In Rehabilitation, original material and character-defining features are protected to the degree possible, and maintained as they are in the Preservation treatment. However, an assumption is made prior to work that existing historic fabric has become damaged or deteriorated over time and, as a result, more repair and replacement will be required. Thus, latitude is given by the Standards to replace extensively deteriorated, damaged, or missing features using either traditional or substitute materials. Of the four treatments, only Rehabilitation includes an opportunity to make possible an efficient contemporary use through alterations and additions. Rehabilitation permits alterations, but when developing a treatment plan, key consideration should be given to the original design intent. Alterations to the truss system should be considered only after less destructive or less intrusive options have been exhausted. If alterations to the structural system are deemed necessary, it is important that they complement the original design and do not detract from it.

Thus, the *Guidelines for Rehabilitating Historic Covered Bridges* have been developed to help interpret the Standards for Rehabilitation specifically as they are applied to historic covered bridges. They provide guidance on

how to rehabilitate and update covered bridges for continuing use in a manner that is compatible with the structural systems that make them so special and that define their historic character. The Guidelines are intended to assist engineers, architects, carpenters, timber framers, bridgewrights, preservation specialists, Federal Preservation Offices (FPO), State Historic Preservation Offices (SHPO), Tribal Historic Preservation Offices (THPO), state and local officials, and individual owners in developing a rehabilitation treatment plan for a historic covered bridge. Careful planning prior to treatment can help prevent irrevocable damage and loss of integrity and, as a result, ensure the long-term safeguarding of the historic resource. The preservation planning process for historic covered bridges should include historical research; inventory and documentation of existing conditions; site analysis and evaluation of integrity and significance; condition assessment; development of a treatment plan to retain covered bridges for active use in transportation with the least possible compromise to their integrity; development of a management plan and management philosophy; development of a strategy for ongoing maintenance; and preparation of a record of treatment (Historic Structure Treatment Report; see sidebar) and future research recommendations.

Documenting and Assessing the Condition of a Historic Covered Bridge

It is essential that historical research and documentation be completed before these Guidelines are applied to the rehabilitation of a historic covered bridge. Research findings can identify the engineer who designed the bridge, the construction methods, and the bridgewright or timber framer who built it. Research can also provide valuable information about prior alterations or repairs to the bridge and when they were done, which will be needed to develop an informed work treatment plan. In addition, research findings may be useful in assisting with satisfying compliance reviews (e.g., Section 106 of NHPA).

A primary objective in documenting a historic covered bridge is to create a record of it as it exists at the present time and, thus, establish a baseline on which to develop the work treatment plan. All character-defining features that contribute to the bridge's historic character should be recorded; this may be done as part of Historic Structure Report (see sidebar). This document includes many of the tasks described by the "Burlington Charter for the Preservation of Historic Covered Bridges."

The level of documentation needed depends on the nature and the significance of the bridge. At a minimum, the bridge should be photographed, have measured field sketches of the structural components and elevation views recorded, and a basic condition assessment prepared. A more thorough documentation would include a full set of measured drawings of the structural components, elevations, cross-sections (both lateral and longitudinal), construction details, and an engineering analysis of the structure to adequately document its condition. The engineering analysis may include: structural analysis, load testing, non-destructive testing of members, and wood species identification.

It is also helpful to determine and record how a historic covered bridge has changed over time, including repairs, replacement of members, and other alterations. The quality of workmanship as well as the presence or lack of certain features may sometimes be attributed to a discrete time period or builder, which may help in dating the structure and determining how it evolved into its current appearance. Physical assessment of the

Documenting a Historic Structure and Developing a Treatment Plan Should Include:

Adapted from "Preservation Brief 43: The Preparation and Use of Historic Structure Reports."⁴

- Preliminary site visit and walk through, or virtual tour
- Research and review of archival documentation
- Oral histories
- An existing condition survey including superstructure features [truss system, connections, fasteners, other structural and support features, floor structure system, lateral bracing system], substructure features [abutments, wing walls, piers and bents] and ancillary features [exterior envelope – wall system, secondary structure features, entrance portal features, windows, roof system features, etc.] See "Feature Master Checklist for Historic Covered Bridges" in Appendices.
- Measured drawings and photographs, preferably following the Secretary of the Interior's Standards and Guidelines for Architectural and Engineering Documentation
- Evaluation of significance
- Discussion with the owner and users about current and future intended uses for the structure
- Selection and rationale for the most appropriate approach to treatment (preservation, rehabilitation, restoration, or reconstruction)
- Structural analysis (may include non-destructive evaluation of members; live, snow, and wind load testing)
- Development of specific work recommendations

⁴Deborah Slaton, "Preservation Brief 43: The Preparation and Use of Historic Structure Reports," Washington, DC: National Park Service, 2005.



Figure 0.6a-c Before/During/After photos of Medora Bridge, IN. A complete rehabilitation was necessary due to failing abutments and a deteriorated roof causing decay in truss members. The crew carefully took apart the abutments, poured a new reinforced concrete slab, and put the original stones back in place.

actual condition of the bridge and its structural members will, of course, be a critical part of the condition report on which the work program will be based. Other aspects of the inspection include assessing the truss alignment, bridge geometry, camber, racking, primary truss members and their connections, substructure components, and exterior siding and roof sheathing. The location and setting, and natural or other cultural resources (such as archaeological sites) that may be impacted by the rehabilitation should be taken into consideration and addressed in the rehabilitation treatment plan proposed for the covered bridge. It should be noted that certain details may not be original (especially the exterior envelope and deck) and that any rehabilitation plans should await careful and thorough historical research on the original appearance.

Sources of Documentation

The National Park Service's Historic American Buildings Survey (HABS)/ Historic American Engineering Record (HAER)/ Historic American Landscapes Survey (HALS) Collection, housed at the Library of Congress (LOC), is a valuable source of information on historic covered bridges. HABS and HAER have documented numerous covered bridges with large-format black-and-white photographs, written historical reports, and measured drawings. In addition, HAER has completed engineering analyses of various truss types. This material is available through the LOC's Prints and Photographs Division

Web site in downloadable, publishable formats.⁵ The National Society for the Preservation of Covered Bridges, state/local covered bridge societies, and the *World Guide to Covered Bridges* are also good sources of information about covered bridges.

Generally, documentation prepared for compliance with Section 110 or Section 106 of the NHPA will follow the *Secretary of the Interior's Guidelines for Architectural and Engineering Documentation* (68 CFR 43159), first developed in 1983 and revised in 2003, and should result in a level of documentation useful in assessing the condition of a historic covered bridge. These Guidelines are not codified but provide a standard format that should be used to document covered bridges.

Many historic covered bridges are listed in the National Register of Historic Places individually or as contributing to a historic district, or as part of a thematic nomination study. There may also be information on bridges determined eligible, but not yet listed in the National Register in the form of draft nominations or determinations of eligibility (DOE). Documentation of listed properties and those previously determined eligible may be obtained from the appropriate State Historic Preservation Office (SHPO).

⁵ Historic American Buildings Survey/Historic American Engineering Record/Historic American Landscapes Survey online collection at the Library of Congress is available at: <http://www.loc.gov/pictures/collection/hh/>

All publicly-owned covered bridges are also recorded by the state and county Departments of Transportation. The corresponding DOTs should have bridge plans, inspection reports, load ratings, and calculations available from the respective bridge department or other agency.

National Historic Landmarks Program and Covered Bridges

National Historic Landmarks are nationally significant historic structures or sites designated by the Secretary of the Interior because they possess exceptional value or quality in illustrating or interpreting the heritage of the United States. The 2012 Covered Bridges Context Study produced for the National Historic Landmarks Program identified the relevant criteria for assessing the potential national significance of this resource type. A covered timber bridge is eligible for designation as a National Historic Landmark (NHL) under Criterion 4 if it is a well-preserved example of a nationally significant truss type or for unique or distinctive characteristics that result in the bridge being an outstanding example of covered bridge engineering. In addition, the bridge must date between 1805 and 1954, be more than 20' long, be an outstanding representative example of covered timber bridge construction, and have a high degree of integrity. The context study determined that, of approximately 690 extant historic covered bridges, twenty had high levels of integrity and were outstanding representative examples of the type, period, and method of construction.⁶

Identifying Character-Defining Features of Historic Covered Bridges⁷

Every historic structure has its own identity and its own distinctive character. Character is established by the combination of all those visual aspects and physical features that contribute to the appearance of any historic covered bridge. Thus, identifying the character-defining features of a historic covered bridge is a major part of the documentation process and necessary to develop

⁶ Lola Bennett, "Covered Bridges NHL Context Study," U.S. Department of the Interior, National Park Service, 2012. Seven covered bridges have been designated as NHLs through the NHCBP initiative: Humpback Bridge, Virginia; Knight's Ferry Bridge and Powder Works Bridge, California; Brown Bridge, Vermont; Duck Creek Aqueduct and West Union Bridge, Indiana; and Eldean Bridge, Ohio.

⁷Adapted from Lee H. Nelson, "Preservation Brief 17: Architectural Character—Identifying the Visual Aspects of Historic Buildings as an Aid to Preserving Their Character," Washington, DC: National Park Service, 1988. See also Checklist for Character-Defining Features for Historic Covered Bridges in Appendix B.

the rehabilitation treatment plan. *The Secretary of the Interior's Standards for the Treatment of Historic Properties* embody two important goals:

1) the preservation of historic materials, and 2) the preservation of a property's distinguishing character. Character-defining features generally include the overall mass and form of the structure; its materials, craftsmanship, structural system, and features; interior spaces; and various aspects of its site and environment. More specifically for a historic covered bridge these visual aspects may include: timber truss type, substructure, materials and craftsmanship (often handcrafted features exist), exterior envelope (siding, roof, and openings), decorative details, and site and setting. Respecting these features and keeping them in focus during the rehabilitation project will ensure that the historic integrity of the bridge is retained. The purpose of this section is to help identify those visual and tangible features or elements that give a historic covered bridge its character and that should be taken into account so that they are preserved to the maximum extent possible without being damaged, destroyed, or obscured during rehabilitation.

Historic covered bridges can be classified by the truss type, such as king-post, queenpost, Town lattice, Burr-arch, Howe, Long, Smith, etc. They may also be significant because of their association with a particular engineer, bridgewright, or timber framer. A covered bridge may also exhibit certain

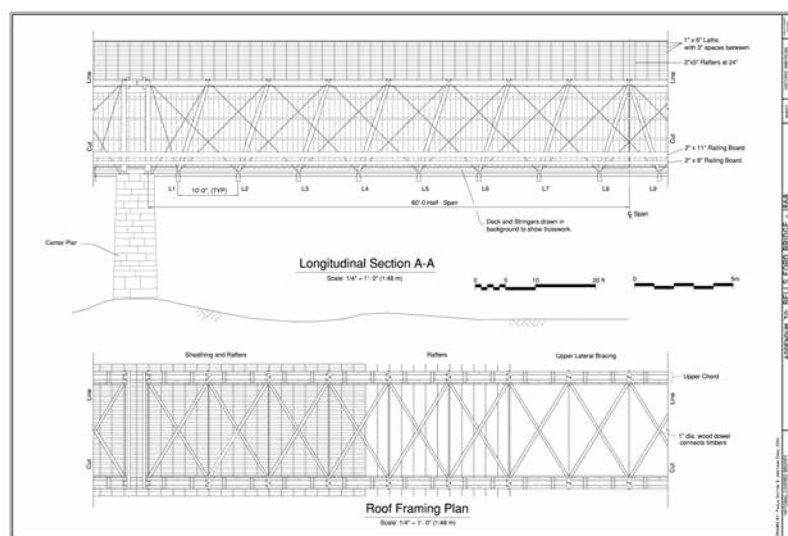
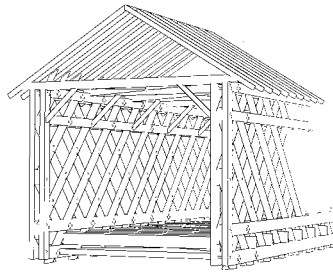


Figure 0.7 Before beginning any rehabilitation project a complete engineering assessment should be conducted. Accurate measured drawings should be completed as part of the documentation and engineering inspection process.

Covered Bridge Trusses



Brown Bridge

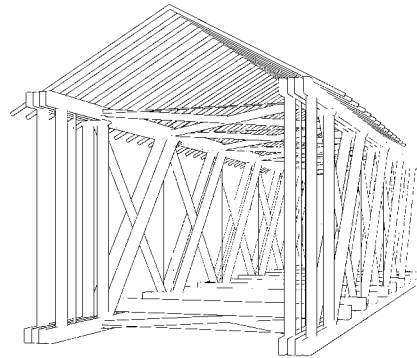
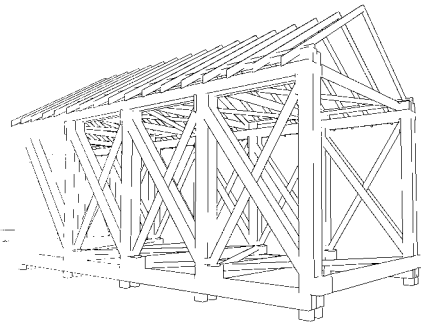
Town Lattice, 1880
 Built by Nicholas M. Powers
 Spanning Cold River
 Upper Cold River Road
 Rutland County, Vermont

HAER No. VT - 28

Eldean Bridge

(Allen's Mill Bridge)
 Long Truss, 1860
 Built by John & William Hamilton
 Spanning Great Miami River
 Farver Road
 Miami County, Ohio

HAER No. OH - 122



Pine Bluff Bridge

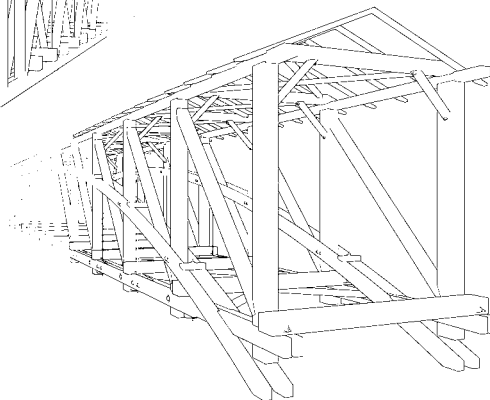
Howe Truss, 1886
 Built by Joseph A. Britton
 Spanning Big Walnut Creek
 Route 950N
 Putnam County, Indiana

HAER No. IN - 103

Pine Grove Bridge

Burr Arch, 1884
 Built by Elias McMellen
 Spanning Octoraro Creek
 Ashville & Forge Roads
 Chester and Lancaster County, PA

HAER No. PA - 586



regional characteristics or the style of a particular builder. Each bridge is unique as an engineered structure designed to fit the particular site and use for which it was built, and those physical manifestations should be preserved.⁸

Identify the Overall Visual Aspects

Begin identifying the overall character of a historic covered bridge by looking at its distinguishing physical aspects without focusing on its details. The major contributors to a covered bridge's overall character are embodied in: the shape and form of the structure (truss type); substructure; the roof and roof features; the portal, siding, and openings; and the general aspects of its setting. A general approach to analyzing a covered bridge such as this will provide a better understanding of its overall character and should be the basis of a checklist to be used for the inspection and condition assessment.

Identify the Visual Character at Close Range

This generally means studying the structure and the materials and craftsmanship that define the bridge. Sometimes the visual character is the result of the juxtaposition of materials that contrast in color and texture. Craft details that contribute to the character of a bridge are evident in the framing members, with hewing or sawing marks visible on the structural members, or "marriage marks" visible on connecting members. Metal tie rods, castings, and original hardware are also important to document. By examining materials at close range it may be possible to differentiate between handcrafted features and machine-made components. There may be other aspects of the structure that help define the character of the bridge, such as the type of trusses and connections, and whether they are covered or exposed, whether the interior framing members are painted or unpainted, or whether there are vestiges of historic signage or graffiti that should be preserved. The combination of all these features makes up the character of a historic covered bridge and distinguishes one historic covered bridge from another.

⁸ A detailed history on the development of American wood trusses can be found in: Justine Christianson and Christopher H. Marston, executive editors, *Covered Bridges and the Birth of American Engineering*, Washington, DC: Historic American Engineering Record, National Park Service, 2015.

Figure 0.8 The four major American truss types developed in the early nineteenth century: the Burr-arch (bottom), Town lattice (top), Long, and Howe.

DELINEATED BY: CHARU CHAUDHRY, KIMBERLY CLAUSER, VUONG DANG, WILLIAM DICKINSON, DAVE GROFF, NAOMI HERNANDEZ, 2002				
NATIONAL COVERED BRIDGES HISTORIC PRESERVATION SERVICE UNITED STATES DEPARTMENT OF THE INTERIOR		PINE GROVE BRIDGE - 1884 SPANNING OCTORARO CREEK AT ASHVILLE & FORGE ROADS LANCASTER COUNTY		PENNSYLVANIA
PINE GROVE		SHEET 2 OF 7		HISTORIC AMERICAN ENGINEERING RECORD PA-586

Protect and Maintain Historic Materials and Features

After identifying the features that are significant and should be retained in the process of rehabilitation work, then it is important to address their protection and maintenance. Protection generally involves the least degree of intervention, is preparatory to other work, and includes the maintenance of historic material. Maintenance treatments should include the regular cleaning of leaves and debris from the structure, the cyclical cleaning of roof systems, and re-applying protective coatings, as well as the maintenance of fire retardant and suppression systems, alarm systems, and other temporary protective measures. Although a historic bridge will usually require more extensive treatment, an overall evaluation of its physical condition should always begin at this level.

Structural Analysis

As part of the overall evaluation, a licensed engineer should complete a structural analysis, which should assess all of the bridge components, noting existing conditions as well as the probable causes of components' failures. The analysis should also determine current load capacities (live, dead, snow, and wind load) and what options are available to maintain, lower, or increase the capacity if desired. Whenever possible, the options should work with and complement the original design, not supersede it.

Repair Historic Materials and Features

If the physical condition of character-defining materials and features warrants additional work, repairing is recommended. Rehabilitation guidance for the repair of historic materials such as wood, masonry, and metals calls for the least degree of intervention possible, such as Dutchman repairs, sistering, consolidating, or otherwise reinforcing or upgrading members according to recognized preservation methods. Repairing also includes the limited replacement in kind, or with compatible substitute material, of extensively deteriorated or missing parts of features when there are surviving prototypes (for example, truss components, knee braces, bedding timbers or portions of wood shingle or metal roofing). Using the same kind of material and species of wood is preferred, but substitute material is acceptable if the form and design as well as the substitute material itself convey the visual appearance of the remaining parts of the feature and finish. For example,

changing the species of wood to allow for greater structural capacity and decay resistance is preferred to augmenting the truss with modern materials such as glulam or steel to achieve increased structural capacity. However, modern materials, such as engineered timber beams, may be acceptable if they are the same size as the historic wood component and generally have the same structural and visual characteristics as the historic wood member.

Replace Deteriorated Historic Materials and Features

When the level of deterioration or damage to materials precludes repair, entire character-defining features should be replaced with new materials. If the essential form and detailing are still evident so that the physical evidence can be used to re-establish the feature as an integral part of the rehabilitation, then its replacement is appropriate. Like the guidance for repair, the preferred option is always replacement in kind. Because this approach may not always be technically or economically feasible, provisions may be made to consider the use of compatible substitute material. For example, if the original wood species is unavailable, substitute a replacement member of a visually compatible species that has an equal structural rating or choose an engineered wood beam over a non-wood (such as steel) structural member. When replacing bridge components, it is important to recognize that all of elements work as a unit and altering or changing any of the components can alter the overall performance of the bridge.

Design for the Replacement of Missing Historic Features

When an entire interior or exterior feature is missing (for example, a truss component, portal feature, or historic signage), it no longer plays a role in physically defining the historic character of the bridge unless it can be accurately recovered in form and detailing through the process of carefully documenting the historical appearance. Although accepting the loss is one possibility, where an important feature is missing, its replacement is always recommended in the Rehabilitation Guidelines as the preferred course of action. Thus, if adequate historical, pictorial, and/or physical documentation exists so that the feature may be accurately reproduced, and if it is desirable to re-establish the feature as part of the bridge's historical appearance, then designing and constructing a new feature based on such information is appropriate. However, a second acceptable option for the replacement feature is a new design that is compatible with the remaining character-

defining features of the historic bridge. The new design should always take into account the size, scale, and material of the historic bridge itself and, most importantly, should be clearly differentiated so that a false historical appearance is not created; it should not negatively impact or take away from the original design intent. Historic and new materials may not always be distinguishable from one another even upon close inspection, as in circular-sawn members of the same or a similar species. New work should therefore be differentiated from the old by dating new elements, and recorded on as-built drawings.

Alterations/Additions for New Use

Some exterior and interior alterations to a historic bridge may generally be needed to ensure its continued use, but those alterations should not radically change, obscure, or destroy character-defining spaces, materials, features, or finishes. Alterations may include supplemental framing to allow increased capacity; providing a pedestrian walkway; installing curbs and/or guardrails; cutting new openings to allow light infiltration; or installing new lighting or fire suppression systems. Alterations may also include the selective removal of bridge features or other features of the environment or site that are intrusive and therefore detract from the overall historic character. The construction of an addition may seem warranted but should be avoided, if possible, and considered only if those needs cannot be met by altering secondary non-character-defining spaces. If, after a thorough evaluation, an addition is still judged to be the only viable alternative, any necessary alterations should be designed and constructed to be clearly differentiated from the historic bridge. The character-defining features should not be radically changed, obscured, damaged, or destroyed.

If implementing any of these alterations it is important to emphasize reversibility; minimal damage to historic material integrity; rehabilitation and continued maintenance of the historic structural system; selection of a method of reinforcing that allows the historic structure to continue carrying at least its own dead load; and a means of reinforcing that works in conjunction with the historic structure to avoid damaging the latter. Some alterations may have been done in previous rehabilitation attempts that are incompatible to the overall design or have done more harm than good. Just because an intervention is more than fifty years old does not mean it is historically correct and should be preserved.

Accessibility and Safety Code Considerations

Work done to meet accessibility and health and safety code requirements is usually not a part of the overall process of protecting or repairing character-defining features; rather, such work is assessed for its potential negative impact on the bridge's historic character and its holistic integration with the character-defining features. A rehabilitation project for a bridge open only to pedestrian traffic may have different structural strictures imposed on it than a bridge rated for vehicular traffic, depending on code requirements for pedestrian loading and occupancy. Due to the varied load requirements, modern materials such as steel beams and glulam timbers are often introduced into the treatment plan. While in some cases it is determined that the only way to keep the bridge viable is to introduce these measures, often other solutions are available. Solutions such as lowering the load limit, bypassing the bridge, using a lighter deck, or using a stronger species at key locations should be exhausted before introducing materials that make the original design obsolete.

Using the Guidelines

The *Guidelines for Rehabilitating Historic Covered Bridges* were developed to ensure that the overall historic character of a historic covered bridge is retained in the rehabilitation. Alterations that are necessary to bring the bridge into compliance with code-mandated requirements and allow the bridge to remain in use should be incorporated in a manner that is compatible with its character-defining features.

The Guidelines therefore focus on the structural and primary character-defining features of a historic covered bridge. They are organized according to their function as part of a bridge in the following order:

1. General principles
2. Superstructure: timber truss system, connections, lateral bracing, and floor system
3. Substructure: abutments, wing walls, and piers
4. Exterior envelope: siding, roof system, wall openings, and penetrations
5. Site features: roadway approaches; drainage features; site, setting, and context; and traffic engineering
6. Safety and protection: features and systems such as lightning protection; fire prevention, detection, and suppression; and lighting



Figure 0.9a-c The 2005 rehabilitation work on the Eldean Bridge in Ohio is a good example of repairing and replacing missing historic character-defining features, and reversing an earlier inappropriate intervention. The 1960s reinforcing rods were removed on the 1860 Long truss, and replaced with wooden wedges driven in at the base of the diagonal counterbraces, thus prestressing the truss as prescribed by Stephen Long.

The Guidelines are intended to assist in applying the Standards to the rehabilitation of a historic covered bridge. They are presented in a two-column format. Those approaches and techniques that are consistent with the Standards (preserving as much as possible of the historic fabric and character of the bridge) are listed in the “Recommended” column on the left. Treatments that could adversely affect the bridge’s historic character and diminish historic features and fabric are listed in the “Not Recommended” column on the right.

To provide clear and consistent guidance, the “Recommended” courses of action in each section are prioritized in the order of historic preservation concerns so that a rehabilitation project may be successfully planned and completed. In order for a rehabilitation project to meet the Standards, the important or “character-defining” features and materials of a historic covered bridge should be identified first, so that they are retained and preserved, while updating the bridge as necessary to keep it in use. Rehabilitation guidance in each section begins with protection and maintenance, the work that should be maximized in every project to enhance overall preservation goals. Next, where some deterioration is present, repair of the bridge’s features and materials is recommended. Finally, when deterioration is so extensive that repair is not possible, the most problematic area of work is addressed: replacement of historic features and materials with new materials. When an entire feature no longer exists, such as a distinctive wall opening or signage, it no longer

plays a role in defining the historic character of the bridge. However, if there is adequate historical, pictorial, or physical documentation, the feature may be accurately reproduced if it is important to re-establish it as part of the bridge’s historic appearance. In some, generally limited, instances, a new design for the missing feature may be appropriate if it is compatible with the still extant character-defining features of the bridge. A new design should be subtly differentiated so that it does not give the bridge a false historical appearance.

Safety and Protection, the final chapter of the Guidelines, focuses on work that must be done to meet code issues. Although this work is quite often an important aspect of rehabilitation treatment projects, it is usually not a part of the overall process of protecting or repairing character-defining features; rather, such work is assessed for its potentially negative impact on the bridge’s historic character. For this reason, particular care must be taken not to radically change, obscure, damage, or destroy character-defining materials or features in the process of undertaking the work of making the bridge code compliant.

These Guidelines are not intended as a technical guide in completing rehabilitation tasks. They are written so that everyone from the individual owner to an experienced bridgewright can understand and interpret the Rehabilitation Standards. Numerous technical references can be found in the Bibliography.



THE SECRETARY OF THE INTERIOR'S STANDARDS FOR REHABILITATION

Rehabilitation is defined as the act or process of making possible a compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values.¹

1. A property will be used as it was historically or be given a new use that requires minimal change to its distinctive materials, features, spaces, and spatial relationships.
2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alteration of features, spaces, and spatial relationships that characterize a property will be avoided.
3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.
4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.
5. Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.
6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.
7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that damage historic materials will not be used.
8. Archeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.
9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work will be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.
10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

¹"The Secretary of the Interior's Standards for Historic Preservation Projects," 36 CFR Part 68, *Federal Register* Vol. 60, No. 133 (July 12, 1995), 35843-44.

Figure 0.10 The oldest Town lattice truss in the country, the Bath-Haverhill Bridge in New Hampshire was stabilized with a series of cross-bracing to maintain the bridge's alignment during rehabilitation. HAER NH-33-14, Jet Lowe, 2003.





RECOMMENDED	NOT RECOMMENDED
<p>Identifying, retaining, and preserving the structural and cladding systems, supports, site, and other related features that are important in defining the overall historic character of the historic covered bridge.</p>	<p>Preparing treatment plans without consulting engineers, bridgewrights, historians, and preservationists knowledgeable about historic covered bridge technology.</p>
<p>Conducting a condition assessment of the historic covered bridge that documents existing conditions, notes deficiencies as well as causes of failure, and prescribes treatment recommendations. Assessment should include an engineering analysis by a licensed structural engineer and a treatment plan developed in consultation with bridgewrights and preservationists, all of whom are experienced in the treatment of historic covered bridges.</p>	<p>Executing a treatment plan without first documenting the existing condition of the historic covered bridges with photos or drawings.</p>
<p>Determining the eligibility of the bridge for the National Register of Historic Places through the prescribed procedure of the state or other jurisdiction in which the bridge is located.</p>	<p>Not documenting a covered bridge prior to a project that will affect its character-defining features.</p>

Figure 1.1 The fully rehabilitated Burr-arch truss at Jericho Road Covered Bridge, MD, in process of being moved into position over its abutments. HAER MD-187-20, Jet Lowe, 2015.

GENERAL PRINCIPLES

RECOMMENDED

Protecting and maintaining features of the original design intent of the covered bridge as part of the character-defining features.

Establishing a cyclical maintenance plan, delineating tasks to be completed periodically (every 1 to 5 to 10 years).

Maintaining all bridge components in sound condition by keeping any metal components free from rust, and treating wood components with appropriate preservatives and coatings.

Maintaining protective coatings like paint, moisture repellents, and fire retardants or re-coating as necessary.

Repairing features using the least intrusive means possible. Any alterations to the historic structure should be reversible.

Constructing non-damaging, temporary shoring and support systems that carry the load of the bridge while undertaking repairs. Prior to needed repairs, the shoring should be adequate to support the dead load and provide for removal of all the stresses in the truss.

Ensuring skilled craftsmen familiar with covered bridge timber framing execute repairs. For example, replicating historic joinery and hand-chiseling joint connections to ensure tight and secure fits.

NOT RECOMMENDED

Allowing a bridge to fall into disrepair from lack of maintenance or letting deferred maintenance become demolition by neglect.

Using treatments or products that accelerate the deterioration of structural material, such as untested chemical applications, sealants that prevent moisture evaporation, or irreversible treatments.

Using coatings that have been untested or may be detrimental to the structure and applying them in a haphazard manner.

Repairing components with dissimilar materials or altering the historic dimensions.

Using temporary stabilization and shoring methods and systems that damage the structure or its character-defining features.

Performing structural repairs while structural members are under stress.

Allowing unskilled workers unfamiliar with traditional timber framing, historic masonry, and covered bridge design and structural engineers inexperienced with covered bridge design to execute repairs.

GENERAL PRINCIPLES



Figure 1.2a-b An engineer inspecting the abutment and lower chord, focused on analyzing the decay at the bearing seat. Below, sweeping the trusses and horizontal surfaces at least once a year is simple yet effective maintenance procedure.



Figure 1.2c-d Using an experienced craftsman to replicate an arch member and recreate character defining features such as notches for a Burr-arch truss.



Figure 1.2e-f Negative camber from decayed lower chord at Adams Mill Bridge, IN. The solution was to jack up the bridge 2 feet and replace the lower chord with four smaller timbers, saving 90% of diagonals and arch members in the truss. A new window was added, allowing visitors to take pictures of the adjacent historic mill while an awning keeps rain out.

GENERAL PRINCIPLES

RECOMMENDED

Replacing in kind, or with substitute material, those components or features that are either extensively deteriorated or are missing when there are surviving prototypes. Substitute material should be of the same form and/or species and convey the same design and overall visual appearance as the historic feature; and, at a minimum, be equal to the original material's load-bearing capabilities. When new material cannot readily be distinguished from old, new elements should be marked with their date of installation.

Reversing an inappropriate intervention or alteration that is more than fifty years old.

Replacing entire structural components that may be repaired and/or supplemented.

Specifying in-kind species and grade for replacement timber when available. When there are questions regarding the structural capacity of new versus old timber, carry out structural testing and design the repair or replacement based upon structural properties as determined by the tests.

Allowing sufficient time in the contract for timber procurement and seasoning (drying).

Specifying appropriate grades of timber needed to serve the appropriate purpose.

Celebrating the conclusion of long rehabilitation project by including all those involved (from the politicians to the timber framers), and inviting the residents and bridge users to participate so that they have a vested interest in protecting the bridge for the future.

NOT RECOMMENDED

Replacing a structural member or other feature of the structural system when it could be augmented and retained.

Installing a visible replacement feature that does not convey the same visual appearance as the original, such as replacing an exposed wood beam with a steel one.

Retaining an inappropriate intervention or alteration just because it is more than fifty years old.

Replacing historic material with engineered material, such as replacing solid, sawn timber with engineered timber. The use of non-historic steel, I-beams, or components should be avoided.

Specifying unrealistic low levels of moisture content, especially for timber.

Specifying higher grades of timbers than are needed to serve the purpose.

Reopening the bridge with little to no fanfare. If the local users have no sense of ownership, there is little motivation for them to invest in maintaining the bridge.

GENERAL PRINCIPLES



Figure 1.3a-b Seasoning timbers outdoors, even over a snowy winter, is the preferred method of drying structural timbers, time permitting. Below, white oak timbers being air-dried in a heated garage. While the drying process is expedited, the exterior of the timbers dry quicker than the interior, which can cause checking or warping. (Note that checks on compression members don't affect its structural capacity.)

Figure 1.3c-d Using come-alongs to correct the racked truss geometry and negative camber at Gilpin's Falls Covered Bridge, MD. Below, after the crew moved the Cataract Bridge, IN, off its abutments, they used bottle jacks to gradually restore camber beneath a replacement lower chord.

Figure 1.3e-f At the end of the project: celebrate! Indiana Governor Mitch Daniels opens the Moscow Covered Bridge leading a motorcycle parade. Below, mounted Maryland state park rangers at the Jericho Road Covered Bridge opening.





RECOMMENDED	NOT RECOMMENDED
<p>Identifying, retaining, and preserving the timber truss and related features that are important in defining the overall historic character of the covered bridge. This includes type of materials (such as wood species), truss type, and features, such as upper and lower chords, arches, diagonal bracing members, and connections (treenails, bolts, tie rods).</p>	<p>Removing or substantially changing visible features of historic structural systems which are important in defining the overall historic character of the bridge, so that, as a result, the character is diminished. Altering the design of the truss system so that the truss no longer functions as originally intended or becomes overloaded.</p>
<p>Protecting and maintaining the structural system by cleaning all dirt, debris, leaves, and vegetation from the structure on a seasonal basis by keeping roofing in good repair; ensuring wood structural members are free from insect infestation and fungal decay; and keeping the structural members protected from moisture infiltration.</p>	<p>Failing to protect and maintain the structural system on a cyclical basis so that deterioration of the structural system results. Changing the use of the bridge, in ways that could overload the existing structural system, or continuing to use it in such a way that overloading occurs.</p>
<p>Ensuring that structural members are free from insect infestation and fungal decay.</p>	<p>Demolishing part of a truss system that could be retained and replacing it with a new truss, either built of wood members or incompatible materials.</p>
<p>Keeping the structural members protected from moisture infiltration.</p>	<p>Using destructive probing techniques that will damage or destroy structural material</p>
<p>Examining and evaluating the physical condition of the structural system and its individual features using non-destructive techniques (such as thermal imaging 3D scanning, impact-echo, probe resistance, and moisture meter).</p>	<p>Upgrading the bridge structurally in a manner that diminishes the historic character of the structure, such as replacing southern yellow pine chord members with steel or glulam beams when similar material or alternate wood species is a viable alternative.</p>
<p>Ultrasound is an effective nondestructive testing method for wooden trusses making it possible to identify truss members that require replacement despite their external appearance.</p>	<p>Relying solely on ultrasound to assess the condition of joints where multiple wooden members connect.</p>

Figure 2.1 Designated a National Historic Landmark, California's Powder Works Bridge exhibits a well maintained Smith Truss and remains open for local traffic. HAER CA-313-10, Jet Lowe, 2004.

SUPERSTRUCTURE FEATURES

Timber Truss and Connections

RECOMMENDED

Repairing the structural system by using the least intrusive means possible.

Repairing deteriorated structural components utilizing recognized preservation treatments such as:

- Dutchman/splicing-in methods – removing deteriorated fabric back to sound wood and replacing with similar material of the same dimensions.
- Augmenting or upgrading individual parts or features. For example, weakened structural members such as posts can be paired with a new member, braced, or otherwise supplemented and reinforced.
- Applying epoxies and fillers where appropriate, following manufacturer recommended application procedures.

Reintroducing positive camber to the bridge structure when possible, but only to the degree that is determined to be original to the bridge in order to avoid damage and changing the intended structural function of the trusses (Town lattice trusses may be an exception).

NOT RECOMMENDED

Repairing structural components with dissimilar material or altering the historic dimensions.

Using substitute material that does not equal the load-bearing capabilities of the historic material and design.

Replacing entire structural components which may be repaired and/or supplemented.

Using fillers or epoxies that have been untested or may be detrimental to the structure and applying them in a haphazard manner.

Using materials that are physically or chemically incompatible.

Leaving negative camber in place (Town lattice trusses may be an exception).

Using substitute material that does not equal the load-bearing capabilities of the historic material and design.

SUPERSTRUCTURE FEATURES

Timber Truss and Connections



Figure 2.2a Copper naphthenate is an excellent preservative to protect from moisture infiltration, recommended to be painted on each timber to timber joint. **Figure 2.2b** Ultrasound field testing at the Salt Creek Covered Bridge, OH. The transducers read measurements which identified defective members in need of replacement.

Figure 2.2 c-d A "brooming" compression failure in this arch required replacement of both the arch section and post. The repair salvaged all other sound timbers, and the splice was bolted in place. Comprehensive repairs to the Medora Bridge, IN, enabled the truss to once again carry its share of the load.

Fig 2.2e Metal bracing saved this rotted joint for years at the Eldean Bridge, OH, until an appropriate repair could be implemented. **Figure 2.2f** Lower chord timbers and fishplates replaced decayed members in an historically accurate manner.

SUPERSTRUCTURE FEATURES

Timber Truss and Connections

RECOMMENDED

Replacing in kind, or with a compatible material, those components or features that are either extensively deteriorated or are missing when there are surviving prototypes. Substitute material must be structurally sufficient, physically compatible with the rest of system, and, where visible, must have the same form, design, and appearance as the historic feature.

Using metal materials (bolts, plates, rods) that are compatible with the original design and with each other and the structural members.

Replicating missing or deteriorated historic hardware such as iron spikes and tie-rods. They should match the original in form, design, and overall visual appearance.

If entire timbers are replaced, consider using sound portions of the removed members as material for other repairs.

Alterations/Additions for New Use

Correcting structural deficiencies or making code-required alterations in a manner that preserves the structural system and individual character-defining features.

NOT RECOMMENDED

Upgrading the bridge structurally in a manner that diminishes the historic character of the structure, such as replacing southern yellow pine chord members with steel or glulam beams when similar material or alternate wood species is a viable alternative.

Using substitute material that does not equal the load-bearing capabilities of the historic material; does not convey the same appearance of the historic material, or is physically incompatible.

Replacing a structural member or other feature of the structural system when it could be augmented and retained.

Installing a visible replacement feature that does not convey the same visual appearance. For example, replacing an iron spike with modern fasteners.

Replacing a historic timber when it could be augmented or retained.

Radically changing or damaging structural features that are character-defining while trying to correct structural load-carrying deficiencies or making code-required alterations.

SUPERSTRUCTURE FEATURES

Timber Truss and Connections



Fig 2.3a-b A rotted section of a lower chord, not discovered until after the siding was removed. Below is a sample of replacement chord members, dressed to accept the arch.

Fig 2.3c-d Replacing the bearing seat in kind at Engle Bridge, OH, which failed due to poor drainage. The rotted ends were replaced by new timbers that were epoxied and bolted to the original timbers.

Fig 2.3e-f Replacement posts and diagonal braces at the Eldean Bridge, OH, matching the original craftsmanship of the historic Long truss.

SUPERSTRUCTURE FEATURES

Bracing Systems

RECOMMENDED

Identifying, retaining, and preserving bracing systems that are important in defining the overall character of the historic covered bridge, such as upper and lower lateral bracing, tie beams, and knee braces.

Alerting vehicle operators to height limitations at bridge approaches to prevent vehicular damage to knee braces.

Protecting and maintaining the bracing system by ensuring that members are free from insect infestation, fungal decay, and moisture infiltration.

Inspecting bracing members for deterioration or damage on a cyclical basis.

Repairing bracing components with similar material that matches the historic in appearance, dimension, load-bearing capacity, and detailing.

Properly executing repairs by replicating historic connections including mortise and tenon, wedges, and bolts.

NOT RECOMMENDED

Removing, covering, or radically changing the visible features of historic bracing systems; or demolishing part of the bracing system that could be augmented and retained, and replacing it using new wood members or incompatible materials.

Not alerting vehicle operators of height restrictions, making knee braces vulnerable.

Failing to provide proper bridge maintenance so that deterioration of the bracing system results.

Repairing bracing components with dissimilar material or altering the historic dimensions.

Repairing bracing using modern fasteners instead of original mortise-and-tenon pegs or iron bolts or spikes.

SUPERSTRUCTURE FEATURES

Bracing Systems



Figure 2.4a-b Top, a very poorly crafted, old but non-original housed mortise-and-tenon joint between a post and upper chord. Below, a finely crafted, tight fitting similar joint in the same bridge.



Figure 2.4c-d Top: Replacing in kind with traditional notched sway bracing, fastened with a nail. Below: Inserting replacement timbers in kind while preserving many of the original hand hewn braces at Taftsville Bridge, VT.



Figure 2.4e-f The repair of the jowl of this low-stressed post incorporates salvaged, in kind material at Gilpin's Falls, MD. Multiple close-fitting pieces of wood were used in the repair process, as was waterproof glue.

SUPERSTRUCTURE FEATURES

Bracing Systems

RECOMMENDED

Replacing in kind, or with a compatible substitute material, those portions or features of the bracing system that are either extensively deteriorated or are missing when there are surviving prototypes such as lateral bracing, knee or check braces, and iron or pegged connections. Substitute material should convey the same form, design, and overall visual appearance as the historic feature; and, at a minimum, be equal to its load-bearing capabilities.

Using metals (bolts, spikes) that are compatible with each other and the structural members to prevent such issues as galvanic corrosion.

Replicating missing or deteriorated historic hardware such as bolts and iron spikes. They should match the original in form, design, and overall visual appearance.

Using ungalvanized hardware or galvanized hardware with the zinc removed from the most visible surfaces.

Repairing bracing components with similar material that matches the historic in appearance, dimension, load-bearing capacity, and detailing.

Alterations/Additions for New Use

Designing and installing missing components if the bracing system feature is missing and physical, historical, or pictorial evidence exists to create an accurate replacement and allows for historically correct reinstallation. Any supplemental component should be reversible.

NOT RECOMMENDED

Installing a visible replacement feature that does not convey the same visual appearance; for example, replacing wood knee braces with steel members.

Failing to reinstall bracing components that were original to the design.

Replacing a structural member or other feature of the bracing system when it could be augmented and retained.

Creating a false historical appearance because the replaced structural components are based on insufficient historical, physical, or pictorial documentation.

Using incorrect types of metal hardware which could lead to galvanic action (corrosion).

Repairing bracing components with dissimilar material or altering the historic dimensions.

SUPERSTRUCTURE FEATURES

Bracing Systems



Figure 2.5a-b Original upper lateral bracing members of the Smith truss at Cataract Bridge, IN, had rotted due to a leaking roof. They were replaced in kind, keeping the original hardware.



Figure 2.5c-d Riveted steel gusset plates were added in the 1950s at Taftsville Bridge, VT. This non-historical intervention was reversed during rehabilitation with traditional timber sway braces.



Figure 2.5e-f An example of a loose diagonal brace with traditional stepped notches in need of adjustment. Below, a replacement tension diagonal matches the double-stepped connection of the original post in a Smith truss at Rinard Bridge, OH.



SUPERSTRUCTURE FEATURES

Floor Systems

RECOMMENDED

Identifying, retaining, and preserving the floor structure system and individual features of that system important in defining the overall character of the historic bridge.

Replacing floor systems or features when the materials have fulfilled their useful service life, or are intended to be replaced in kind on a long-term cyclical schedule.

Protecting and maintaining the floor system by establishing a cyclical maintenance plan.

Ensuring the floor system is free from insect infestation, fungal decay, dirt, and debris.

Maintaining positive drainage to prevent water from reaching the floor system components.

Repairing the floor system by using the least intrusive means possible.

Ensuring adequate bearing surface is provided for floor beam members.

Replacing in kind—or with substitute material—those portions or features of the floor system that are either extensively deteriorated or are missing when there are surviving prototypes such as joists, stringers or floor planks, and iron or steel connections.

Using metals (bolts, plates, rods) that are compatible with the original design, with each other, and with the floor system members to prevent such issues as galvanic corrosion.

NOT RECOMMENDED

Altering the design of the floor system so that the floor structure no longer functions as originally intended.

Demolishing part of the floor system that could be augmented and retained and replacing it with incompatible materials.

Changing the load rating of the bridge which could overload the existing floor system.

Not providing for proper drainage of all components within close proximity to the ground.

Repairing floor components with dissimilar material or altering the historic dimensions.

Using substitute material that does not equal the load-bearing capabilities of the historic material and design.

Upgrading the bridge structurally in a manner that diminishes the historic character of the floor system, such as replacing floor beams with non-wood materials such as steel beams.

Replacing a structural member or other feature of the floor system when it could be augmented and retained.

SUPERSTRUCTURE FEATURES

Floor Systems



Figure 2.6a Transverse deck plank, laid below a curb and rub rail at Zumbrota Bridge, MN. **Figure 2.6b** Running boards act as a sacrificial wear surface, are often installed to accommodate heavier traffic, prolong the life of the decking, and can also act as a speed deterrent.



Figure 2.6c-d Newly installed longitudinal decking (running plank) at Forsythe Bridge, IN. Below, even a weathered and worn floor system should be inspected carefully to see if it could perform as required. Repairs and/or additional fasteners might preserve the floor's rich visual record of service.



Figure 2.6e Diagonal decking found at Rinard Bridge, OH. **Figure 2.6f** Nail-laminated decking is typically not a historically correct treatment and should be replaced in most cases (unless it was the original decking system).



SUPERSTRUCTURE FEATURES

Floor Systems

RECOMMENDED

Replicating missing or deteriorated historic hardware such as iron spikes and bolts that match the original.

Designing and installing missing components if the structural feature is gone but physical, historical, and/or pictorial evidence exists to inform the creation of an accurate replacement and correct re-installation.

Installing a new floor system when mandated by project-driven code requirements if such an alteration maintains the character and appearance of the original and does not obscure, damage, or destroy character-defining features.

Exploring all available options and alternatives such as lowering load limits before installing a new or upgraded floor system that alters or destroys the character-defining features.

Alterations/Additions for New Use

Ensuring the design of a new floor system does not have a detrimental impact on the original design intent of the bridge.

NOT RECOMMENDED

Installing a visible replacement feature that does not convey the same visual appearance (for example replacing an exposed wood beam with a non-wood component or wood components that are visually intrusive).

Creating a false historical appearance because the replaced floor system components are based on insufficient historical, physical, and/or pictorial documentation.

Radically changing or damaging floor system features that are character-defining while trying to correct structural load-carrying deficiencies, such as installing a new floor system that incorporates steel or engineered lumber.

Installing a new floor system when such radical changes will damage, obscure, or destroy character-defining features of the historic covered bridge.

Adding floor structure components that will potentially increase the weight of the bridge, affecting the overall engineering design.

Installing a new floor system that functions independently of the truss system.

Installing wearing surfaces that negatively impact the floor structure system, such as increasing the dead load. Also, multiple layers may promote an environment for decay to develop.

SUPERSTRUCTURE FEATURES

Floor Systems



Figure 2.7a-b A transverse subfloor being installed over historic sleepers at Eldean Bridge, OH. A layer of V-shaped diagonal decking was nailed over top. Below, a laminated subfloor at Taftsville Bridge, VT.



Figure 2.7c-d Detail showing spacers below the curb, allowing for dirt and runoff to easily leave the deck, reducing rot on the deck and lower chord below, at Henniker Bridge, NH. Below, original diagonal stringers preserved at King's Bridge, PA.



Figure 2.7e-f Metal straps and bolts used as part of the historic fishplate design on the Moscow Bridge, IN. Replacing lower lateral bracing in kind on a Howe truss at Stonelick-Williams Bridge, OH.





SUBSTRUCTURE FEATURES

CHAPTER 3

RECOMMENDED	NOT RECOMMENDED
<p>Identifying, retaining, and preserving substructure features that are important in defining the overall historic character of the bridge, such as stone or concrete abutments, piers, wing walls, and approaches.</p>	<p>Removing or radically changing substructure features. Replacing or rebuilding major portions of exterior masonry abutments or wing walls that could be repaired, resulting in essentially new construction.</p>
<p>Conducting an assessment of existing conditions, noting causes of failure and listing potential treatment options. The assessment should include a structural analysis of the abutments and piers.</p>	<p>Failing to evaluate and treat the various causes of the deterioration of substructure components, such as leaching water, water infiltration, capillary action, extreme weather exposure, substandard materials, mechanical damage, or differential settlement of the structure.</p>
<p>Understanding the engineering principles, hydrological conditions, and geotechnical considerations of an existing historic covered bridge substructure engineering system, design, and construction methodology including materials and techniques.</p>	<p>Proceeding without a complete understanding of engineering principles, hydrological conditions, and geotechnical considerations of a bridge's substructure system.</p>
<p>Protecting and maintaining bridge components that are subjected to erosion from scouring, flooding, and/or ice flow events by regularly scheduling visual inspections.</p>	<p>Neglecting to inspect bridge substructure features after severe weather events that may cause structural deficiencies.</p>
<p>Providing proper drainage in and around substructure components to keep water and snowmelt from reaching wooden components.</p>	<p>Failing to provide proper drainage around substructure components and allowing water to collect, thereby damaging wooden components.</p>
<p>Ensuring that mortared stone masonry is provided with weepholes at the base of the foundation through the mortar.</p>	<p>Plugging weepholes because they are interpreted by untrained masons as open head- joints.</p>

Figure 3.1 Original dressed sandstone was removed and then reinstalled to face a new concrete abutment after rehabilitation at Bennett's Mill Bridge, Kentucky. Bedding timbers support the lower chord, sitting on a concrete seat, seen behind tie down rods, which were historically used as a flood prevention measure. HAER KY-49-6, Jet Lowe, 2004.

SUBSTRUCTURE FEATURES

Abutments and Piers

RECOMMENDED

Cleaning masonry surfaces with the gentlest method possible, such as using low-pressure water, detergents, and brushes.

Removing all vegetation that abuts or surrounds the substructure elements.

Always following manufacturer's recommendations for applying liquid coatings.

Applying compatible protective coatings and paint systems as necessary to maintain in sound condition. Coatings should be vapor permeable.

Protecting substructure elements from stream scour, and removing drift from piers when it builds to significant piles.

Bolster beams or bedding timbers should be cleaned annually to deter formation of decay.

NOT RECOMMENDED

Cleaning masonry surfaces using dry or wet grit or other abrasives. These methods may damage the surface of the masonry material and actually accelerate deterioration.

Allowing vegetation to overtake a structure (trees, vines, etc.) thereby obscuring ongoing deterioration caused by roots and foliage.

Using a cleaning method that involves water or liquid chemical solutions when there is any possibility of freezing temperatures.

Applying coatings such as concrete, shotcrete, or stucco parging to masonry that has been historically uncoated to create a new appearance; applying paint to previously unpainted elements.

Failing to maintain maintenance protocols for substructure features.

Not completing annual inspections for needed maintenance or after a weather event, such as a flood.

Allowing debris to collect on bolster beams or bedding timbers that fosters decay.

SUBSTRUCTURE FEATURES

Abutments and Piers

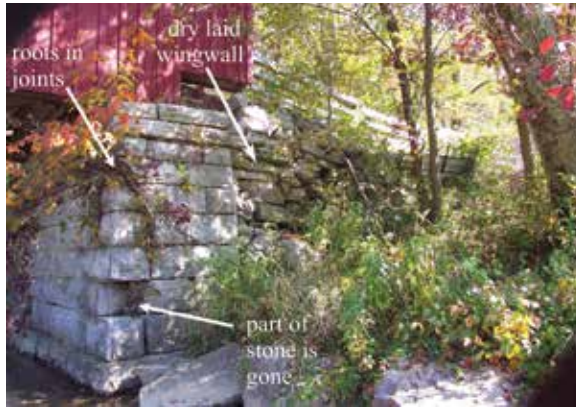


Figure 3.2a-b The engineer's assessment at Cataract Bridge, IN, detected deterioration due to vegetation and roots in the joints. After repair, the abutment stones were relaid to match and riprap added for protection.



Figure 3.2c-d Flood debris piling up on the center pier at Beech Fork Bridge, KY. The condition required emergency removal to avoid further damage to the bridge. Below, evidence of splintered siding due to flooding at Zacke Cox Bridge, IN.



Figure 3.2e-f A circle of scour around a center pier at Medora Bridge, IN. Below, a bolster beam for a Town lattice truss at Henniker Bridge, NH. It sits on a granite pedestal, with spacer blocks below and on top, which allows for easy maintenance and good air circulation.



SUBSTRUCTURE FEATURES

Abutments and Piers

RECOMMENDED

Repairing mortared masonry abutments and piers by repointing the mortar joints where there is evidence of deterioration, such as cracks in mortar joints, loose stone, and damp walls.

Duplicating historic mortar in strength, composition, color, and texture.

Duplicating historic mortar joints in width and in joint profile.

Removing deteriorated mortar by carefully hand-raking the joints to avoid damaging the masonry.

Repairing masonry by removing the damaged material and installing new material that duplicates the historic in strength, composition, color, and texture.

Filling voids with a low-pressure grout mix that is lower in strength than the surrounding substructure elements.

Cutting damaged concrete back to remove the source of deterioration (often corrosion on metal reinforcement bars). The new material should match the historic in composition, texture, color, and strength. The new patch must be applied carefully so it will bond satisfactorily with, and match, the historic concrete.

NOT RECOMMENDED

Removing non-deteriorated mortar from sound joints, then repointing the entire abutment, wall, or pier to achieve a uniform appearance.

Repointing with mortar that is of a higher strength than the surrounding masonry, or changing the width or joint profile when repointing.

Using power equipment rather than hand tools to remove deteriorated mortar from joints prior to repointing.

Repointing with a synthetic caulking compound.

Repairing substructure elements without removing the source of deterioration.

Repairing substructure elements without determining whether the below-grade construction is stable or not.

Backfilling voids with material that is higher in strength than the surrounding substructure elements.

Removing sound masonry; or repairing with new masonry that is stronger than the historic material or does not convey the same visual appearance.

Using substitute material for the replacement component that does not convey the visual appearance of the surviving parts of the masonry feature or that is physically or chemically incompatible.

SUBSTRUCTURE FEATURES

Abutments and Piers



Figure 3.3a-b The timber bearing seat was rotted at Otway Bridge, OH, and replaced by a solid new timber bearing seat (bolster beam, below). Several stones were kept in place in the abutment, while some were replaced in kind.



Figure 3.3c-d The reconstructed wingwall at Eldean Bridge, OH, while being cleaned of all loose mortar and being prepared for repointing. **Figure 3.3d** Not recommended: Mortars should be analyzed to determine compatibility with the surrounding masonry components. Mortar repairs should match both the color and strength of the historic material.



Figure 3.3e-f Reconstructing the dry-laid wing wall behind the abutment at Cataract Bridge, IN. The reconstructed wall matches the original in composition, color and texture, while improving its strength.

SUBSTRUCTURE FEATURES

Abutments and Piers

RECOMMENDED

Applying new or non-historic surface treatments, such as water-repellent coatings, to masonry only after repointing and only if masonry repairs failed to arrest water penetration problems. Coatings should be tested prior to application and should be vapor permeable.

If replacing or adding entire elements, use actual unit masonry in lieu of concrete with masonry-like form liners.

Where timber spread footings (grillage) are found to support abutments and piers, protect the timber from exposure to air by packing with stone and gravel or by other reversible means.

Repairing masonry features by patching, piecing in, or consolidating the masonry using recognized preservation methods.

Repairing dry masonry by traditional methods, as by chinking with stone chips and wedges, thus allowing the structure to self-adjust and drain as intended.

Where streambed erosion may cause headcutting and undermining of piers or abutments, armor the bottom of the stream or divert the force of the current as appropriate to preserve the integrity of the bridge substructure.

NOT RECOMMENDED

Applying waterproof, water repellent, or non-historic coatings such as stucco to masonry as a substitute for repointing and masonry repairs. Coatings are frequently unnecessary, expensive, and may change the appearance of historic masonry as well as accelerate its deterioration.

Installing form liner in lieu of unit masonry features or encasing substructure elements in veneer panels.

Encasing exposed timber spread footings (grillage) of piers or abutments in concrete which will cause deterioration, or using other non-reversible methods of protection.

Removing and replacing masonry features that could be repaired.

Installing mortar in walls that were historically dry laid, allowing hydrostatic pressure to build up and possibly cause significant structural damages.

Disregarding obvious structural deficiencies which may allow primary structural components to fail (such as displacement or settling of piers or abutments from scour), which may allow a bridge's camber to become unsymmetrically loaded and cause collapse of a truss system.

SUBSTRUCTURE FEATURES

Abutments and Piers



Figure 3.4a-b When repairing or replacing masonry elements, similar materials and construction techniques should be utilized. If possible, modern veneer panels should be avoided, such as at Pine Grove Bridge, PA, where the original floor system was replaced by steel I-beams.



Figure 3.4c-d Structural failure due to cracking in the center pier at Deers Mill Bridge, IN. The crack was patched and a new concrete apron poured underneath to stabilize the pier.



Figure 3.4e-f Chinking (filling joints with small stones) rather than the introduction of mortar is the proper rehabilitation method for a dry-laid wall. Below: Preserving the original stonework at Rinard Bridge, OH. The hold down rods (an original design feature) have been replaced in kind, which helps keep the bridge in place during a flood event.



SUBSTRUCTURE FEATURES

Abutments and Piers

RECOMMENDED

Replacing in kind an entire masonry feature that is too deteriorated to repair, using the physical evidence as a model to reproduce that feature.

Dismantling and rebuilding a masonry feature that is too deteriorated to repair using available original materials, such as stone, and supplementing with in kind material, to replicate the original masonry feature. Examples can include large sections of an abutment, piers, and approach wing walls. If using the same kind of material is not technically or economically feasible, then a compatible substitute material may be considered.

Designing and installing a new masonry feature, such as a pier, when the historic feature is missing, and physical, historical, and/or pictorial evidence exists to inform an historically accurate replacement and re-installation.

Alterations/Additions for New Use

Limiting any new excavations adjacent to the historic abutments or piers to avoid undermining the structural stability of the bridge. Studies should be done to ascertain potential damage to archeological resources.

NOT RECOMMENDED

Replacing an entire masonry feature such as an abutment when repair of the masonry and limited replacement of deteriorated or missing parts are appropriate.

Creating a false historical appearance because the replaced feature is based on insufficient physical, historical, and/or pictorial evidence.

Replacing a deteriorated historic masonry feature with a replica feature not consistent with the character-defining features of the historic covered bridge. This includes in size, scale, material, and color.

Introducing a new substructure feature that is incompatible in size, scale, material, and color.

Installing new substructure components that will alter the original design and intent of the truss, such as installing piers where none existed historically.

Carrying out excavations adjacent to an historic covered bridge that could cause the historic abutment to settle, shift, or fail; or could destroy significant archeological resources.

SUBSTRUCTURE FEATURES

Abutments and Piers



Figure 3.5a-b The abutments at Medora Bridge, IN, were sinking and spreading. The solution was to tag and remove each stone, pour a new reinforced concrete footing slab, and then put most of the original stones back in place. Note new skewback.



Figure 3.5c-d Before/after abutment at Gilpin's Falls Covered Bridge, MD. The arch, chord, and post were all encapsulated in concrete, leading to heavy decay. The reconstructed abutment was designed to allow ease of cleaning and maintenance. Note the use of rot-resistant black locust bearing blocks and copper naphthanate to protect and defend the arch ends, end post, and end brace against decay.



Figure 3.5e-f Before/after abutment at Knox Bridge, PA. The arch, chord, and post were all encapsulated in concrete, leading to heavy decay. The reconstructed abutment was designed to allow ease of cleaning and maintenance. Note the use of rot-resistant black locust bearing blocks and copper naphthanate to protect and defend the arch ends, end post, and end brace against decay.



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EXTERIOR ENVELOPE

CHAPTER 4

Siding, Portals and Wall Openings

RECOMMENDED	NOT RECOMMENDED
<p>Identifying, retaining, and preserving wood features that are important in defining the overall historic character of a covered bridge's exterior (such as siding, portals, wall openings, and decorative features).</p>	<p>Failing to identify, evaluate, and treat the causes of wood deterioration, including faulty roofs, cracks and holes in siding, environmental degradation, plant material growing too close to wood surfaces or insect or fungus infestation.</p>
<p>Conducting a condition assessment noting existing conditions, deficiencies, possible causes of failure, and potential treatment recommendations.</p>	<p>Removing or radically changing features and materials that are important in defining the overall character of the historic covered bridge so that, as a result, the character is diminished.</p>
<p>Protecting and maintaining wood features by providing proper drainage so that water is not allowed to pond/pool or potentially reach wooden components.</p>	<p>Failing to identify and treat the causes of wood deterioration, such as leaking roofs, cracks and holes in the siding, or insect or fungal infestation.</p>
<p>Applying chemical preservatives, water repellants, or paint to wood features that are subject to weathering and are traditionally unpainted, such as siding, portals, and wall openings</p>	<p>Using chemical preservatives (such as creosote) which, unless they were used historically, can change the appearance of wood features.</p>
<p>Retaining coatings (such as paint or stain) that protect the wood from moisture and ultraviolet light. Paint removal should be considered only where there is paint surface deterioration and as part of an overall maintenance program involving repainting or applying other appropriate protective coatings.</p>	<p>Radically changing the type of finish or its color or accent scheme so that the character of the exterior is diminished.</p>
<p>Inspecting painted/stained wood surfaces to determine whether recoating is necessary or if cleaning is all that is required.</p>	<p>Stripping paint or other coatings from wood features without recoating.</p>
<p>Retaining historic paint colors in-situ provided that there is evidence that the colors have been used for at least fifty years.</p>	<p>Painting a bridge that has not been previously painted. Applying paint over surfaces which have not been properly prepared.</p>
	<p>Removing paint that is firmly adhering to, and thus, protecting wood surfaces.</p>

Figure 4.1 The portal at the Forsythe Bridge, IN, exhibits several character defining features of a historic Archibald M. Kennedy-built bridge, such as decorative brackets, scrollwork, and trim. HAER IN-106-8, James Rosenthal, 2004.

EXTERIOR ENVELOPE

Siding, Portals and Wall Openings

RECOMMENDED

Applying compatible coating systems to historically-coated wood following proper surface preparation.

Repainting/staining wood features with colors that are appropriate to the original design of the historic bridge.

Evaluating the overall condition of the wood to determine whether more than protection and maintenance, such as repairs to wood features, will be necessary.

Repairing exterior wood by patching, splicing, consolidating, or otherwise reinforcing (or supplementing) the wood using recognized preservation methods. Repair may include the limited replacement in kind, or with a compatible substitute material, of those extensively deteriorated or missing components of wood features when there are surviving prototypes, such as sections of siding, pieces of moldings, or other decorative elements.

Replacing in kind an entire wood feature that is too deteriorated to repair (if the overall form and detailing are still evident) using physical evidence as a model to reproduce the feature or when replacement can be based on historic documentation. Examples of such wood features include siding, decorative details, and architectural features such as brackets, scrolls, and millwork. If using wood is not feasible, then a compatible substitute material may be considered.

NOT RECOMMENDED

Failing to follow manufacturers' product and application instructions when recoating exterior wood features. Cleaning wood components with abrasive materials that can damage historic fabric or its finish.

Using paint/stain pigments on historically-coated wood features that are not appropriate to the bridge.

Failing to undertake adequate measures to ensure the protection of wood features.

Replacing an entire wood feature when repair of the wood and limited replacement of deteriorated or missing components is feasible. Removing wood that could be stabilized, repaired, and conserved, or using untested consolidants and unskilled personnel, potentially causing further damage to historic materials.

Removing a wood feature that is un-repairable and not replacing it, or replacing it with a new feature that does not match.

Altering the historic design or placement of materials, such as installing siding vertically when it was originally installed horizontally. Using substitute material for the replacement that does not convey the same appearance of the surviving components of the wood feature.

EXTERIOR ENVELOPE

Siding, Portals and Wall Openings



Figure 4.2 a-b Before/after views of the Engle Mill Bridge, OH. When rehabilitating the Smith truss, the bridge team re-sided and repainted in kind, maintaining the same openings to match the original.

Figure 4.2c-d Conducting an inspection to assess the condition of the siding and painted surface. Below, a technician wears a protective suit and uses a high pressure sprayer to apply fire retardant to the truss and interior siding.

Figure 4.2e-f Local volunteers apply a fresh coat of bright white paint to the timber railings protecting the truss at the Esther Furnace Bridge, PA. Below, a new coat of white paint is applied to the exterior of the Henninger Farm Bridge, PA.

EXTERIOR ENVELOPE

Siding, Portals and Wall Openings

RECOMMENDED

Designing the Replacement for Missing Features

Designing and installing a replacement wood feature, such as a bracket, portal, or siding, when the historic feature is completely missing. It may be an accurate replacement based on documentary and physical evidence, but only when the historic feature to be replaced coexisted with the features currently a part of the bridge. Or, it may be a new design that is compatible with the size, scale, material, and color of the historic bridge.

Reconstructing openings using historical, pictorial, and/or physical documentation if they have been closed in.

Alterations/Additions for New Use

Designing and installing additional exterior features (such as openings) if required for the new use. Such design should be compatible with the overall design of the bridge and should be clearly differentiated from the historic openings.

NOT RECOMMENDED

Creating an inaccurate appearance because the replacement for the missing feature is based upon insufficient physical or historic documentation, is not a compatible design, or because the feature to be replaced did not coexist with the features currently part of the bridge.

Introducing a new wood feature that is incompatible in size, scale, material, or color.

Installing new openings if no historical, pictorial, and/or physical evidence exists.

Installing new opening configurations that are incompatible with the bridge's historic appearance or that obscure, damage, or destroy character-defining features.

Introducing a new design for an opening that is incompatible with the historic character of the bridge.

EXTERIOR ENVELOPE

Siding, Portals and Wall Openings



Figure 4.3a-b Although a tornado destroyed most of the Moscow Bridge in Indiana, its Kennedy Bridge character-defining features: vine decorations, roof brackets, and elliptical arch opening were carefully reconstructed, before being painted its original white.

Figure 4.3c-d After the Town lattice truss was rehabilitated, the exterior board-and-batten siding was replaced in kind, and a new standing seam metal roof installed at the Newton Falls Covered Bridge, OH.

Figure 4.3e-f Replacement cedar siding in process of being applied to vertical nailers at Gilpin's Falls Bridge, MD. Above, pieces are individually trimmed to fit the shape of the portal. Below, note how the lap siding follows the camber of the bridge.

EXTERIOR ENVELOPE

Siding, Portals and Wall Openings

RECOMMENDED

Replacing in kind an entire opening that is too deteriorated to repair using the same configuration and other design details. If using the same kind of material is not technically or economically feasible when replacing openings deteriorated beyond repair, then a compatible substitute material may be considered.

Designing and installing a new wood feature such as a bracket, portal, or siding when the historic feature is completely missing. It may be an accurate replication using historical, pictorial, and/or physical documentation.

Reconstructing openings using historical, pictorial, and/or physical documentation if they have been closed in.

Alterations/Additions for New Use

Designing and installing additional openings if required for the new use. Such design should be compatible with the overall design of the bridge and should be clearly differentiated from the historic openings.

NOT RECOMMENDED

Replacing an entire opening when repair of materials and limited replacement of deteriorated or missing parts are appropriate.

Creating a false historical appearance by basing a replacement wood feature on insufficient documentation.

Introducing a new feature that is incompatible in size, scale, material, and color.

Installing new openings if no historical, pictorial, and/or physical evidence exists.
Introducing a new design for an opening that is incompatible with the historic character of the bridge.

Installing new opening configurations that are incompatible with the bridge's historic appearance or that obscure, damage, or destroy character-defining features

EXTERIOR ENVELOPE

Siding, Portals and Wall Openings



Figure 4.4a-b Scraping off mud dauber nests to keep roof and truss components free from infestation. Above, an engineer performs a periodic inspection of the roof covering.

Figure 4.4c-d A neglected, porous roof allowed moisture and mold onto the truss and lateral bracing below. After removal, most of the bracing and rafters were repaired and kept intact, and a new shingle roof was replaced in kind.

Figure 4.4e-f An example of mold accumulating on the bottom side of an arch member beneath a leaking roof. Below, internal decay found in upper chord timbers due to roof leakage. Both were repaired with limited replacement in kind.

EXTERIOR ENVELOPE

Roof Systems

RECOMMENDED

Identifying, retaining, and preserving roofs and their functional systems and decorative features that are important in defining the overall historic character of the covered bridge.

The form of the roof is significant, as are its structural components and decorative features (such as weather vanes, snow guards, and lightning protection systems), roofing material (such as slate, metal, wood, roll roofing, or shingles), and size, color, and patterning.

Protecting and maintaining a roof by cleaning the roof covering, ensuring proper roof drainage, and maintaining it in good repair (cladding and flashings). Roof sheathing should also be checked for indications of moisture due to leaks.

Using corrosion-resistant roof fasteners (nails, clips, and screws) to repair or extend the life of the roof.

Protecting a leaking roof with plywood, building paper, or tarps until it can be properly repaired.

Repainting a roofing material that requires a protective coating and was painted historically (such as a standing seam metal roof) as part of regularly-scheduled maintenance.

Applying compatible paint coating systems to historically-painted roofing materials following proper surface preparation

Ensuring that the roof sheathing allows for adequate ventilation (such as wood shingles).

NOT RECOMMENDED

Removing or substantially changing roofs which are important in defining the overall historic character of the covered bridge so that, as a result, the character is diminished.

Stripping the roof of sound historic material, such as wood shingles, shakes, and sheet metal when it still has a service life.

Failing to maintain and clean the roof structure properly so that water and debris collect and cause damage to the roof features, fasteners, sheathing, and the underlying roof structure.

Allowing flashing, caps, and exposed fasteners to corrode, which accelerates deterioration of the roof.

Permitting a leaking roof to remain unrepaired so that accelerated deterioration occurs in the bridge's structural system.

Failing to repaint a roofing material that requires a protective coating and was painted historically as part of regularly-scheduled maintenance.

Applying paint or other coatings to roofing material if they were not coated historically.

Failing to allow for adequate ventilation in roof sheathing.

EXTERIOR ENVELOPE

Roof Systems

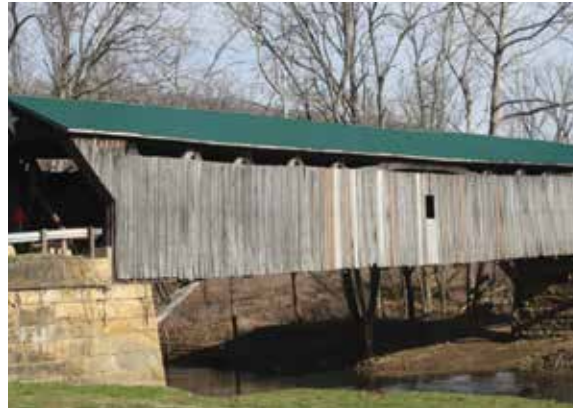


Figure 4.5a-b Nailing down new roof framing purlins, then installing a new replacement metal standing seam roof at Moscow Bridge, IN.

Figure 4.5c-d Ohio's Otway Bridge suffered from 9" of negative camber, was 6" out of alignment, and had worn siding and an old roof. After the lower chords were replaced and the Smith truss was repaired, it received natural stained board-and-batten siding and a new green standing seam metal roof, matching the colors of the original.

Figure 4.5e-f Installation of replacement 24" clear cedar shingles offering triple coverage, in process of being nailed to the purlins atop the Bowmansdale Covered Bridge, PA.

EXTERIOR ENVELOPE

Roof Systems

RECOMMENDED

Repairing a roof by ensuring that the existing historic or compatible non-historic roof structure and covering is sound and waterproof. Repair may include the limited replacement in kind or with a compatible substitute material (such as wood shingles or metal pans), as well as those extensively deteriorated or missing components of features when there are surviving prototypes, such as rafters and tie beams.

Replacing in kind an entire roof covering or feature that is too deteriorated to repair (if the overall form and detailing are still evident) using the physical evidence as a model to reproduce the feature or when the replacement can be based on historic documentation. Examples could include a large section of roofing, exposed rafter tails or sheathing boards. If using the same kind of material is not feasible, then a compatible substitute material may be considered.

Replacing only missing or damaged wooden shingles, shakes or metal pans rather than replacing the entire roof covering.

Designing the Replacement for Missing Historic Components

Designing and installing a new roof covering for a missing or damaged roof, when the historic feature is completely missing. It may be an accurate restoration based on documentary and physical evidence, but only when the historic feature to be replaced coexisted with the features currently a part of the bridge. Or it may be a new design that is compatible with the size, scale, material, and color of the historic bridge.

Alterations/Additions for New Use

Designing and installing additional structural supports if required for correcting structural deficiencies (such as the addition of tie beams or supplemental rafters to accommodate snow loads) or non-historic systems or equipment (such as lightning protection, height restrictions, monitoring or detecting equipment). Such design should be compatible with the overall design of the bridge and should be clearly differentiated from the historic components.

NOT RECOMMENDED

Replacing an entire roof feature, such as the rafters or surface covering, when repair of the historic materials and limited replacement of deteriorated or missing components are feasible.

Failing to extend the service life of a roof covering by not properly repairing or replacing missing components (such as repairing holes in sheet metal roofs or replacing missing shingles).

Installing a visible replacement feature that does not convey the historic visual appearance.

Failing to reuse intact shingles, shakes or pans in good condition when only the sheathing or fasteners need replacement.

Creating an inaccurate appearance because the replacement for the missing roof feature is based on insufficient historical, pictorial, and/or physical documentation, is not a compatible design, or because the feature to be replaced did not coexist with the features currently a part of the bridge.

Introducing a new roof feature that is incompatible in size, scale, material, and color.

Installing new roof features that are incompatible with the bridge's historic appearance or will obscure, damage, or destroy character-defining features.

Changing a character-defining roof form or structural feature, or damaging or destroying character-defining roofing materials as a result of an incompatible roof addition or improperly installed system or equipment.

EXTERIOR ENVELOPE

Roof Systems



Figure 4.6a-b New roof rafters and purlins at Gilpin's are framed prior to receiving cedar shingles. Below, a harnessed crew laying out purlins prior to nailing cedar shake shingles at Jericho.

Figure 4.6c-d After the Siegrist's Mill Bridge, PA, was lost in a flood, the replacement Burr-arch truss was replaced in kind. Above, using a bucket lift to install the replacement shingle roof. Below, the bridge shown fully sheathed.

Figure 4.6e-f Decorative rake boards capping the roof overhang, matching shape and paint color in kind at Bowmansdale Bridge, PA. Below, a new standing seam roof being installed above a rehabilitated truss at Forry's Mill Bridge, PA.



WEIGHT
LIMIT
131
161
191

JERUSALEM
VILLAGE
COVERED
BRIDGE



RECOMMENDED	NOT RECOMMENDED
<p>Identifying, retaining, and preserving bridge approach and site features that are important in defining its overall character. Approach features may include roadway approaches, drainage features, railings, and signage. Site features may include circulation systems such as roads, paths, or parking; vegetation, such as trees, shrubs or herbaceous plant material; landforms, such as terracing, berms or grading; furnishings such as seating, lighting, and fencing; and subsurface archeological resources.</p>	<p>Removing or radically changing those approach and site features which are important in defining the overall historic character of the bridge site so that, as a result, the character is diminished.</p>
<p>Retaining the historic relationship between the bridge and the site.</p>	<p>Removing or relocating bridge's or landscape features, thus destroying the historic relationship between bridge and the site.</p>
<p>Protecting and maintaining the approaches to the bridge site by providing proper drainage to ensure that water does not erode the soil that supports the bridge abutment or cause deterioration of the bridge components.</p>	<p>Failing to maintain positive drainage at the approach so that the historic covered bridge and other site features can be damaged or destroyed.</p>
<p>Providing continued protection and maintenance of the bridge site through cyclical cleaning and removal of leaves and debris; reapplication of protective coatings such as asphalt sealer; and maintaining the roadway in good condition.</p>	<p>Failing to provide adequate protection of material on a cyclical basis so that deterioration of a bridge approach results.</p>
<p>Installing approach features that are designed to protect the bridge and encourage safety, such as height and weight limiting, appropriate signage, and traffic calming devices.</p>	<p>Failing to install approach features that protect the covered bridge and encourage traffic calming.</p>
<p>Planning and carrying out any necessary investigation of areas where the terrain will be altered, using professional civil engineers, landscape architects, and/or archeologists to assess and design minimum impact treatments when preservation in place is not feasible.</p>	<p>Failing to survey the bridge site prior to the beginning of rehabilitation work, resulting in damage to, or destruction of, important landscape features or archeological resources.</p>
<p>Using signs or interpretive markers to identify the bridge, including history, builder, dates of construction and alteration.</p>	<p>Failing to identify and interpret the bridge, or removing signage or markers.</p>

Figure 5.1 Telltales warn drivers of the height restrictions of the bridge which in turn limit the weight as well. Hung well away from the bridge, these telltales do not detract from the visual setting of the bridge. HAER MD-187-26, Jet Lowe, 2016.

SITE FEATURES

Approaches and Drainage

RECOMMENDED

Protecting and preserving in place important archaeological resources.

Ensuring railings and signage are installed in such a manner that they do not harm the historic fabric and do not damage or obscure the character-defining features of the bridge.

Preserving historic advertisements and markings; bridge name and builder's plates; and other signage integral to the history of the bridge.

Protecting covered bridges and landscape features against arson and vandalism (graffiti) before rehabilitation work begins by erecting temporary fencing and installing alarm systems that are keyed into local protection agencies.

Preserving historic roadside markers placed by governmental agencies and other organizations.

NOT RECOMMENDED

Leaving known archeological material unprotected so that it can be damaged during rehabilitation work.

Installing railings and signage in areas that will damage or obscure the character-defining features of the bridge or damage historic fabric.

Failing to protect historic advertisements, builder's plate cards, and other signage integral with the history of the bridge, thereby losing historic fabric and historical materials.

Permitting the site to remain unprotected so that the bridge and landscape features or archeological resources are damaged or destroyed.

Failing to protect historic roadside makers during a rehabilitation project, thereby losing historic fabric and historical information.

SITE FEATURES

Approaches and Drainage



Figure 5.2a-b All traffic and safety signage should be placed in a prominent location, be clearly visible, and far enough away as to not detract from the appearance. Signage too close is not recommended. Below: Protecting the abutment by clearing the wingwall of invasives.

Figure 5.2c-d Original timbers with historic markings should be preserved as part of the historic fabric of the structure. Below: Graffiti from vandalism may be removed with a gentle cleaning through a low power pressure wash. A commercial stone mortar sealant can be applied to ease future graffiti removal.

Figure 5.2e-f Height restriction bars help restrict oversize vehicles from damaging the bridge and should be placed far enough way as to not interfere with the view of a photographer. Bells Mill Bridge, PA.

SITE FEATURES

Approaches and Drainage

RECOMMENDED

Repairing approach and site features by reinforcing /supplementing the components using appropriate preservation methods. Repair may include limited replacement in kind or with a compatible substitute material of those extensively deteriorated or missing parts of approach or site features when there are surviving prototypes, such as sections of paving, drainage, railing, fence or walkway.

Replacing in kind an entire feature of the site that is too deteriorated to repair (if the overall form and detailing are still evident) using the physical evidence as a model to reproduce the feature. If using the same kind of material is not feasible, then a compatible substitute material may be considered.

Designing the Replacement for Missing Historic Features

Designing and installing a new feature on the site when the historic feature is completely missing, such as a historic sign or interior curbing. The design may be an accurate restoration based on documentary and physical evidence, but only when the feature to be replaced coexisted with the features currently on the site. Or it may be a new design that is compatible with the historic character of the bridge and site.

NOT RECOMMENDED

Replacing an entire feature of the approach or site (such as a portion of the roadway, guide rail, or fence) when repair of materials and limited compatible replacement of deteriorated or missing parts are appropriate.

Removing a character-defining feature of the site that is unrepairable and not replacing it; or replacing it with a new feature that does not convey the same visual appearance.

Adding conjectural features to the approach, such as a railing or fences, that are historically inappropriate, thus creating a false sense of historic development.

Creating a false historical appearance by basing the replaced feature on insufficient historical, pictorial, and/or physical documentation.

Introducing a new feature that is incompatible in size, scale, material, and color. For instance, elaborate new signs over the portals should be avoided and portals should be made compatible with historic photographs.

SITE FEATURES

Approaches and Drainage



Figure 5.3a-b This deteriorated country approach road at Medora Bridge, IN, required regrading and new paving to maintain the alignment of the historic approach.

Figure 5.3c-d Storm grates are effective at protecting the bridge deck from runoff, but need to be maintained and cleared of leaves and debris to remain serviceable.

Figure 5.3e-f Repair and replacement of an approach sometimes requires replacement of the entire abutment and flooring system, such as at Knox Bridge, PA. Below: New steel-backed timber guardrails and historical marker after the reconstruction of the approach at Taftsville Bridge, VT.

SITE FEATURES

Materials and Landscape

RECOMMENDED

Alterations/Additions for New Use

Designing new approach and onsite features (such as trench drains, parking, bollards, benches, or lighting), when required by a new use, so that they are as unobtrusive as possible, retain the historic relationship between the bridge and the landscape, and are compatible with the historic character of the site.

Placing interpretive materials in parking areas so as to not endanger the historic bridge or the safety of visitors to the site.

Working with local disability groups, access specialists, and historic preservation professionals to determine the most appropriate solution for accessibility as required for a new use.

Complying with accessibility requirements in such a manner that character-defining features are preserved or impacted as little as possible, and are compatible with the historic bridge and the setting.

Installing pedestrian railings or walkways that are sympathetic to the historic materials but are clearly differentiated from historic components if required for a new use.

Installing and maintaining load limit signs and, in certain cases, height barriers near the bridge and also at the closest point that trucks might turn around.

Establishing an emergency response plan with surrounding entities that describes how a response team will deal with a specific emergency, such as fire, flood, structural failure, overloaded vehicle, etc.

NOT RECOMMENDED

Radically changing or damaging features that are character-defining while trying to correct drainage deficiencies.

Placing interpretive materials without considering their effect on the historic bridge and site or the safety of pedestrians.

Altering, damaging, or destroying character-defining features in an attempt to comply with accessibility requirements.

Designing new or additional means of access without considering the impact on the historic bridge and its setting.

Altering, damaging, or destroying character-defining exterior features or features of the site while making modifications to the bridge or its site to comply with accessibility requirements.

Undertaking code-required alterations before identifying those features and finishes that are character-defining and must therefore be preserved.

Installing load limit signs on the bridge without also considering other locations where oversized vehicles might have the ability to turn around and detour.

Failing to develop an emergency response plan for a historic covered bridge incident.

SITE FEATURES

Materials and Landscape



Figure 5.4a-b A view of the new landscaping at Eldean Bridge, OH, now a National Historic Landmark. A new ADA-compliant walkway leads from a picnic pavilion to an interpretive panel and bench. The panel discusses the bridge's history, its truss patent, and designer.



Figure 5.4c-d Strategies for limiting height include "headache" bars, which are a cost effective way to protect the portal and knee-braces of the bridge, and control entry of overweight vehicles.



Figure 5.4e-f To provide accessibility to the Sachs Covered Bridge in Pennsylvania, Adams County employed matching stone for an ADA compliant ramp. A simple boulder is used as a bollard on the pedestrian-only Henniker Bridge, NH.





SAFETY AND PROTECTION FEATURES

CHAPTER 6

RECOMMENDED	NOT RECOMMENDED
<p>Identifying, retaining, and preserving systems that are important in protecting the covered bridge, such as traffic engineering signage, fire prevention systems, lightning protection systems, and lighting fixtures.</p>	<p>Removing or radically changing features of protection systems that are important in defining the overall historic character of the bridge.</p>
<p>Protecting and maintaining historic covered bridges from damage due to speeding vehicles and overloaded vehicles with appropriate, visible signage that indicates height, load, and speed limitations.</p>	<p>Failing to provide adequate signage at the approach to the entrance of a historic covered bridge to include height, weight, and speed limits.</p>
<p>Applying fire-retardant coatings to wooden bridge components, with preference for products that do not change their historic character or physical appearance.</p>	<p>Installing traffic signs and signals in areas that are not clearly visible.</p>
<p>When cleaning timbers in preparation for applying fire retardants, using very low water pressure so that the wood's appearance is not altered.</p>	<p>Using fire-retardant coatings that alter the appearance of the bridge components, or cleaning so abrasively that timber appearance is affected.</p>
<p>Repairing functioning historic protection systems by augmenting or upgrading system parts, such as installing new down-lead cables or aerial terminals for historic lightning protection systems, or new wiring for historic lighting fixtures. Care should be taken to make these protection systems as unobtrusive as possible.</p>	<p>Replacing a protection system or its functional parts when it could be upgraded and retained.</p>

Figure 6.1 Utility boxes for sprinkler, lighting, and fire detection are hidden from plain view at Utica Mills Covered Bridge, MD. Thomas Vitanza, 2017.

SAFETY AND PROTECTION FEATURES

RECOMMENDED

Replacing in kind, or with compatible substitute materials, those visible features of protection systems that are either extensively deteriorated or are prototypes, such as lighting systems.

Alterations/Additions for New Use

Installing a completely new protection system so that it causes the least possible alteration to the historic covered bridge and does not damage the historic bridge material.

Providing adequate structural support for new protection systems.

Installing sensitively-designed fire suppression systems, such as dry suppression systems, that result in less moisture damage and higher retention of historic features.

Installing vertical and horizontal runs of wires and pipes as unobtrusively as possible.

Installing lighting features that do not alter, damage, or obscure character-defining features.

Establishing an emergency response plan with surrounding entities that describes how a response team will deal with a specific emergency, such as fire, flood, structural failure, overloaded vehicle, etc.

NOT RECOMMENDED

Installing visible replacement features that do not convey the same appearance.

Installing a new protection system that radically changes, damages, or destroys character-defining structural materials.

Failing to consider the weight and design of new protection systems, thus weakening historic structural members.

Altering, damaging, or destroying character-defining features while making modifications to a bridge or site to comply with safety codes.

Installing vertical and horizontal runs of wires and pipes in places where they will obscure character-defining features.

Failing to develop an emergency response plan for a historic covered bridge incident.

SAFETY AND PROTECTION FEATURES



Figure 6.2a-b Sprinkler hose and solar panels protecting the Arthur A. Smith Bridge, MA. Below, spraying fire retardant on timbers as a fire prevention measure.

Figure 6.2c-d Emergency fire suppression system placed beneath the bridge out of view of the main truss; fire alarm housing subtly tucked inside a shelter panel at Utica Mills Bridge, MD.

Figure 6.2e-f New lighting installed at Eldean helps prevent vandalism. Below, conduits are tucked inside the roof structure at Roddy Road Bridge, MD; one to a light fixture atop the tie beam, another to a heat detector near the eave.



APPENDIX A

Burlington Charter for the Preservation of Historic Covered Bridges

Approved June 6, 2003

First National Best Practices Conference for Covered Bridges, Burlington, Vermont

Covered bridges are vitally important cultural, economic, educational, aesthetic, and historic resources. Although public support for preserving them is strong, many are vulnerable to the effects of deterioration due to neglect, limited funding, and limited knowledge of appropriate treatments. Consequently, their structural, material, and functional integrity is often at risk. This charter establishes the following goals for insuring the long term safeguarding of historic covered bridges.

1. To preserve the historic structural and material integrity of covered bridges to the maximum extent possible, consistent with public safety.
2. To identify, document, and preserve examples of covered bridge design, ingenuity in timber and masonry construction, and unique practices or solutions to specific problems, and to encourage future generations to summon similar ingenuity.
3. To retain covered bridges for in active use for transportation, with the least possible compromise to their structural and material integrity.
4. To identify, document, and preserve all surrounding features that define the historic character of covered bridges and their settings, including approach roads, historic cultural landscapes, and views.
5. To interpret and publicize individual covered bridges and the overall importance of the covered bridge to the history of transportation, engineering, and community life.
6. To establish partnerships among bridge owners; local, state, and federal governments; non-profit organizations; design and construction professionals; craftspeople; and others in order to provide the best opportunities for cooperative stewardship of covered bridges.
7. To undertake research to develop tools essential to the preservation of historic covered bridges, including studies of appropriate treatments of historic materials; methods of structural analysis; techniques for repair and strengthening; and the economic benefits of preserving historic covered bridges.
8. To develop management practices that ensure timely identification of needs and prioritization of treatments.
9. To encourage government agencies and other public and private entities to provide adequate and effective funding to implement the above goals.

RESOLVED: *Participants of the First National Best Practices Conference for Covered Bridges hereby adopt this Burlington Charter for the Preservation of Historic Covered Bridges. Be it further resolved that we respectfully ask the U.S. National Park Service to develop guidelines that apply and adapt the Secretary of the Interior's Standards for Preservation, Rehabilitation, Restoration, and Reconstruction to historic covered bridges in a manner consistent with these goals and objectives, and to present these guidelines at the Second National Best Practices Conference for Historic Covered Bridges, time and place to be announced.*

APPENDIX B

Character-Defining Features for Historic Covered Bridges Checklist

This checklist for historic covered bridges is derived from NPS "Preservation Brief 17." This document introduced the concept of "character-defining features", and their importance to the preservation community. While the original checklist is oriented to historic buildings, the Three-Step Process outlined in the brief has been applied to many specific resource types including maritime vessels and cultural landscapes. Its application to historic covered bridges maintains this approach while incorporating the various bridge nomenclature lists available from the Bridge Inspector's Reference Manual and the National Bridge Inspection Standards. They have been organized as per the Preservation Briefs Checklist/ Questionnaire.

Step 1. Identify the Overall Visual Aspects

Shape and Form: structural and architectural—truss type; abutments and piers; length, width, height; siding, portal, roof; color; and other structural or architectural design elements.

1. **Roof and Roof Features:** roof system, roof cladding, details and color
2. **Openings:** portal and side wall openings
3. **Projections:** overhangs, eaves, cornices, portal details or covered walkways
4. **Trim and Secondary Features:** structural or architectural features—siding, trim, details such as pilasters, arches, cornices, other design or ornamental features
5. **Materials:** wood type for structure, siding, roofing; masonry, metals, etc.
6. **Setting:** landscape features, roadway approaches, signs, historical markers

Step 2. Identify the Visual Character at Close Range

1. **Materials at Close Range:** structural and architectural—wood, masonry, fasteners, exterior coverings—siding, roof covering, finishes—inherent texture, tool marks, weathering, and patina
2. **Craft Details:** structural or architectural—exposed structural details in truss, bracing, substructure; connection and construction details; other examples of craftsmanship: handmade or machine made; tools and processes, surface qualities

Step 3. Identify the Visual Character of the Interior Structure, Features and Finishes

1. **Exposed Structure:** interior of through truss bridge, truss work exposed or covered, roof framing system, hardware, fasteners, patina of materials
2. **Surface Finishes and Materials:** unpainted/painted materials, historic signage, match marks, tool marks, historic graffiti, etc.
3. **Related Spaces and Sequence of Spaces:** bridge to setting and roadway approach, bridge to district setting

APPENDIX C

Feature Master List for Historic Covered Bridges

Adapted from the bridge component nomenclature as used in the National Bridge Inspection Standards Regulation (NBIS), and the Bridge Inspector's Reference Manual (BIRM).¹⁰

Superstructure Features

- ◇ Timber Truss
(overall structural system, truss type, size and arrangement of timbers)
 - Connections and fasteners (treenails, pegs, nails, bolts, etc.)
 - Structural Features (upper chord, lower chord, vertical members, diagonal members, other horizontal members, buttresses, splice features, etc.)
 - Support Features—bearing blocks, bolster beams
 - Craft Features (size of timbers, species, method of fabrication (tool marks, etc.)
- ◇ Floor Structure System
 - Floor structure (beams, stringers, diaphragms, transverse beams)
 - Floor surface (decking—transverse/longitudinal/diagonal)
 - Interior curbing, railing, other details
- ◇ Lateral Bracing System
(upper and lower as applicable, knee braces, tie rods, etc.)

Substructure Features

- ◇ Abutments and Piers
 - Piling, pile cap, footing, stem wall, backwall (stone, brick, concrete/historic, modern)
- ◇ Wing Walls
 - Parapets/coping (stone, brick, concrete)

Exterior Envelope

- ◇ Siding
 - Truss cladding structure separate from truss siding and portals (clapboards, weatherboards, shingles, corrugated metal, etc.)
 - Siding surface features: finish, signage, trim
- ◇ Portal
 - Parapet/portal extension—overhang, shelter panel
 - Portal opening shape and design
 - Ornament—brackets, pilasters, cornice, etc.

- ◇ Wall Openings
- ◇ Roof System
 - Roof sheathing—boards/planks/shingles/sheet metal
 - Roof structure—purlins, rafters, lathe, collar ties, cross beams, etc.
 - Roof eaves, cornice or overhang

Approach, Site and Setting Features

- ◇ Overall setting/context—historic district, original location, relocated
 - Cultural landscape components
- ◇ Roadway Approach
 - Traffic signs, railings
- ◇ Drainage Features
 - Culverts, slot drains, swales
- ◇ Supplemental Components
 - Historic markers, roadside features, wayside exhibits

Safety & Protection Features

- ◇ Fire Prevention, Detection, and Suppression
 - Fire retardant treatments
 - Dry hydrant systems
- ◇ Lightning Protection
- ◇ Lighting
 - Internal and external fixtures
- ◇ Traffic Engineering
 - Height or weight restriction components, traffic signals and signage

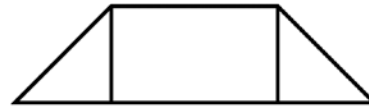
¹⁰ "National Bridge Inspection Standards," 23 CFR Part 650, Federal Register Vol. 69, No. 239 (December 14, 2004), 74419-39; Thomas W. Ryan, J. Eric Mann, Zachary M. Chill, Bryan T. Ott. *Bridge Inspector's Reference Manual (BIRM)*. Publication No. FHWA NHI 12-049, 2012.

APPENDIX D

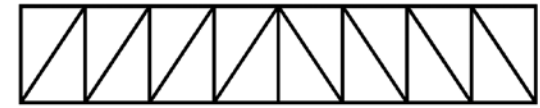
Truss Types



KINGPOST

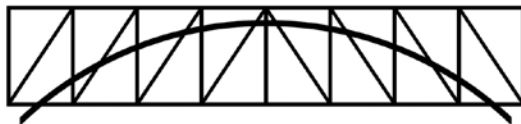


QUEENPOST

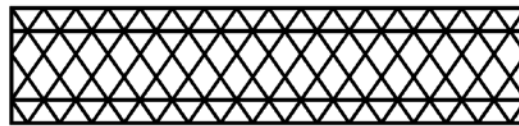


MULTIPLE KINGPOST

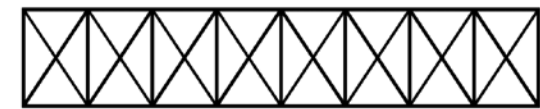
ANCIENT TRUSS TYPES



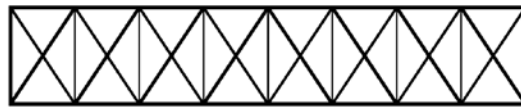
BURR ARCH



TOWN LATTICE



LONG

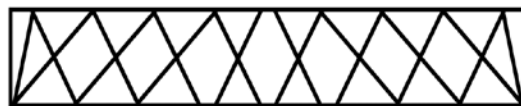


HOWE

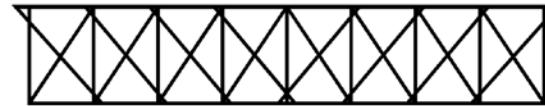


PRATT

MAJOR DEVELOPMENTAL TRUSS TYPES



SMITH

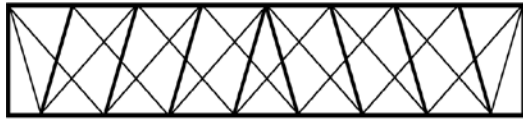


PADDLEFORD

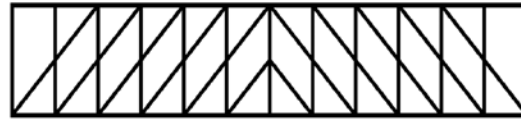
SIGNIFICANT REGIONAL TRUSS TYPES

APPENDIX D

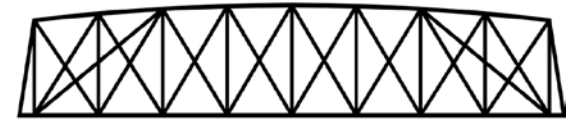
Truss Types



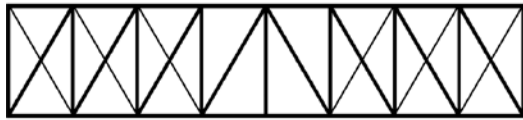
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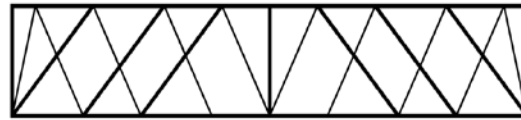
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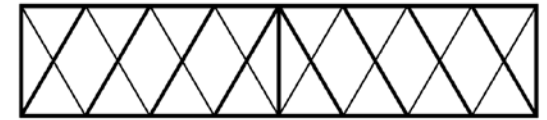
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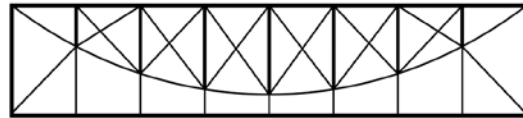
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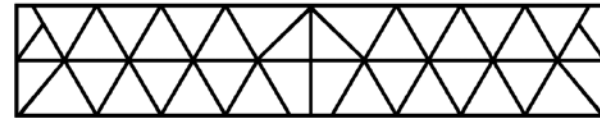
PARTRIDGE



BROWN



INVERTED BOWSTRING



WHEELER

MINOR TRUSS TYPES

Figure 7.2 Diagram by Thomas Behrens, Lola Bennett, Pavel Gorokhov, and Christopher Marston, 2006, 2014.

APPENDIX E

Covered Bridge Terminology



The stone facewall of an abutment. Reinforced concrete skewbacks support the arches.

Italicized and bracketed words in the glossary are the words used by builders such as Burr and Long, and were normal and customary to the period in which most bridges were built.

Abutment: An abutment consists of a face wall, a cap, back wall, and wing walls. The **face wall** is the broad side of the abutment facing the crossing. The **cap** (top) of the abutment, above the face wall, supports the bed timber(s), upon which the bridge superstructure is set. The **back wall** (also known as mudwall) is constructed atop the abutment and behind the chord bedding area to serve as a retainer wall for the road bed. The **wing walls** extend back from the face wall to stabilize the side slopes of the approach roadway embankment. The abutments are built upon bedrock, stone footing, timber cribs (grillage) or driven wooden pilings. A backfill of loose stone is laid behind the abutments to provide expansion space to keep frost or ice from pushing the abutment walls.

Angle block: A triangular block of wood or iron placed at the junction of a post, brace, or arch, serving as a seat, as in the Howe truss.



Two sets of timber arches sandwich around a multiple kingpost truss in this Pennsylvania Burr-arch truss.

Arch: In wooden bridges, a curved timber, or arrangement of timbers, forming an arc used to support or brace a span. A timber arch consists of large timbers joined end to end, while a laminated arch consists of numerous scantlings laid one atop another, nailed and bolted together to form a large cross section. Arches may bear upon the abutment face or attach to the bottom chord (tied-arch).

Bearing blocks: Timber components used to shim between two bridge components (e.g. between a bolster beam and the lower truss chord).

Bed timbers: Transverse timber components typically located between the top of an abutment or pier and the underside of the truss bottom chord. Bed timbers serve as sacrificial components; they are easily replaced when deteriorated from rot, thus protecting the truss components from similar deterioration.

Bolster beams: Timbers used to reinforce, or bolster, the bottom chords of a bridge truss. They rest upon the bed timbers, are parallel to the chords, usually extend beyond the abutment's face wall, and distribute the bridge loads over a larger area. The bolsters are supported by bed timbers or pedestals. Typically Town lattice trusses are supported with bolster beams.

APPENDIX E

Covered Bridge Terminology



Bolster beams supporting a Town lattice truss. Note the bearing blocks used as spacers beneath the lower chord.



A second layer of longitudinal floor-planked bridge deck serves as the wearing surface for this Burr-arch truss.

Bridge deck (Floor): A deck incorporates several members and can be arranged in different configurations. Floor beams, floor joists, and floor plank comprise the bridge deck. Town lattice and Howe trusses typically use floor joists (closely spaced and transverse to the chords) with longitudinal floor plank atop. Burr-arch trusses use widely spaced floor beams, transverse, with joists (also known as stringers) longitudinal, with floor plank arranged transverse to the trusses.

Buttress: An assembly of timbers or iron rods placed along the outside of both sides of a bridge. Rods or timbers are connected to the top of the truss work and anchors at the abutments or at the ends of extended floor beams. When anchored to an extended floor or needle beam, it is sometimes referred to as a “flying buttress.” The system is used to control vertical alignment and to prevent sway (lean) of the trusses.

Camber: An upward curvature introduced into the trusses during construction to compensate for deflection, caused by timber creep and dead and live loads. The amount of camber varies greatly among bridges. When a bridge loses its camber and sags, it is sometimes referred to as having “negative camber.”



Flying buttresses or outriggers outside the trusses help control the vertical alignment of the bridge.

APPENDIX E

Covered Bridge Terminology



Bottom chords, lower lateral bracing, and floor joists support this Smith truss.

Check brace: A brace designed to aid the truss posts in resisting the rotational and shear forces transmitted by the main braces.

Chords (Strings): The upper and lower longitudinal members in a truss, extending the full length of the truss and carrying the forces of tension and compression away from the center of the span. A chord may be a single piece of timber or a series of joined pieces.

Clear span: The span of a bridge measured from bearing point to bearing point between supports.

Compression member (Strut): An engineering term that describes a timber or other truss member that is subjected to a force pushing the ends together.

Crib: Assembled from logs, hewn or sawn timber, framed to each other or simply stacked. Cribs are used to support masonry abutments (below water level), or stacked and bound together and infilled with stone to create an abutment or pier. Cribs are used when putting a bridge across a stream or to support jacks when raising a bridge for repairs.



Replacement timber cribs sit atop concrete piers to support the Pulp Mill Covered Bridge, VT.

Cross Beam/Brace (Collar tie, tie beam): Transverse timber tying both trusses together at the upper chords and part of the upper lateral bracing system.

Dead load: The weight of materials that make up the bridge structure itself.

Distribution beams: Longitudinal timber components aligned and supported by the floor beams or floor joists of the bridge to help spread out or distribute vehicle axle loads.

Double-barrel: A colloquial name for a covered bridge with two separate roadways. There is always a third truss between the lanes.

False work: Consists of a temporary shore-to-shore platform supported by cribs or bents. False work is used to support a bridge under construction or major repairs.

Floor beams: Heavy beams installed at or near panel points, spanning between the trusses which support longitudinal floor joists and transverse floor plank.

APPENDIX E

Covered Bridge Terminology



The double-barrel Pulp Mill Covered Bridge, VT, accommodates two lanes of traffic.

Free of Heart Center (FOHC): Any timber or lumber that does not contain the pith or heart of the tree. Early builders like Burr and Long specified all timber used in the construction be free of heart because of its superior rot and insect resistance.

Gusset: A flat, smooth plate of wood, iron or steel, serving to connect the members of a joint and hold them in correct alignment and position.

Inferior brace: A timber or beam slanting upward from the face of an abutment or pier to the underside of a bridge, usually lending additional support to the main bridge chords. It is so named because the brace occupies a position below that of other braces and beams, also called arch bracing.

Inverted arch: Deformation of an arch caused by overloading the bridge or by the incorrect adjustment of the suspension rods in the laminated arch bridge. Over-tightening or tightening the suspension rods in an incorrect order can result in an inverted arch.



Stringer joists, laid parallel to the lower chords, sit atop the floor beams to support the deck.

Joists (stringers): Timbers laid longitudinally on the floor beams of the bridge when closely spaced and attached to the chords, or placed atop floor beams and aligned parallel to the chords. The floor planking is applied to the joists.

Key: A wood or iron member framed into a connection to "lock" adjacent members together.

Kingpost: The mid-span vertical in a paneled truss supported by two truss braces. A multiple kingpost truss contains one kingpost supported by two braces and several posts supported by a single brace. A Burr-arch truss is one example of a multiple kingpost.

Knee brace: A short timber inclined at or near a 45-degree angle used inside a covered bridge between a truss and upper crossbeam or collar tie to resist wind loads, and maintain vertical alignment. Often referred to as "sway bracing."

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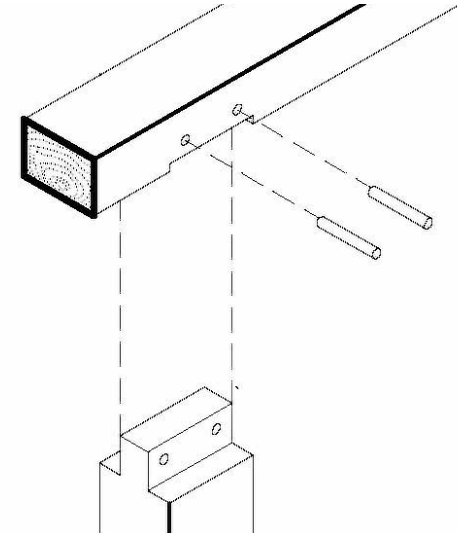
Covered Bridge Terminology



A single kingpost truss supports this short 48' long bridge.



An upper lateral bracing system, with a series of knee braces at every tie beam.



Mortise cavity in upper chord accepting tenon at top of post, held together by wooden pegs.

Lateral bracing: A system of all wood or a combination of wood and iron, constructed to maintain a straight horizontal alignment between trusses. Lateral bracing systems are, in effect, horizontal trusses, creating a single unit to brace the bridge against transverse forces, such as wind.

Live load: Any temporary or moving forces that act on a bridge, which may include vehicles, people, and animals.

Longitudinal: The direction parallel to the bridge span.

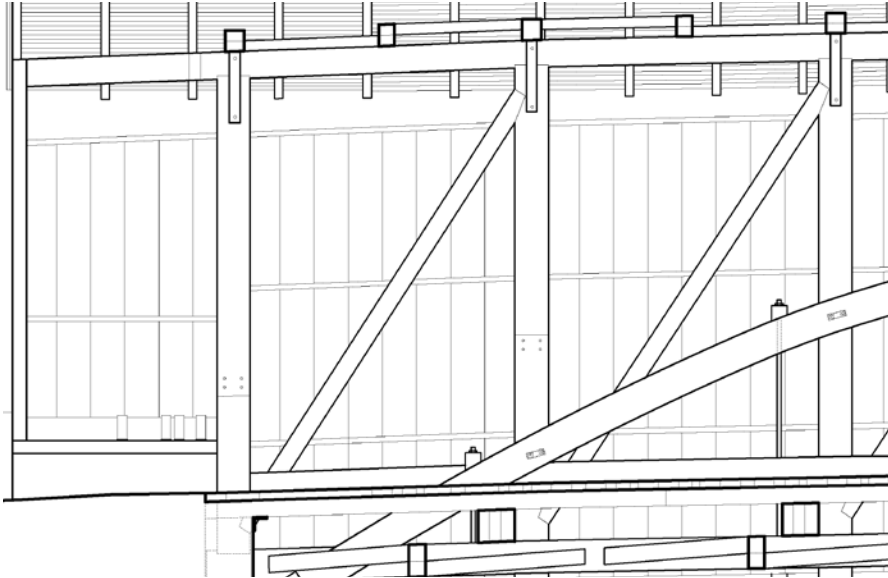
Mortise: A rectangular recess or cavity cut into a beam to receive the tenon of a connecting member to create a tying joint.

Panel: A rectangular section of a truss between two panel points; panel points being the section of truss work where principal members of posts, braces and counter braces attach to the chords. Where no braces or counter braces are employed, the panel is so described as being open.

Pier: A bridge support built in the stream bed between the abutments.

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Covered Bridge Terminology



Two truss panels with braces (right); the end panel is an open shelter panel (left).

Plank: A large member whose depth is at least twice the width, such as 4"x8", 4"x12", 6"x12" lumber; any wooden element smaller than 2" in either dimension.

Plate (fly plate, rafter beam): A supplemental horizontal member located above the upper chords or attached to collar ties, supporting the lower ends of the roof rafters.

Pointing: To fill and finish the joints of stonework masonry abutment or pier with cement or mortar.

Portal: General term for the entrance of a covered bridge.

Post: An upright or near vertical timber in a bridge truss.

Purlins: Longitudinal roof support members connected to the rafters, used to support roofing (shingles or metal) or roof boards.

Rafters: The rows of small timber (scantlings) arranged in the form of inverted V's that support the roofing of a covered bridge.



Portal of Shoreham Railroad Bridge, VT.



Rafters supporting purlins and sheet metal roofing. A collar tie braces every third pair of rafters.

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Covered Bridge Terminology



Paired, vertical iron tension rods in a Howe truss.

Rod: Iron or steel, round or square, used as vertical, diagonal, or horizontal tension members in truss or lateral bracing systems.

Running planks: Second layer of longitudinal planking placed over a bridge deck to provide an easily replaceable wearing surface. They are usually found over bridge decks constructed of transverse joists.

Sag: A permanent downward deflection of trusses at the middle of the span, also known as negative camber. Considerable sag suggests bridge repairs are needed.

Scaffolding (falsework): A temporary wooden or metal platform built to support the erection or repair of a bridge.

Scantlings: Small timbers having a small cross section less than 5"x5"; such as 2"x4", 3"x4", 4"x4", 4"x5".

Scarf joint: A joint in which the ends of beams are cut so that they overlap and join firmly. Scarf joints are used to splice chords or stringers end-to-end.



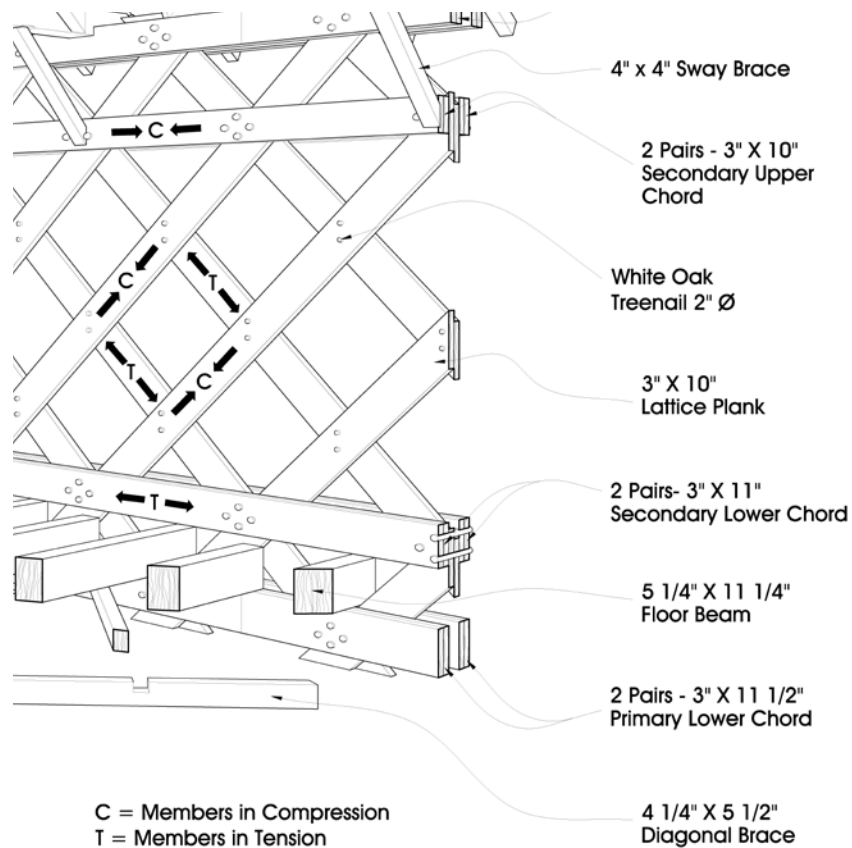
Running planks laid atop transverse decking provide an added layer as a wearing surface.



A splayed scarf joint repair abuts a replacement arch leaf. Both Burr-arch segments are secured with a single through bolt.

APPENDIX E

Covered Bridge Terminology



Primary upper and lower chords are supplemented by secondary chords on this Town lattice truss.

Secondary Chords: The chord or pair of chords between the upper and lower chords in a Town lattice truss.

Shear: A force acting on a member, which causes the member or connection to slide or slip apart and fail. Shearing action can also take place within a solid timber or iron rod.

Shear key: A spline, or piece of hardwood, usually oak, fitted into a slot or groove between two parts to resist shear forces.



A stone skewback receiving a pair of arches, backed by a cast-iron plate.

Shelter panel: The first panels at the portals of some types of covered bridge trusses to prevent blowing rain from reaching the primary timbers. Shelter panels are attached to the main trusses, but do not support the floor system or floor loads.

Sistering: To place a supplemental timber next to a deteriorated member to assist the deteriorated member in carrying its load. The use of sistering helps retain original material.

Skewback: A sloped, stepped, or notched section on the face of an abutment, to receive the end of an arch. In some instances, skewbacks are crafted from wood and introduced into the abutment.

Span: The length of a bridge between abutments or piers. Clear span is the distance measured from the inner face of bearing point to the face of the other bearing point. The length of a covered bridge is usually calculated using the truss bottom chord length or the distance between the truss end posts, regardless of how far the truss may overreach the actual abutment.

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Covered Bridge Terminology



A tension splice with iron straps, strengthened with a shear key, connects two abutting sections of a bottom chord.

Splice: A joint or the act of joining timbers end-to-end.

Strut: The historical name given to a member in compression.

Tenon: A diminished section of timber at the end, cut to fit into a mortised member, pinned to the mortised member to create a tying joint. The mortise-and-tenon connection is used to join a post and a beam.

Tension member: Any timber or rod of a truss which is subjected to a pull, or a stretch, see compression member.

Tension splice: An interlocking splice, where two timbers touch end-to-end, in a tension member, usually a bottom chord. The splice is designed to resist slippage caused by tension forces. The interlocking surfaces are usually strengthened with a hardwood shear key, a bolt-of-lightning joint, or iron straps with bolts.

Tie rod: A slender structural unit (rod or bar) used to tie both trusses together at upper or lower chords.



Treenails are paired at lattice intersections, and in a diamond pattern at the upper and lower chords.

Timber: A large member whose cross section depth is less than twice its width, and is 5" x 5" or larger; such as 5" x 5", 6" x 6", 6" x 8", 6" x 10", 10" x 12".

Transverse: 1. A direction from side to side, as in planking cut and installed at right angles to the length of a bridge deck. 2. Forces, such as those from the wind or water, acting upon a bridge structure from the side.

Treenails (pronounced "trunnels" and occasionally spelled that way): The large wooden pins driven into the holes drilled into multiple members to fasten them together, typically in a Town lattice truss.

Truss: A framework, typically consisting of long beams or planks connected in a series of triangles, used to support the entire weight of the bridge dead load and any live load. The triangular form is the only geometric form that when fixed at each crossing becomes stable.

Truss brace (Strut): A diagonal timber in a truss that slants upward toward the mid-point of the span, and is in compression.

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A long truss, with paired braces and single counterbraces.

Truss counter brace (Web): A diagonal timber in a truss that slants in the opposite direction from the brace. It is usually in tension and sometimes in compression (as in both the Howe and Long trusses).

Turnbuckle: An internally threaded metal loop or tube placed between sections of iron rods or steel cables, for introducing tension.

Windbracing: The lateral bracing system in the roof and under the floor, designed to brace the bridge against transverse forces, such as the wind.

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APPENDIX G

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1.3e	Moscow Bridge, IN; James Barker, 2010	3.3e-f	Cataract Bridge, IN; James Barker, 2004	5.3c	Lower Humbert Bridge, PA; Christopher H. Marston, 2017
1.3f	Jericho Bridge, MD; Christopher H. Marston, 2016	3.4a	Pine Grove, PA; HAER field photo, 2002	5.3d	Thomas A. Vitanza, 2014
		3.4b	Pine Grove, PA; Thomas Vitanza, 2009	5.3e	Knox Bridge, PA; Michael Chorazy, 2016
2.2a	Jericho Bridge, MD; Christopher H. Marston, 2015	3.4c-d	Deers Mill Bridge, IN; Matthew Reckard, 2000, 2009	5.3f	Taftsville Bridge, VT; Matthew Kierstead, 2017
2.2b	Salt Creek Bridge, OH; David Simmons, 1995	3.4e	Sharon Feeney, 2014	5.4a-b	Eldean Bridge, OH; James Barker, 2015
2.2c-d	Medora Bridge, IN; James Barker, 2002, 2010	3.4f	Rinard Bridge, OH; Martin Stupich, 2015	5.4c	Burkholder Bridge, PA; Christopher Marston, 2017
2.2e-f	Eldean Bridge, OH; James Barker, 2003, 2006	3.5a-b	Medora Bridge, IN; James Barker, 2003, 2010	5.4d	Rupert Bridge, PA; James Smedley, 2015
2.3a	Gilpin's Fall Bridge, MD; Will Truax, 2009	3.5c	Gilpin's Falls Bridge, MD; Will Truax, 2009	5.4e	Sachs Bridge, PA; Christopher H. Marston, 2017
2.3b	Gilpin's Fall Bridge, MD; Christopher H. Marston, 2009	3.5d	Gilpin's Falls Bridge, MD; Christopher H. Marston, 2010	5.4f	Henniker Bridge, NH; Christopher H. Marston, 2009
2.3c-d	Engle Mill Bridge, OH; James Barker, 2011, 2013	3.5e-f	Knox Bridge, PA; Michael Chorazy, 2015, 2016		
2.3e-f	Eldean Bridge, OH; Doug Christian, 2006	4.2a-b	Engle Mill Bridge, OH; James Barker, 2011, 2013	6.2a	Arthur A. Smith Bridge, MA; Matthew Kierstead, 2017
2.4a-b	Zacke Cox Bridge, IN; VS Engineering, 2016	4.2c	Sachs Bridge, PA; Christopher H. Marston, 2017	6.2b	Sachs Bridge, PA; Christopher H. Marston, 2017
2.4c	Sharon Feeney, 2014	4.2d	Gilpin's Falls Bridge, MD; Kinsley Construction, 2010	6.2c	Arthur A. Smith Bridge, MA; Matthew Kierstead, 2017
2.4d	Taftsville Bridge, VT; Matthew Kierstead, 2015	4.2e	Esther Furnace Bridge, PA; James Smedley, 2015	6.2d	Utica Mills Bridge, MD; Christopher Marston, 2017
2.4e-f	Gilpin's Fall Bridge, MD; Timothy Andrews, 2009	4.2f	Henninger Farm Bridge, PA; James Smedley, 2012	6.2e	Eldean Bridge, OH; Doug Christian, 2015
2.5a-b	Cataract Bridge, IN; James Barker, 2002, 2004	4.3a	Moscow Bridge, IN; Ed Derringer, 2008	6.2f	Roddy Road Bridge, MD; James Smedley, 2017
2.5c-d	Taftsville Bridge, VT; Matthew Kierstead, 2011, 2015	4.3b	Moscow Bridge, IN; James Barker, 2010		
2.5e	Richland Creek Bridge, IN; James Barker, 2005	4.3c-d	Newton Falls Bridge, OH; Randy L. Smith, 2005, 2007		
2.5f	Rinard Bridge, OH; Martin Stupich, 2015	4.3e	Gilpin's Falls Bridge, MD; Christopher H. Marston, 2010		
2.6a	Zumbrota Bridge, MN; Martin Stupich, 2015	4.3f	Gilpin's Falls Bridge, MD; W. Earl Simmers, 2010		
2.6b	Sharon Feeney, 2014	4.4a-b	Sachs Bridge, PA; Christopher H. Marston, 2017		
2.6c	Forsythe Bridge, IN; James Barker, 2003	4.4c-d	Medora Bridge, IN; James Barker, 2003, 2010		
2.6d	Sharon Feeney, 2014	4.4e	Medora Bridge, IN; Matthew Reckard, 2006		
2.6e	Rinard Bridge, OH; Martin Stupich 2015	4.4f	Eldean Bridge, OH; James Barker, 2003		

APPENDIX G

Image Credits

Terminology

(listed by page and HAER number, Left to Right; Top, Bottom)

82 L	Bridgeport Bridge, CA; HAER CA-41-5, Jet Lowe, 1984
82 R	Griesemer Bridge, PA; HABS PA-1020-2, Cervin Robinson, 1958
83 L	Hall Bridge, VT; HAER VT-40-7, Jet Lowe, 2009
83 TR	Dreibelbis Bridge, PA; HAER PA-587-10, Jet Lowe, 2005
83 BR	Beaverkill Bridge, NY; HAER NY-329-10, Jet Lowe, 2003
84 L	Powder Works Bridge, CA; HAER CA-313-6, Jet Lowe, 2004
84 R	Pulp Mill Bridge, VT; HAER VT-31, figure 5, Martin Stupich, 2015
85 L	Pulp Mill Bridge, VT; HAER VT-31-5, Martin Stupich, 2015
85 R	Gross Bridge, PA; HAER PA-67-19, Ralph E. Menne
86 TL	Pine Brook Bridge, VT; HAER VT-37-8, Jet Lowe, 2006
86 R	Pine Grove Bridge, PA; HAER PA-586, sheet 7, Vuong Dang, 2002
86 BL	Shoreham Railroad Bridge, VT; HAER VT-32-4, Jet Lowe, 2003
87 L	Pine Grove Bridge, PA; HAER PA-586, sheet 4, Kimberly Clauer, William Dickinson, 2002
87 TR	Shoreham Railroad Bridge, VT; HAER VT-32-1, Jet Lowe, 2003
87 BR	Neal Lane Bridge, OR; HAER OR-126-7, Jet Lowe, 2004
88 L	Doe River Bridge, TN; HAER TN-41-7, Jet Lowe, 2002
88 TR	Jackson Bridge, IN; HAER IN-48-7, James Rosenthal, 2004
88 BR	Gilpin's Falls Bridge, MD; HAER MD-174-25, David Ames, 2010
89 L	Brown Bridge, VT; HAER VT-28, sheet 6, Naomi Hernandez, 2002
89 R	West Union Bridge, IN; HAER IN-105-10, James Rosenthal, 2004
90 L	Leatherwood Bridge, IN; HAER IN-40-8, Ed Sels, 1979
90 R	Brown Bridge, VT; HAER VT-28-3, Jet Lowe, 2002
91	Staats Mill Bridge, WV; HAER WV-31-4, West Virginia DOT, 1982



INTRODUCTION

The following rehabilitation case studies were prepared to illustrate the technical points of the Guidelines and provide examples of best practices, something that has not been readily available to transportation engineers and historic preservation professionals. These case studies provide detailed, technical, real-world examples that can be used in planning and executing rehabilitation projects that capture the intent of *The Secretary of the Interior's Standards for the Treatment of Historic Properties*.

The outline used for the case studies was derived from a variety of sources, including AASHTO's *Case Studies on the Rehabilitation of Historic Bridges* (SRI Foundation, 2011) and the FHWA submission requirements and selection criteria for its Discretionary Grant Programs. Individual case studies may not address all points in the outline. Each case study is representative of the bridge, the project, the engineers and craftspeople involved, and the funding. It is a snapshot in time, and therefore, all are different in content.

The editors wish to thank the author teams that took the time to write these case studies:

1. Ashuelot Covered Bridge, NH: Sean T. James, Robert H. Durfee, Timothy Andrews
2. Cataract Covered Bridge, IN: Matthew Reckard, James Barker, Mary E. Kennedy
3. Cornish-Windsor Covered Bridge, VT: Laura S. Black, James L. Garvin, Mark W. Richardson
4. Fitch's Covered Bridge, NY: Phillip C. Pierce
5. Gilpin's Falls Covered Bridge, MD: Jeremy Mauro, Christopher H. Marston, Timothy Andrews
6. Goodpasture Covered Bridge, OR: Gregory W. Ausland, Anthony LaMorticella, Matthew Sevits, Kaitlyn Lange
7. Johnson Creek Covered Bridge, KY: Arnold M. Graton, Meg Dansereau Graton, Jen Spangler Williamson, Patrick Kennedy

8. Kings Covered Bridge, PA: William J. Collins, Samer H. Petro
9. Moscow Covered Bridge, IN: James Barker, Matthew Reckard, Mary E. Kennedy
10. Pulp Mill Covered Bridge, VT: Josif Bicja, Sean T. James
11. Swann Covered Bridge, AL: Winston Sittton, Manjeet H. Ahluwalia, Evan C. Lowell

Since these case studies were completed in 2013, some bridges have suffered from the effects of time and man (mostly careless drivers). Several have been damaged and repaired since 2013—this is especially true of the Cornish-Windsor Covered Bridge, which has survived two incidents and is now in better condition than ever thanks to scrupulous maintenance.

As a member of the team developing these Guidelines and the coordinator of the case studies, I can say it was a joy to work with all the authors. All volunteered their time to contribute to the completion of their case study. Many were developed over a period of several months and in some cases more than a year to get the case study “just right.” In reviewing them in their final form I am reminded of the diversity of truss types, the conditions of the bridges prior to rehabilitation, and the devotion of all involved in every repair project.

Jim Barker, who wrote about the Moscow Covered Bridge, recalled his experiences reconstructing that bridge and its impact on locals. He reflected: “Historic bridge preservation matters to people, a lot. The bridge touched people more than most things in their environment....When the first span was placed on the piers, several bystanders teared up.” May these Guidelines help to preserve many, many historic covered bridges, which have such an important place in their communities.

Thomas A. Vitanza
Historic Preservation Training Center
November 2018

CASE STUDIES

1. Ashuelot Covered Bridge Cheshire County, New Hampshire



Figure C1.1 Upstream elevation of Ashuelot Covered Bridge. Sean T. James, 2012.

CASE STUDIES

1. Ashuelot Covered Bridge

Cheshire County, New Hampshire

By Sean T. James, Robert H. Durfee, Timothy Andrews

Administrative Data

Bridge Name

Ashuelot Covered Bridge

Bridge Structure Type

Town lattice truss (two 86'-8" spans) with twin cantilever sidewalks

Date of Original Construction

1864

Bridge Owner/ Client

Town of Winchester, New Hampshire

World Guide Number:

29-03-02

Structure Number (NBIS or local designation)

NHDOT Bridge No. 082/087
NBIS No. 027900820008700

National Register Number and Date

NRIS 81000069, February 20, 1981

Description of Location

The bridge is located at the intersection of New Hampshire Route 119 and Bolton Road in the unincorporated village of Ashuelot, Town of Winchester, Cheshire County, New Hampshire, and spans the Ashuelot River.

Description of Setting

The bridge is situated in a rural area 2.5 miles west of downtown Winchester.

Historical Background and Context

Construction of a new bridge over the Ashuelot River had been discussed since 1853, but it was not until March 8, 1864, that the Town of Winchester passed a Town Warrant for the Ashuelot Covered Bridge. This warrant reads: "To see if the Town will vote to build an X or Lattice Bridge with split stone abutments, a sidewalk on open sides over the Ashuelot River at Ashuelot at or near the place where the old bridge now stands, choose a building committee and raise money therefore and act thereon." The \$4,650 bill was registered as paid on March 10, 1865.

The Ashuelot River provided water power to local manufacturers as well as access to markets along with the Ashuelot Railroad. At the time of its construction, the village of Ashuelot supported woolen mills, wood product manufacturers, and machine shops. The Ashuelot Railroad, which was completed in 1851 and later absorbed into the Boston and Maine system, was located within 100 feet of the bridge. The railroad continued operation until 1984, at which point the line was abandoned. The State of New Hampshire purchased the rail line in 1995, and today it serves as a converted rail-trail system offering 23 miles of recreational opportunities.²

The main structural components of the bridge, with the exception of the floor deck and floor beams, are largely original members, with only one known extensive rehabilitation of the bridge done in 1999.

Physical Description of Bridge

The Ashuelot Covered Bridge is a two-span continuous Town lattice truss on stone abutments and a stone and concrete pier. The bridge consists of two 86'-8" long spans over the Ashuelot River. The bridge sections include two trusses spaced 18'-4 1/2" center to center and a sidewalk on the upstream and downstream sides of the bridge that extends 4'-8 3/4" from the centerline of each truss. The original truss system carries the weight of the bridge and is in its original location. The bridge is posted for a maximum height of 9'-8" and a maximum live load of 3 tons. [Note that all member sizes used in this section are actual (not dressed) sizes.]

CASE STUDIES

1. Ashuelot Covered Bridge

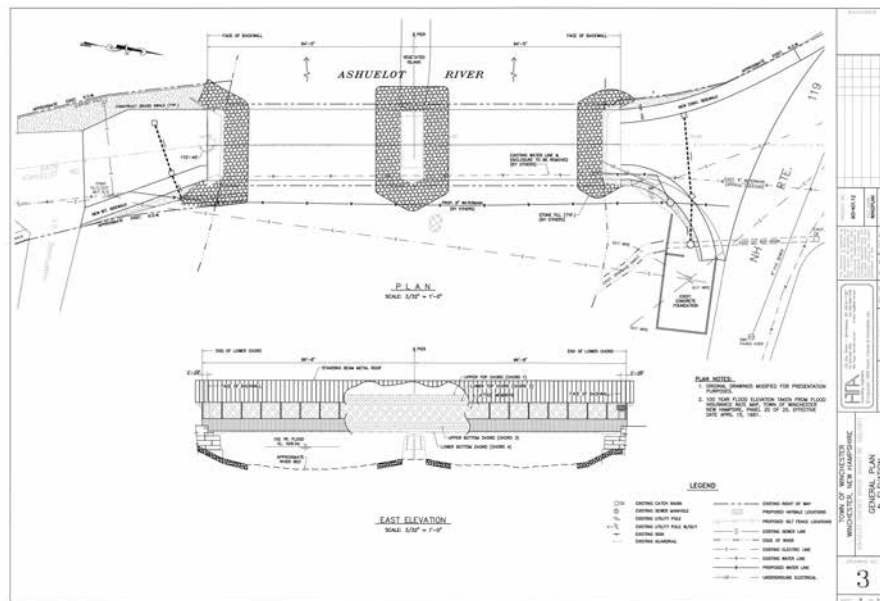


Figure C1.2 General plan and elevation. Drawing by Hoyle, Tanner & Associates, Inc., 1999.

Both approaches to the bridge are paved and graded to direct water away from the bridge. The east approach includes a raised concrete sidewalk with a decorative metal rail downstream and a paved, at-grade sidewalk with timber rail upstream. The approach extends approximately 50' to New Hampshire State Route 119. The west approach to the bridge includes a raised, paved sidewalk upstream and an at-grade short section of sidewalk on the downstream side of the approach. Timber railing is in place at each corner of the bridge on the west approach. The west end of the bridge is approximately 50' from an intersecting side street and an active rail-trail just beyond.

The standing-seam metal roof is red, as is the portal trim. The rest of the bridge is white. The siding is 4'-6" high and located along the outer edge of the sidewalk. The roof extends beyond the edge of the sidewalk, which affords protection to the trusses from rain and snow. Two signs with the text "ASHUELOT COVERED BRIDGE 1864" and "\$5 FINE FOR RIDING OR DRIVING OVER THE BRIDGE FASTER THAN A WALK" have been added to each portal.

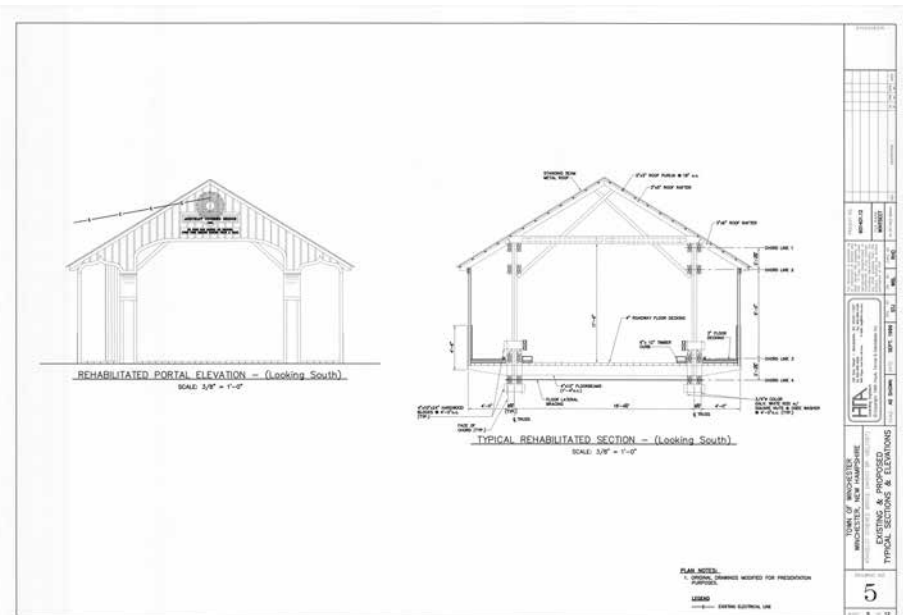


Figure C1.3 Typical bridge and portal sections. Drawing by Hoyle, Tanner & Associates, Inc., 1999.



Figure C1.4 Reconstructed signs. Sean T. James, 2001.

CASE STUDIES

1. Ashuelot Covered Bridge

The roof framing consists of 2" x 3" purlins at 1'-6" on center (o.c.) supported by 3" x 5" rafters at 4'-0" o.c. The rafters alternate between a single piece member that extends from the roof ridge over the sidewalk and a rafter that frames into the top of the cross beam, with an adjacent, shorter rafter spanning from the truss to a support member at the sidewalk. The upper lateral bracing includes 6" x 10" cross beams with two sets of 5" x 4" X lateral bracing between cross beams. The 4" x 4" knee braces are in place at each cross beam and span from the rafter. The knee braces are notched at the cross beam and have birdsmouth notches at the lower, upper truss chords. Lower lateral bracing consisting of 5" x 5" X braces with 1"-diameter steel rods between the trusses was added as part of the 1999 rehabilitation. The rods are spaced at 12' o.c. except for two sections spaced at 8' o.c. over the pier.

The Town lattice trusses consist of four, four piece 3" x 10 3/4" chords and two layers of 2 3/4" x 10 3/4" lattice oriented at a 45-degree angle. The lattice and chords are held together by 1-3/4" diameter trenails. The trusses support 3 1/2" x 11 1/2" floor beams at 1'-4" o.c. Every third floor beam at 4'-0" o.c. extends 4'-8 3/4" beyond the centerline of the trusses to support the sidewalks. The



Figure C1.5 Interior view of trusses, deck and unpainted 4" x 12" bridge guardrail. Sean T. James, 1998.

roadway portion of the bridge uses 3 1/2"-thick decking, while 3"-thick decking is used on the sidewalks.

An interesting feature of the trusses is the interior bridge railings, which are supported on bolster blocks on top of the upper, lower chord. Two steel rods connect the bolster block to the small block below the lower, lower chord. This system serves a dual function of supporting the interior roadway railing and providing an additional load path within the truss.



Figure C1.6 Exterior sidewalk showing bolster blocks and rod clamp system on right; original 4" x 5" molded handrail on left. Scott Wagner, 2005.

Figure C1.7 Lower guardrail support. Note tapered long floorbeams supporting 3" decking for sidewalk. Sean T. James, 1998.

Chronology of Development and Use

The National Register nomination for the Ashuelot Covered Bridge indicates that the bridge incorporated some members of the bridge it replaced; however, these members were replaced in 1936 as part of repairs made to the bridge after a hurricane.

Although limited historical data is available on the bridge, notes provided by Stan Snow of the National Society for the Preservation of Covered Bridges provided some information. The first bridge at this site was built in the 1850s to facilitate hauling the wood needed to stoke wood-burning engines used on the railroad. In 1874-75, A. P. Tufts earned \$91.25 for snowing the bridge. At an unknown date, the center pier was faced with concrete to deflect ice, and in 1947, the Town of Winchester installed piping for its water system on the east

CASE STUDIES

1. Ashuelot Covered Bridge

side of the walkway. A 100th anniversary celebration was held in 1964. Gary O'Neal gifted signs reading "Ashuelot Covered Bridge – 1864" for each end of the structure in 1993.

More recent repairs to the bridge, prior to the 1999 full rehabilitation, have been better documented in town files. On September 26, 1990, New Hampshire Department of Transportation bridge inspectors noted numerous broken floor beams and closed the bridge. Seven 4" x 12" x 28' and five 4" x 12" x 28' replacement Douglas fir beams were sistered to the originals. The total repair cost was \$4,753.96. In fall 1994, Gerard LaFlamme, Inc. installed a "Protectorwire" fire detection system for \$26,900, funded by a combination of federal, state, and local funds [Federal Aid Project STP-TE-X-0005(078)]. A vehicle damaged two lattice members on September 11, 1995, and 3G Construction repaired the damage at a total cost of \$14,875. The company was also paid \$1,900 to clean the bridge, replace select side boards and railings, and drill and spike down fifty deck planks.

Description of Most Recent Rehabilitation Project

The Town of Winchester retained Hoyle, Tanner & Associates, Inc. (Hoyle, Tanner) of Manchester, New Hampshire, to design a rehabilitation of the Ashuelot Covered Bridge. The completed rehabilitation won the 2003 Special Palladio Award for Covered Bridges.

Inspection and Design

At the initial inspection in January 1997, the bridge was posted for 3 tons. The inspection noted the following deficiencies: poor condition of the metal roof including numerous holes; twenty-nine cracked, split, or broken floor beams; and eighteen truss chord members, thirty treenails, and twenty-eight truss lattice members that were rotten, broken at the ends, split, or cracked. In addition, the 8"-diameter waterline housed along the upstream truss on the sidewalk was leaking, causing the truss members below to rot. The trusses were also out of alignment; the bridge supports were rotten, broken, or inadequate; and the granite pier and abutments had sustained ice damage and were bulging and missing mortar.

To properly analyze the bridge, small samples were taken from bridge members that would likely be replaced during the bridge rehabilitation and tested to determine the species. The trusses were determined to be eastern white pine with white oak treenails and were thought to be largely original. The floor beams included eastern white pine and Douglas fir with a pressure-treated red oak deck. There was no direct evidence or records to determine the age of the eastern white pine floor beams; however, the Douglas fir floor beams and decking were clearly not original to the bridge.

The bridge was analyzed utilizing the STAAD structural analysis program with a 2-D plane model. The design codes applied included the AASHTO Standard Specifications (Allowable Stress), National Design Specifications (NDS), and BOCA Building Code. From a bridge analysis standpoint, Ashuelot Covered Bridge is unique because it has a roof, which AASHTO does not specifically address, as well as two sidewalks. Three load combinations were evaluated for the trusses including: 1) dead and truck live load; 2) dead, truck live, and snow load; and 3) dead, truck live, and sidewalk live loads. A combination of dead, sidewalk live, truck live, and snow load was not evaluated due to the remote possibility of such an extreme loading occurrence. In determining the controlling capacity of the trusses, load combination 1 was used at the AASHTO Inventory level while 2 and 3 were evaluated at the higher Operating level. The Operating level was utilized due to the low probability of the bridge being subjected to all of the full non-dead design loadings simultaneously. The controlling load rating was determined to be for load combination 3 with a rating of H6.0 (6 tons). This rating ultimately controlled the posting for the bridge as the deck and floor beams both had capacities above this value. Plans and specifications were then prepared for the rehabilitation of the bridge. Those contractors with satisfactory covered bridge experience were pre-qualified to bid on the project. Four bids were received on July 31, 1998, all of them coming in higher than the budgeted amount. With town approval, Hoyle, Tanner requested that the two lowest bidders make changes to the specifications that would bring the budget and contract amount more in line with each other. Mackin Construction / Barns and Bridges of New England (B&B) were awarded the contract at \$523,122.

Several of the costs saving ideas proposed by B&B were incorporated into the work. The existing bridge sported 3 ½" x 11 ¼" floor beams of dressed timber,

CASE STUDIES

1. Ashuelot Covered Bridge

spaced 1'-4" o.c. Full sawn 4" x 12"s with a higher grade (select structural) were substituted for the 3 1/2"x11 1/4", and the spacing between floor beams was increased to 2'-0". Physical evidence was found to support the change in floor beam spacing. By returning the floor system to its original configuration, material costs were reduced and dead load decreased. The existing Douglas fir floor beams were repurposed as the guardrail supports and clamps depicted in figures 5-7.

At some point, a modern 2" x 4" sidewalk handrail was installed above the original 4" x 5" molded handrail. After consultation with the town's insurance company, these non-historic railings were removed rather than replaced, reducing costs, and removing a non-historical feature.

Construction

The construction portion of the project began with installation of temporary shoring underneath and within the bridge. Temporary bearing pads of crushed gravel were installed in front of each abutment and on both sides of the pier. Concrete blocks with timber cribbing above were then installed at the bearing pad locations to support longitudinal steel beams underneath the bridge. Next, the floor beams and decking were removed. The longitudinal steel beams supported additional timber cribbing and the steel needle beams supporting the top chords of the truss, spaced at regular intervals at every third lattice. The specifications required a shoring system capable of relieving all internal stresses within the Town lattice trusses, so the lattice plank and chord sections could be removed and replaced without harming the adjacent, historical members.

During the shoring installation, the waterline was removed from the bridge sidewalk. A new waterline was installed in the summer 1998 upstream of the bridge and under the riverbed as part of a separate project. Removal of the waterline uncovered previous fire damage to the upper, lower chord of the trusses. The cause or timing of the fire damage is unknown.

Once the temporary shoring was in place, the crew replaced truss lattice and chord members with select structural grade Douglas fir members that matched the dimensions of the existing truss members. The replacement members were held in place and new holes drilled for the treenail connections. B&B turned all



Figure C1.8 Shoring underneath bridge. Sean T. James, 1998.



Figure C1.9 Interior shoring. Sean T. James, 1998.

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1. Ashuelot Covered Bridge



Figure C1.10 Previous fire damage of lower chord. Sean T. James, 1998.



Figure C1.11 Tim Andrews fabricating replacement treenails on his Trevor treenail lathe. Sean T. James, 1998.

treenails for the project on site using specialized machinery. During construction twenty-three additional lattice members were discovered to have splits at their ends (relish) above or below their chord connections. These twenty-three members were retained and repaired by installing $\frac{1}{2}$ " x 14" carriage bolts and epoxy and wood Dutchmen at their split ends.

Repairs to the abutments and piers were made concurrently with the repairs to the trusses. The original bearings at both abutments and pier consisted of a single transverse bed timber, supporting short bolster beams, which run parallel and directly below the bottom chords. The rather small bed timbers (a mere 6" x 10" in section) provided insufficient bearing area to transfer the live and dead loads from bridge structure to abutment/pier tops. These existing bed timber deficiencies caused the misalignment of the trusses.

The design plans called for installing 18" x 48" concrete pedestals at each bearing location, which would increase the bearing area substantially. Cut and hand-split granite pedestals were installed in lieu of the concrete, since granite matched the materials used in the original abutments. Once the trusses had

CASE STUDIES

1. Ashuelot Covered Bridge



Figure C1.12 Installation of floor beams and decking; note steel needle beams supporting the top chord, spaced at every third lattice opening, 1998. Sean T. James, 1998.

been repaired, the bridge was returned to its bearings on new bolster beams and spacer blocks. The next portions of the bridge to be completed were the lower lateral bracing, floor beams, and decking. The new members were installed from one end of the bridge to the other, which allowed for easy removal of the temporary shoring along the new bridge deck.

At the approaches both roadway and sidewalks were in poor shape. On the south approach where water had been diverted towards the bridge, the walkway approaches had deteriorated so they were hazardous for users. Plans called for removing the asphalt approaches, correcting the grade to alleviate drainage and access issues, and removing and replacing unstable soils behind the abutment back walls.

Excavation of the unstable soils revealed substantial evidence that the approaches had been raised some 3', perhaps soon after the bridge was first built. Once 3' of gravel had been removed, a loamy soil was uncovered with a silver coin dating from the 1870s found in this layer.

Removal of the asphalt and fill also unearthed large cut granite cap stones extending the full width of the roadway approaches and positioned in the fill as if they were cast off and buried during previous road work. One of these back wall cap stones was recovered whole, the other was found broken in two. Excavation revealed that the stone back walls were thin and unstable, built mostly with small field stone, with little or no mortar. The discovery of the 10" x 12" x 17' granite cap stones and substandard back walls required a change in scope. The rehabilitation team agreed that reconstructing the back walls with stone and mortar and returning the granite cap stones to their former locations was both a welcome and desirable change. The sidewalk approaches received the same treatment, as they also required reconstruction.

The siding, portal trim, and a select few sections of the post/rail assembly were replaced in kind, using the same species of wood. Missing features were replicated based on existing duplicate examples or replicated based upon visual evidence in historic photographs.

Fire Protection

In 1993, three covered bridges in New Hampshire were lost to arson, including the Slate Covered Bridge in the neighboring Town of Swanzey. The fire damage uncovered at the Ashuelot Covered Bridge and the loss of the three bridges raised local awareness of the vulnerability of these structures to arson. As a result, a fire detection system was installed in the bridge in 1994. This system provides warning of an arson attempt but does nothing to prevent the arson itself, so the design team also specified the application of a fire-retardant coating to the bridge. Due to funding limitations, this work was let in a separate contract at the completion of the rehabilitation.

The majority of covered bridges are unpainted and therefore fire retardant coatings are applied directly to the (unpainted) wood surface. Nochar Fire Preventer clear coating was applied to unpainted wood not directly exposed to sunlight while Andeck Polaseal EFM Fire Retardant Wood Sealer clear coating was used in locations exposed to sunlight. In the case of the Ashuelot Covered Bridge, much of the bridge had previously been painted; therefore Nochar S320 Fire Retardant Sealer was applied to all painted surfaces. This coating is pigmented and resembles "regular" latex paint but is specifically manufactured

CASE STUDIES

1. Ashuelot Covered Bridge

for previously painted surfaces. If additional touch up was required, latex paint was applied over the Nochar S320. As with all painting projects, proper surface preparation and temperatures are crucial to adherence and functioning of the coating. Painting of the bridge was completed in July 1999 under a separate \$26,700 contract to Advanced Environmental Services.

Analysis of Treatment and Standards That Have Been Applied

1. A property will be used as it was historically or be given a new use that requires minimal change to its distinctive materials, features, spaces, and spatial relationships.

The bridge is on its original abutments and pier and continues to operate as a self-supporting wood truss without modern support. The bridge still serves as a vehicular and pedestrian crossing.

2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alteration of features, spaces, and spatial relationships that characterize a property will be avoided.

The visual character of the bridge was not compromised, and all character-defining features were retained. The geometry of the bridge was returned to its original configuration with the removal of a waterline from the sidewalk. Recovery and reuse of the extant granite cap stones reestablished a lost feature; physical evidence existed to support their reuse.

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.

No changes were made that would create a false sense of historical development. All character-defining features were respected and retained as products of their time within the period of significance.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

The only known change made to the bridge after its original construction date was the addition of a waterline along the upstream truss. The waterline was not believed to contribute to the historic significance of the bridge and was removed due to the ongoing damage it was causing to the bridge.

5. Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

The members of the truss that were not beyond repair were preserved. Replacement members were made from similar materials and craftsmanship that replicated historic construction methods. Other character-defining features were retained and/ or replaced in-kind with traditional materials and methods, such as the decorative trim work on the portals.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.

Repair work was completed with in-kind materials where possible and same sized members of different species where required for strength.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

No chemical treatments were used in the project.

8. Archeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

The abutments remained in place, so archeological disturbance did not occur.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work will be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

There were no new additions, exterior alterations, or related new construction.

10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

There were no additions or adjacent new construction.

CASE STUDIES

1. Ashuelot Covered Bridge

Section 106 Compliance Information

A formal Section 106 review of the rehabilitation project was not completed as it was not required at the time of construction.

Lessons Learned

The Ashuelot Covered Bridge is considered a successful rehabilitation project that retained as much original fabric as practical and maintained the overall appearance of the bridge. A team approach was adopted early in the construction phase with owner, engineer, and builder working with mutual respect and appreciation of what each party had to offer. The team approach allowed for changes that retained or preserved more fabric and features than initially proposed. As with all projects, there are many lessons learned in the design and construction phases of the project. Some of the more important lessons learned with this project are listed below.

1. A thorough hands-on inspection during design followed up by an additional inspection during construction once the siding is removed is highly recommended.
2. Engineering judgment is required when determining load combinations for covered bridges.
3. Overweight vehicles were the primary cause of the twenty-nine split and broken floor beams.
4. Pre-qualifying contractors provided assurance that only capable and experienced bridgewrights would be performing the work.
5. The original roof construction material was most likely wood shakes. Installation of a new colored metal roof conformed to the historic precedent set by almost all covered bridges in New England having metal roof replacements.
6. Timber member sizes on historic covered bridges do not match the dressed sizes of timbers supplied by the industry. High-strength structural timber (Douglas fir or southern pine) is readily available and can be procured in sawn dimensions and lengths to match existing member sizes on the bridge.

7. The Town lattice truss is a relatively stiff structural element. Jacking and shoring to remove negative camber is not possible without removing numerous treenails before jacking, then replacing treenails after the truss has been jacked to its final position.

8. Long term creep (distortion) can occur in truss elements (treenails and treenail holes) leading to permanent negative camber.

9. Bridge owners should require contractors to be bonded and insured for the entire project costs to protect their investment in bridge rehabilitation.

Project Particulars

Rehabilitation Project Team

Robert H. Durfee, P.E., Project Manager;

Sean T. James, P.E. Project Engineer, Hoyle, Tanner & Associates, Inc.

Mackin Construction

Tim Andrews, Bridgewright, Barns & Bridges of New England

William Truax, timber framer

Leo Maslan, timber framer

John Gomarlo, Town of Winchester representative

Date of Project

September 1998 to June 1999

Cost for Treatment Project

\$523,122

Case Study Team

Prepared by Sean T. James, P.E., Hoyle, Tanner & Associates, Inc., Manchester, New Hampshire; peer reviewed by Robert H. Durfee, P.S., Dubois & King, Inc., Laconia, New Hampshire, 2013.

CASE STUDIES

1. Ashuelot Covered Bridge

Sources

"Ashuelot Covered Bridge," National Register of Historic Places Nomination, NRIS 8100009, February 20, 1981.

Hoyle, Tanner & Associates, Inc. Project files, Manchester, New Hampshire.

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Pritchard, Catherine. "2 Winchester Bridges Fail Test of Time." *Keene Sentinel*, no date.

Rails to Trails Conservancy website,
<http://www.railstotrails.org/news/recurringfeatures/trailmonth/archives/0302.html>, accessed December 1, 2012.

Town of Winchester, New Hampshire, files.

Footnotes

¹ "Ashuelot Covered Bridge," National Register of Historic Places Nomination, NRIS 8100009, February 20, 1981.

² Rails-to-Trails Conservancy, <http://www.railstotrails.org/news/recurringfeatures/trailmonth/archives/0302.html>, accessed December 1, 2012.

³ "Ashuelot Covered Bridge," National Register of Historic Places Nomination.

⁴ The term "snowing" refers to paying someone to bring snow into the bridge and cover the deck so that sleighs could cross the bridge.

CASE STUDIES

1. Ashuelot Covered Bridge

CASE STUDIES

2. Cataract Falls Covered Bridge Owen County, Indiana



Figure C2.1 Cataract Falls Covered Bridge after rehabilitation. Matthew Reckard, 2006.

CASE STUDIES

2. Cataract Falls Covered Bridge

Owen County, Indiana

By Matthew Reckard, James Barker, Mary E. Kennedy

Administrative Data

Bridge Name

Cataract Falls Covered Bridge

Bridge Structure Type

Twelve panel Smith double truss spanning 129' from abutment to abutment

Date of Original Construction

1876

Original Builder

Smith Bridge Company, Toledo, Ohio

Bridge Owner/ Client

Indiana Department of Natural Resources

FWHA project identification number

STP-9960 / (INDOT Designation Number: 0101231)

World Guide Number

14-60-01

Structure Number (NBIS or local designation)

INBI 600029

HABS/HAER/HALS Documentation Number:

HAER IN-104

National Register Number and Date

NRIS 05000339, listed May 27, 2005

Description of Location

The bridge is located on the northern edge of the unincorporated village of Cataract, in Jennings Township, Owen County, Indiana. The bridge spans Mill Creek within the Cataract Falls State Recreation Area.

Description of Setting

The bridge is in a rural area about 100 yards upstream (south) of the top of Cataract Falls, the largest waterfall in Indiana. It is about 40 yards downstream (north) of a bridge built in 1988 to bypass the covered bridge. The left (west) bank between the covered bridge and the falls is a grassy picnic area set between mature trees; the right (east bank) is undeveloped woodland.

Historical Background and Context

Early settler Isaac Teal built a mill near the lower falls on what was then called Eel River about 1820. In 1841, Theodore Jennings, for whom Jennings Township would be named, purchased Teal's mill, both falls, and 1,000 acres of surrounding land. Jennings built water-powered mills for flour, wool, and lumber, and a community grew up around them. By 1876 Cataract had a population of about 100 and was the principal settlement of Jennings Township.¹

A bridge was built just below the Upper Falls before 1875, linking the mills and community at Cataract with residents across the river in the northern and eastern sections of Jennings Township. This bridge was swept away, along with more than a dozen other bridges in Owen County, by a flood in August 1875. Soon after, Owen County commissioners sought bids for a new bridge at Cataract, specifying a "Smith Wooden Truss" like a nearby bridge spanning the White River at Gosport that had survived the flood.²

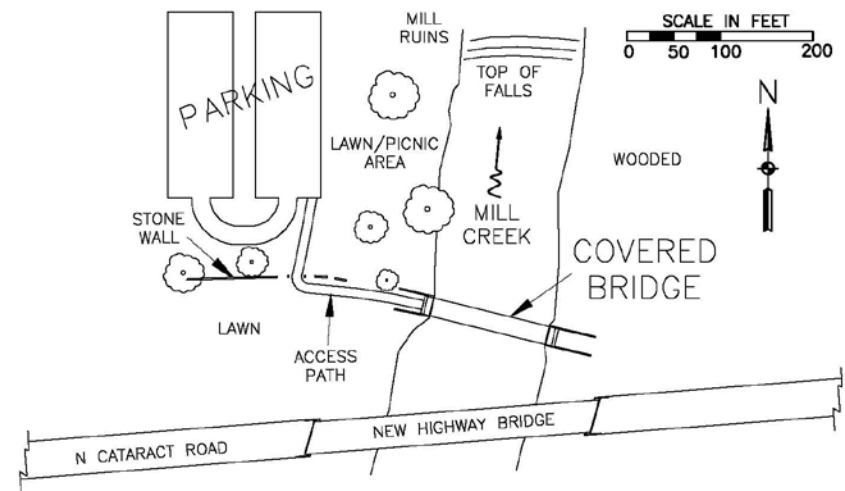


Figure C2.2 Cataract Falls Covered Bridge Site Plan. Drawing by Matthew Reckard, 2012.

CASE STUDIES

2. Cataract Falls Covered Bridge

On October 22, 1875, the commissioners awarded the contract for the new bridge at Cataract to the Smith Bridge Company of Toledo, Ohio.³ A separate contract for the abutments was awarded to William Baragan. The Smith Bridge Company fabricated the new bridge trusses at their Toledo factory, match marked the timbers, and shipped them to Cataract for assembly. The bridge was built just above the upper falls, near Jennings' mill complex. The Commissioners' Record shows payments for the abutments (\$1,678.84) and the bridge (\$2,009.00) on December 5 and 6, 1876.⁴

In 1883, John Steiner and David Wallace bought Jennings' 1,000 acres around the falls. Steiner and his descendants operated a horse racetrack on the property and, after 1916, a resort. The upper falls and 37 adjacent acres, immediately downstream of the covered bridge, were donated to the state of Indiana as a memorial to Agnes Wallace Steiner in 1952. Her daughter continued to operate the property as a resort under lease until 1967. The 37 acres was later merged with other public lands surrounding Cagle's Mill Reservoir to create Cataract Falls State Recreation Area.⁵ The covered bridge was added to the park property after it was bypassed by a new bridge in 1988. It has been open to pedestrian traffic and used as a picnic shelter since then.

Physical Description of Bridge

Cataract Falls Covered Bridge is one of the best-preserved Smith truss structures remaining. It is a single-span structure on stone abutments with a gabled wood shake roof and vertical board-and-batten siding. The bridge provides a clear roadway 14' wide and 13'-5" high. The span is supported by twelve-panel Smith trusses, an all-timber parallel-chord system patented in 1867. Truss lower chords are 140' long; the bridge is 150' long including roof extensions. The portal bracing and lateral bracing, like the trusses, are all-timber systems patented by Robert Smith. The bridge spans 129' between faces of the mortared stone abutments and has about 10' of vertical clearance over normal creek levels. Dry-laid stone wingwalls, 16' apart and perpendicular to the abutments, retain the fill of the approach roadways.

The historic fabric of both superstructure and substructure are remarkably complete; approximately 85 percent of the truss and lateral bracing timbers are original. They carry the bridge loads without added supports or reinforcement of

any kind. Most other structural components are also original, including the truss bolts and iron castings, roof rafters and skip sheathing, floor beams, and the lower layer of timber decking. Abutment stones, with one exception, are original. Materials directly exposed to weather and traffic, such as the roof shakes, board-and-batten siding, and the upper layer of the plank deck, are in-kind replacements of original materials.

The bridge's setting has changed considerably over time, with the prominent exception of the waterfall, which gave the bridge and nearby village their names. At the time of the bridge's construction, operating mills and stores as well as residences dotted the mostly deforested landscape. Within a few decades, however, the area downstream became a rural resort, with scattered homes nearby. The present land use—rural park downstream and scattered homes in wooded hilly country elsewhere—is consistent with that of the past century.

The function of the bridge itself changed radically in 1988 with the construction of the bypass bridge. Instead of carrying highway traffic it has become a part of the park, serving as an historical artifact, a picnic shelter, and a viewing platform for the falls. The new bridge detracts from the old one's setting; it is out of scale and creates a physical and visual barrier between the covered bridge and the bucolic creek and its wooded banks upstream.

Trusses

The Smith trusses have three-piece horizontal upper and lower chords that sandwich two sets of connecting web members in adjacent vertical planes, what inventor Robert Smith called a "double truss." Each web set has a vertical post at each end; all other web members are diagonals. The trusses are divided lengthwise into twelve panels, and in each panel diagonals from the two webs cross. The trusses thus appear as a series of twelve adjacent 'Xs' between upper and lower chords. End posts and tension diagonals (those tilting away from midspan) extend beyond the chords. The extended members and the chords are notched where they cross. Compression diagonals (tilting towards midspan) are not notched; rather they butt against tension diagonals just inside the chords. All truss and lateral bracing timbers are finished to about ¼" less than the nominal dimensions given in this account. Originals were eastern white pine; replacements made during rehabilitation are Douglas fir.

CASE STUDIES

2. Cataract Falls Covered Bridge

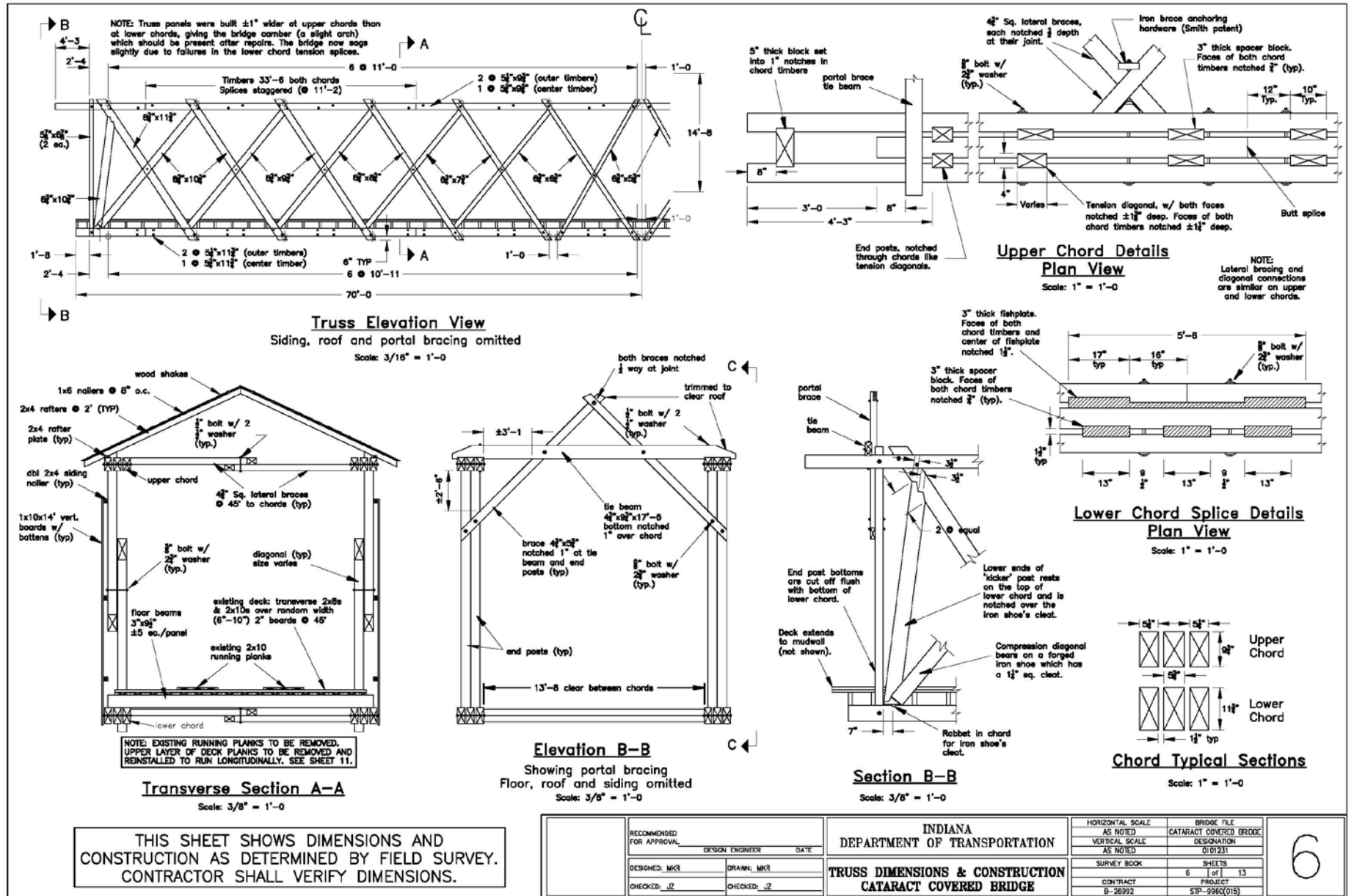


Figure C2.3 Cataract Falls Covered Bridge, sheet 6. Drawing by Matthew Reckard, 2012.

CASE STUDIES

2. Cataract Falls Covered Bridge

The middle of the three lower chord timbers is 6" x 12"; the others are 5 1/2" x 12". The timbers are three panel lengths long (33'-6") with staggered joints, thus there is one chord splice at the middle of each panel. Splices are made with C-shaped timber "fishplates" that fit into notches in the timbers' faces.

Upper chord timbers are the same thicknesses as those in the lower chord but are 10" high. Like the lower chords, they are three panels long with staggered splices. The splices are simply butt joints without fishplates. Truss diagonal timbers are all 7" thick. Their width decreases in 1" increments from 12" at the ends of the trusses to 7" at midspan. Similarly, compression diagonals vary from 11" wide at the truss ends to 6" at midspan. The outermost compression diagonals bear on the inclined faces of cast-iron shoes on the lower chord just inside the end posts.

The lateral bracing between the upper chords and the bracing between the lower ones is identical. Like the truss webs, they are comprised of two adjacent planes of diagonal timbers that cross in the center of each panel (and are bolted together there), forming a series of twelve 'Xs'. The ends of the lateral bracing timbers are notched together and fastened to the chords with iron castings and long bolts. Clamped to the chords in this way, the lateral bracing timbers (all 5" x 5"s) can act either in tension or compression.

The ends of the trusses rest on large bed timbers extending transversely under the ends of the bridge rather than directly on the stone abutments. This was common practice for covered bridges. The bed timbers spread the weight of the bridge over the surface of the abutment bearing stones, while at the same time separating the trusses from the moisture and debris on top of the abutment and thus protecting the bridge from decay. The bolsters themselves are designed to be sacrificial. When they rot, the bridge can be jacked up and the bolsters replaced.

Substructure

The bridge abutments are of rock-faced limestone set in courses with rubble cores. They are founded directly on the limestone bedrock that forms the bed of the creek. The abutments are about 23' wide and 6' thick, with the west one about 14 1/2' tall and the east one about 12'. The stones may have come from a

quarry, now overgrown, on the east bank near the top of the falls less than a hundred yards from the bridge.

The lowest course of each abutment extends about 6" beyond the masonry above, forming a plinth. Stones in the plinth courses are about 2' thick and as much as 6' long. The courses become thinner higher in the abutments so that the stones near the top are about 9" thick but still as much as several feet long. The top two courses are the thinnest, about 8", and are corbelled several inches out from the masonry below. Although relatively thin, most of these top stones are very large, as much as 6' square.

The abutments' original wingwalls were of dry-laid limestone rubble, also presumably local in origin. Although they included occasional boulders, individual stones tended to be much smaller than those in the abutments and were crudely stacked. None appear to have been hammer-trimmed to fit.

Floor

The bridge's floor is composed of wooden beams spanning between lower chords covered with two layers of planks. The beams are about 3" x 9 1/2", five per truss panel evenly spaced (i.e. about 26" on center). The lower layer of decking is 2" thick x 6" to 10" wide, set at 45 degrees to the floor beams. The upper layer consists of nominal 2" x 6" and 2" x 8" planks set longitudinally. There are 4" x 6" timber curbs on each side of the deck. All floor wood is oak. About a dozen of the floor beams are recent replacements; the rest of the sixty-six beams are probably original, as are most of the planks in the lower layer of decking.

Roof and Siding

Wood roof shakes are nailed to 1" x 6" skip sheathing. Sheathing boards are spaced 8" apart and are nailed to 2" x 4" rafters spaced 2' apart. Rafters are nailed to 2" x 4" sills that are nailed flatwise to the top of the outermost of the three upper chord timbers. The rafters have birdsmouth notches cut to fit over the sills. Eaves extend about 15" beyond the vertical 1" x 10" board-and-batten siding. Most rafters and 1" x 6" sheathing boards are old and may be original; newer ones can be distinguished by their appearance. Siding is mostly cedar

CASE STUDIES

2. Cataract Falls Covered Bridge

installed in 1995. Siding on the portals (the bridge ends) is poplar; this siding and the roof shakes were installed as part of the 2004-5 rehabilitation.

Chronology of Development and Use

Little is known about the post-construction history of Cataract Falls Covered Bridge. Presumably the roof shakes and some of the board siding, at least, were replaced more than once in the bridge's 125-year history. The siding, shakes, and the top layer of board decking were replaced in 1995, but the trusses and substructure were not repaired then. The bridge originally had no windows. The first was created in 1980 when vandals cut out part of the north wall to remove artwork painted there in 1977. Three windows were installed as part of the 1995 repairs, all on the downstream side overlooking the falls.⁶

The 1995 work did not address structural problems in the bridge's trusses. These problems, largely caused by severe (if localized) decay, threatened the survival of the structure. The Indiana Department of Natural Resources (IDNR) obtained funding for an extensive rehabilitation project under the Federal Highway Administration's Transportation Enhancement and National Historic Covered Bridge Preservation Programs in 2001. IDNR hired J.A. Barker Engineering, Inc. (Barker Engineering) of Bloomington, Indiana, to perform detailed physical and historical investigations and design the repairs to the bridge and its stone abutments and approaches. Barker Engineering also researched the bridge's history to support a National Register nomination. Matthew Reckard, P.E., M.S. Historic Preservation, led the project and was the designer of record, while Mark Brown, PhD, completed the historical research.

The bridge required emergency stabilization in August 2002 to prevent collapse and was moved off the river in January 2003. In 2004 and 2005, Intech Contracting, LLC of Lexington, Kentucky, rehabilitated the bridge and moved it back over the river. McAlister Stone, LLC of Lancaster, Kentucky, who was responsible for the dry-laid and mortared masonry, assisted them. The rehabilitation received the 2007 Indiana Historic Preservation Award given by the Division of Historic Preservation and Archaeology (IDNR).

Description of Most Recent Rehabilitation Project

Detailed inspections of the bridge began in December 2001. Significant problems were found with the bridge's trusses, including accumulations of fallen leaves, dirt, and raccoon droppings on the abutments in front of the mudwalls. The debris buried the ends of the bridge, allowing moisture retention and promoting rot. Consequently, all timbers at the lower corners were rotten, as were the "bolster" timbers on which they rested. Another problem area was found in the northeast corner of the bridge where the roof had leaked for a long time, causing several truss members to become badly rotted. The 2" x 4" rafter sills nailed to the upper chords helped retain rainwater. The result was that a portion of the middle upper chord was entirely destroyed with raccoons nesting in the hollow center of what remained. Rainwater had drained down the diagonal timbers to the lower chords, where the joints held the moisture. As a result, there was decay in the diagonals and lower chord timber joints. Finally, the investigation revealed a dozen splices in the lower chords had broken through shear failure either in the chord timber notches or in the fishplates. Similar shear failures were also located in the notch at the bottom of one tension diagonal. Steel rods connecting steel channels above the upper chord and below the lower one had been added at an unknown date to replace the lost tension capacity. Another tension diagonal had been replaced at an unknown date, probably because of a similar joint failure. The replacement fir timber was mismatched in size for its location in the truss.

In addition to these acute problems, some other chord timbers had local areas with less severe decay and a few splits and cracks. Some bolts were badly rusted in locations that stayed wet. Due to the deterioration of the trusses, the bridge sagged by several inches.

Significant problems were also found with the bridge's substructure. Much of the dry-laid rubble wingwalls had collapsed due to large tree roots growing through them. Unsuccessful attempts had been made to stabilize the failing slopes using boards supported by metal fence posts, large chunks of concrete, and other materials. Most of the original, soft mortar in the abutments had deteriorated with repointing in limited areas done at an unknown date using harder mortar. There were extensive voids within the rubble cores of the abutments, probably the result of sand, fine gravel, and uncured lime mortar being

CASE STUDIES

2. Cataract Falls Covered Bridge

flushed out of open joints during periods of high water. Finally, the large bearing stones immediately under the ends of the trusses had broken, apparently the result of the rotting away of bearing timbers under the bridge ends (resulting in point loading on the stones) and loss of bedding mortar (resulting in uneven support for the stones).

With rehabilitation design underway in 2002, inspectors noticed the sag at one corner of the bridge had increased pronouncedly. Investigation revealed that the lower chord was breaking near the abutment, leaving the bridge in imminent danger of collapse. The bridge was immediately closed to park visitors. Barker Engineering quickly prepared plans for emergency stabilization. IDNR hired F.E. Gates Co. of Indianapolis for the work through an accelerated bidding process.

F.E. Gates installed the temporary shoring in August 2002. First the crew lifted the bridge back to approximately level with hydraulic jacks. They then placed a heavy timber under each end of the bridge, one panel away from the abutments in the angles between the lower chords and the protruding bottom ends of tension diagonals. Steel pipe supports anchored into the bedrock at the base of the abutments held the timbers. The jacks were then removed. The work was accomplished without fasteners or alterations of any kind in the original bridge materials. The contract price was \$25,540.



Figure C2.4 Temporary shoring installation. J. A. Barker Engineering, August 2002.

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2. Cataract Falls Covered Bridge



Figure C2.5 Moving bridge off the river. J. A. Barker Engineering, January 2003.

IDNR feared that the shoring could be knocked out by the large trees and other debris that is often swept down Mill Creek during floods. Consequently they decided to move the bridge off the river pending the rehabilitation project. Dillabaugh, Inc., of Crown Point, Indiana, performed the move in January 2003. This, too, was done without any destruction of original fabric in the superstructure, aside from some of the west approach embankment. Moving the bridge onto shore facilitated the rehabilitation that followed, somewhat offsetting its \$66,000 cost.

J.A. Barker Engineering completed designs for the rehabilitation in early 2004. The Indiana Department of Transportation (INDOT), acting through a cooperative agreement with IDNR (the bridge's owner), awarded the low-bid contract that September to Intech Contracting, LLC of Lexington, Kentucky. Two John Craces, father and son, were Intech's project superintendents. Rodney Ison was their lead craftsman for the truss timber joinery. McAlister Stone, LLC of Lancaster, Kentucky, led by owner Richard McAlister, assisted Intech with the dry-laid and mortared masonry. INDOT's Crawfordsville district office administered the contract, with technical assistance from Barker Engineering. The

major tasks in the rehabilitation are shown in Figure C2.6. (next page) The project objective was to restore the bridge's structural and historical integrity to the greatest extent possible consistent with its modern use as a pedestrian bridge and picnic shelter. This included reconstruction of lost features (the portals and timber curbs) where there was good evidence of their original construction. A few non-original features were deliberately incorporated into the project when necessary for the bridge's modern use or when original construction had failed structurally.

Examples of the latter include windows and paved approaches. Windows overlooking the falls, although not an original feature, are important to the bridge's present function as a picnic shelter and viewing platform. The project left the existing windows (dated to the late twentieth century) and added awnings over them for weather protection (the bridge's upstream side, seen in Figure 1, is without windows). Similarly, accessibility requirements dictated that approaches be paved, have gentle slopes, and connect to handicapped parking spaces.

Original features that exhibited structural failure included the mortar in the abutments and the dry-laid (mortarless) wingwalls. As discussed below, the mortar used in the rehabilitation was harder than the original but softer than the abutment stones. The poorly built original wingwalls were replaced with dry-laid structures with far greater strength, durability, and (to most eyes) beauty than the originals.

Tension joints in truss timbers (both lower chord splices and lower chord/diagonal joints) had also failed in numerous locations. The present use of the bridge, however, puts less stress on these joints than did previous highway loadings. These failed joints were restored as originally built, rather than strengthened, because structural analysis indicated they were as strong as needed for current use.

Other non-original materials were used in limited quantities where there was specific justification. Principal among these were epoxies used to consolidate wood or, along with bolts, to splice new wood to old. This allowed more of the original truss timber to remain in service than would have been otherwise possible. Another non-original material was geotextile fabric, used to reinforce the approach embankments. The fabric is not visible in the completed project.

CASE STUDIES

2. Cataract Falls Covered Bridge

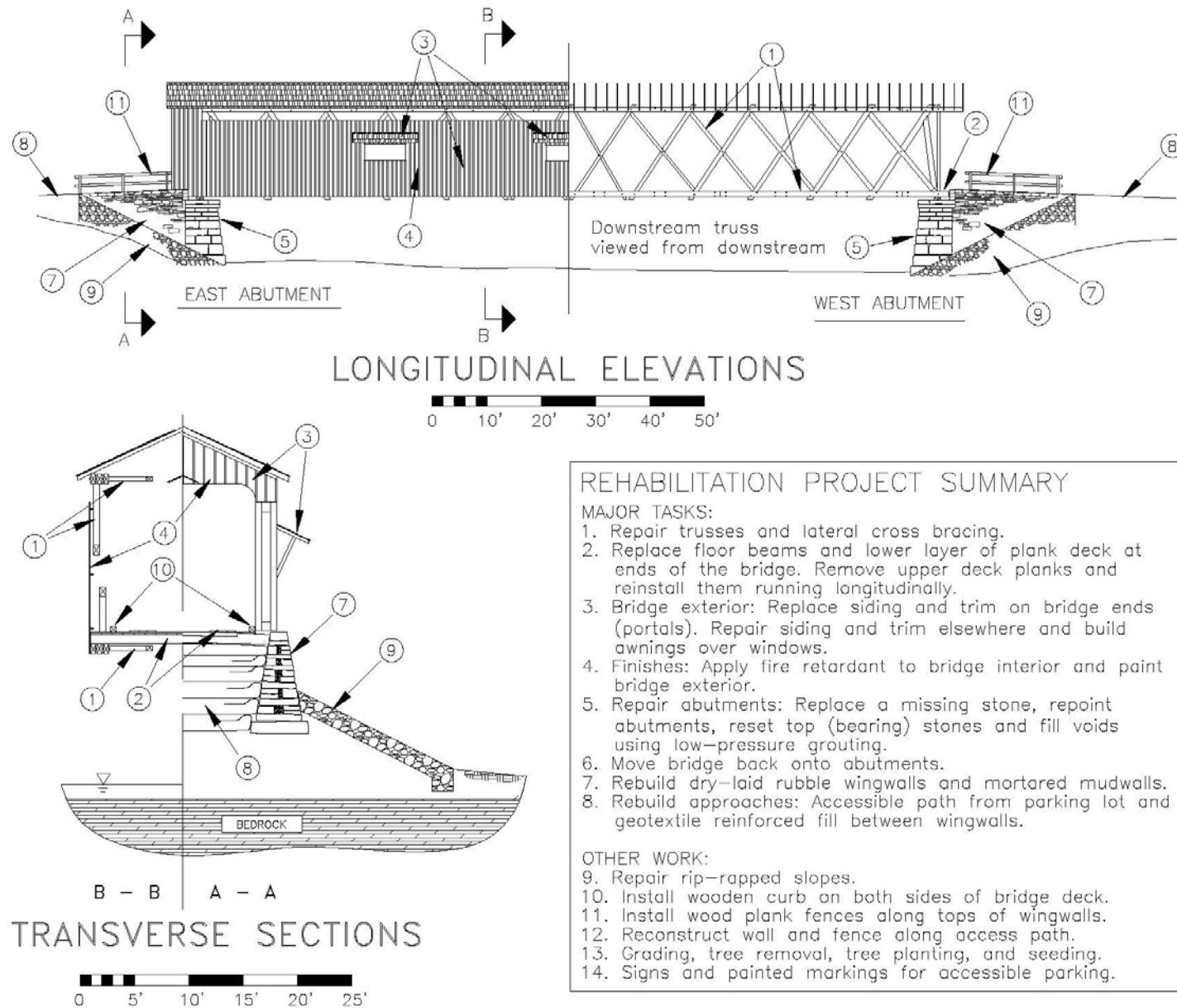


Figure C2.6 Cataract Falls Covered Bridge Elevations, Sections, and Rehabilitation Summary. Drawings adapted from project plans by Matthew Reckard, November 2012.

CASE STUDIES

2. Cataract Falls Covered Bridge

Damaged truss tension members were generally replaced in their entirety even if the damage was limited to one end of the piece, due to the difficulty of making strong tension joints in heavy timber. Four tension diagonals, three full-length lower chord timbers (33'-6"), and the two shorter of the three lower chord timbers at each corner of the bridge (i.e. four at 8'-7" and four at 19'-9") were replaced. The longest chord timber at each corner was also rotten, but since stress in the chords near the supports is low it was determined that a bolted and glued lap joint would provide adequate strength there. This saved about 80 percent of the original long timbers.

Where a compression member was rotten only at one end, that end was generally cut off and a new end spliced on with a bolted, glued lap joint, unlike the tension members that were replaced in full. This was done on four upper chord timbers, one compression diagonal, and six (of eight) truss end posts.

The contract specifications required that, where practical, truss timber repairs be made from wood salvaged from other original timbers that were being replaced. This was desirable for historic reasons (replacing old growth eastern white pine with like material) and aesthetic ones (wood grain and patina in the two pieces would closely match), plus it minimized the chance that shrinkage would cause separation and weaken the joint.



Figure C2.7 Timber repairs using new Douglas fir (left) were conspicuous. Those using salvage from original timbers (right) were nearly invisible. The Douglas fir repairs, having weathered a few years, are now less noticeable. J. A. Barker Engineering, 2004.



Figure C2.8 Decay at the bearings required extensive reconstruction. At the southwest corner, shown here, the two shorter lower chord timbers were replaced, while new ends were spliced onto the longest chord timber, both end posts, and a diagonal. J. A. Barker Engineering, March 2004.

Some shrinkage in new timber was anticipated even though the contract called for seasoned or kiln-dried wood (which, for the large timbers, required specialty microwave kilns). For new wood, contract specifications indicated a preference for eastern white pine to match the original species. It was recognized, however, that big timbers of that species might be unavailable, so #1 Douglas fir was used as a substitute. Intech brought a large portable sawmill to the site, enabling them to mill timbers to the exact dimensions needed with relative ease.

Once repairs were largely complete, the trusses were jacked to restore the camber (slight arch) they had when new. Wood shims were then cut to fit the resulting gaps at the upper ends of compression diagonals. With these shims in place, the trusses retained the camber after jacks were removed.

Truss repairs at the ends of the bridge required the removal and later replacement of nearby floor beams, deck planking, and siding. Most of these materials had to be removed regardless, so this added little extra work or expense.

CASE STUDIES

2. Cataract Falls Covered Bridge



Figure C2.9 Trusses were jacked to restore camber, then held in that position by inserting shims at the top of truss compression diagonals, as shown here. J. A. Barker Engineering, 2004.

The first two floor beams at each end of the bridge, and some of the diagonal lower level planking there, were decayed and replaced in kind. The planks in the top deck layer, new in 1995, were not rotten but had been installed transversely. They were removed and later replaced longitudinally on the bridge, both because this was the historically correct alignment and because it is stronger since the planks span between floor beams.

Inspections revealed vertical bolt holes through some floor beams, a few with long bolts still in them, evidence that the deck originally had timber curbs on each side. Such curbs fastened with bolts like those at Cataract have been found still intact on the Engle Mill Bridge in Greene County, Ohio. Engle Mill is a near twin to the Cataract Falls Covered Bridge; it is also a Smith truss structure built by the Smith Bridge Company and is just 4' shorter and one year younger than the one at Cataract Falls. Curbs at Cataract were reconstructed based on dimensions of those at Engle Mill Bridge.

The bridge's portals are perhaps the most visible parts of the bridge to the casual visitor, and they were the only places on the original bridge that had

decorative (if simple) trim. Non-historic siding at the ends of the bridge was removed and the historic portal appearance reconstructed using planed poplar boards. The reconstruction was based on scaled measurements of historic photographs of the bridge.

Abutment rehabilitation was greatly eased by having the bridge moved off the river. Layers of large, broken bearing stones were removed, the tops of the abutments were cleaned, and the stones were reset in new mortar. A broken stone low on the east abutment was cut back square and a new limestone block mortared in to the void. Joints were repointed using Type N lime-cement with acrylic latex additive, which is more durable than the original all-lime formula (that had failed badly and extensively), yet still relatively soft and flexible. Grout was injected into the abutments under pressure to fill voids. The grout was a low-strength cement and sand slurry (capable of being removed as needed in the future) designed to penetrate voids but not pores in soil or stone.

The bridge was moved back onto the abutments in October 2004, after repairs to both were largely complete. Once that was done, the approaches were excavated to enable construction of the new wingwalls. Preparation for the new wingwalls included removal of several small trees and one very large sycamore growing in the existing embankments.

The dry-laid stone wingwalls were the first such walls built under an Indiana state highway department contract in a century. Due to the unfamiliarity of the construction, J. A. Barker Engineering used a belt-and-suspenders design: either the stone walls or the geotextile earth reinforcement in the approach fills between them could theoretically support the embankments by themselves.

Initial plans for the new wingwalls were based on inspection of the existing, largely collapsed construction, with allowance for minor modifications to match original details that would only be revealed once excavation of the approach fills began. The excavation, however, revealed that original construction had been even poorer than expected, merely stones stacked at the edge of the fill to create steeper slopes. This helped explain why so much of the slopes had failed.

CASE STUDIES

2. Cataract Falls Covered Bridge



Figure C2.10 Dry-laid wingwalls under construction. The reconstructed bridge portal is complete except for paint. The top of the falls is visible in the background. McAlister Stone LLC, January 2005.

The original, failed wingwall construction was not replicated. The new ones are of far higher quality and should be far more durable. They are compatible with the historic bridge and its abutments in appearance. The project benefited greatly from the skills of Richard McAlister, one of the nation's premier practitioners of the ancient, labor-intensive craft of drywalling.

Minor work completed as part of the rehabilitation project included McAlister Stone building mortared limestone mudwalls, similar to the originals, immediately behind the abutments. These separate the approach fill from the ends of the wooden bridge. Intech built a wheelchair-accessible path connecting the bridge and visitor parking lot. Plank fences were installed along the tops of the wingwalls, and an abandoned telephone cable was removed from the bridge. The exterior was repainted in the existing (and historic) brick red color, while the interior and those portions of the exterior accessible from land were sprayed with a nontoxic, colorless fire retardant that produces a Class A flame spread rating. Fill slopes were protected with riprap, the disturbed ground was seeded, and a few trees were planted. Temporary erosion and pollution control measures were taken during construction.

Analysis of Treatment to Standards That Have Been Applied

1. A property will be used as it was historically or be given a new use that requires minimal change to its distinctive materials, features, spaces, and spatial relationships.

The present use of the Cataract Falls Bridge required minimal changes to the historic structure.

2. The historic character of the property will be retained and preserved. The removal of distinctive materials or alteration of features, spaces, and spatial relationships that characterize a property will be avoided.

The only significant changes introduced by the rehabilitation project were awnings placed over the late twentieth-century window openings (to protect the structure from rain), a flatter grade on the west approach (to allow wheelchair access), improved dry-laid stone wingwalls (originals had failed structurally), and wood fence at the top of the wingwalls (for pedestrian safety).

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.

No changes were made that would create a false sense of historical development.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

This was not an issue at this bridge.

5. Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

Replacement components were made from similar materials and craftsmanship that complemented the historic structure.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.

CASE STUDIES

2. Cataract Falls Covered Bridge

Original materials were replaced only where repair was impractical. Broken bearing stones on the abutments, for example, were rebedded in new mortar rather than replaced. New material, where required, matched the original to the extent possible. This effort went to the extent of salvaging sound wood from timbers being replaced and using it in repairs to timbers left in place, because the original type of wood (old growth white pine) was otherwise unavailable. The structure was repaired rather than replaced: there is no concrete, steel, or other non-historic structural support in the completed project. The rehabilitation restored several lost historic features to the bridge: the appearance of the portals, the orientation of deck planking, and the timber curbs. All of these were done based on documentary and physical evidence as required.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

A clear fire retardant was sprayed on the timbers for fire protection.

8. Archaeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

The Area of Potential Effect was broadened to consider the surrounding area, but no historic resources other than the bridge were located.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work will be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

The changes to the bridge are compatible.

10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

The changes to the bridge are reversible.

Section 106 Compliance Information⁷

Due to the funding received from the Federal Highway Administration, this project was subject to review as a federal undertaking under Section 106 of the National Historic Preservation Act. The Section 106 consultation process began in January 2002 when Barker Engineering sent out consulting party invitations. While two parties accepted the invitation, the State Historic Preservation Officer staff (SHPO) and Historic Landmarks Foundation of Indiana (now Indiana Landmarks), only the SHPO provided comment during the process.

The SHPO comments and questions focused on understanding to what extent the character-defining features of the bridge might be diminished as a result of the project. The comments were concentrated on three main areas: 1) assessing all resources within an adequate Area of Potential Effect (APE); 2) the type of mortar utilized; and 3) non-historic window openings.

In the course of consultation, Barker Engineering expanded the APE at the SHPO's suggestion in order to adequately take into account indirect effects beyond the project's construction limits. No historic properties other than the bridge were located within the APE. Thus, the rest of the consultation focused on effects to the bridge.

With regard to mortar, the SHPO recommended that Barker Engineering follow the suggestions provided in the National Park Service publication "Preservation Brief #2: Repointing Mortar Joints in Historic Masonry Buildings." The project did ultimately follow most of the recommendations in the brief, but not all as the brief focuses on masonry walls in buildings, whose inherent properties are very different from those of bridge abutments and thus warrant different treatments. Additionally, using a mortar that duplicated the original mortar, as encouraged by the brief, was not prudent since the original mortar had failed so extensively. Instead, Barker Engineering proposed use of a mortar that was harder than the original but much softer than stone, which was expected to provide both permeability and flexibility. The SHPO was satisfied with the proposed mortar after being provided a detailed explanation of the reasons behind the selection.

CASE STUDIES

2. Cataract Falls Covered Bridge

The SHPO expressed concerns with installing windows on the bridge that were not present historically because they would not be compatible with the historic character of the bridge during its period of greatest significance, and they would alter the material integrity of one of a few remaining examples of a Robert W. Smith-designed bridge. Additionally, the SHPO did not want the installation of new windows to create a false sense of historic development.

Barker Engineering explained that no new windows would be installed on the bridge; simply those openings that had already been created in the 1980s and 1990s would be retained and rehabilitated. Additionally, Barker Engineering explained the value of the windows for the bridge's current recreational use. They allowed for picturesque viewing of Cataract Falls that could not be duplicated elsewhere without construction of a structure that would intrude on the bridge's setting. Additionally, the windows enhanced the bridge's use as a picnic shelter on a daily basis and for special catered dinners. Elimination of the existing windows would hinder the recreational function of the bridge. After receiving the clarifying information about the windows, the SHPO agreed that retention of the existing window openings was acceptable.

As a result of the Section 106 consultation process, in September 2002 the FHWA issued a finding of "No Adverse Effect" with respect to the project's impacts on the historic bridge.

Lessons Learned

The project's success was due in part to having well-qualified and experienced designers and contractors as well as adequate funding that allowed the major structural issues to be addressed. There was also ample time in the early stages of the project for thorough historical research, inspections, and structural analysis. The historical investigation of the bridge by J.A. Barker Engineering, the rehabilitation designers, facilitated accurate reconstruction of lost features, notably the portals and wheel guards. The efforts of the Owen County Road Department in keeping a decent roof over the structure for 100 years (with the exception of the northeast corner) resulted in preservation of 85 percent of the original truss timbers.

Project Particulars

Rehabilitation Project Team

Owner: Indiana Department of Natural Resources, Indianapolis
Division of Engineering: Tom Hohman, Director
Champak Patel, Chief/Operations
Christopher Baas, Architect

Builder: Intech Contracting, Inc., Lexington, Kentucky
John Crace & John Crace, Jr. Project Superintendents
Rodney Ison, Timberwright
McAlister Stone, Lancaster, Kentucky
Richard McAlister, Dry-laid Stone Mason

Engineer: J.A. Barker Engineering, Inc., Bloomington, Indiana,
(now VS Engineering, Inc.)
Matthew Reckard, P.E., M.S. Historic Preservation, Senior Engineer
Mark Brown, PhD, Historian

Indiana Department of Transportation, Crawfordsville District

Date of Project⁸

Design process, December 2001 to May 2003
Environmental review process, January 2002 to December 2002
Project construction, March 2004 to May 2005

Cost

2001 FHWA grant: \$70,000⁹
Total cost: approximately \$600,000

Case Study Team

Prepared by Matthew Reckard, P.E., and James Barker, J.A. Barker Engineering, 2013.
Peer reviewed by Mary E. Kennedy, Indiana Department of Transportation.

CASE STUDIES

2. Cataract Falls Covered Bridge

Footnotes

¹Owen County Historical and Genealogical Society, *A History* (Spencer, IN: Owen County Historical and Genealogical Society, 1994), 58-59.

²*Owen County Journal* [Spencer, Indiana], August 5 and 12, 1875.

³Owen County, *Commissioners' Record* 10 (October 22, 1875), 141, located in Owen County Archives, Spencer, Indiana, hereafter cited as *Record*.

⁴Owen County, *Record* 10 (December 5, 1876), 276, and (December 6, 1876), 285, 287.

⁵Indiana DNR information online at <http://www.cataractfalls.com/historypage3.html>, accessed November 27, 2012.

⁶Cataract, photo file folder, and "Vandals Remove Art Work. . . And Wall . . . From Cataract Covered Bridge," unattributed newspaper clipping, March 30-31, 1980; "Cataract Covered Bridge To Be Dedicated Saturday, Oct. 7," *Evening World* [Spencer, Indiana], September 29, 1995, in Covered Bridge Folder. Both folders are located in the Owen County Information Cabinet, Genealogical Collection at Owen County Public Library, Indiana.

⁷Section 106 Compliance Information provided by Mary E. Kennedy via email, July 24, 2013.

⁸Date information provided by Mary E. Kennedy via email, July 24, 2013.

⁹National Historic Covered Bridge Preservation Program, 2001 Project Selections <http://www.fhwa.dot.gov/bridge/hcb0901.cfm>, accessed August 24, 2012.

CASE STUDIES

2. Cataract Falls Covered Bridge

CASE STUDIES

3. Cornish-Windsor Covered Bridge

Sullivan County, New Hampshire and Windsor County, Vermont



Figure C3.1 View of Cornish-Windsor Covered Bridge from the New Hampshire side. Scott Wagner, 2013.

CASE STUDIES

3. Cornish-Windsor Covered Bridge

Sullivan County, New Hampshire and Windsor County, Vermont

By Laura S. Black, James L. Garvin, and Mark W. Richardson

Administrative Data

Bridge Name

Cornish-Windsor Covered Bridge

Bridge Structure Type

Two-span modified continuous Town lattice truss spanning approximately 450' at floor level. The gable ends extend beyond, for a total roof ridge length of approximately 462'.

Date of Original Construction

1866

Original Builder

James F. Tasker (1826 – 1903) and Bela J. Fletcher (1811 – 1877)

Bridge Owner/ Client¹

New Hampshire Department of Transportation (95%) (1936 – Present) and Vermont Agency of Transportation (5%)

FWHA project identification number

RS-345(1) S-4134

World Guide Number

29-10-09#2; 45-14-14#2

Structure Number (NBIS or local designation)

NHDOT 064/108; NBIS 005500640010800

HABS/HAER/HALS Number

HAER NH-8

National Register Number and Date

NRIS 76000135, listed 1976

American Society of Civil Engineers designated the bridge a National Historic Civil Engineering Landmark, 1970

Description of Location

The bridge crosses the Connecticut River between the east end of Bridge Street in the town of Windsor, Windsor County, Vermont, and State Route 12-A in the town of Cornish, Sullivan County, New Hampshire. The New Hampshire state boundary line is located at the Vermont-side low water mark of the Connecticut River. Most of the bridge structure is located in New Hampshire.

Description of Setting

The bridge is situated adjacent to a small grouping of residences along State Route 12-A near the Cornish State Wildlife Management Area in New Hampshire. It is at the end of the residential Bridge Street in the community of Windsor, Vermont.

Historical Background and Context

Constructed in 1866, this bridge is the fourth at this crossing of the Connecticut River. Previous structures built in 1796, 1824, and 1850 were all lost to floods or ice.

Beginning in 1784, Jonathan Chase of Cornish, New Hampshire, operated a ferry across the Connecticut River between Cornish and Windsor, Vermont. In 1792 Chase petitioned the New Hampshire General Court to replace the ferry with a toll bridge. The request was approved in 1795, and Chase's toll bridge was constructed the following year. This first structure was destroyed in a spring flood and replaced in 1824. The second toll bridge was replaced in 1850 after it too was destroyed in an 1849 flood. The 1850 bridge was subsequently destroyed in 1866 by an ice floe, which removed the structure from its abutments and carried it downriver where it collided with a railroad bridge.

While a ferry system was temporarily put back into service, the Proprietors of Cornish Bridge quickly began planning for another replacement. James Tasker of Cornish, New Hampshire, and Bela Fletcher of Claremont, New Hampshire, won the contract and had constructed the currently existing Cornish-Windsor Covered Bridge by September 1866 for a cost of \$9000. Like the one before it, the fourth and final bridge was a covered Town lattice truss, with some modifications. One adaptation was the use of notched and bolted timbers instead of planks in the lattices. Originally patented in 1820 by Ithiel Town, a Connecticut architect, the Town lattice truss was an innovative design that gained recognition from the bridge-building community and popularity for the benefits over other truss systems, including its use of comparatively light timber and relative ease of assembly.

The Cornish-Windsor Covered Bridge exhibited alarming sag early on and required a series of repairs by Tasker and others within a few decades after

CASE STUDIES

3. Cornish-Windsor Covered Bridge

construction. In 1908 the bridge's deficiencies were evaluated by J.P. Snow, bridge engineer for the Boston & Maine Railroad, who corresponded with J.W. Storrs, a consulting engineer from Concord, New Hampshire, and recommended solutions to rectify the structure's issues. These included adding arches, though concerns over potential ice impacts persisted. In the end, however, only smaller repairs were completed in the following years.

In 1943, about seven years after the Cornish Bridge Corporation transferred ownership of the bridge to the State of New Hampshire (and seventy-seven years after community members pushed unsuccessfully for a free river crossing), the state's legislature removed the toll. Until then, tolls were collected on the Vermont side of the bridge where a tollhouse still sits at 45 Bridge Street.

Although extensive repairs to the bridge were carried out in 1954, unrectified structural issues and increasing sag in the structure required serious attention by the 1980s. A planned rehabilitation project spurred a multi-year debate among a wide group of interested parties to determine the best approach to preserve the bridge and maintain safe traffic conditions. Consultation included, but was not limited to, the Federal Highway Administration, the New Hampshire Department of Transportation, the New Hampshire Division of Historical Resources (NH SHPO), the Vermont Agency of Transportation, the Vermont Division for Historic Preservation (VT SHPO), the Committee for an Authentic Restoration of the Cornish-Windsor Covered Bridge including well-known timber bridge craftsmen Milton S. and Arnold M. Graton, other covered bridge enthusiasts, civil engineers, local municipalities, and community residents and politicians.

The Cornish-Windsor Covered Bridge continued to carry traffic until 1987 when the New Hampshire Department of Transportation finally closed the bridge to regular traffic due to increasing safety concerns. Federal and state agencies responsible for the rehabilitation project reached agreement in 1988. General contractor Chesterfield Associates, David C. Fischetti (the engineer who initially suggested and designed the agreed-upon rehabilitation solution), and timber framer Jan Lewandoski carried out the rehabilitation. The bridge was re-opened to traffic with much fanfare on December 8, 1989.²



Figure C3.2 View inside bridge showing notched lattice truss, prior to being closed. HAER NH-8-10, Jet Lowe, 1984.

CASE STUDIES

3. Cornish-Windsor Covered Bridge

Physical Description of Bridge

The following general description reflects the condition of the Cornish-Windsor Covered Bridge prior to the 1988-89 rehabilitation project. For changes to these conditions, see the description of the rehabilitation below. The two-span continuous Town lattice truss was approximately 450' at floor level. The end portals of the bridge extended beyond for a total length of approximately 462'. The two spans were 204' and 203' from center to center of bearings. The overall width of the bridge was approximately 24', and the roadway width was approximately 19'-6". The bridge had a vertical clearance of approximately 12'-9". The Town lattice webbing was constructed of notched and bolted squared timbers rather than the more common treenailed plank construction.

The bridge sat upon mortared, irregular cut granite abutments and a center pier set on a timber crib. In 1921 the New Hampshire abutment was faced with concrete, which was repaired in 1980. Bed timbers were comprised of pairs of mixed original and newer pieces of wood measuring about 10" x 16" x 14' and cantilevered out 7'. Timber bearing blocks showed some deterioration.

Each chord of the superstructure was comprised of approximately 3" x 10" planks paired with 5" x 10" timbers to form 8" x 10" x 32'-long timbers with wooden shear blocks and bolts across breaking joints. Previous repair/strengthening efforts were evident in the pre-1908 additional chord members and steel plates from 1954-55. Areas of rot found in the upper chords in the 1980s were typically at locations of roof leakage into joint areas. The lower chords exhibited greater deterioration issues.

Sandwiched between the chords, the Town lattice web consists of 6" x 8" timbers notched 1 1/4" and bolted. These were generally in good condition, although they also exhibited prior repair efforts. Timber framer Jan Lewandoski noted that almost all the notched connections were wedged with small maple wedges, which he speculated could have been necessary due to shrinkage between the cutting of the timber in the spring of 1866 and the structure's construction in the fall of that year.

The upper lateral system consisted of two sets of braces, one set flush with and one set below the truss' tie beams. The top set of X braces was comprised

of 4" x 5" members connected to the tie beams via mortise-and-tenon joints. The bottom set of X braces consisted of 6" x 6" timbers, wrought-iron tension rods, and cast-iron seat plates. The system, apparently original to the bridge, was generally in good condition. The tie beams were also found to be in good condition. Many of the diagonal wind braces attached to the beams were replacements. Impact damage to multiple elements of the system revealed overhead clearance limitations.

The galvanized corrugated-metal roof on the bridge in the 1980s dated to a 1924 replacement of the original wood shingles. While some rust, open nail holes, and leaking through overlapping joints was discovered, the sixty-year-old roof was otherwise in good condition. Intact nailers dating to the 1924 roof replacement consisted of 1" x 4" boards. Rafters of 2" x 8" timbers were also found to have minimal deterioration.

By the 1980s the floor system consisted of a mix of original and (mostly) replacement floor beams and a replacement timber deck. The floor beams represented a variety of approximately 20'-long timbers of different size, type, construction date, and condition. Many were 4" x 16" creosoted timbers installed during the 1954-55 rehabilitation, while some dated to the 1980s. The timber decking was also a 1954-55 replacement. After three decades of use, the deck was described as being in "fair to poor condition." The bottom lateral bracing was similar to the lower set of upper lateral bracing. Its condition, however, was poor.

Repairs to 1954-55 flush tongue-and-groove siding occurred after ice damage in 1977. Some of the boards were in deteriorated or damaged condition prior to their replacement in the 1988-89 project. Eighteen 2' x 3' square framed window openings feature hoods. The portal openings are arched.³

Chronology Of Development and Use

Despite an as-built structural deficiency and numerous damaging floods and ice encounters, the extant Cornish-Windsor Covered Bridge has survived far longer than any of its predecessors, carrying traffic between Cornish, New Hampshire, and Windsor, Vermont, for the majority of its 146-year existence.

CASE STUDIES

3. Cornish-Windsor Covered Bridge

The Cornish-Windsor Covered Bridge's roof was re-shingled in 1884. James Tasker returned to the bridge in 1887 to complete extensive repairs. New plank flooring was laid in 1892. A broken member in the lower chord was replaced in 1919. The east abutment was faced with concrete in 1921 after settlement was discovered. Corrugated steel replaced the wood shingle roof in 1924. There were also repairs in 1925 and 1929. Flood and ice-damaged lattice members on the north side of the east span were replaced in 1936, the year the State of New Hampshire purchased the bridge.

Under the auspices of the New Hampshire Department of Public Works and Highways (precursor to the Department of Transportation), the bridge was closed for six months in 1954 and underwent extensive repairs. These included replacing floor beams, patching chords with steel plates, and installing new siding and decking. The bridge was also jacked up to remove sag, which returned by the mid-1960s. Ice damage in 1977 required repairs to broken timbers, floorboards, and siding.

A load restriction was imposed in 1981, but lowered to 3 tons a few years later due to increasing concerns about the bridge's structural stability. The bridge was subsequently closed to all but pedestrian traffic and then closed to all traffic until completion of the 1988-89 rehabilitation project. It was reopened in 1989 with a posted 10-ton load rating.

Maintenance projects since the 1988-89 rehabilitation include installation of a Protectowire fire detection system and a dry sprinkler system on the bridge in 2000. In 2007, the bridge was closed for a short period for the replacement of its wooden deck and installation of new lighting. The most recently proposed project for the bridge involves scour protection.⁴

Description of Most Recent Rehabilitation Project

The 1988-89 Cornish-Windsor Covered Bridge project faced multiple challenges. Extensive evaluation and contemplation, innovative ideas, and compromise finally fixed structural problems that had been evident in the bridge since its construction while retaining a safe river crossing for traffic between Cornish, New Hampshire, and Windsor, Vermont, in a sensitive manner.



Figure C3.3 Tower system erected prior to rehabilitation work. James L. Garvin, December 1988.

Following strong support for an option to rehabilitate the bridge (for limited traffic use) at an initial public hearing in 1981 and subsequent evaluation of alternate crossing locations, both states determined that the project to deal with the structurally-problematic covered bridge would not involve construction of a new replacement bridge but would instead focus on rehabilitating the existing structure. The first challenge to overcome was that of funding, as Federal Bridge Replacement Funds could not be utilized for a rehabilitation project that would not open the bridge to all traffic. In 1983 both New Hampshire and Vermont applied to reclassify the bridge and its approaches as part of the Federal-Aid Secondary Highway System, which then opened a new source of significant federal project funding.⁵

As environmental and cultural resource studies proceeded in 1983-84 to determine potential impacts adjacent to the bridge, the controversy over what rehabilitation method was feasible and most appropriate began in earnest. A number of rehabilitation options for the bridge were suggested, evaluated, and discussed during the course of the extended planning phase of project development.

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3. Cornish-Windsor Covered Bridge

Rehabilitation in-kind was an early alternative preferred by both states' transportation and cultural resource agencies; however, it was determined to be not feasible. The plan would replace bridge members with larger, stronger timbers, but solid timbers with sufficient strength to meet project goals were not available. In addition, chord replacement of this type would result in spliced chord members in areas of high stress. Other options presented included the introduction of an orthotropic steel deck constructed within the covered bridge. This idea did not appear to meet the project's structural needs and was also not generally favored for preservation purposes. Another option, the "flitched beam" option, would have inserted 1/4" steel plates between the two timbers that comprised each chord member. These options both introduced steel members into the structural system of the bridge. While these options received various levels of support or dismissal during the course of project consultation, it was another rehabilitation method that received the most attention.⁶

The Committee for an Authentic Restoration of the Cornish-Windsor Bridge (Committee) proposed retrofitting the Town lattice structure with supplemental laminated timber arches. Milton S. Graton, craftsman, detailed the plan in 1984.

The committee, in conjunction with Mr. Graton and his son Arnold, were strong advocates for this plan up through the final implementation of the rehabilitation project. The plan would have introduced four mechanically laminated 20'-deep arches of untreated Douglas fir on the outside of the trusses. To accommodate the arches and keep their feet out of the path of ice, the bridge would have been raised 4' under this plan, with accompanying elevation of roadway approaches and introduction of concrete thrust block supports on each abutment and the center pier. Additional floor beams and needle beams were recommended to increase the structural capacity of the bridge.⁷

While the laminated timber arch approach has a long history (in fact J. P. Snow recommended it in a 1908 study of the bridge) and some positive elements, it had drawbacks. Proponents of the arches plan argued in favor of traditional construction methods and materials and the strength and rigidity that could be added to the bridge by the arches. Opposition to the plan included reasons related to preservation philosophy as well as physical preservation of the structure. Introduction of new arches would have caused visual changes to the



Figure C3.4 Above central pier, showing removal of Chord 3. James L. Garvin, June 1989.

side view, cross section, and end view of the bridge. Raising the bridge and its approach roadways would have altered the historic relationship between the bridge and its setting as well as necessitated the elevation of multiple residences. In addition, the arches would have altered the functional structural system of the original Town lattice bridge. From an engineering standpoint, the arches would have introduced horizontal thrust to abutments designed for vertical load (to date in good condition) and would have sat on supports outside of the protection of the enclosed bridge leaving the connection exposed to the elements.⁸

In early 1988, engineer David C. Fischetti suggested the use of glued laminated timber members (glulam) to replace sections of the bridge's chords subject to high stress. While the glulam option had some disadvantages, the agencies ultimately determined that they could be overcome and that the benefits outweighed the remaining drawbacks. This "compromise solution" preserved the appearance of the bridge and its Town lattice structural system, while minimizing the amount of new steel in the bridge and meeting modern highway standards.⁹

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3. Cornish-Windsor Covered Bridge

As project engineer, David Fischetti ran computer models (using a STRAAD 3-D frame analysis program) to determine forces for all the lattice and chord members. The “results of the analysis were magnificent,” and provided the information needed to make key decisions in the design and implementation of the rehabilitation project.¹⁰ The major issues of the bridge were mostly related to as-built structural design, not deterioration. According to the project’s timber framer, Jan Lewandoski, the bridge suffered from “sag, rack and bow, but remarkably little rot” in its red and white spruce timber members. Steel plates from twentieth-century repairs were the most deteriorated element discovered.¹¹ The rehabilitation plan focused on replacing and strengthening the lower chords and the upper chords over the center pier, repairing and sistering problem lattice members, and strengthening wind and upper lateral bracing systems.

When originally built, the bridge framework was erected in a nearby Vermont pasture and then assembled in place over the river on falsework. Since the bridge was in good condition, the project team decided to rehabilitate the structure in place. The issue of how to deal with an over-winter construction period and expected ice and flooding on the Connecticut River was eventually solved with the construction of three 80’ steel towers set on either shore and the center pier. Steel needle beams were threaded through the web beneath the upper chords of the bridge and connected to the towers with high strength Dywidag™ threaded steel rods. The cable-stayed system let the rehabilitation continue through the winter and allowed a symmetrical rehabilitation rather than one span at a time. The team was also able to raise the bridge and introduce positive camber, with the hope that when the repairs were completed and the suspension system was released some camber would remain.¹²

After the siding and center portion of the roof system had been stripped, the first major task was removing the lower chords. Lewandoski revealed that removing 8,000 linear feet of timber peppered with bolts “was grueling and convinced those doing it that the bridge was not near failure.”¹³ Afterwards the mostly ice-damaged Town lattice web was repaired and sistered. Cornish-Windsor Covered Bridge’s lattice is comprised of 6” x 8” timbers notched 1 1/4” and bolted at each lattice connection and at each lattice-to-chord connection. These connections integrated old and new timbers in the bridge, which was critical to its rehabilitated performance. Lattice replacement members were of Douglas fir.



Figure C3.5 Town lattice sistering. James L. Garvin, June 1989.

The lower chords of the bridge were replaced completely with glued laminated (glulam) southern yellow pine members, because glulam timber members are available in long lengths and are stronger than solid wood. The 116’ and 110’ lengths used in the project allowed the timber framers to span high tension areas without joints. Glulam butt joints, located at low tension areas, were connected by TECO metal shear plates and steel fishplates. The upper chords were similarly replaced, though only in the section of highest tension over the center pier. Glulam members 88’ in length were used in the upper chords. The remaining sections of the upper chords were repaired with 32’ pieces of Douglas fir with wooden shear blocks and bolts, where necessary, to match the original design of the chords.

Another project task was the strengthening of the upper lateral bracing system. Tie beams were doubled in number using new members of red and white spruce in the same size as the originals. The original lateral braces were then cut in two and mortised from the end of one tie beam into the middle of the next, new, tie beam. The extra tie beams accommodated the doubling of the number of diagonal

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3. Cornish-Windsor Covered Bridge



Figure C3.6 Glulam lower chords and floor beams, showing butt joints with TECO plate system. James L. Garvin, June 1989.



Figure C3.7 Original upper chords with glulam replacement chord. James L. Garvin, June 1989.

wind braces as well. The lower system of upper lateral bracing was removed, apparently regarded as unnecessary with the new design.

The bridge's foundation supports were also improved to better serve the truss. The existing bed timbers were pairs of a mix of original and newer timbers cantilevered 7'. New white oak pieces of the same 10" x 16" x 14' size replaced the bed timbers as necessary. Glulam timber members of 11" x 35" were then placed inside of these, tied to a concrete footing. These cantilevered out 13', further shortening the bridge span. The bolster beams are inactive except under extreme live loading when the bridge deflects to place a load on this supplemental support system. Double-cantilevered glulam bolster beams support the bridge at the center pier.

Additional tasks completed during the 1988-89 rehabilitation project included the installation of a new 4" Douglas fir deck, new glulam deck joists, pine siding, spruce rafters, and a galvanized-metal roof.¹⁴ The deck, siding, and roof had all been replaced before.



Figure C3.8 White oak bed timber and glulam bolster beam in new concrete footing, supporting truss. James L. Garvin, June 1989.

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3. Cornish-Windsor Covered Bridge

The project ended in November 1989, with a rededication on December 8, 1989. According to Lewandoski, the structure lost only 4" of camber the first week after the temporary suspension system was removed and only 2" more the following month. The bridge continues to exhibit positive camber.

Analysis of Treatment and Standards That Have Been Applied

1. A property will be used as it was historically or be given a new use that requires minimal changes to its distinctive materials, features, spaces, and spatial relationships.

The bridge continues its historic use, carrying two lanes of traffic over the Connecticut River.

2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alterations of features, spaces, and spatial relationships that characterize a property will be avoided.

The significant timber Town lattice truss system remains functional, and the general appearance of the bridge and its relationship to its setting remains intact.

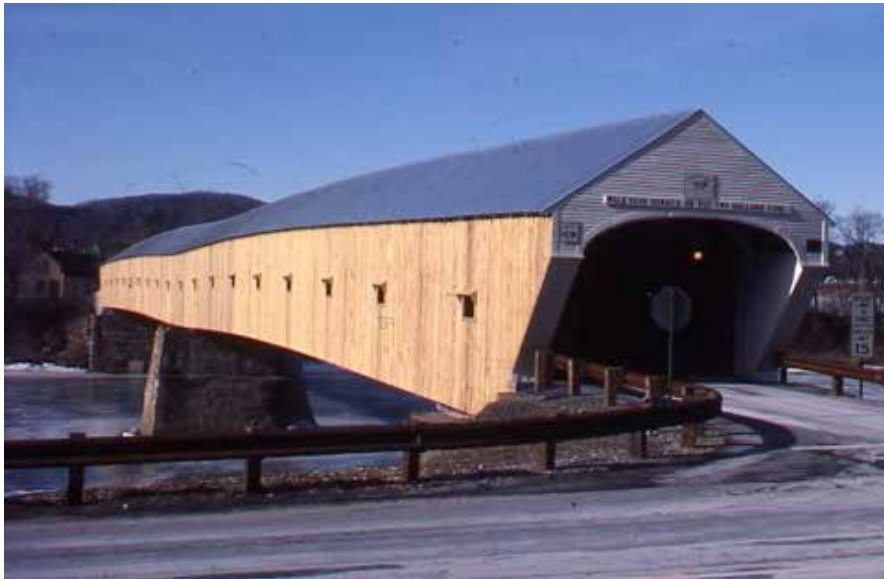


Figure C3.9 Completed rehabilitation. James L. Garvin, March 1990.

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.

Elements were replaced with no change to the engineering function of the bridge and minimal change to appearance. The glulam chords that were used were determined to be compatible with the structure but clearly of their own time, whereas the timber arches could have been confused as historic.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

Records differ as to when the lower set of the upper lateral bracing system was constructed. Agency agreement to remove the lower X-braces required the reuse of the timbers as knee braces, resulting in cost savings, use of more historic materials in the bridge, and improved interior aesthetics.¹⁵

5. Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

The finished chords come close to replicating the bridge's original construction. Members of the Town lattice web were sistered to supplementary members so as not to necessitate replacement.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.

Only elements of the bridge that were either severely deteriorated or could not meet the structural capacity necessary for the bridge to continue to be in use were replaced. Repairs rather than replacement were completed when possible, such as splicing and sistering of the Town lattice web members.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

Surfaces were left untreated.

CASE STUDIES

3. Cornish-Windsor Covered Bridge

8. Archaeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

No archaeological resources were disturbed during the project.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

The rehabilitation solution chosen for the project was an interior/internal solution. Exterior work was limited to elements that had previously been altered, such as the roof and siding.

10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

The project involved no new additions or adjacent new construction.

Section 106 Compliance Information

When this project was developed in the 1980s, Section 106 consultation in New Hampshire did not include the same level of discussion, review, or process documentation as it does currently. Section 106 considerations often became secondary to other pressures, and Federal Highway Administration/Department of Transportation coordination with the two states' SHPOs appears inconsistent over the course of this project's development.¹⁶ Correspondence from the SHPOs to a variety of recipients focused on the need for the transportation agencies to gather the data and analysis necessary to determine whether each rehabilitation option met the Secretary's Standards. Once it became clear that replacement of original materials in-kind—particularly the lower chord—was not feasible, the transportation agencies, with SHPO concurrence, determined that the glulam option met the Secretary's Standards most closely since the original structural system would be maintained.

Records available for this case study do not include the final effect finding.

Lessons Learned

Necessity of appropriate analysis—The results and usefulness of the computer analysis conducted by David Fischetti demonstrates the importance of similar thorough computer analysis for subsequent covered bridge projects. Furthermore, Fischetti noted how important it is to appropriately recognize the difference between historic timber and modern timber and to analyze the structural properties of historic bridge timber on a case-by-case basis, rather than to apply modern timber structural properties in a more generic way.¹⁷

Innovative ideas—While glulam was previously available and used in a variety of structures in the decades prior to this bridge project, the use of the material in a covered bridge rehabilitation project was new. This project demonstrated that glulam can solve problems that cannot be solved any other way. Though still controversial for philosophical reasons from a preservation perspective, the material continues to improve and is now used widely.

Durability of wood, if covered, and strength of Town lattice design—Despite its as-built limitations, the generally good condition of the bridge structure approximately 120 years after it was built confirmed that wood is a very durable construction material for bridges, as long as it is covered and maintained, and that the Town lattice is a structurally sound truss design.

Careful documentation of information and project technical files—This case study was prepared using research and documentation accumulated over thirty years ago. A surprising amount of inconsistent and/or inaccurate information was discovered in the project files and subsequent project-related materials, and the case study team was unsuccessful in obtaining a copy of the final environmental/cultural resource technical documents prepared for the project in the late 1980s. Nevertheless, for the purposes of preparing this case study all attempts were made to compile the most accurate information possible and appropriately summarize consultation as revealed through many years' worth of meeting notes and correspondence. Note also that not every aspect of the project's development is discussed in this case study.

CASE STUDIES

3. Cornish-Windsor Covered Bridge

Project Particulars

Rehabilitation Project Team

Chesterfield Associates, General Contractor
David C. Fischetti, P.E., Project Engineer
Jan Lewandoski, Timber Framing
Federal Highway Administration
New Hampshire Department of Transportation
Vermont Agency of Transportation
New Hampshire Division of Historical Resources (NH SHPO)
Vermont Division for Historic Preservation (VT SHPO)

Date of Project

1988 –1989

Cost for Treatment Project

Approximately \$4.6 million

Case Study Team

Prepared by Laura S. Black, New Hampshire Division of Historical Resources; with assistance from James L. Garvin, retired New Hampshire State Architectural Historian, and Mark W. Richardson, P.E., New Hampshire Department of Transportation Bridge Design Bureau, 2013.

Sources

Andrews & Clark, Inc. Inspection, Rating, Evaluation and Recommendations Report: Cornish-Windsor Covered Bridge. Prepared for the New Hampshire Department of Transportation, 1986.

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CASE STUDIES

3. Cornish-Windsor Covered Bridge

Footnotes

¹Vermont Agency of Transportation and New Hampshire Department of Transportation, "Interstate Bridge Maintenance Agreement between the states of New Hampshire and Vermont, 2004," Bridge Design Bureau Files, New Hampshire Department of Transportation, Concord, New Hampshire. This 2004 agreement established ownership percentages for the purposes of establishing cost sharing for maintenance, preliminary engineering, and rehabilitation/reconstruction actions for New Hampshire—Vermont Connecticut River bridges.

²Lola Bennett and Dorottya Makay, with Justin Spivey, "Addendum to Cornish-Windsor Covered Bridge," HAER No. NH-8, Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, 2003, 7-12, 17; correspondence between J. P. Snow and John W. Storrs, 1908, in Cornish-Windsor Covered Bridge, Multi-Town Bridge Files, New Hampshire Division of Historical Resources, Concord, New Hampshire.

³Andrews & Clarke, Inc., Inspection, Rating, Evaluation and Recommendations Report: Cornish-Windsor Covered Bridge (prepared for the New Hampshire Department of Transportation, 1986), 9-13; Jan Leo Lewandoski, "The Restoration of the Cornish-Windsor Bridge," *Society for Industrial Archaeology, New England Chapters* 10, no. 1 (1990): 14.

⁴Bennett, Makay, and Spivey, 4-5, 12-13; Andrews & Clark, Inc., 4-6; Kristen Senz, "Cornish Bridge Work to Slow Down Traffic," *New Hampshire Union Leader*, August 22, 2007, B8; "Cornish-Windsor Bridge Repairs," *New Hampshire Highways* (May-June 2007), 39; Cornish-Windsor Covered Bridge, Multi-Town Bridge Files.

⁵Vermont Agency of Transportation and New Hampshire Department of Public Works and Highways, "Cornish, N.H. – Windsor, Vt. Covered Bridge Study: Public Information Meeting No. 1 Informational Pamphlet," and "Cornish, NH – Windsor, VT. Covered Bridge Study: Public Information Meeting No. 2 Informational Pamphlet," both in Cornish-Windsor Covered Bridge Project, Review and Compliance Files, 1981-1989, New Hampshire Division of Historical Resources, Concord, New Hampshire.

⁶David C. Fischetti, *Structural Investigation of Historic Buildings: A Case Study Guide to Preservation Technology for Buildings, Bridges, Towers, and Mills* (Hoboken, NJ: John Wiley & Sons, Inc., 2009), 230; Cornish-Windsor Covered Bridge Project, Review and Compliance Files, 1981-1989.

⁷Fischetti, 229-30.

⁸Fischetti, 230; Lewandoski, 11-12.

⁹Fischetti, 227, 237.

¹⁰Fischetti, 233.

¹¹Lewandoski, 12.

¹²Fischetti, 234; Lewandoski, 12.

¹³Lewandoski, 12.

¹⁴Lewandoski, 14.

¹⁵"Conference Report, 18 November 1988," in Cornish-Windsor Covered Bridge Project, Review and Compliance Files, 1981-1989.

¹⁶Shirley G. Adamovich, Commissioner, New Hampshire Department of Libraries, Arts and Historical Resources to Wallace Stickney, Commissioner, New Hampshire Department of Transportation, April 1, 1987, in Cornish-Windsor Covered Bridge Project, Review and Compliance Files, 1981-1989; Eric Gilbertson, Director, Vermont Division for Historic Preservation to Vermont State Representative Richard A. Harris, January 15, 1987, in Cornish-Windsor Covered Bridge Project, Review and Compliance Files, 1981-1989.

¹⁷Fischetti, 238.

CASE STUDIES

4. Fitch's Covered Bridge

Sullivan County, New Hampshire And Windsor County, Vermont

By Phillip C. Pierce



Figure C4.1 Fitch's Covered Bridge after completion with new diamond openings. Note timber railing system at left at north approach. Phillip C. Pierce, 2002.

CASE STUDIES

4. Fitch's Covered Bridge

Sullivan County, New Hampshire And Windsor County, Vermont

By Phillip C. Pierce

Administrative Data

Bridge Name

Fitch's Covered Bridge

Bridge Structure Type

Single lane, single-span Town lattice truss

Date of Original Construction

Built 1870, dismantled and moved to current site ca. 1885

Original Builder

James Frazier and J. Warren

Bridge Owner/ Client

Delaware County, New York

World Guide Number

32-13-02#2

Structure Number (NBIS or local designation)

3352270

National Register Number and Date

NRIS 99000508, listed April 29, 1999

Description of Location

The bridge carries Fitch's Bridge Road over the West Branch Delaware River, which is located 3.5 miles northeast of the junction of NY 28 with NY 10 in Delhi, Delaware County, New York.

Description of Setting

The bridge is located in a generally rural, active agricultural area. A cluster of houses, a museum park, and a church are situated nearby.

Historical Background and Context

James Frazier and James (also referred to as Jasper in some sources) Warren built Fitch's Covered Bridge in 1870 to carry Kingston Street over the West Branch Delaware River in the village of Delhi, New York. It replaced an earlier covered bridge at this location that had been destroyed by floods. The bridge structure cost about \$1,900. M. Hathaway and W. A. Cummings built the stone abutments for \$725. When the town decided to replace the covered bridge with a modern iron bridge from the popular Groton Bridge Company, officials decided to relocate the fifteen-year-old covered bridge to a site upstream in East Delhi. The relocation of the span occurred in 1885 and is credited to David Wright and a town crew.

The Delaware County Department of Public Works, the agency responsible for maintenance of the bridge, has no records of repairs made prior to 1976, although physical evidence suggests some were made. Work in 1976 included rehabilitation of the west abutment, repairs to the timber trusses, replacement of the timber floor, installation of new siding with paint and new approaches, and grading and drainage improvements. The cost of the repairs was \$64,000.

Physical Description of Bridge

Town lattice trusses, so named for Ithiel Town who received his first patent for this truss configuration in 1820, support the single-span, one-lane Fitch's Covered Bridge. The trusses contain two levels of bottom chords as is typical of the Town lattice design. The chords are comprised of two lines of timber planks on both sides of the lattice with butt joints. Wooden pegs connect the six layers of planks. This bridge was built with only a single level of top chord elements, perhaps based on the preference of the builder since many other Town lattice truss bridges were built with secondary top chord elements.

At the time of the 1976 rehabilitation, the chords of the trusses were made up of nominal 3" x 12" members with a maximum length of 20'. The lattice elements were 3" x 10". The center of the bottom chord to the center of the top

CASE STUDIES

4. Fitch's Covered Bridge

chord was 12'-6" with lattice spacing at 4'-0". The bottom chords were 97'-8" long, and the out-to-out length of the trusses was 105'-8". The bottom chords were supported at each corner only over a length of approximately 3'.

The bridge opening at the portals provided 16' of horizontal clearance and 10' of vertical clearance over the center of the 10'-8" wide roadway, reduced at the outside corners by knee braces. The trusses were spaced at 17'-8". The bridge deck provided 14' of clearance between timber curbs. The floor was comprised of 4"-thick laminated wood spanning transversely supported by seven 3" x 12" timber stringers. Timber floor beams measuring 8" x 12" or 10" x 12" with non-uniform spacing from a minimum of 4'-0" to a maximum of 12'-0" supported the stringers.

Overhead bracing included 6" x 8" tie beams at 8'-0" spacing with 5" x 5" X bracing elements. Knee braces of 3" x 5" were connected at each tie beam and attached to adjacent rafters. The 3" nominal rafters tapered from approximately 5" deep at the peak to 7" deep at the eaves. Roof boards measuring 1" thick supported a metal roof.

At the time of the 2001 rehabilitation, four exterior bracing elements were positioned along the bridge on each side to provide supplemental lateral support for the tops of the trusses. There is no consensus on the proper term for these elements, which are referred to as knee braces, buttresses, or the slang term "elephant ears." These elements do not appear in Town's patent sketches but exist on some extant Town lattice covered bridges in various locations throughout the United States. It is not known if these are original to the bridge. These braces connected to transverse beams hung below the bottom chord.

In addition, the lattice members exhibited the original hole pattern for a traditional parallel lattice prior to the 2001 rehabilitation. Comparison of the open original holes demonstrates how the members were rotated about one of the holes in the top chord.

Bridge elements in place prior to the 1976 rehabilitation were made from local softwoods. It is unknown how much of the original material may have remained at that time.

Chronology of Development and Use

No detailed records of work performed on the bridge prior to 1976 have been found. Fitch's Covered Bridge was modified at some point before 1976 according to photographic evidence. This modification resulted in the splaying of the last four lattice elements at the ends of the trusses, which is not like Town's patent and the vast majority of extant lattice trusses. However, splayed lattices can be found on other extant covered bridges in this area, indicating it may have been a regional development. The splay arrangements might be the result of trying to fit the bridge onto the existing abutments for a shorter span at Fitch's crossing. The result of the splay modification was significantly deteriorated lattice elements at the truss ends, so large steel "gusset" plates were installed in 1976 for additional support.

During the 1976 rehabilitation, work was probably done on the abutments. A concrete cap was placed on the dry-laid stone of the south abutment. Concrete was also installed in front of the dry-laid stone of the north abutment with steel sheet piling along the downstream wing wall.



Figure C4.2 Historic view of Fitch's Covered Bridge, note outriggers. Richard Sanders Allen.

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4. Fitch's Covered Bridge

A ramp floor appears in an undated but pre-1976 interior photograph of the north end of the span. This ramp transitions to a floor that appears to be at the correct elevation to have been supported beneath the lower bottom chords. In 1976, the floor was modified for installation onto the lower bottom chord in accordance with the conventional approach for this type of bridge.

A number of factors contributed to the need for another rehabilitation in 2001. The metal roof had begun leaking, resulting in deterioration of the roof boards, rafters, and top chord elements. The installation of metal gusset plates at each bottom chord corner caused interior condensation and reduced drying through evaporation, which caused the timber to rot. The relatively short (20') bottom chord elements installed in 1976 did not distribute sufficient chord forces to the lattice and adjacent chords since there were few intersections of treenail connections. Town lattice trusses that have survived the longest without major rehabilitation more commonly utilize longer chord elements of 32' or 36'. Finally, powder post beetles had infested many of the treenails, weakening them.



Figure C4.3 Prior to the start of the 2001 rehabilitation, a steel falsework system with adjustable work platforms was installed. This photograph shows the falsework and the installation of new tie beams. Delaware County Department of Public Works (DCDPW).

Description of Most Recent Rehabilitation Project

The 2001 rehabilitation involved conducting research on the structure. Bridge Diagnostics, Inc. of Boulder, Colorado, performed field instrumentation on portions of the existing Town lattice trusses to assess the distribution of forces around chord interruptions and treenail connections of chords and lattice elements. Bridge Diagnostics installed forty-six strain transducers at various locations on the bridge and then recorded the information from the passage of a 10-ton vehicle. To the project team's knowledge, this work was the first of its type for this kind of application. The test results indicated actual strains were less than predicted and generally supported implications from finite element modeling of similar lattice trusses.

In addition, a spare transducer was mounted to the bottom of a transverse floor beam during the field instrumentation. That floor beam, scheduled for replacement due to inadequate strength, was tested to failure. The beam failed at a load much higher than expected. While this particular test could not be used in any conclusive way, due to a lack of multiple samples, the information was nonetheless interesting.

The rehabilitation project involved rebuilding the Town lattice trusses with replacement solid-sawn elements to address deterioration in the bottom chord and lattice elements. The majority of the top chord elements were retained, as were many of the lattice elements in the center of the span. The short bottom chord elements, purportedly installed during the 1976 work, were replaced with longer elements to better replicate good practices of Town lattice construction. Hardwood pegs were used in keeping with the original construction techniques and as found in typical Town lattice trusses. The reuse of large portions of the existing top chord and mid-span lattice elements prevented opportunities to induce a more positive camber of the trusses that would have been aesthetically desirable.

Isolated top chord elements were sufficiently deteriorated from the rot resulting from long-term leaks in the roof to warrant replacement. The trusses had also been permanently distorted such that in many cases, the transverse wooden peg connectors were no longer straight or horizontal. Accordingly, retention of an inside element but not the corresponding exterior element

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4. Fitch's Covered Bridge



Figure C4.4 New concrete caps with pockets for longer trusses were installed on the abutments. DCDPW.

required drilling new holes in the new material. In some cases, the process led to misplaced holes in the new material so that it was not properly positioned vertically. Some existing elements had to be replaced in order to have acceptable peg locations in the new material.

While it is generally desirable to have smoothly-curved trusses when finished, the position of the existing trusses had to be retained. Otherwise, the intersections of lattice and chords with existing holes would not have been possible. Accordingly, the camber could not be adjusted to any significant degree during the rehabilitation of the truss without resulting in the need for more material and/or replacing existing treenails with oversized pegs in reamed holes. In this bridge, the downstream truss had more camber and more uniform curvature than the upstream one. Both trusses retained enough of a positive curvature to not require extensive replacement. The roof lines were smoothed by adjusting the birdsmouth of the rafters.

The tops of the abutments were reconstructed to provide a longer bearing area to support the trusses, and this also allowed the use of traditional (and original) parallel lattice elements throughout the length of the bridge. The ends of



Figure C4.5 The 1976 floor system has been partially removed. The near edge of the floor is the transverse nail laminated decking. The longitudinal stringers are obviously not uniformly spaced. DCDPW.

the trusses were finished vertically without the overhang from the earlier bridge modifications. Mimicking details found in the other two covered bridges in the county, 8'-wide interior "shelter panels" were installed at the ends of the bridge to protect the truss ends from wind-borne rain and vehicle splash. This detailing replicated the intent of the overhang of the top of the bridge pre-1976.

Carefully detailed 3" x 10" posts supplemented with timber filler pieces strengthened the truss ends. Treenails connected the posts and truss ends to ensure good distribution of loads from the timber bearing blocks to the various lattice and chord elements. More traditional closely-spaced floor beams that matched the spacing of the lattice and longitudinal timber deck planks replaced the weakened and deteriorated 1976 floor system. The floor beams were designed to accommodate heavy (albeit illegal) axle loads. The installation of 6 3/4" x 16 1/2" glulam elements provided fully-treated floor beams for longer life. The timber 4" x 12" Douglas fir deck planks were pressure treated. White oak 2" x 8" running planks were installed as sacrificial wearing elements atop the deck planks over the central 10' strip of the deck area.

CASE STUDIES

4. Fitch's Covered Bridge



Figure C4.6 New transverse glulam floor beams were carefully threaded through the lattice opening-s atop the lower bottom chord. DCDPW.

The bottoms of the floor beams were dapped 2" for their support atop all four of the bottom chord truss elements. Transverse metal tie rods were installed to pull the floor beam daps tight against the inside edge of the bottom chord elements, thereby providing a strong horizontal diaphragm system to resist lateral loads.

The elimination of the external bracing for the top of the bridge was compensated for by installing an especially strong internal knee brace system. The existing 6" x 10" tie beams were spaced 20' apart with 5" x 5" X lateral bracing elements connected to the tie beams with traditional mortise and tenon joinery, held tightly by timber folding wedges. In keeping with rehabilitation work performed at the two other county covered bridges, a 3" x 12" principal rafter was installed beside and notched into the side of the tie beam. It provided a strong connection to the 4" x 8" replacement knee braces. A 5" x 10" collar tie at mid-height of the principal rafter provided the necessary fill thickness and additional transverse strength. Common rafters of 2" x 8" spaced 2' apart supported 2" x 4" rough-cut No. 2 Southern pine nailers. The replacement roofing was ½" thick by 24" long, random-width, premium-grade red cedar shingles, planed on one side.



Figure C4.7 Staggered longitudinal deck planks have been installed; these were then covered with hardwood running planks. Note the darker lattice elements, which are original. DCDPW.

The replacement 1"-thick hemlock siding featured the use of nailers as spacers to hold the siding outboard of the metal tie rods beneath the floor and to provide ample ventilation around the bottom chord. Careful siding details around the three windows on each side of the bridge protected the truss elements from wind-borne rain. As in the previous siding, battens were installed to prevent rain penetration through shrinkage gaps between siding boards.

The existing south abutment retained its dry-laid random rubble stone masonry construction under a relatively small concrete cap. The north abutment had earlier been faced with concrete and had a concrete cap as well. A rusty steel frame at the corner of the back wall and transverse from the north abutment that had been used during the 1976 rehabilitation remained. Both concrete bearing seats were removed, along with the steel frame. New wider and longer concrete caps were installed on the abutments, along with new concrete backwalls. Shallow raised concrete pedestals were cast in the top of the cap for the two bearing walls at each end. Pressure-treated timber bearing blocks supported the truss ends over an approximately 10' distance. Two 1"-diameter steel anchor bolts were

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4. Fitch's Covered Bridge



Figure C4.8 Most of the original upper lateral members were retained, but the tie beams and knee-braces were replaced with stronger components. Traditional wooden peg connectors and matching timber wedges were used, similar to those in the original construction. The darker upper lateral members are original. DCDPW.

installed at each corner as hold-down devices against floods or high winds. Finally, although the entrance to the bridge at the north approach involved non-standard geometry, it had been used without incident. Accordingly, the non-standard geometry was retained, but an approach railing system comprised of heavy timbers was installed.

Analysis of Treatment and Standards That Have Been Applied

1. A property will be used as it was historically or be given a new use that requires minimal changes to its distinctive materials, features, spaces, and spatial relationships.

The bridge has remained in use by vehicular traffic, although it has been restricted to weights of 3 tons or less since the 1976 rehabilitation.

2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alterations of features, spaces, and spatial relationships that characterize a property will be avoided.



Figure C4.9 Siding being replaced with rough-cut 1" x 12" hemlock with battens. DCDPW.

Project planners decided early in the project to address the known deficiencies of the bridge with replacement of elements as required and installation of different or modified feature with the goal of providing a long service life. Work on the bridge followed rehabilitation projects of two other publicly-owned covered bridges in Delaware County. During the project development process, the New York State's Office of Historic Preservation was consulted to sign off on the construction permit required from the New York State Department of Environmental Conservation.

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.

Elements of the historic character of the bridge were replicated, including the use of replacement solid-sawn elements and hardwood pegs. Alterations to the bridge were in keeping with historic bridge building techniques.

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4. Fitch's Covered Bridge

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

The four external buttresses were added at an unknown date, but they were removed because they are not typical of Town lattice trusses.

5. Distinctive materials, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

Battens were installed to replicate the previous siding, and the non-standard geometry of the north approach was retained. In addition, the shelter panels installed at the ends of the bridge replicated the original overhang of the top of the bridge.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.

Only the severely deteriorated portions of the bridge were removed and replaced. Traditional building techniques were used on the replacement elements.



Figure C4.10 The metal roofing was replaced with traditional red cedar wood shakes, based on community preference. DCDPW.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

Existing material was not treated as part of this project.

8. Archaeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

No archaeological resources were disturbed.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

The rehabilitation project used solid sawn truss and bracing elements, wooden peg connectors for the Town lattice trusses and primary bracing, wedges in the upper lateral system connections, and cedar shake roofing, all of which is compatible with the historic features of the bridge.

10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

The only new construction was an approach railing system that did not change the non-standard geometry of the north approach.

Section 106 Compliance Information

Fitch's Covered Bridge is listed in the National and State Register of Historic Places. New York State inventoried its historic bridges in 1984 and was in the process of updating its inventory at the time of the rehabilitation. In addition, two other Delaware County-owned covered bridges had been rehabilitated prior to Fitch's. The two rehabilitation projects had cost twice the available state and federal funds, so the county had to cover the deficits and was going to have to fund the entire Fitch's Covered Bridge rehabilitation. However, the county was committed to rehabilitating the bridge in accordance with the Secretary of the Interior's Standards and with the same care as the other covered bridge rehabilitation projects. The Delaware County Department of Public Works' Engineering

CASE STUDIES

4. Fitch's Covered Bridge

Department planned and designed the rehabilitation. The Department of Public Works' highly-skilled bridge crews were going to complete the work as funding became available. Relatively late in the pre-construction process, an application for supplemental funding via the National Historic Covered Bridge Preservation Program was approved, allowing construction preparation to commence in 2000.

The New York State Historic Preservation Office (NY SHPO) reviewed the proposed details, and some minor modifications were made to address concerns. Public meetings about the project were also held. Ultimately, the NY SHPO issued a determination of No Adverse Effect for the proposed project.

Lessons Learned

Hidden deterioration: In general, the project went quite smoothly and according to plan. As is typical of a rehabilitation of existing Town lattice trusses, the extensive number of hidden faces led to inaccurate initial assessments of all elements. Many of the elements of Town lattice trusses are positioned adjacent to mating elements (e.g. chord elements over the top chord or chord/lattice elements at their intersections). Over the life of the structure, in this instance over 130 years, deterioration from roof leaks led to significant section loss of elements. Similarly, powder post beetles had infested many of the hardwood pegs and surrounding primary element materials. The extent of the damage caused by insects was more extreme than anticipated. In one unusual case, the initial damage by insects led to a rodent entering the chord area and hollowing out the pair of mating chord members, leaving only a shell remaining. No outward appearance of distress was evident, however, and no inspections identified the issue.

Currently, there are no practical means available to identify such deterioration in advance of disassembly of the truss during its reconstruction. Accordingly, almost all Town lattice trusses are found to have more deterioration during reconstruction than anticipated during the engineering phase of the project, and this was true in the case of Fitch's Covered Bridge. Ample allowance should be made in planning for funding the purchase of additional material.

Necessity of support structure: The proper design and detailing of an easily adjustable temporary support system is paramount on such a large structure. Based on materials available in Department of Public Works' storage sheds, a

two-span frame of twin large beams supported by piles was installed inside the shell of the superstructure. The frame had 6 x 6 x 36'-long box beam grid rails installed transversely from which threaded rods supported lower level work platforms. This system allowed maximum flexibility in removing and installing truss elements.

Project Particulars

Rehabilitation Project Team

Design and Construction: Delaware County, Department of Public Works
Wayne D. Reynolds, P.E., Commissioner of Public Works

Design and Detailing: Phillip C. Pierce, P.E., Deputy Commissioner

Construction: John Cammer, Deputy Commissioner

Field Instrumentation Research: Bridge Diagnostics, Inc.

John Pioch, Local Projects Liaison, served as the Region 9, New York State Department of Transportation contact. The New York State Parks Recreation & Historic Preservation Office representative was Ken Markunas, Technical Assistance & Compliance Unit.

Date of Project

Late 2001 – 2002; bridge opening ceremony held June 2002

Cost for Treatment Project

DPW Engineering costs	\$14,954
Material costs	\$121,875
DPW Construction equipment costs	\$112,051
DPW Construction labor costs	\$175,459
Total costs	\$424,339

Case Study Team

Prepared by Phillip C. Pierce, P.E., 2013. Pierce was the Deputy Commissioner of the Delaware County Department of Public Works when this project was undertaken.

Sources

All information in this report came from the Delaware County, New York Department of Public Works files.

CASE STUDIES

4. Fitch's Covered Bridge

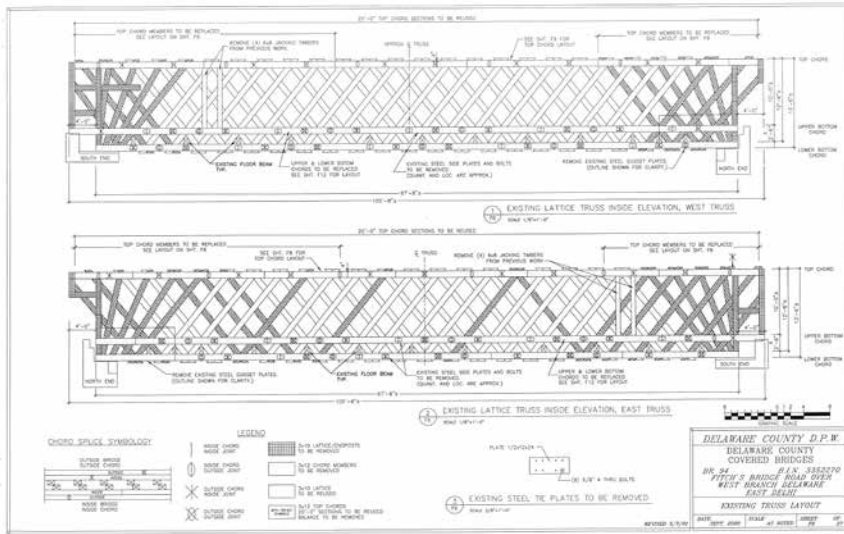


Figure C4.11 Existing Truss Layout. Delaware County DPW BIN 3352270, Sheet F6, 2000.

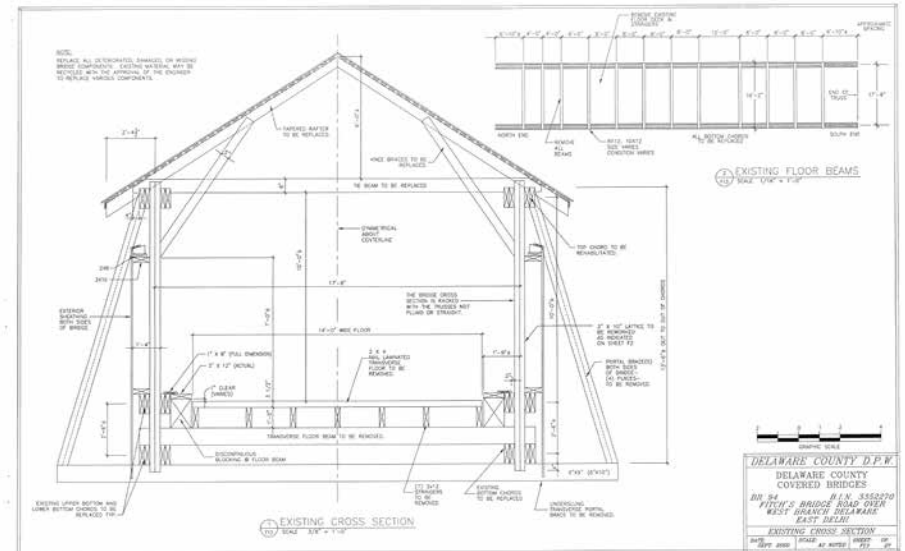


Figure C4.13 Existing Cross Section. Delaware County DPW BIN 3352270, Sheet F13, 2000.

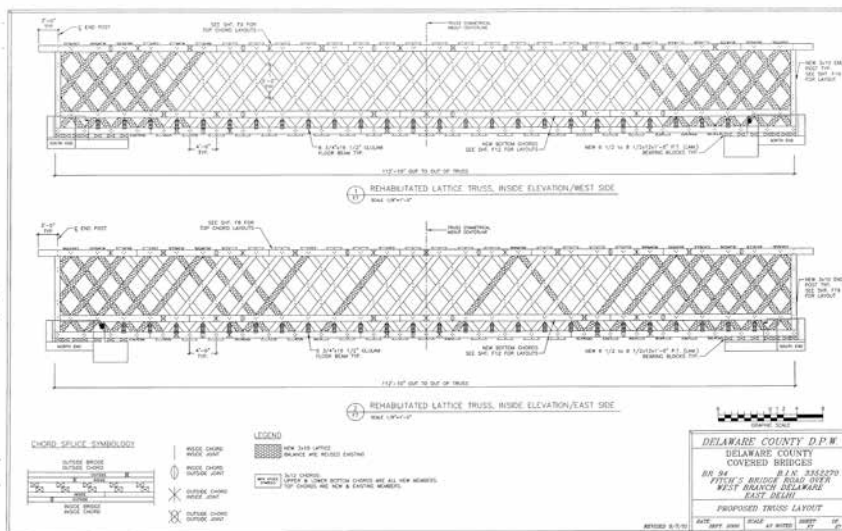


Figure C4.12 Proposed Truss Layout. Delaware County DPW BIN 3352270, Sheet F7, 2000.

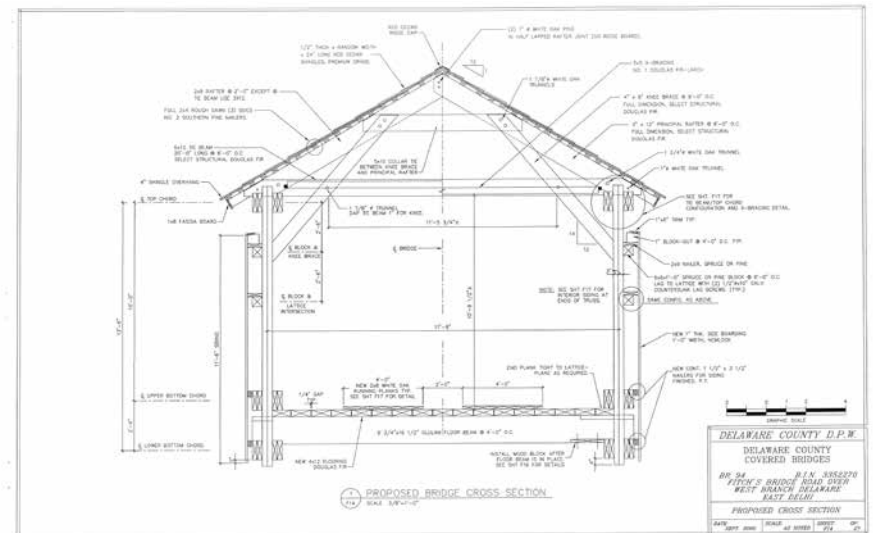


Figure C4.14 Proposed Cross Section. Delaware County DPW BIN 3352270, Sheet F14, 2000.

CASE STUDIES

5. Gilpin's Falls Covered Bridge Cecil County, Maryland



Figure C5.1 Completed rehabilitation of Gilpin's Falls Covered Bridge. W. Earl Simmers, 2010.

CASE STUDIES

5. Gilpin's Falls Covered Bridge

Cecil County, Maryland

By Jeremy Mauro, Christopher H. Marston, Timothy Andrews

Administrative Data

Bridge Name

Gilpin's Falls Covered Bridge

Bridge Structure Type

Ten panel Burr-arch truss that spans 100' from abutment to abutment, 119' from portal to portal

Date of Original Construction

1860

Original Builder

Joseph George Johnson (1831-1900)

Bridge Owner/ Client

Cecil County, Maryland

FWHA Project Identification Number

CE0110

World Guide Number

MD/20-07-01

HABS/HAER/HALS Number

HAER MD-174

National Register Number and Date

NRIS 0800125, listed 2008

Description of Location

The bridge is located approximately one mile north of the boundary of North East in the unincorporated town of Bayview, Cecil County, Maryland. The bridge spans North East Creek and is located next to Maryland State Route 272.

Description of Setting

The bridge is situated in a rural area on 1.249 acres of Cecil County park land.

Historical Background and Context

Gilpin's Falls Covered Bridge crosses North East Creek at the point where the creek empties into the remains of a small mill pond that served water-powered industry from 1735 to 1926. Samuel Gilpin established the first water-powered businesses, a sawmill and a flour mill, at this site in 1735. A woolen mill later replaced the early mills, and finally in 1905, a hydroelectric plant was established. In the 1980s, American Hydro of Philadelphia rebuilt the hydroelectric plant. The covered bridge replaced an earlier bridge located nearby.¹ An eighteenth-century house remains adjacent to the bridge site.

Gilpin's Falls Covered Bridge was built in 1860, as part of a county-wide bridge-building campaign that resulted in the construction of several covered bridges. Cecil County Commissioners approved \$2,000 for its construction. Joseph G. Johnson won the contract on September 11, 1860, and in December 1860 the *Cecil Whig* reported that the bridge was nearly complete.

The bridge carried vehicular traffic until 1936 when it was bypassed. The earliest recorded repair to the bridge was in 1932. In 1959, Harry C. Eastburn & Son of Newark, Delaware, repaired the roof, which had collapsed a year earlier, for \$11,000. The Historical Society of Cecil County and the State Roads Commission of Maryland initiated that rehabilitation. The bridge was repaired again in 1971 after several incidents of vandalism.

Ownership of the bridge transferred from Maryland State Highway Administration to Cecil County in 1986. As part of the transfer, the state included a \$50,000 grant for repairs, and an engineering study was done in 1990. As the bridge approached 130 years of service, it became apparent that the cumulative effects of time and weather were undermining the structural integrity of the bridge. Another engineering study done in 1997 reported that the bridge had significant structural problems and insect infestation. Upon the completion of the report the bridge was closed to pedestrian traffic. Several years after its closure a flood caused further damage to the bridge and left the span in danger of collapse. In 1989, members of the Historical Society of Cecil County began a multi-year campaign to save the bridge. The Cecil County Department of Public Works

CASE STUDIES

5. Gilpin's Falls Covered Bridge

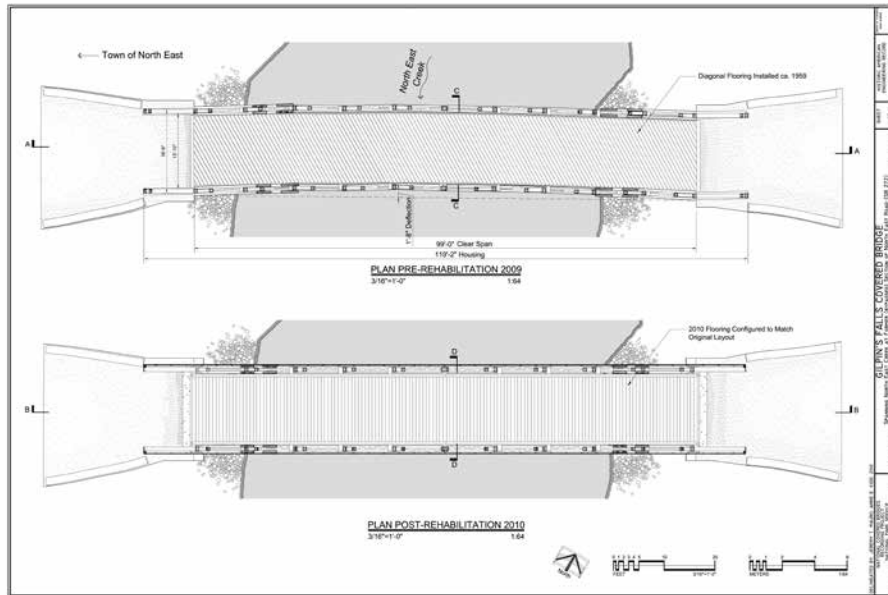


Figure C5.2 Upper drawing shows upstream deflection of bridge prior to being straightened during rehabilitation. HAER MD-174, sheet 2, Jeremy Mauro and Anne E. Kidd, 2010.

applied for funding for an extensive preservation project, which the Federal Highway Administration's National Historic Covered Bridge Preservation Program awarded in 2007. Wallace, Montgomery & Associates engineers completed the design. Using a qualified bid process, the project was awarded to Kinsley Construction in 2008, with Timothy Andrews, proprietor of Barns and Bridges of New England, serving as the required bridgewright. Andrews directed the rehabilitation onsite and worked alongside timber framers William Truax and Jeremy Woodliff. Work began on the bridge during summer 2009 to repair truss failures and areas of rot threatening to destroy the bridge. The project was completed in February 2010, with an official ribbon cutting held in June 2010.²

Physical Description of Bridge

Gilpin's Falls Covered Bridge is a single-span Burr-arch truss covered bridge on stone abutments that have been reinforced with concrete. Prior to the rehabilitation, the bridge measured 119'-8" overall, and afterwards it was restored to its original length of 121'-9". The bridge is 119' long (portal to portal) and has a clear span of 99'. The structure is 16'-6" wide between the outer faces of the trusses,

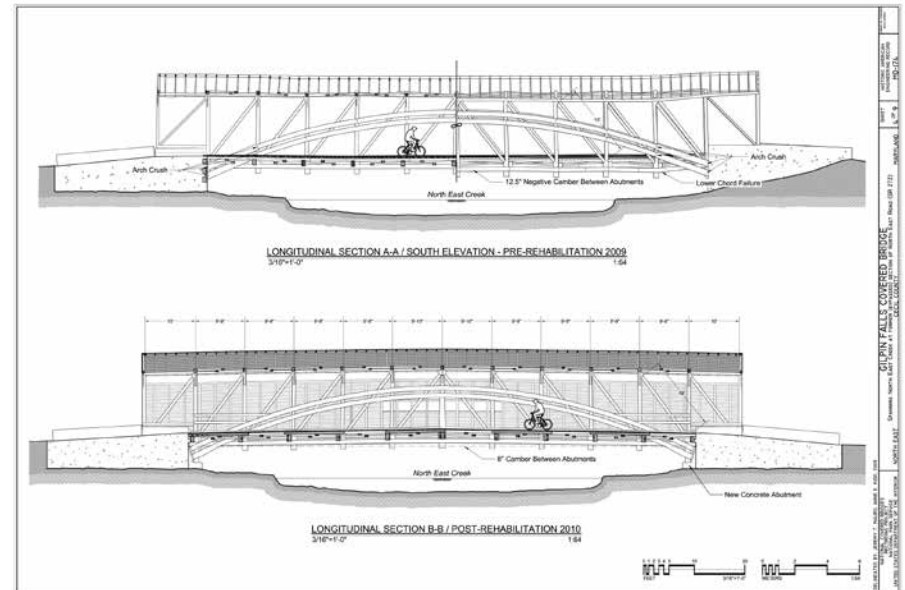


Figure C5.3 Upper drawing shows negative camber prior to rehabilitation. Lower section documents the positive camber resulting from the rehabilitation. HAER MD-174, sheet 4, Jeremy Mauro and Anne E. Kidd, 2010.

with a 13'-wide roadway that is open only to pedestrian traffic. The trusses are 20' high from the top of the top chord to the bottom of the bottom chord. The arches rise 12'-0" from end post to end post. Clearance is 12'-3". The original truss system carries the weight of the bridge, and there are no additional supports or materials that change the nature of the truss. The bridge is set at its original location.

The gravel road that leads to the bridge rises slightly at the abutments and is flanked by low, rounded wing walls. The bridge spans North East Creek at the north edge of a now defunct mill pond. The site contains architectural ruins of industries that once drew power from the pond. A modern bypass and active highway, SR 272, are directly adjacent to the bridge.

The camber of the bridge (12" between abutments) causes a noticeable arch in the roof and rise to the deck. The cladding is laid in curved lines to match the camber. The clapboard siding terminates below the eaves leaving a gap that allows air circulation. The clapboards are fastened to a series of vertical nailers

CASE STUDIES

5. Gilpin's Falls Covered Bridge

on the outer faces of the trusses. The exterior of the siding is painted red, while the trusses and interior finishes are unpainted. The original arches and posts have a dark patina from 150 years of use. The members have graffiti, some of which dates to the 1860s. Two rectangular, hooded windows are centered on either side. The portals have straight, squared openings with clipped corners. The gable roof, clad with cedar shingles, ends flush with the face of the portals.

The kingpost trusses have ten structural panels and two shelter panels each. Each truss is composed of a single web of vertical posts cut from 10" x 16" timbers. The posts are 10" x 8" through the middle section and have 10" x 16" jowels, or haunches, at the ends to meet the diagonal brace. The center post tapers from 7-¾" x 9-⅝" at the neck to 10" x 16" at the base. The diagonal braces are 7" x 8" and are angled down toward the ends of the bridge. The top chords are 6" x 10" timber with a mortise and tenon joint pinned with two 1"-diameter pegs at each post. The bottom chords are two lines of 5" x 10" timber notched and bolted to the lower ends of the vertical posts.

A pair of timber arches flanks each truss. The arches are notched into the vertical posts and fastened with ⅝"-diameter bolts. Each arch has two ribs composed of 5" x 10" timbers butted together, end-to-end. The arches spring from below the truss at the abutments, rise 13' to the crown, and span 101'.

The ends of the bottom chords are bolted to the end-posts, which rest on concrete pads that are part of the abutments. The floor system is composed of 10" x 16" transverse floor beams seated on the bottom chords at each panel point. The outer ends of the floor beams are bolted to the posts. There are ten lines of 6" x 6" stringers on top of the floor beams. The wearing surface is plank decking laid transversely on top of the stringers.

Upper lateral bracing comprises 7" x 7" tie beams with collar ties notched into the top chord at each panel point and pinned with ⅜" x 8" wrought-iron spikes. The 4" x 5" cross bracing is notched into the tie beams. There are 2" x 4" knee braces between the vertical post and tie beam at each panel point. The gable roof is supported on rafters that taper from 2" x 5" at the eaves to 2" x 4" at the ridge and are spaced approximately 2' apart. Wood shingles fastened to nailers on top of the rafters cover the roof.



Figure C5.4 View of the bridge four years before the rehabilitation project. Failures in the lower chord contributed to the noticeable negative camber. W. Earl Simmers, 2005.

Before the 2009 work began it was generally agreed the bridge was nearing structural failure and in danger of collapse. The bridge was considerably out of alignment in plan, elevation, and cross-section. It sagged 12 ½" at mid-span, was racked (twisted along its length), and bowed 1'-8" upstream. The lower chords had stretched lengthwise causing shear keys to fail and had failed completely at the northeast corner. The arches had buckled and deformed. The timbers embedded into the face of each abutment (removed in 2009) were rotten and crushed by the ends of the arches.

Before work began, it was estimated that 20 percent of the truss timbers needed to be replaced, but after disassembly it became evident that the percentage was far higher. Water damage and insect damage in the joints had hollowed out many of the timbers beyond repair (as seen in Figure C5.5). The connection between each post haunch and the diagonal was particularly deteriorated. Further investigation showed that the entire upper chord, collar ties, upper lateral braces, floor beams, and lower lateral braces were compromised beyond repair. Water penetrating the roof system had resulted in the complete decay of the upper chord at every post connection. The collar ties and lateral braces,

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5. Gilpin's Falls Covered Bridge



Figure C5.5 This photo of the top of a post shows the typical condition of truss members between joints. Timothy Andrews, 2009.

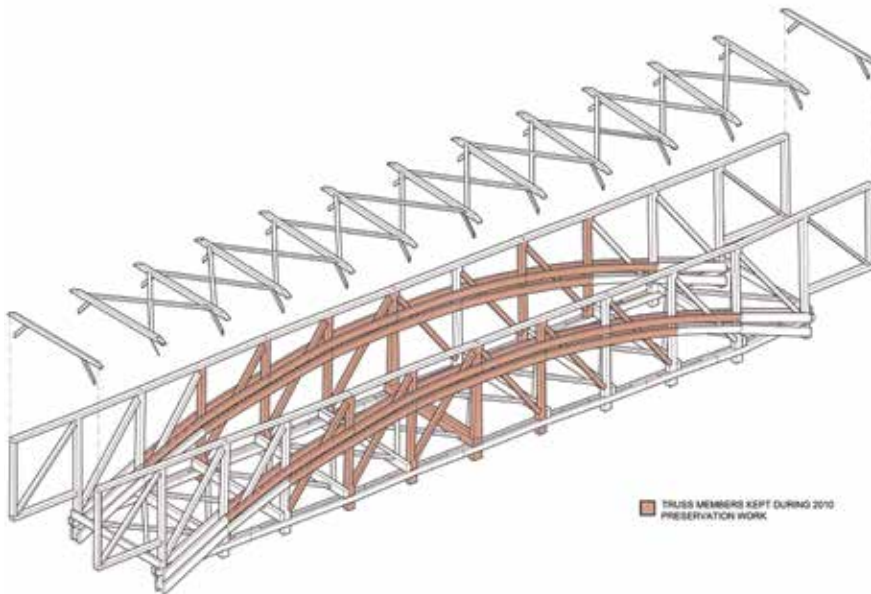


Figure C5.6 Illustration showing original truss members that were retained during the rehabilitation. The hatched sections of the truss indicate the historic fabric that was saved. All other material was replaced in-kind. Adapted from HAER MD-174, sheet 8, Jeremy Mauro, 2010.

installed during the 1959 repairs, were affected by rot as well and were found to be of a smaller size than the original collar ties. The entire upper part of the truss and roof needed replacement. The floor beams (installed in 1959) were infested with powder post beetles. Investigative measures showed that the beetles had penetrated the middle of the floor timbers, and the stringers below the floor planks were also infested. The lower lateral braces were not salvageable due to the tenons being destroyed.³

Chronology of Development and Use

The bridge was repaired in 1932, 1959, 1971, and sometime after 1989. Records do not detail the specific repairs completed for each date other than indicating that the repairs in 1959 cost \$11,000 and fixed the collapsed roof. However, project bridgewright Tim Andrews was able to piece together a timeline of repairs based on evidence he found at the site and from historic photos. The following information details his findings.

In 1932, oak fish plates measuring 2" thick and 20' long were sistered to the lower chord to address shear failure. The timbers bedded into the face of the abutments were original to the 1860 construction and may have been replaced at this time or in 1959. The original floor configuration consisted of 2" planks perpendicular to the chords. The planks rested on boards with a rabbited groove and were clamped down with a curbing. This was removed in either 1932 or 1959 and 3" decking was laid diagonally. In 1971 the siding and possibly the roof were replaced. Photos from 1959 show thicker, square clapboards on the bridge, rather than the tapered siding that was found in 2009. In 1959 or 1989, the arch ends were replaced with wood that did not match the original arches in size, species, or shape. At some undetermined time the north weather panel was shortened.

Description of Most Recent Rehabilitation Project

Project Goals

The intent of the 2009 project was to address all structural issues found in the truss by completing a more extensive rehabilitation than any previous repair work using treatments that would last for the longest possible time. The project aimed to rehabilitate the bridge's historic structural system and maintain the character-defining features of an historic covered bridge. Upon

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5. Gilpin's Falls Covered Bridge

completion the bridge would be open to pedestrian traffic only. Success of the project depended on the ability of the bridge to serve as an example of nineteenth-century American wood bridge engineering that could be safely experienced by visitors.

Rehabilitation was chosen because of the amount of historic fabric that would have to be replaced in-kind and the necessary slight changes to its existing condition, such as redesigning the abutments to ensure stability, lengthening the shear keys in the lower chord to increase strength, and returning many of the replacement members to their original dimensions and configuration.

Craftsmanship is another defining feature of the bridge. During the 2009 rehabilitation, timber framers used traditional tools such as adzes, slicks, and chisels to create connections between wood truss members. No modern engineering solutions replaced the historic wood joints. Using traditional methods of joinery for the truss's overall strength required a high degree of skill and accuracy. The result was a working Burr-arch truss that gives visitors an opportunity to experience an example of American wood bridge engineering that dates to the 1860s.

Description of Rehabilitation

Timothy J. Werner, the Senior Engineer at Wallace, Montgomery & Associates, the firm hired to oversee structural engineering at Gilpin's Falls, determined that the bridge was too fragile to attempt removal from the abutments. In order to complete the preservation work while leaving the bridge in place over North East Creek, a temporary support system was constructed consisting of a platform made of steel beams resting on poured concrete abutments that spanned approximately 100'. It provided a surface above the water to stage work activities and carried the weight of the bridge when it was freed from the abutments. Since the temporary platform sat just above the water level, the engineers designed it to be jacked up higher in an emergency, like another flood.

With the temporary platform in place, bridgeworker Timothy Andrews of Barns & Bridges of New England and timber framers Will Truax and Jeremy Woodliff began to stabilize and re-align the bridge. The first step of this process was to cross brace the structure diagonally through its interior using chains and jacking the lower chord at panel points. The cross bracing lessened the lateral stresses



Figure C5.7 Cross chains installed to straighten the bridge in plan. Also note the deck planks are laid diagonally. The diagonal configuration was not original, and they were returned to a perpendicular arrangement later in the project. Jeremy Mauro, 2009.

while the jack supports relieved the abutments and truss of carrying the load of the bridge. By relieving tension from the truss and tightening the cross chains at specific points, it was possible to straighten the bridge laterally. After removing the lateral bow, a second alignment technique called longitudinal clamping was initiated. Four threaded 1"-diameter rods were positioned in pairs running the entire length of both lower chords and threaded through wood blocks placed near the bottom of each post. The rods acted as temporary lower chords and were tensioned by turning nuts set against the wood blocks. This technique of longitudinal clamping both "gathered back" gaps created by failures in the bottom chord and fixed the position of each post. The next step involved stacking numerous 6" x 7" x 4' timbers into tall temporary crib towers, or falsework, that raised the height of the upper chord. These supports carried and controlled the upper part of the truss and helped return the bridge to positive camber. Finally, a series of eight 4" x 4"s, post-tensioned with chains attached to the steel bridge, acted as temporary outriggers by buttressing the bridge posts and holding them securely in a vertical position.

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5. Gilpin's Falls Covered Bridge



Figure C5.7 Cross chains installed to straighten the bridge in plan. Also note the deck planks are laid diagonally. The diagonal configuration was not original, and they were returned to a perpendicular arrangement later in the project. Jeremy Mauro, 2009.

With the bridge stabilized and aligned, the crew removed the roof system, exterior horizontal cladding, upper and lower cross braces, flooring, stringers, and floor beams. At this stage it was possible to begin in-kind replacement of many of the truss components, such as posts, diagonals, and sections of the upper and lower chords. To make certain that the bridge would not shift position, these components were replaced one-at-a-time in a “one out, one in” fashion using a crane (when available), a backhoe with an extended boom, or by hand using a come-along. As new truss members were inserted, the joints were finely chiseled by hand to ensure proper fit between the vertical posts and diagonal braces. After carefully replacing truss members, the rotten ends of the arches were addressed. New arch segments were shaped in place against the other components they interlocked. The joints of replacement sections of the arches matched the original and were staggered every other post to increase strength and prevent them from acting like a hinge under load.



Figure C5.8 Tim Andrews (top) and Jeremy Woodliff (below) guide a new end post into position. A crane, not shown in the photo, is lowering the post. Tim Andrews, 2009.

Figure C5.9 and Figure C5.10 Historic fabric was repaired rather than replaced whenever possible. The photo on the left shows a repair to the end of a diagonal brace. The photo on the right shows a Dutchman repair to the arch. Epoxy was used only to fill non-structural holes and gaps. Left: Tim Andrews, 2009; right: Jeremy Mauro, 2009.



The goal of returning the truss' structural integrity was evident in the high-quality materials selected by the rehabilitation team. The first rehabilitation plans in 2009 had called for using laminated, preservative-treated timbers of a different size to achieve the needed dimensions, but that plan was amended in favor of using solid timbers matching the original species. The rehabilitation team refused the first shipment of timber because its quality did not match the structural qualities of the original bridge timber, so higher-quality, larger timbers sawn in Wisconsin were instead obtained. A substantial amount of smaller structural members were harvested and sawn in nearby Pennsylvania as well.

The rehabilitation team examined every member of the truss for structural integrity. If a piece was not sound, repair remedies were sought to preserve the

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5. Gilpin's Falls Covered Bridge

historic timber. These included removing sections of deterioration and attaching new pieces of wood using a traditional Dutchman type joint. Epoxy was used to reinforce rotted end-grain where necessary. For many of the timbers no reasonable repair remedies could be found to restore the structural integrity, so these members were replaced in-kind.

Some minor design changes were implemented for the purpose of preserving the truss over the long-term and inhibiting decay.

- The concrete abutment connection was redesigned. The 2009 condition of the bridge revealed how relatively quickly the 1959 timbers imbedded in the abutment faces disintegrated compared to other bridge components. Due to their location, the timbers gathered moisture from the concrete and rapidly rotted without sufficient air circulation. This moisture gathering spot also damaged the arches. Concrete skewbacks were designed to allow for air to circulate around the arch ends and post end to alleviate this condition.
- The length of the shear keys was doubled to increase their strength. The original keys had failed over time. The knee braces and collar ties were returned to their original dimensions of 4" x 5", replacing the undersized knee braces installed in 1959. The siding was also restored to its original thickness of 5/8", and the decking to its original layout perpendicular to the chord.
- To prevent dirt and debris from collecting on the lower chord, spacers were placed between the lower chord and siding nailers, creating a gap for easy removal of the dirt and debris and allowing air to freely flow around all areas of the chord, thus preventing decay. A similar gap was introduced at the connection between the arches and floor beams to allow dirt to be flushed through rather than gather at the vulnerable spot between the arch and beam.
- Nearly disintegrated iron bolts were replaced with galvanized bolts of the same dimensions in areas not visible. Those bolts needing to be replaced in visible parts of the bridge were replaced with #32, 8" to 14" spikes wrought by a blacksmith from salvaged wrought-iron bolts. The spikes were used to attach the lower ends of the knee braces to the posts. The iron spikes also replaced the large wire cut nails that were not original to the bridge.
- A chemical for wood preservation, a chemical fire inhibitor, and an insect repellent were applied to the bridge during the 2009 work. Copper Naphth- enate was brushed between all wood connections to inhibit rot. Nochar Fire Preventer (NFP) was applied to all wood surfaces from the top chord down.

Boracare (Nisus Corporation) insecticide was applied to the weather panels on both ends of the bridge prior to the application of the fire retardant for the most effective barrier. The roof sheathing and roof shingles were pressure treated to extend their service life; these were the only components that received this type of treatment.

During the 2009-2010 rehabilitation work, all truss members, posts, diagonals, chords, lateral braces, and arches were sawn from eastern white pine because of its tensile strength, resistance to rot, and relative light weight. Sleepers and decking were made from southern yellow pine, while poplar was used for the knee braces and rafters. The bridge was clad with Atlantic white cedar siding and western red cedar shingles. Treenails, pegs, and wedges were made from black locust. Truss members were sawn from large tight-grain pine timbers and



Figure C5.11 and Figure C5.12 The repair of this post required three stages of glueing to create a tight fitting Dutchman for this complex timber joint. Timothy Andrews, 2009.



Figure C5.13 View of completed arches, trusses, bracing, and newly installed deck; awaiting curbing and sheathing. HAER MD-174-17, David Ames, 2010.

CASE STUDIES

5. Gilpin's Falls Covered Bridge

interlocked with wood joinery. A high degree of craftsmanship was apparent in the woodworking that connects the posts to the upper and lower chord, arches, diagonals, and upper and lower struts. The woodworking included a variety of techniques, such as pegged mortise and tenon, lap joints, butt joints, shear keys, and wedges. The members of the truss are whole timbers and are not laminated.

Analysis of Treatment And Standards That Have Been Applied

1. A property will be used as it was historically or be given a new use that requires minimal changes to its distinctive materials, features, spaces, and spatial relationships.

The bridge is on its original abutments and continues to operate as a self-supporting wood truss without modern support. The bridge still serves as a pedestrian crossing of the creek and is identified by a state historical marker.

2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alterations of features, spaces, and spatial relationships that characterize a property will be avoided.

The visual character of the bridge was not compromised and all character-defining features were retained. The geometry of the bridge (camber, panel spacing) remains. Every member of the truss was carefully examined and retained if possible. New materials match in-kind the material they replaced or a historical antecedent.

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken. No changes were made that would create a false sense of historical development. All character-defining features were respected as products of their time within the period of significance.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

Changes to the structure made after its original construction were determined to not contribute to the historic significance and were not character-defining features. The changes were extraneous to the Burr-arch truss and were removed.

5. Distinctive materials, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

The most important members of the truss, as well as other character-defining features, were preserved, and other character-defining features were retained.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.

Repair work was completed with in-kind materials using traditional craftsmanship techniques. Replacement members were made from in-kind material using craftsmanship that replicated historic construction methods. Other character-defining features were retained and/or replaced in kind (horizontal siding, for example) with traditional materials and methods. However, more work needs to be done (in the way of research/testing) with sufficient information to allow for more repair than replacement.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

Chemical treatments were used sparingly, and non-toxic chemicals were chosen when possible. No chemicals were used that would have changed the original appearance/patina of the structure.

8. Archaeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

The abutments remained in place. Archeological disturbance did not take place.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

The replacement materials are identifiable upon inspection of their color and patina. Many of the new members had the date noted in hidden areas. Replacement materials have been documented and recorded by the Historic American

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5. Gilpin's Falls Covered Bridge

Engineering Record, as well as in as-built drawings retained by Cecil County Department of Public Works.

10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

There were no additions or adjacent new construction.

Section 106 Compliance Information

The rehabilitation had no adverse effect. Maryland Historical Trust provided grant monies to help fund the rehabilitation and holds a perpetual preservation easement on the structure.

Lessons Learned

Significant modification of the original design intent, which allowed for the proper rehabilitation of the bridge, would not have been possible without the cooperative efforts of a number of agencies and people, including the Cecil County Department of Public Works; Maryland Historical Trust; Wallace, Montgomery & Associates; Kinsley Construction, Inc.; Barns & Bridges of New England; and W. Earl Simmers of the Historical Society of Cecil County.

Project Particulars

Rehabilitation Project Team

Timothy J. Werner, P.E., Senior Engineer, Wallace, Montgomery & Associates
Kinsley Construction, Inc.

Timothy Andrews, Bridgewright, Barns & Bridges of New England

Jeremy Woodliff, timber framer

William Truax, timber framer

Jonathan Pohlman, Cecil County Department of Public Works

Richard Brand, Maryland Historical Trust (retired)

W. Earl Simmers, Historical Society of Cecil County

Date of Project

June 2009 – February 2010

Cost for Treatment Project

The original contract was awarded for \$1.2 million, but change orders brought the final total to \$1.4 million. The funds came from a variety of sources, including a \$1,040,000 grant from Federal Highway Administration's National Historic Covered Bridge Preservation Program in 2007. Historical Society of Cecil County raised and donated some \$22,000 while the National Society for the Preservation of Covered Bridges donated \$8,000. Tim Andrews donated an estimated \$20,000 worth of labor to complete the project.

Case Study Team

Prepared by Jeremy Mauro, Architect, Historic American Engineering Record (HAER), National Park Service, 2013. Assistance from Christopher Marston, Project Leader, HAER National Covered Bridges Recording Project, and Timothy Andrews, Barns & Bridges of New England. It was peer reviewed by W. Earl Simmers, Historical Society of Cecil County.

Sources

Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior. "Gilpin's Falls Covered Bridge." HAER No MD-174.

Interviews by author with Timothy Andrews, Barns & Bridges of New England, 2009-2012.

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"Rehabilitation of Gilpin's Falls Covered Bridge." http://www.wallacemontgomery.com/wma_media/20SERVandPROJ-pages/ProjectsCompletedPDFs/servproj_bridge_gilpin.pdf, accessed May 6, 2013.

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5. Gilpin's Falls Covered Bridge

Footnotes

¹ From original specifications for the bridge, advertised in the Cecil Whig, August 18, 1860, available at <http://www.mdcoveredbridges.com/gilpinswhig.html>, accessed May 15, 2013.

² Lola Bennett, Jeremy Mauro, and Rachel Sangree with Hannah Blum, "Gilpin's Falls Covered Bridge," HAER No. MD-174, Historic American Engineering Record (HAER), National Park Service, U.S. Department of the Interior, 2009-2012.

³ Interviews by author with Timothy Andrews, June 2009 – July 2010.

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5. Gilpin's Falls Covered Bridge

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6. Goodpasture Covered Bridge Lane County, Oregon



Figure C6.1 Goodpasture Covered Bridge, looking north, 2009. All photographs by OBEC Consulting Engineers, except where noted.

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6. Goodpasture Covered Bridge

Lane County, Oregon

By Gregory W. Ausland, Anthony LaMorticella, Matthew Sevits, Kaitlyn Lange

Administrative Data

Bridge Name

Goodpasture Covered Bridge

Bridge Structure Type

Eleven-panel, three-leaf Howe truss spanning 165' from pier to pier, plus timber stringer and decking approach spans for a total bridge length of 238'

Date of Original Construction

1938

Original Builder

Lane County Engineering Department using a design by the Oregon State Highway Commission

Bridge Owner/ Client

Lane County, Oregon

FWHA Project Identification Number

X-BRO-2385(065)

World Guide Number

37-20-10

Structure Number (NBIS or local designation)

39C118

HABS/HAER/HALS Number

HAER OR-136

National Register Number and Date

NRIS 79002100, November 29, 1979

Description of Location

Goodpasture Covered Bridge is located just south of Highway 126, near Vida, Lane County, Oregon, making the bridge highly visible along this popular east-west travel route.

Description of Setting

The bridge is located in a dramatic, heavily wooded, steeply cut river valley through the foothills of the Cascade Mountains.

Historical Background and Context

Lane County Engineering Department, under the supervision of veteran bridge builder A. C. Striker, built Goodpasture Covered Bridge in 1938 based on a standard design developed by the Oregon State Highway Commission. The total cost for construction of the bridge was \$13,155.

In 1925 there were 450 covered bridges in use in Oregon. By 2003, replacement, removal, and destruction had reduced that number to fifty-one.¹ Goodpasture is the longest extant covered bridge in Oregon that is still open to vehicular traffic on an active roadway and the second-longest covered bridge in the state.

Physical Description of Bridge

Goodpasture Covered Bridge is a five-span timber structure spanning the McKenzie River in eastern Lane County, Oregon. The river is one of America's most pristine waterways and home to many protected species of aquatic life, and it is also very popular with boaters and anglers. The bridge is a lifeline link providing the only access to a neighborhood of approximately 300 residents. A short approach span from Oregon Highway 126, which is one of the major east-west state highways, leads to the bridge, a 165'-long covered Howe truss followed by three simple timber approach spans with a total length of 238'. The entire superstructure of all five spans is built from locally-harvested Douglas fir. This includes the siding of the main span as well as all of the structural parts. The present roof on the main span is clad with western red cedar shingles as discussed below. The concrete piers supporting the main span are original, but the concrete abutments were replaced in 1987. The original timber bents supporting the south approach spans were also replaced in 1987 with bents of steel piling with concrete caps. This single-lane bridge has carried logging, recreational, and local traffic, but for several years it has been weight-restricted because of structural distress. Goodpasture Covered Bridge still carries approximately 750 vehicles per day, of which approximately seventy-five are trucks.

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6. Goodpasture Covered Bridge

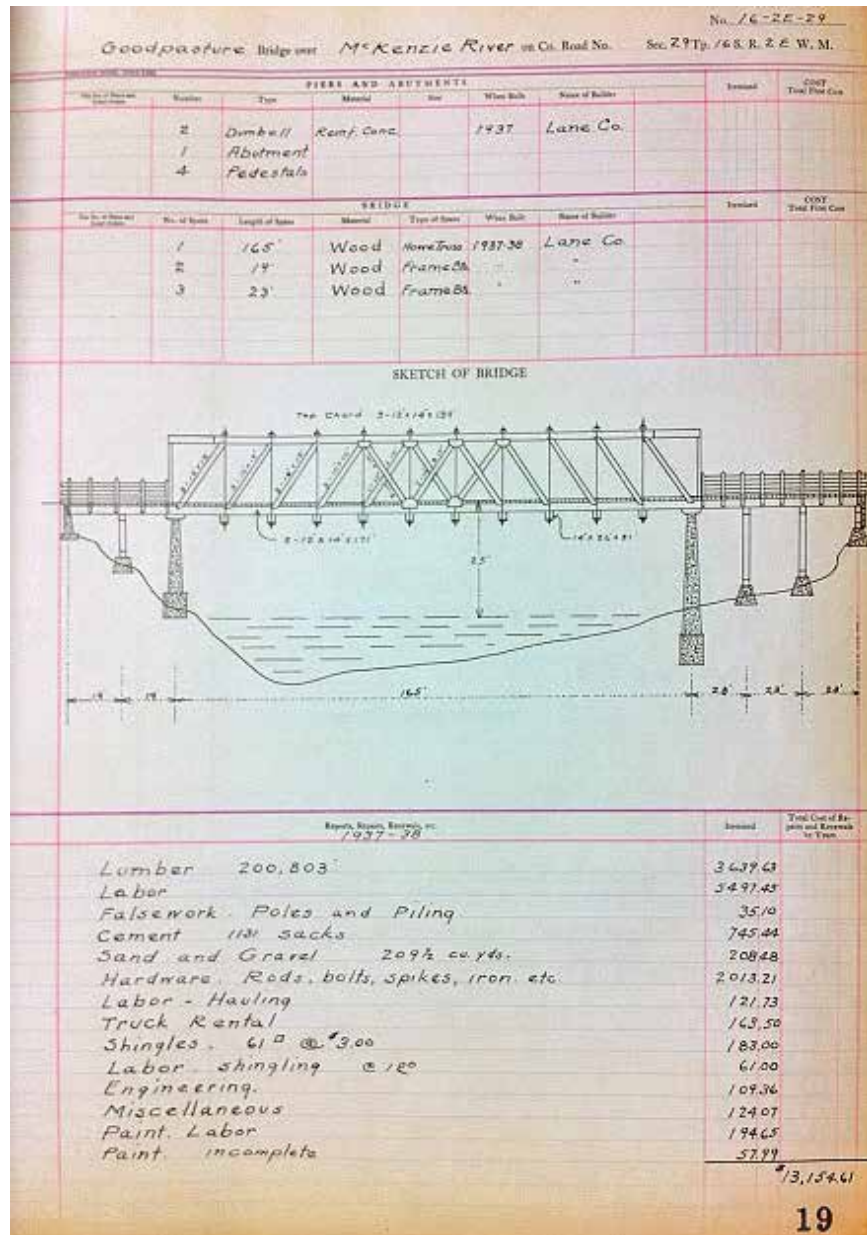


Figure C6.2 Invoice for original construction from Lane County Bridge Ledger. Courtesy of Lane County Historical Museum.

Each of the inner and outer leaves of the bottom chords of both trusses are four-piece members, while each of the middle leaves consists of three members. Of the sixteen resulting bottom chord splices, eight are broken, although they had been repaired with heavy steel tie-rod and plate assemblies lag screwed to the timber chord members in the 1970s and again in the 1980s. The repairs were only marginally effective. When OBEC Consulting Engineers (OBEC) inspected the bridge in 2010, there were gaps between the ends of timber members at all of the repaired splices, some over 1/2" wide, and the bridge sagged over 4" at mid-span.

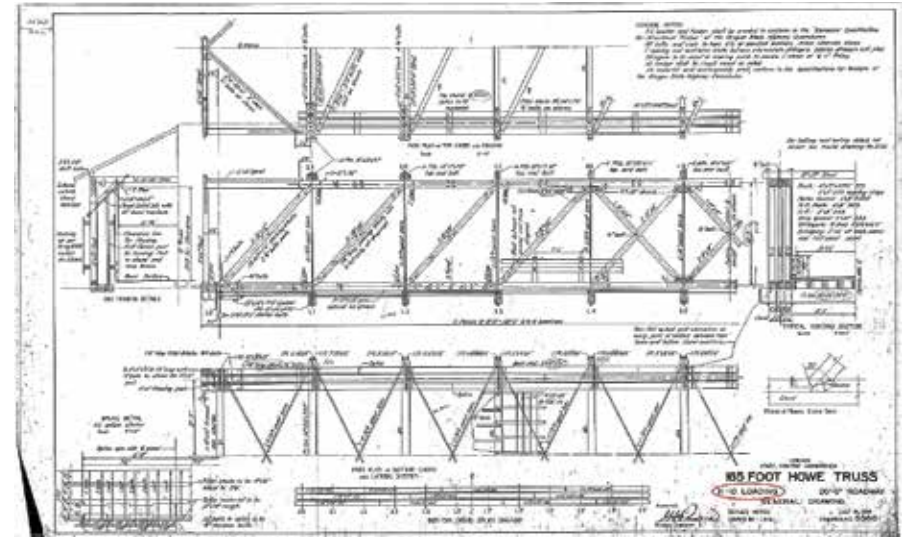


Figure C6.3 1938 standard drawing for 165-foot Howe Truss by the Oregon State Highway Commission.

Chronology of Development and Use

The original design was for H-10 (10-ton) loading. However, for many years, especially from the post-war period through the 1970s, logging along the McKenzie River was very heavy. Traffic across the Goodpasture Covered Bridge included log trucks and other heavy-haul vehicles weighing as much as 80,000 pounds each, four times the design capacity of the structure. Exactly when the bottom chord splices of the bridge trusses began to break is unknown, but the repairs made in the 1980s were part of a major rehabilitation that was necessary because of the serious stress the bridge had endured. By 2010 the

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6. Goodpasture Covered Bridge

overall condition had again deteriorated to the point that the state inspection report from that year gave it an overall sufficiency rating of 49 out of a possible 100. That year the existing heavy composite roofing was replaced with a much lighter cedar shingle roof, allowing the posted weight restriction of 15 tons to remain in effect.

Because of site constraints and concerns of local residents, an alternate crossing was not possible even as a temporary detour. Consequently, all work on the bridge had to be performed under traffic with only very short-term closures. To further complicate matters, the in-water work period recommended by the Oregon Department of Fish and Wildlife is July 1 through August 15. In other words, all work in the active channel had to be completed within a period of only six weeks. In this location, the river bottom is rock and over 30' below the main span. The water here is swift, carrying debris that sometimes includes large trees, and the water level can rise several feet in a few days when the heavy rains begin. Therefore, even if a work bridge or temporary support could have been erected during the in-water work period, leaving it in place through a rainy season would have been extremely hazardous.



Figure C6.4 Interior of bridge showing center spans of Howe truss and boxed windows prior to rehabilitation. HAER OR-136-7, Jet Lowe, 2004.

Description of 2013 Rehabilitation Project

Although Goodpasture Covered Bridge was originally designed to carry only a 20,000-pound live load, it was sufficiently robust that only the bottom chords proved inadequate to carry legal loads. By strengthening the bottom chords, weight restrictions could be removed. However, replacing chord members would not be possible without closing the bridge for an extended period of time. Therefore, an alternate load path had to be provided to relieve the bottom chords. The selected approach was to post-tension with high-strength steel strand. However, the geometry of the truss had to be corrected before any compression was applied to the bottom chords or the repair would have magnified the sag.

The challenge then, in light of access limitations outlined above, was to lift the center of the bridge without any support from below while keeping the bridge open to traffic. This was accomplished by constructing a pair of tube steel trusses that fit inside the covered bridge and had sufficient capacity to bear the entire weight of the covered bridge and live loads up to 15 tons. Two feet were cut from each edge of the bridge decking to make room for the steel trusses, the bridge rail was removed, and a temporary guardrail was installed. The temporary steel trusses bore directly on the concrete piers, narrowing the roadway from 16' to 12' during this phase of construction. This narrowing of the lane was not a major inconvenience to users as the bridge had always functioned with a single lane. Each steel truss was manufactured in three pieces and assembled inside the timber bridge. Then a series of lifting platforms was installed below the floor beams of the timber bridge and connected by steel rods to hydraulic jacks on the steel trusses. The timber bridge was lifted 8" at mid-span to achieve 4" of positive camber. The vertical hanger rods of the timber bridge were tightened while the steel trusses held them in the correct shape. The post-tensioning (PT) system consisted of 6 ½"-diameter Grade 270 strands on each side of each bottom chord. Each strand was jacked to 20,000 pounds, yielding a total compressive force of 240,000 pounds on each bottom chord; this reduced tensile stresses in the bottom chords enough to enable the covered bridge to safely carry legal loads. Then the tube steel trusses were disassembled and removed. Finally, a new deck was installed, damaged siding was replaced, and the entire exterior of the bridge was repainted.

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Figure C6.5 Installation of first temporary steel truss during night closure, 2013.



Figure C6.7 One of twenty 50-ton jacks on temporary steel truss used to lift the bridge to proper camber, 2013.



Figure C6.6 Both temporary steel trusses in place; bridge open to traffic, 2013.



Figure C6.8 Jacking the PT strand, 2013.

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To complete the project, bridge lighting was installed, and an interpretive display devoted to the history of the bridge was added at the top of an existing stairway leading to the river bank at the southeast corner of the bridge. Goodpasture Covered Bridge is located on a blind curve of a heavily-travelled road passing through a dense forest. Prior to the rehabilitation, the bridge was very hard to see at night, since there is no turn lane and no shoulder for west-bound traffic. Multiple accidents resulted from people slowing suddenly to make the turn. Lighting was added to make the bridge more visible at night and to improve safety. High-efficiency LED lights were installed in the windows, under the eaves, and behind the barge rafters at the portal ends, activated by an external light sensor and discretely illuminating the ends and side walls from concealed fixtures.

For many years local residents have traditionally decorated the bridge for the winter holidays. Large wreaths were hung over the portals, and colored lights were placed in the windows making them alternately red and green. Lane County had reservations about allowing the public to install electric lights on an historic wooden structure. To satisfy residents and simultaneously relieve the county of some liability, the window lights were programmed so they can be changed from white to alternate red and green by the flip of a switch located in a locked panel concealed behind a hidden door in the wrap-around siding. The residents can still hang their wreaths and are provided access to the switch at the beginning of the holiday season. The installation is both safe and efficient.

The setting of the Goodpasture Covered Bridge is particularly dramatic and picturesque. It is said to be the most photographed covered bridge in Oregon and is a popular tourist destination. It is a vital resource, functionally, historically, and aesthetically.

Analysis of Treatment and Standards That Have Been Applied

Keeping the bridge in operation during the rehabilitation was a key element of the project. The design solution of installing temporary tube-steel trusses allowed the existing truss elements to be raised prior to the installation of the post-tensioning system, without any permanent physical or visual effects. All modifications and repairs to the bridge were designed in compliance with the



Figure C6.9 Interpretive display, 2013.

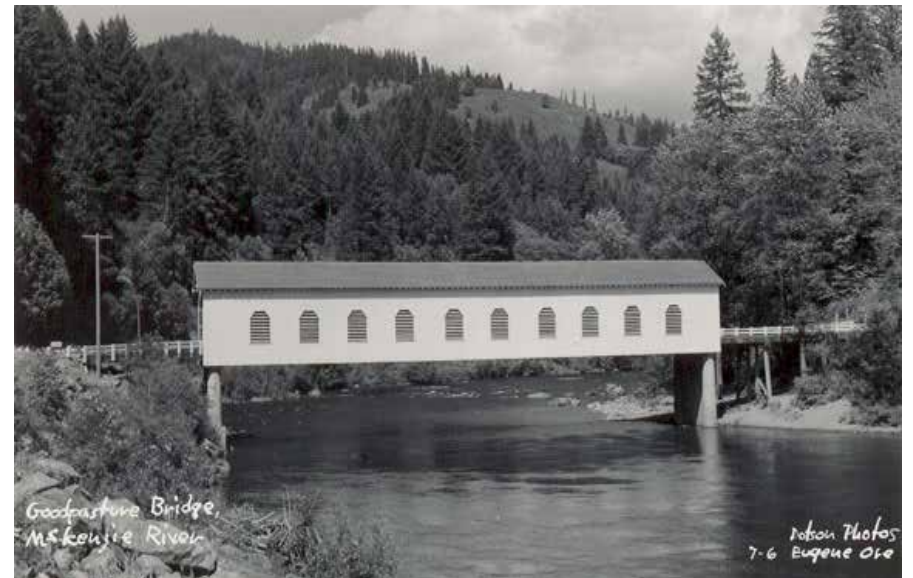


Figure C6.10 Goodpasture Covered Bridge, looking east, ca. 1950s. Postcard, collection of George Kramer.

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Figure C6.11 Goodpasture Covered Bridge after rehabilitation, looking west, 2013.



Figure C6.13 Goodpasture Covered Bridge at night, looking north from Highway 126, 2013.



Figure C6.12 Goodpasture Covered Bridge at night, looking west, 2013.

Secretary of the Interior's Standards for Rehabilitation Nos. 5 and 6, preserving the key design characteristics and replacing deteriorated features in-kind. Structural augmentation, in the form of the post-tensioning system that allows the bridge to meet required load capacity, was located on the outer face of the lower chords so as to have minimal visual impact from most accessible viewpoints, in accordance with Standard No. 9. The installation of lighting, improving the function of the bridge, and reducing the potential for future damage, was undertaken to have minimal visual impact during daylight hours and is entirely removable, in accordance with Standard No. 10.

1. A property will be used as it was historically or be given a new use that requires minimal changes to its distinctive materials, features, spaces, and spatial relationships.

The bridge continues in its historic use to convey traffic over the McKenzie River.

2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alterations of features, spaces, and spatial relationships that characterize a property will be avoided.

Historic character has been retained.

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6. Goodpasture Covered Bridge

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.

No changes have been made that would have created a false sense of historical development.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

No changes have been made to the bridge that had acquired significance.

5. Distinctive materials, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

Distinctive character-defining materials, features, finishes, and craftsmanship have been retained.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.

Deteriorated features have been retained and repaired where possible. Only those that were too deteriorated to repair have been replaced in kind to match existing features.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

No chemical treatments were used.

8. Archaeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

Archeological resources were not disturbed.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be

compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

The new post-tensioning system, additional structural augmentation required to meet load capacity, was installed discretely on the outer face of the lower chords, where it has minimal visibility and does not negatively impact the historic character of the bridge. New lighting was similarly located.

10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

The project involved no new additions or adjacent construction.

Section 106 Compliance Information

The Goodpasture Bridge Rehabilitation Project allowed the continued use of the Goodpasture Bridge as a functional element of the Lane County transportation system. Since the rehabilitation and structural/functional upgrades were designed in compliance with the Secretary of the Interior's Standards for Rehabilitation, the Oregon State Historic Preservation Office found that the project would have No Adverse Effect under the Section 106 review process.

Project Particulars

Rehabilitation Project Team

OBEC Consulting Engineers – Prime Consultant

DKS Associates – Traffic Study

Heritage Research Associates, Inc. (HRA) – Cultural and Historical Resources

Sea Reach Ltd. – Interpretive Exhibits Design and Fabrication

Balzhiser Hubbard Engineers, Inc. – Lighting Design

Lois Cohen Associates – Public Involvement

David Place Consulting – Construction cost estimating and value engineering

Date of Project

September 2011 – March 2013

Cost for Treatment Project

\$1,807,000

CASE STUDIES

6. Goodpasture Covered Bridge

Case Study Team

Prepared by Gregory Ausland, Tony LaMorticella, Matt Sevits and Kaitlyn Lange, OBEC Consulting Engineers, 2013.

Sources

Kramer, George. *Oregon Inventory of Historic Properties, Section 106: Level of Effect*, February 2012.

Footnotes

¹George Kramer, *Oregon Inventory of Historic Properties, Section 106: Level of Effect*, February 2012.

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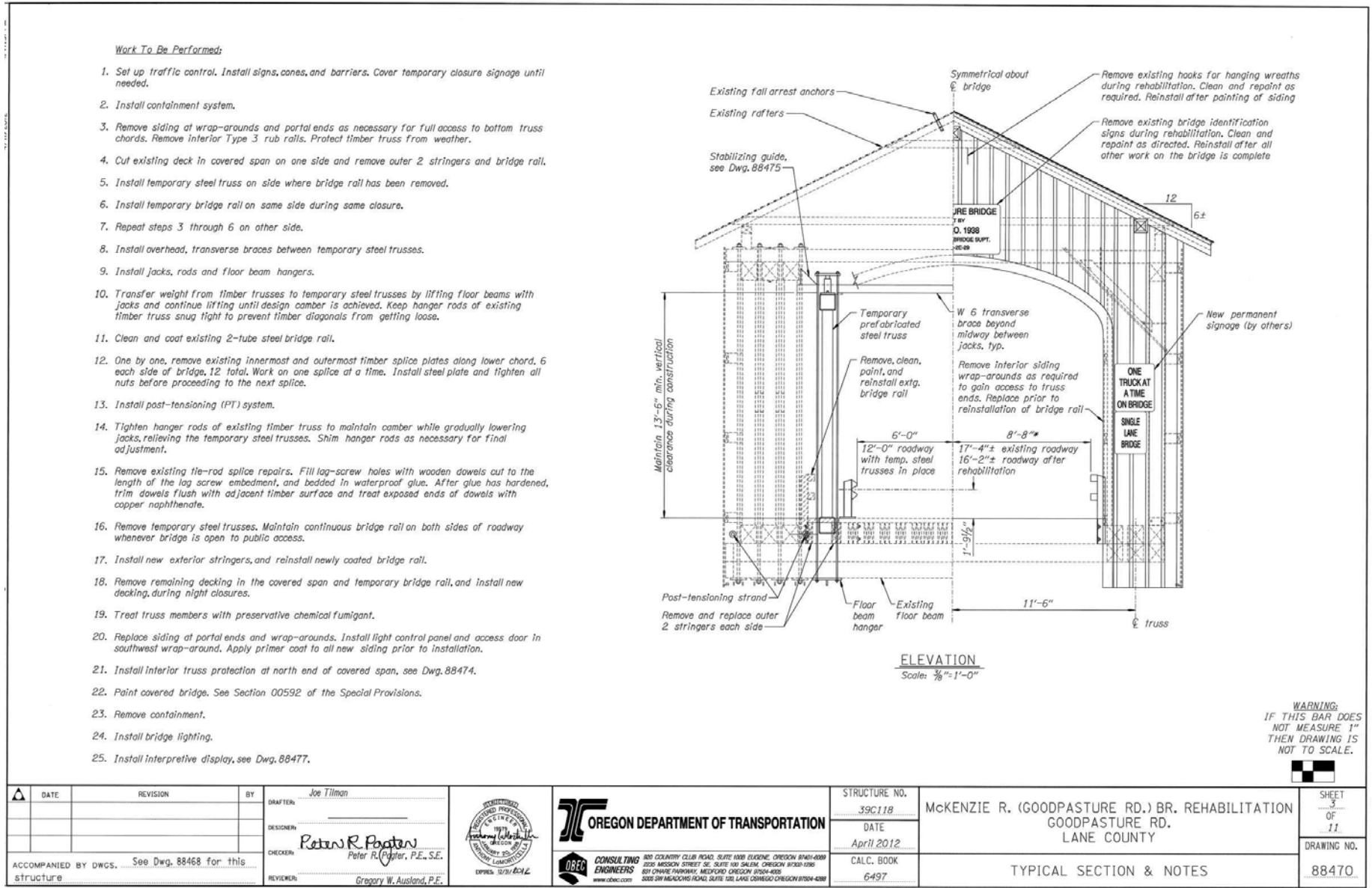


Figure C6.14 Portal Elevation. OBEC Consulting Engineers, 2012.

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7. Johnson Creek Covered Bridge Robertson County, Kentucky



Figure C7.1 Johnson Creek Covered Bridge after rehabilitation. Jen Spangler Williamson, 2010.

CASE STUDIES

7. Johnson Creek Covered Bridge

Robertson County, Kentucky

By Arnold M. Graton, Meg Dansereau Graton, Jen Spangler Williamson, Patrick Kennedy

Administrative Data

Bridge Name

Johnson Creek Covered Bridge

Bridge Structure Type

A variant of the Smith truss, Type 4, it was modified in 1914 with the addition of a single vertical 1" iron rod through the center of each X brace that extended through both lower and upper chords. Wood arches were also added and bolted to the inside members of the truss braces.

Date of Original Construction 1882

Original Builder

Jacob N. Bower

Bridge Owner/ Client

Original Owner: Robertson County, Kentucky

Owner during restoration: Commonwealth of Kentucky, Transportation Cabinet

Present Owner: Commonwealth of Kentucky, Tourism Arts and Heritage Cabinet, Department of Parks

World Guide Number

17-101-01

Structure Number (NBIS or local designation)

NBIS 101B00020N

National Register Number and Date

NRIS 760000941, listed September 29, 1976

Description of Location

The bridge is located 1.6 miles north of the junction with U.S. Highway 68 and 2.2 miles on Kentucky Highway 1029. It is 5 miles southeast of Mount Olivet in Robertson County, Kentucky. The bridge spans Johnson Creek, which is a part of the Licking River watershed. Licking River is a tributary of the Ohio River.

Description of Setting

The surrounding area is rural with some active agricultural activity. The bridge was bypassed in 1966 by a concrete bridge. As of 2013, Johnson Creek Covered Bridge can still be traversed by automobile and has a 6-ton load rating.

Historical Background and Context

The *Kentucky Tribune* reported in 1882 that Jacob N. Bower had been awarded the contract for the construction of the Johnson Creek Covered Bridge. Robertson County Commissioners N.A. Tilton, Jas. Kenton, and H.L. Wilson approved \$1,700 to pay for its construction. This bridge is the only remaining example of a Kentucky Smith truss variant, and it is the last extant bridge known to have been built by Jacob N. Bower, whose son and grandson continued the family occupation of covered bridge building.



Figure C7.2 Johnson Creek Bridge in September 1951. Courtesy of John E. Thierman Photographic Collection, 1944-1970, PA 2, Special Collections, Transylvania University, Lexington, Kentucky.

The new bridge was to be built along the Sardis and Battle Ground turnpike and connect Route 68 with Mt. Olivet, the relatively new county seat of Robertson County established in 1867. The bridge site is now located 4 miles north of Blue Licks Battlefield State Park. As constructed, the single-span

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7. Johnson Creek Covered Bridge

bridge was 110'-0". The siding stopped 18" from the roof, and there were slightly angled shelter panels at each portal.

The bridge experienced such heavy use that in 1914 Louis S. Bower, son of the original bridge builder, modified the structure by installing 1" iron reinforcing rods. Since many of Kentucky's covered bridges were originally sided in horizontal yellow poplar planks, it is assumed that Johnson Creek Covered Bridge was also sided in that material. In the 1914 restoration, vertical plank siding was installed and painted red. The portals were painted green and white as was typical of Kentucky bridges and bridges constructed by the Bower Bridge Company.

In 1925, under a directive from the State Highway Commission, the County Road Department installed an off-center pier to correct sagging at that point. The off-center pier would eventually exacerbate loading issues by changing the dynamics of the bottom chord. Concrete pilasters were installed next to the stone abutments at the same time for reinforcement.

The bridge carried vehicular traffic until 1965 when it was bypassed by a new concrete bridge. The new road alignment made the covered bridge less visible, and it became an attractive target for vandalism and arson.

At one time, there were hundreds of covered bridges in Kentucky. As of 2013, only thirteen remain. In 1993, the Commonwealth of Kentucky's Transportation Cabinet began a process of investigation and comprehensive assessment of the state's remaining covered bridges. The initiative was well received and became the basis of a work plan to ensure that the bridges endure as heritage landscape and tourism features. After a few restoration efforts, including the unpopular 2002 Walcott Covered Bridge project in Bracken County, in which the 1880s bridge was disassembled and then reconstructed with a high percentage of replacement materials, public concerns were raised.

The issue came to a head in 2003 in Fleming County, home to three of the state's thirteen remaining covered bridges and host to an annual covered bridge festival. At an April 22, 2003, meeting, over 200 citizens packed a local elementary school to voice concerns about the offsite reconstruction and restoration methodology of the county's Goddard 'White' Covered Bridge. In response to the public outcry, the Kentucky State Legislature passed KRS

176.400, which designated wooden covered bridges as state shrines. The legislation also established the Covered Bridge Authority bodies and set requirements for public meetings to provide for citizen input in conjunction with and prior to any work taking place on the state's covered bridges. By mid-2004, project leaders had altered the plans for the Goddard Bridge restoration, including adding an experienced historic preservation bridgewright (Arnold M. Graton) and engineer (David C. Fischetti) as consultants to the team. The Goddard Bridge restoration was the transitional model that would eventually lead to the acceptance of a design-build project delivery methodology, as opposed to the traditionally accepted design-bid-build process.

Local individuals and groups in Robertson County, including Bill Wheaton with the Robertson County Historical Society, continued to advocate for the restoration of the troubled Johnson Creek Bridge. In this period of restructuring the manner in which covered bridge restoration would be undertaken, the construction contract on Johnson Creek, which had already been let, was canceled. This project then became the first design-build project for the Kentucky Transportation Cabinet. The team of Arnold M. Graton and David C. Fischetti, DCF Engineering, was selected for the Johnson Creek Bridge Restoration project, and work began in 2007.

Physical Description of Bridge

The single-span Johnson Creek Covered Bridge consists of a variant of the Smith truss, Type 4, measuring 110'-0". The structure is 19'-0" wide between the outer faces of the trusses, with a 15'-3" roadway. The trusses are 15'-8" high from the top of the top chord to the bottom of the bottom chord. Clearance is 13'-3". The original truss and auxiliary iron rods and laminated arch installed in 1914 carry the bridge's weight. The bridge is in its original location and is open to traffic with a 5-ton rating, although it has been bypassed.

The bridge was raised 18" during rehabilitation to reduce the risk of impact by flooding, and this differential is visible in the approaches, which are raised and supported on drystone masonry.

An initial assessment report completed in 1997 by Brighton Engineering and HNTB Corporation notes that within the primary structure of the bridge, the lower chords are constructed of four 4" x 8" original oak timbers. Each truss

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7. Johnson Creek Covered Bridge

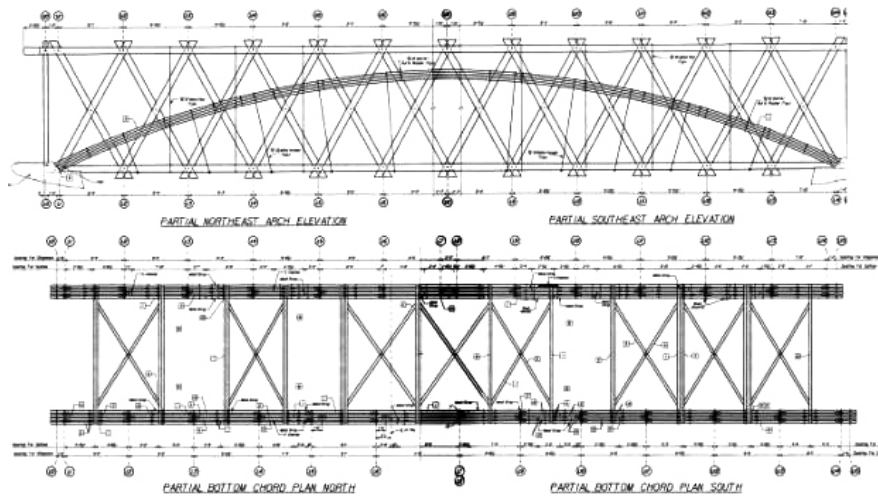


Figure C7.3 Johnson Creek Bridge elevation and plan. Brighton Engineering (now DLZ) Bridge Inspection Report for Johnson Creek Covered Bridge prepared for the Commonwealth of Kentucky, Transportation Cabinet, September 1997.



Figure C7.4 Bridge interior in September 1951. Courtesy of John E. Tierman Photographic Collection, 1944-1970, PA 2, Special Collections, Transylvania University, Lexington, Kentucky.

consists of twelve Xs, with each X made up of a pair of braces with a single counter brace. Each is framed from 4" x 6" timbers, except the end Xs which are 4" x 8"s. In 1914, 1"-diameter iron rods were added, along with arches of laminated poplar measuring 4" x 5" and stacked to form a 4" x 20" member. The arches are bolted to the inside members of the truss braces. The rods run from the arch through the lower chords where they are tied together beneath.

The bridge is clad with vertical plank siding that extends 21" below the bottom of the upper chord and provides ventilation and light within the bridge. Although there is no official documentation concerning this bridge, most of the covered bridges in this region were originally sided with horizontally-oriented, wide yellow poplar siding that has since been replaced with smaller, vertically-oriented boards cut from pine and oak. During rehabilitation those vertical siding boards that were not deteriorated were salvaged and reused. The roofing and siding extend to an angled shelter panel at each portal. The roofing material is galvanized 5v metal roofing.

The bridge is braced laterally by 4" x 6" overhead tie beams with 4" x 4" braces crossing just below every other beam. The beams rest on top of the top chords, are spaced approximately 9' apart, and are bolted to the chords. The crossing braces are mortised into wood angle blocks attached to the face of the upper chords. These braces are notched at their crossing points and bolted to tie beams overhead. It is assumed that the original lateral bracing below was probably similar.

In addition to the tie beams and crossing braces, the bridge is braced laterally by 2" x 6" knee braces attached at each post. These braces are bolted to the tie beams approximately 3' out from the posts and to the post about 2' below the tie beams.

Chronology of Development and Use

After the 1914 addition of iron rods and auxiliary arch by Louis Bowers, the Kentucky Department of Highways began removing the siding and wood shingle roofs from covered bridges in an attempt to increase their carrying capacities in the 1920s. Johnson Creek was reroofed in galvanized iron, and the vertical siding was painted red. The mid-span support was also installed at that time.

"Stock" Bower, Louis' son, made repairs in 1968 and 1972 following an arson attempt in 1968. Wood & Wood Builders of Brooksville, Kentucky, made a number of repairs to the bridge in 1986. These included minor repairs to the

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trusses, stabilization of the bridge, and the installation of new flooring, siding, and roofing. The Buffalo Trace Covered Wooden Bridge Authority provided the funding.

Description of Most Recent Rehabilitation Project

Project Goals:

The Johnson Creek Covered Bridge and adjacent properties were transferred to the state parks system, and projects were undertaken in 2007 and 2009 to fully restore the bridge to a rated utility, even though the property and the setting no longer function as a transportation corridor. Given the state's previous experiences with the Walcott and Goddard Creek covered bridges, the preservation and retention of a high degree of historic material, craftsmanship, and character were primary project objectives. The project team and design-build approach were critical to accomplishing these objectives.

Description of Rehabilitation

The restoration was completed in two phases due to limitations of funding sources. Stabilization and shoring were the first order of business. The project team of Arnold M. Graton and David Fischetti, DCF Engineering, began with a visual field assessment. The team determined which members could be sistered or spliced versus those that needed complete replacement. They developed a shoring scheme to protect the bridge between restoration phases. Since a relatively short time separated the phases, demobilization was not a factor.

A steel truss, the first of its kind to be used in covered bridge restoration, was designed to shore the bridge while clear spanning the creek. Needle beams (temporary members) were installed on the steel truss to support the wooden top chord throughout the restoration. The truss span reached well beyond the abutments. The steel truss maintained the alignment of the bridge throughout the restoration process.

The steel truss was also utilized for staging and for jacking camber back into the bridge. At the time of the restoration, Johnson Creek Covered Bridge had negative camber of 21". The roof reflected the same 21" of negative camber on the downstream side, and the bottom chord was completely separated. The



Figure C7.5 View of shoring system, with steel truss through bridge, with horizontal needle beams supporting the top chord. Note negative camber, which measured up to 21." William Caswell, 2007.

upstream side showed a little less loss of camber because the bottom chord was supported somewhat by the pier installed during a prior restoration.

In order to install the steel truss, the siding placement was documented for reuse and then removed. Each approach was graded, and a platform was built of 4" x 8" x 16' pressure-treated materials. Stations of 6" x 7" x 4' timbers were built on these platforms, creating a crib to support the truss as it was fed into the bridge. The steel truss rested on a duplicate crib on the far side.

Three bids were received for the truss fabrication, and Ranger Steel, Inc., a local steel company from Maysville, won the contract. The main part of the steel truss was 160' and was assembled at the bridge in 40' sections supported by a crane, bolted together, and fed through the bridge as it was assembled. The truss was slowly eased through the bridge on wooden and steel rollers using a hand-operated cable/winch tool. A 50' nose piece attached to the truss allowed the cantilevered truss to reach the far side of the bridge without putting any load onto the bridge since it was much lighter than the truss. After two days, the bridge was secured by the truss.

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7. Johnson Creek Covered Bridge



Figure C7.6 View of bridge after camber was restored to 9". William Caswell, 2008.

Phase 1

The first step in the restoration process was to relieve the load of the bridge by removing the floor. To accomplish this, 28' needle beams were fed through the top chord of the truss at each post. This supported the top chord. Temporary jacking stations were set up under each needle beam at each post.

The jacking process was started at the maximum camber point and then gradually to each cribbing station until positive camber was restored to 9". During the jacking process, some prior repair work to the bottom chords was removed to allow the bridge to come back to its original configuration.

Needle beams were then fed under the steel truss at each post. This supported the lower chord for removal and replacement as well as being used to set up staging on each side of the bridge. All floor joists were removed and documented for reuse. Jacks were used to spring open the bottom chord. Care was taken to ensure that the truss members and chord replacement were accurately documented.

Historic hand-forged iron rods, both vertical and diagonal, were removed and documented for replacement. As the bridge camber became negative, many

of these iron rods bent. The existing bottom chords were removed and saved as the pattern for the new bottom chord. There was only one piece of original chord as the rest had been replaced over the years.

The roof was left in place to protect the structure. Although poplar and oak had been used as original chord material, Douglas fir was instead used as a replacement because of its strength. The original chord configuration was carefully replicated. With the bottom chord removed, truss members were replaced or spliced. All joinery of the members was dressed using traditional hand tools (slicks, framing chisels, and broad axes) to ensure proper fit. As much historic material as possible was retained in accordance with the Burlington Charter for the Preservation of Historic Covered Bridges and the Secretary of the Interior Standards for the Treatment of Historic Properties. Historic material was preserved using half laps on the braces and counter braces. Truss members were replaced in kind using oak and poplar. Historical graffiti was noted for placement, but newer and inappropriate graffiti was removed, if possible. All the timbers removed were given to the Buffalo Trace Covered Bridge Society.

The newly-framed bottom chord was fed into place and aligned. Wedge-shaped shear blocks were placed in notches between the chord and members, since the wedge shape allowed for the self-adjustment needed in cases of movement or shrinkage of the lower chord members. Lateral bracing was framed to the bottom chord. By using half laps approximately 50 percent of the original lateral bracing material was saved, which worked well as all the bracing was in compression. This concluded the work of Phase 1.



Figure C7.7 Panorama of steel truss inside of bridge, after camber was restored to 9". The center pier was removed after the truss was repaired. KTC, 2007.

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Phase 2

The arch was in need of repair because all five members of the arch, both sides and both ends, were rotted. The rotten arches were forcing the ends of the bridge down and putting additional load on the bottom chord. The arch was covered with numerous carvings dating back many years. Members of the community often visited the bridge to locate their family initials or names, so these were saved wherever possible. The arch end replacements were staggered, with butt joints in compression holding them in place. The arch itself was in good condition, so approximately one tenth was replaced. Replacement lengths varied from 3' to 20'. In-kind poplar was used after soaking it in water to make the timber flexible so it would conform to the original arch.

The next step in the restoration started with jacking and shoring the roof so that the upper chord and bracing could be addressed. The same procedure for documentation and replacement of the bottom chord was used for the top chord, truss members, and upper lateral bracing. The top chord was in relatively good shape and only about one third of it was replaced.



Figure C7.8 Detail of the upper chord, showing the typical joinery used throughout. Arnold M. Graton, Inc., 2007.

The ends of the roof rafters were rotted and needed to be completely replaced. The purlins also had to be replaced, and the original rafter system was duplicated. A new five rib, galvanized metal roof was installed.

Next, the abutments and center pier had to be addressed. The center pier was removed so the ends could bear the load when the bridge settled. This allowed the truss to again work as a single span as originally designed.

Concrete had been poured around the ends of the chords and arches, probably to hold the bridge in place. However, the moisture trapped in the concrete caused these critical ends to rot. The concrete was removed, and new thrust blocks for the arches were poured. The arch ends now rest on the concrete. The county also poured a new slab and approach wall to keep the dirt and moisture away from the bridge. The Dry Stone Conservancy replaced the wing walls with dry-laid stone.

Kentucky Transportation Cabinet officials and the design-build team collectively decided that the bridge would be kept 18" higher than its original setting point to safeguard it from flooding. The bridge was lowered on to bearing blocks so



Figure C7.9 Cracks in concrete column and abutment at north end prior to rehab, KTC, ca. 2005.



Figure C7.10 Dry-laid stone approach wall offset from the original dry-laid stone abutment. The approach wall was installed after bridge was raised 18" for flood prevention. Jen Spangler Williamson, 2010.

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7. Johnson Creek Covered Bridge



Figure C7.11 Patrick Kennedy inspects the rehabilitated lower chords and flooring system, Jen Spangler Williamson, 2010.



Figure C7.12 View of completed truss and deck, restored to its original geometry and camber. William Caswell, 2011.

that the shoring still carried the load. After the iron vertical and diagonal rods were repaired by welding new ends and using heat and pressure to straighten them, they were reinstalled. The rods were then adjusted so that the uniform load was established as the shoring was released. The process of lowering the bridge was slow and meticulous: up a little, down a little, adjusting shims so that the trusses and arches were working in harmony. A day-and-a-half was spent lowering the bridge approximately 12". The engineers and the build team had a pool to guess how much camber the bridge would lose. Graton bet $\frac{1}{2}$ " of settlement while the engineers predicted 4". The actual loss of camber was $\frac{3}{8}$ ".

The crew proceeded to finally disassemble the shoring, but the lower portion remained in place while the siding was replaced. Approximately two-thirds of the original siding was used. The new siding was installed in a single section to preserve the character of aged siding on a portion of the bridge, and care was taken to retain historical graffiti. The portals were trimmed to match the original. No char application, a fire retardant, was applied after all clean-up was done.

Analysis of Treatment to Standards That Have Been Applied

1. A property will be used as it was historically or be given a new use that requires minimal change to its distinctive materials, features, spaces, and spatial relationships.

The bridge is on new abutments but continues to operate as a self-supporting wood truss without modern support. Though used as a pedestrian bridge, as of 2013 it can still be traversed by automobile and has a 6-ton load rating.

2. The historic character of the property will be retained and preserved. The removal of distinctive materials or alteration of features, spaces, and spatial relationships that characterize a property will be avoided.

The historic character of the bridge was not compromised. The geometry of the bridge (such as camber and panel spacing) was reestablished. Every member of the truss was carefully examined and retained if possible.

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as

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adding conjectural features or elements from other historic properties, will not be undertaken.

No changes were made that would create a false sense of historic development.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

The 1914 rod alterations, installed by the original builder's son, are still employed.

5. Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

Timber-framed bridge construction illustrating traditional technique and craftsmanship was preserved. The most important members of the truss were preserved. Replacement members were made from in-kind material and craftsmanship.

Since the bridge was raised to reduce potential flooding threat to the structure during high creek flow events, the approaches were also raised approximately 18". Dry-laid stone sidewalls support the new, higher approaches. These walls were offset from abutment dry-laid stone supports to distinguish the new construction from the historic material.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.

Only those members, or portions of members, that were deteriorated beyond repair were replaced in accordance with the Burlington Charter and the Secretary of the Interior Standards for the Rehabilitation of Historic Properties.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

Graffiti was left in place. Anti-graffiti treatment typically required by the Commonwealth of Kentucky Transportation Cabinet was not employed because it has a glossy finish that would not be in keeping with the historical character of the bridge, and because the seal would be potentially detrimental to the wood members by trapping moisture behind the finish.

8. Archaeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

Archeological disturbance did not take place.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work will be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

The replacement materials are identifiable upon inspection by their color and patina.

10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

There were no additions or adjacent new construction.

Section 106 Compliance Information

The rehabilitation project was found to have no adverse effect.

Lessons Learned

The project has been recognized as a success both by the community served and by the various associated state agencies. It allowed the bridge to be restored in place, it allowed for the greatest retention of material and character of the historic resource, and it met budget expectations without rising costs through change orders. The design-build delivery method has been adopted for all future covered bridge restorations in Kentucky.

Project Particulars

Rehabilitation Project Team

Arnold M. Graton (Bridgewright), Don Walker (Timber Framer), and Meg Dansereau Graton; Arnold M. Graton Associates, Inc.

David C. Fischetti, P.E., DCF Engineering, Inc.

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7. Johnson Creek Covered Bridge

Ronald W. Anthony (Wood Scientist), Anthony & Associates, Inc.

Jim Simpson (Project Manager), Nasby Stroop, P.E., and Roy Sturgill, P.E.;
Kentucky Transportation Cabinet

Patrick Kennedy (Restoration Project Manager), Kentucky Heritage Council,
State Historic Preservation Office

Bill Wheaton, Buffalo Trace Covered Bridge Authority

Brighton Engineering and HNTB Corporation produced the 1997 Preliminary
Bridge Inspection Report and Architectural Conditions and Historical Survey

Date of Project

April 2007 – April 2009

Cost

\$600,000 phase 1

\$500,000 phase 2

Case Study Team

Prepared by Arnold M. Graton, and Meg Dansereau Graton, Arnold M. Graton
Associates, Inc.; Jen Spangler Williamson, Staff Architect, Kentucky State
Historic Preservation Office; and Patrick Kennedy, Restoration Project Manager,
Kentucky State Historic Preservation Office, 2013.

References

Architectural Conditions and Historic Survey for Johnson Creek Covered Bridge.
HNTB, September 1997.

Bridge Inspection Report for Johnson Creek Covered Bridge. Brighton Engineering
(now DLZ), September 1997.

CASE STUDIES

8. King's Covered Bridge Somerset County, Pennsylvania



Figure C8.1 Completed rehabilitation of King's Covered Bridge. Simone Collins Landscape Architecture (SCLA), 2008.

CASE STUDIES

8. King's Covered Bridge

Somerset County, Pennsylvania

By William J. Collins and Samer H. Petro

Administrative Data

Bridge Name

King's Covered Bridge

Bridge Structure Type

Multiple-kingpost truss retrofitted with nail-laminated arches that spans 116'

Date of Original Construction

1857; rebuilt 1906

Original Builder

Unknown

Bridge Owner/ Client

Middlecreek Township, Somerset County, Pennsylvania

World Guide Number

38-56-06

HABS/HAER/HALS Number

HAER PA-638

National Register Number and Date

NRIS 80003632; listed December 11, 1980

Description of Location

King's Bridge spans Laurel Hill Creek. It was bypassed by PA 653, which runs 1.8 miles west of New Lexington, Middlecreek Township, Somerset County, Pennsylvania.

Description of Setting

The bridge is situated in a rural area in Somerset County, Pennsylvania.

Historical Background and Context

The total rehabilitation of King's Bridge in Somerset County, Pennsylvania, was completed in 2008, culminating an eleven-year effort by the non-profit Southern Allegheny Conservancy (SAC) and a private-public partnership utilizing 100 percent federal funding from two Federal Highway Administration programs—the National Historic Covered Bridge Preservation Program and the Transportation Enhancements Program. The timber covered bridge boasts a colorful history and provides examples of rare structural systems that are now preserved, including the original lattice floor joist system under a restored deck. Most of the major historic members and much of the historic fabric were preserved in place. Arches that had been retrofitted after initial construction and tied to the lower chords of the original multiple-kingpost truss system were rehabilitated. Using an innovative engineering strategy, arches were extended through the lower chords to create a hinged arch that serves like a Burr-arch structure by bearing on the abutment.

The structure remains a museum-quality artifact for pedestrian use. Bridge ownership was transferred from the Southern Allegheny Conservancy (SAC), the non-profit that managed the rehabilitation project, to the local municipality after site improvements for visitors were completed in spring 2009. The King's Bridge site now serves as one half of a new twin covered bridge municipal park connected by a bike route to the Barronvale Bridge, also owned by Middlecreek Township and located a mile upstream.

King's Bridge spans 116' over Laurel Hill Creek. The original multiple-kingpost truss structure was constructed circa 1857 by an unknown builder and retrofitted with nail-laminated arches circa 1906. Fortunately, the historic structure was bypassed in the 1930s, and the original structural systems were never "modernized" like many timber bridges to serve increased vehicular loads for highway traffic.

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8. King's Covered Bridge



Figure C8.2. Bridge before rehabilitation with stabilization falsework in place at east portal. SCLA.

Physical Description of Bridge

The King's Bridge multiple-kingpost truss is estimated to date from ca. 1860 or earlier, while the arches were added around 1906. The following description is of the extant structural system at the time of rehabilitation.

Trusses

The lengths of the truss panels were neither identical nor were they constructed using the typical geometric conventions of the time. The longer panels were found in the center bays where tension forces were greater in the lower chords. Several hand-hewn posts remained in the trusses, but most members were sawn, indicating later repairs. Tie beams were dropped into slots at the tops of posts and pinned with timber pins or treenails. Rafter sills were bearing on the outrigger ends of the tie beams. Knee braces were joined using mortises between tie beams and posts. Horizontal X-bracing was alternately nailed and housed between the tie beams of each bent. Lower.



Figure C8.3 After rehabilitation at east portal SCLA, 2008.

Arches

Nail-laminated arches, constructed of circular-sawn boards were not let in, but were bolted to truss members, indicating their later addition. The combined structure of trusses and arches was intended to carry the live load. Because the arches were tied to the lower chords (not hinged), they imparted a significant horizontal thrust into those members and contributed to the failure of both in locations weakened by water damage. These subsequent chord failures changed the distribution of the loads through the arches dramatically by visibly deforming them, but not to failure.

Struts

Instead of extending the arches to create a hinged arch, the early re-builders installed diagonal struts from the bottom chords (in the general location of the arch connection) to the abutment faces. These struts were similar to arch extensions in appearance but able to carry much less force. The wood struts decayed at their abutment seats and ultimately transferred no forces from the arch directly into the abutment. This resulted in greater forces imparted from

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Figure C8.4 Lattice floor joist system, and lower tie beam added after original construction. SCLA.

the arches horizontally into the lower chords. The deteriorated lower chords failed, but the trusses tied to the arches did not fail, instead spreading at the ends. The abutments resisted these forces, but not without damage to the substructures that were originally built to receive only vertical loading from the multiple-kingpost superstructure.

Substructure

The bridge was bearing on cut ashlar limestone abutments that had seats for later struts carved into their faces. As suspected, construction excavation revealed that the abutments and wingwall substructures were a single course deep, and backfilled with rubble and compacted earth.

Joists /Floor

A lattice system of floor joists was used below the timber deck, where one layer of diagonal joists was overlaid by a second layer at an opposite angle. These light, circular sawn 5" x 6"s were bearing on two levels of individual ledger blocks nailed to the inside face of the lower chords. Overlapping joists were not

fastened at their intersections like lattice trusses. The longer joist spans created by this design appear to have combined the purposes of transverse beams, longitudinal stringer beams, and under floor diagonal bracing into one system that carried floor loads and provided lateral bracing. The lower layer of decking was laid transverse, while the upper was laid longitudinally.

Sheathing

The trusses were clad with board and batten siding. The roof consisted of deteriorated asphalt shingles installed on top of deteriorated wood shingles attached to circular sawn nailers that had been mounted on sawn rafters fastened at the apex with treenails. Wainscoting and a canted cap were in place to protect the lower area of the inside of the trusses from traffic debris.

Chronology of Development and Use

From the 1930s until 2002, the King family of Middlecreek Township, a local farming family, owned and maintained the bridge. The family retrofitted King's Bridge to serve as a livestock barn over the water. Former gates and fences from this agricultural use were saved to re-install on the bridge after rehabilitation. Remnants of rubber tire hinges still exist on the lower downstream chord where the Kings hung a "floating fence" to prevent livestock from wandering up the creek in low flow periods.

Project engineers agree that it was the King family who was responsible for ensuring the bridge's survival by maintaining the roof and installing a remarkably astute homespun system of tension rods when both lower chords began to fail. During the rehabilitation, these rods were untensioned and ultimately left in place, to acknowledge the family's interventions and to interpret the full structural history of the bridge.

By 1997, both lower chords had failed completely, and only the arches and the repair rods installed by the Kings prevented the bridge from imminent collapse. In 2000, a temporary support system was engineered and installed with two longitudinal, queenpost-tensioned trusses supported on timber crib towers. Transverse needle beams were installed between the two steel queenpost trusses below the upper chords to bear the suspended weight of the covered bridge until rehabilitation could be fully funded and engineered and construc-

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8. King's Covered Bridge



Figure C8.5 Human and livestock gates at east portal. Note the diagonal repair rods through the truss braces, which were installed early in the twentieth century. SCLA.

tion completed. The falsework remained in place through 2007 and served as the construction staging for the rehabilitation contractor, which enabled the work to be completed in place with minimal disturbance to Laurel Hill Creek below.

The temporary stabilization system was engineered and installed, and a funding strategy was developed under an initial state-funded project for \$90,000. By 2004, SAC and partners had secured \$860,000 in federal funds to engineer and carry out a total rehabilitation project.

Description of Most Recent Rehabilitation Project

Prior to the rehabilitation project, an engineering investigation of the structural conditions of the bridge was conducted. Inspection revealed that water damage posed the greatest challenge to the bridge in three structural areas.



Figure C8.6 Same gates from outside. SCLA.

Lower Chords

Breaches had occurred in the corresponding bays on the opposite ends of each truss. These weaknesses (breaks or failures) were recognized in time by the Kings, who skillfully made a series of vernacular repairs, including metal rods, wood splints, and iron brackets, to keep the bridge standing. Removing wainscoting during the engineering investigation revealed that other wood scabs had been added across the faces of truss posts and braces in the area of failure. Several areas of deterioration occurred in those sections of the lower chords fastened by traditional “lightning bolt” tension splices. This complicated the repairs by requiring removal of the entire length of a chord section or splicing in short new chord sections.

Truss Posts

Roof leaks above the lower chord failures also resulted in damage to joints and several truss posts and shouldered truss braces in King's Bridge. The heads of two posts failed in shear at the joints due to excessive new loading patterns

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resulting from the lower chord failures. Several of the posts were found to be only partially damaged, while one required total replacement.

Arches / Struts

The arches were visibly deformed above the locations of lower chord failures, exhibiting the transfer of loads from the adjacent truss posts through the arch and back into the trusses and lower chords to the foundations. Struts were installed below the lower chords and were never sheathed by the bridge siding. The hearts of these untreated heavy timbers decayed at the bearing seats and remained in place suspended by metal tie rods only.

In 2004, the rehabilitation design team inspected the structure, assisted by personnel from the U.S. Department of Agriculture Forest Service and the Forest Products Laboratory (FPL) in Madison, Wisconsin. An FPL engineer performed a series of non-destructive evaluation tests on various bridge truss members that were identified as deteriorated or potentially deteriorated based upon a visual condition assessment. The non-destructive testing (NDT) techniques included moisture content testing, stress wave analysis, and resistance drilling. Samples were retrieved from the structure in locations where member replacement was imminent, and those were also tested by FPL for species and strength. It was determined that white oak was the original species to be matched where replacement of structural members was required. All adjusted moisture content measurements were less than 16 percent, except for one test location that was slightly higher at 19 percent. These results indicated that the truss members were drier than the threshold moisture content level required for decay. Stress wave velocities ranged from 180-220 ft/m-second and were near the threshold level for the presence of internal deterioration. Several micro-drill resistance measurements reported consistently low wood density and confirmed the stress wave measurements. Both truss members had a relative drilling resistance below 15 percent, with the interface between members visible at approximately 7.5 inches drilling depth.

The arch-truss system of King's Bridge was modeled and analyzed assuming a linear-elastic behavior using STAAD structural analysis software. The geometry of the bridge was developed based upon centerlines of the members measured directly from the bridge in its existing state. Section and material properties

were also used to describe the members. The material properties of the white oak truss members were determined from small-scale laboratory testing conducted by the Forest Products Laboratory. The tests conducted by FPL in October 2004 also included various nondestructive techniques conducted on site on selected bridge members to determine moisture content, decay, and defects (i.e., checks, splits, etc). In addition, mechanical testing conducted by FPL on small-scale samples retrieved from the bridge determined species, specific gravity, moisture content, MOE, and MOR values. An MOE value of 1.4 x 10⁶ lb/in² was used in the analysis.

Due to the complexity of the geometry and variety of connections, a conservative approach was followed in the modeling. A primary issue was the behavior of the joints at the intersections of verticals, diagonals, chord members, and the arches. The ends of the diagonals and the ends of the posts were assumed to be pinned (i.e., free to rotate). The chord members and the arches were assumed continuous, and all other joints were assumed fixed. This was considered to be a conservative approach and an accurate model of the bridge, and is in line with earlier analyses of Burr-arch truss systems. The supports of the truss were modeled as pinned at the left end and roller supported (resisting only vertical movement) at the other end. This was considered to be the most probable state of the original construction and to have generated the greatest forces in the bottom chord. The arches were modeled as pinned at both ends and resting in a corner of the stone abutment. The arch, which actually is a double arch (i.e., each half of the arch is composed of nine nail-laminated 2" x 4" members) straddling the truss members, was approximated by a series of twenty straight members and was modeled as a continuous member.

Dead loads were approximated by measuring timber dimensions on site, including truss members, top and bottom bracing, deck, roofing, siding, etc. These volumes were multiplied by a unit weight of white oak approximated at 43 lb/ft³ and placed at upper and lower chord panel joints in a manner approximating the actual loading conditions. Physical testing of small samples retrieved from King's Bridge indicated that the specific gravities ranged from 0.59 to 0.68, which corresponded well with published values of density in the Forest Products Laboratory's *Wood Handbook*. The live load used was a pedestrian load of 85 lb/ft² as specified by the 1997 AASHTO Guide Specifications for Design of Pedestrian Bridges. The live load was divided between the two trusses and

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placed at the lower chord panel joints in a manner approximating the actual loading conditions. Since the AASHTO bridge specifications and PennDOT DM4 Bridge Design Manual do not adequately address the issue of wind load or snow loads for covered bridges, a conservative approach was followed in selecting snow and wind loads and load combinations. A snow load of 35 lb/ft² was used and placed at the upper chord panel joints. A wind load pressure of 12.5 lb/ft² based on ANSI/ASCE 7, Minimum Design Loads for Buildings and Other Structures, Section 6.4, Method I Simplified Procedure, corresponding to a basic wind velocity of 100 mph was used and divided between the upper and lower chord panel joints in a manner approximating the actual loading conditions.

In this analysis, a combination of dead, live, wind, and snow loads was followed. The load combination used was in accordance with ANSI/ASCE 7, Minimum Design Loads for Buildings and Other Structures (Section 2.4), Dead + (Wind + Live + Snow)*0.75, which is considered conservative for analyzing extant covered bridges (according to the Federal Highway Administration's Covered Bridge Manual) A three dimensional (3-D) space frame model of the bridge was developed using STAAD with the loads applied at the top and bottom panel joints as per the ANSI/ASCE 7 load combinations. The versatility of the 3-D model made possible the addition of the top X-bracing members and their analysis for the lateral loads. The 3-D model also made possible a very realistic representation of the actual structure. The continuity of the top and bottom chords and the arches was preserved, although the bottom chord was severely damaged (i.e., ruptured) at two locations that were not modeled. The results from the STAAD analysis containing member forces, moments, and joint deflections were analyzed with two objectives in mind: 1) to compare the computed stresses with allowable stresses (obtained from the National Design Specification (NDS) for wood construction) to ascertain the degree of safety of the member in question; and 2) to achieve some understanding of how the arch-truss system behaves, such as, stress distribution and deflections. From the analysis it was determined that the most important structural characteristic of the arch-truss system of the King's Covered Bridge when compared to the original multiple-kingpost system was the stiffness associated with deflections. The addition of the Burr-arch greatly reduced the deflection by a factor of approximately three under full load, suggesting the synergy of both the arch and truss producing a structure that is stiffer than the kingpost truss acting alone. For long-span timber bridges, such as King's Bridge, the arch provides a



Figure C8.7 3-D Rendering (STAAD Model) of King's Bridge. SCLA.

necessary stiffening of the truss so that deflections resulting from live and dead loads are controlled to acceptable limits. The addition of the arch also accomplished a reduction of member stresses and even the critical lower chord-arch joint member was satisfactory.

Rehabilitation methods and techniques were conceived and conducted in accordance with the Secretary of the Interior's Standards for the Rehabilitation of Historic Properties. The rehabilitation of King's Bridge minimized interventions and required repairs in-place without dismantling and replacement of deteriorated members in kind where possible.

The engineering strategy adapted conserved the remaining structural integrity of King's Covered Bridge and focused on rehabilitating and stiffening the trusses by extending the arches to bear directly on the stone abutments, and employing traditional nineteenth-century timber joinery methods such as "joggle" splice joints to replace deteriorated members. Epoxy adhesives and Glass Fiber Reinforced Polymer (GFRP) rebar and plates were also used to splice new members to existing ones, as well as to stiffen members. Only where rot damage was so severe that repairs could not be made in compliance with conservation best practices were irretrievable members replaced with other wood material. The first option for replacement timber was from salvaged members of the bridge that had been removed because they were deemed to be not historically significant and were not designated for repair.

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Figure C8.8 Stabilization of the bridge, showing tension cables tied to steel I-beams. HAER PA-638-3, Jet Lowe, 2005.

The rehabilitation project focused on the following areas:

Extend the arches

The arches were extended below the lower chords by adding in-kind laminations to the existing nail-laminated arches. The cross section area of the arch was removed from the corresponding section of each lower chord member to allow the new arch extension to bypass the chord unfastened.

While the bridge was elevated for rehabilitation, the new arch extensions were installed and scribed to meet the new seats carved in the stone abutments before the bridge was lowered into place. The ends of the timbers were treated with wood preservative and elastomeric pads were used as compressive and thermal insulators between the stone and wood at the bearings. The new arch extensions were intended to remedy the damage to the trusses caused by the previous tied arch geometry. The deformed arch sections were separated, reshaped, and re-laminated in place. Repairs were also made by extending the laminations past the lower chords by dapping (notching) a portion of the



Figure C8.9 Arch tied to chord and strut below to abutment. SCLA.

Figure C8.10 Laminated arch extended to reinforced abutment. SCLA.

bottom chord members. The new laminations follow the existing butt joint pattern and are also nail-laminated, stitched, and joined with epoxy. This repair includes the addition of a GFRP flitch plate with epoxy applied to both sides of the GFRP plate to reinforce the notched bottom chord.

Rebuild/reinforce stone abutments

A system of abutment reinforcements was designed to buttress the existing stone abutments. The abutments and wingwalls were completely excavated and formed to receive flowable backfill to create the buttress that would withstand the new forces created by the extended arches. An estimated 20 percent of the substructure stone was removed and re-laid in the rehabilitation process. The old Portland cement grouting was removed, and all joints were re-struck with a softer mix using a greater percentage of lime to avoid spalling at the edges of the softer stone. New white oak sills were installed to replace the previous sills that had deformed under the horizontal loads imparted after the chord breaches.

Replace posts, braces and chords (full and partial)

Based on visual inspection, the nondestructive testing conducted by FPL, and the results of the structural analysis, several repair types were implemented. Glass Fiber Reinforced Polymer (GFRP) reinforcing rods embedded in epoxy were used to repair existing timber members where deterioration was such that an epoxy mortar repair was not appropriate, where a new section of wood was to be added to an existing original member, or where a fractured original

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Figure C8.11 Excavated abutment before reinforcement. SCLA.

member was restored. Another repair type intended to repair an existing fractured or missing timber section required the installation of a new white oak implant “joggle” at the splice location. This repair method represents a traditional timber joinery splice consistent with that period.

Restore Other Members and Sheathing Materials

The members of the lattice joist floor system were replaced in kind. Some of the decking was reused as subflooring, but most of the remainder was replaced by rough-sawn hemlock boards. Both courses were laid transverse with staggered joints. The rafters were replaced in kind, and rough-hewn cedar shingles replaced all lath. Most of the siding was replaced in kind, with some reused as battens. The wainscoting and cap material was stockpiled and then reinstalled.



Figure C8.12 GFRP post repair. SCLA.



Figure C8.13 Joggle splice repair. SCLA.

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Figure C8.14 South elevation – rehabilitated. SCLA.

Analysis of Treatment and Standards That Have Been Applied

1. A property will be used as it was historically or be given a new use that requires minimal changes to its distinctive materials, features, spaces, and spatial relationships.

The bridge is on retrofitted abutments, and the arches have been extended to the abutments. The bridge continues to operate as a self-supporting wood truss without modern support. The bridge now serves as a pedestrian crossing of the creek and is in a municipal park where another covered bridge is located just a mile away.

2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alterations of features, spaces, and spatial relationships that characterize a property will be avoided.

The visual character of the bridge was not compromised and all character-defining features were retained. The geometry of the bridge, such as the nail-laminated arches, was altered to remedy a structural defect. Every member of the



Figure C8.15 Interior rehabilitated. SCLA.

truss was carefully examined and retained if possible. Any new materials match in kind the materials they replaced or were based on historical antecedent.

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.

No changes were made that would create a false sense of historical development. All character-defining features were respected as products of their time within the period of significance. Glass Fiber Reinforced Polymer (GFRP) reinforcing rods were also used as a method of repairing existing timber members (as opposed to total replacement) where deterioration was such that an epoxy mortar repair was not appropriate and where a new section of wood was to be added to an existing original member.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

The changes, such as the extension of the nail-laminated arches, were deemed

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structurally necessary to remedy the damage to the trusses caused by the previous arch installation and were preserved.

5. Distinctive materials, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

The most important members of the truss were preserved. Replacement members were made from in-kind material and traditional craftsmanship including joinery techniques that replicated historic construction methods.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.

Repair work was completed with in-kind materials and traditional craftsmanship techniques including joinery methods. Other non-traditional repair was carried out using GFRP rods to repair and strengthen existing members.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

Chemical treatments were used sparingly, and non-toxic chemicals were chosen when possible.

8. Archaeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

The abutments remained in place, and a system of abutment reinforcements was designed and installed to buttress the existing stone abutments.

Archeological disturbance did not take place.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

The additions/replacement materials have been documented and recorded in the construction drawings of the project and are available from the owner.

10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

There were no additions or adjacent new construction.

Section 106 Compliance Information

The project was determined to have no adverse effect.

Project Particulars

Rehabilitation Project Team

Rehabilitation Designer: Simone Collins Landscape Architecture

Structural Engineer: Gannett Fleming Inc.

Stabilization Engineer: DCF Engineering Inc.

Stabilization Contractor: Arnold M. Graton Associates

Construction Contractor: Allegheny Restoration

Technical Assistance: USDA Forest Service

Forest Products Laboratory

Somerset County Conservation Service

Funding: Federal Highway Administration

Project Partners: Pennsylvania Department of Transportation

Somerset County

Middlecreek Township

Rockwood Area Historical Society

Owner: Middlecreek Township

Date of Project

1997 to 2008

Cost for Treatment Project

\$90,000 [Initial State (PA) Funds]

\$860,000 [FHWA]

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8. King's Covered Bridge

Case Study Team

William J. Collins, RLA, VP, Simone Collins Landscape Architecture, and Samer H. Petro, P.E., Herbert, Rowland, & Grubic, Inc. prepared the case study with assistance from Christopher H. Marston, Project Leader, Historic American Engineering Record, 2013.

Sources

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CASE STUDIES

9. Moscow Covered Bridge Rush County, Indiana



Figure C9.1 The rebuilt Moscow Covered Bridge. Arthur Gatewood, 2010.

CASE STUDIES

9. Moscow Covered Bridge

Rush County, Indiana

By James Barker, Matthew Reckard, Mary E. Kennedy

Administrative Data

Bridge Name

Moscow Covered Bridge

Bridge Structure Type

Two-span Burr-arch truss spanning 316' with 9.5' weather extensions added on each end

Date of Original Construction

1886

Original Builder

Emmett L. Kennedy

Bridge Owner/ Client

Rush County, Indiana (1886 - Present)

World Guide Number

The original Moscow Bridge is listed as 17-70-07x to reflect its loss in the 2008 tornado; the rebuilt bridge is renumbered as 17-70-07#2.

Structure Number (NBIS or local designation)

Rush County Bridge 191; NBIS No. 7000176

HABS/HAER/HALS Documentation Number:

N/A¹

National Register Number and Date

NRIS 83000096, listed 1983

Description of Location

The bridge carries County Road 900 South over the Flatrock River at the northeast edge of the town of Moscow in east central Indiana. Moscow is located in Rush County, about ten miles southwest of Rushville, the county seat.

Description of Setting

The bridge is situated in a predominantly rural area at the edge of Moscow (pop. 80). The bridge spans a long-abandoned flume of a former mill, as well as the Flatrock River.

Historical Background and Context

The 1886 bridge was built on the abutments and piers of a previous bridge. The earlier bridge was also a Burr-arch truss, as evidenced by the pockets for its arches that are discernible in the pier several feet below the bearing seats for the present timber arches. A change in stonework is also visible, and it appears that the structure was raised for this superstructure. It is likely that the earlier bridge was lost due to flood.

The Flatrock River flows under both spans when in flood, although the ground under the span closer to Moscow is several feet higher and is dry at low flow. A sluiceway feeding a nearby mill once flowed under that span. There, not a hundred feet from the bridge, two large burr stones for grinding flour were found in the 1930s, buried in the mud. The stones were in good condition and were given to Spring Mill State Park, where they continue to be used in grinding cornmeal today.

The Kennedy family, prominent Indiana builders of covered bridges, constructed the Moscow Bridge. Three generations of Kennedys exclusively built covered bridges from 1870 to 1918. By the time the Moscow Bridge had been designed and built, the second generation was managing the firm. The family business completed twenty-three covered bridges between 1880 and 1885, but thereafter the pace slowed as competition from iron spans increased. All told, the Kennedys



Figure C9.2 Original ribbon-cutting ceremony in 1886. Rush County Heritage, Inc.

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9. Moscow Covered Bridge



Figure C9.3 Interior view prior to the tornado. Large windows are not original. Galen Frysinger, 2005.

built at least fifty-eight covered bridges, including six two-span bridges and several three-span bridges. The Moscow Bridge is the only surviving Kennedy Bridge having more than one span.

The bridge carried county road vehicular traffic continuously from its opening in 1886 to 2008. Connection failures and decay of timbers led to the addition of semi-permanent shoring in the mid-twentieth century. Further major repairs were made in 1986 and 2000. The bridge continued to be a main access route to Moscow, even as the village diminished in population, and contributes to the town's identity. The covered bridge became increasingly valued as other major timber spans were replaced or lost. Several weddings have been performed on the bridge. The town began holding a spring festival in 1985 to celebrate the bridge and raise money for maintenance. The festival was held annually for twenty-six years and grew to attract more than 5,000 people.

On June 5, 2008, a Class 3 tornado came through Moscow. It damaged or destroyed many buildings and killed one resident. The tornado funnel passed roughly parallel to the bridge and less than a hundred yards to one side. The



Figure C9.4 Moscow Bridge after the tornado. It seems hopeless. Wayne Goodman, Indiana Landmarks, 2008.

tremendous rush of air into the vortex caused the bridge to collapse and fall into the river. Some lighter parts of the bridge were lost when they were sucked into the tornado. The townspeople were devastated by the loss of the bridge because they felt like the town had lost its pride and identity. Indiana Governor Mitch Daniels, after visiting the devastation, reported to the media that he was surprised to learn that residents were most hurt by the loss of their beloved bridge.

In spite of the seemingly irreversible collapse, within a few days the residents of southwest Rush County began to explore the possibility of rebuilding the bridge. Within a month Governor Daniels had declared his intention to help. The project to salvage the timbers from the river began immediately. This case study is the story of not only rebuilding the bridge but also of the efforts of people to rebuild an important cultural legacy.

Physical Description of Bridge

The Moscow Bridge is a two-span Burr-arch bridge with a 148'-6" long span adjacent to the town and a 162' long span over the channel of the Flatrock River. Extensions on each end for weather protection and a 5'-6" space between trusses

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at the pier bring the total portal-to-portal length to 335'. The two spans are not structurally connected, but act independently. The bridge carries one 14'-8" wide traffic lane, with the trusses being placed 16'-11" apart, center to center. The upper chord centerline is 16'-1" above the lower chord's centerline, but the clear height for traffic is only 13'-10" at the middle of the road.

Most two-span covered bridges have equal spans with identical trusses. However, in 1886 when the Moscow Bridge was built reusing the substructures of the earlier bridge, the trusses were positioned for unequal span lengths. Thus, the two spans have different numbers of panels, different panel lengths, and different radii for the arch ribs. Both spans have the same truss height.

The bridge was a typical Burr-arch truss exhibiting the characteristic details of almost all Kennedy bridges. These details included the following.

- All main diagonals were double notched. The Kennedys believed this was stronger than single notching, because double notches cut less deeply into the vertical posts.
- Floor beams were located at each panel point, with stringers supporting the deck between.
- Floor beams were positioned against the truss vertical timbers on the side opposite to that where the diagonals notched in so as to brace the verticals against the thrust of the diagonals.
- Eastern white pine was used for all truss members except the ends of the arch ribs and stringers, which were oak. Rafters may also have been oak. The Kennedys liked the easy workability of white pine, which had adequate strength but was light per cubic foot.
- Diagonal timbers of the lateral bracing were framed into mortises in floor beams and upper cross timbers, rather than pressing directly against the chords. Kennedy bridges contained no iron castings and little other metal.
- The trusses were kept plumb by bolting the floor beams and upper cross timbers tightly to the chord timbers to form a rigid frame. No knee bracing was employed.
- Horizontal lap siding was used. The Kennedys may have believed it strengthened the bridge.
- Portals had an elliptical entrance and elaborate decoration, thus adding a modicum of grace and more than a little advertising to the utilitarian structure.

The bridge was in generally good condition immediately prior to the tornado of June 3, 2008.

Chronology of Development and Use

Before the development of roads that allowed rapid travel to county seats and beyond, smaller commercial centers were established every few miles. The town of Moscow, Indiana, was one such intra-county commercial site in southern Rush County. By 1885 a bridge had been built across the adjacent Flatrock River, but it was lost to unknown causes. The present Moscow Bridge was built in 1886 to maintain the town's commercial viability and has carried county road traffic ever since.

Alterations to the bridge before 1980 are poorly recorded, but several may be inferred. The original Kennedy design included latticed windows near the pier, but these must have provided inadequate light. By 1960, large windows had been added in both spans to further light the interior. In the early twentieth century, overload had crushed a vertical post near the northeast end. A steel tower support was built underneath the broken post.

By 1986, the bridge had developed serious problems. The arch timbers had rotted severely at the northeast abutment. The river span sagged more than a foot at midspan, and the pier stones had deteriorated near the ground. In addition, almost every tension connection in the river span's lower chords had failed and pulled apart. A locally-funded repair project in 1986 reinforced the broken chord connections with steel tension rods, repaired the pier's stonework, and replaced the decayed ends of arch timbers.²

In 2001, a federally funded repair project further modified and strengthened the structure. Several timbers were replaced in kind. The crushed connection was replaced, and the support tower was removed. Many steel plates were added to strengthen the lower chords, and a third large timber was added along each top chord to reinforce the original two. However, epoxy adhesives were used profusely to attach the new plates and timbers. The deck, stringers, floor beams, and roof were also replaced. Glulam beams were used for the replacement stringers and floor beams. These repairs raised the load limit to 10 tons, which was maintained until the 2008 tornado destroyed the bridge.

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Figure C9.5 View of Moscow Bridge after the 2008 tornado. Part of the east portal remains, but the river washed away most of the span. Ed Derringer, 2008.

Description of Most Recent Rehabilitation Project

The tornado left widespread destruction in its path. Town residents were unanimous in their desire to see the bridge salvaged and rebuilt regardless of cost, because the bridge was central to their concept of the town and their sense of place. The higher load limit of a new bridge was less important to the community than salvaging the original one. The Rush County Commissioners listened and were sympathetic, but they had to determine if it was technically feasible and, if so, at what cost. The commissioners asked for and received the support of Governor Mitch Daniels. They also spoke to master timber framer Dan Collom of Square and Level Construction and to Jim Barker of J. A. Barker Engineering and learned that it would be technically feasible to rebuild the bridge using surviving timbers and augment them with new wood to replace broken or missing members. Furthermore, the cost of rebuilding the bridge (albeit on the surviving, relatively undamaged substructure) was estimated to be less than the cost of a new bridge.



Figure C9.6 Pulling the bridge out of the water. Previous repairs included liberal use of epoxy adhesives, making it impossible to reuse these lower chord timbers. James Barker, J.A. Barker Engineering, Inc., 2008.

Although Governor Daniels could not commit state monies to the project, he agreed to supply free timber from state forests. He also offered to help raise funds by donations, beginning a spirited fundraising campaign with a goal of raising \$600,000.

Closer inspection of the collapsed bridge revealed that many timbers were repairable. The tornado did not explode the bridge; instead, it passed to one side, and the rush of air into the vortex blew the bridge over in a somewhat orderly manner. Many compression members of the truss simply fell out as the spans blew over. Each arch timber is about 16' long, so many of them survived with damage only at the ends. With skillful repair work, about 30 percent of the primary structural timbers could be reused, while other timbers could be used as patterns. Thus, in spite of the overwhelming appearance of total destruction, there was a significant amount of reusable material. The decision was made to rebuild the historic bridge using salvageable materials with new timbers dimensioned and detailed to match the originals. The goal was preserve and put back into service 30 percent of the Kennedy material and 98 percent of the Kennedy technology.

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Fortunately, even before the decision was made to rebuild the bridge, timbers had been pulled out of the river. However, during the salvage operation, timbers were intermingled, which complicated the task of reconstruction.

Timbers were inspected and sorted on high ground near the bridge site. Repairable timbers were placed to one side in stacks according to their position in the bridge: verticals in one stack, diagonals in another, arch ribs, upper chords, lower chords, lateral bracing and floor beams in other stacks, and so on. Potentially reusable timbers were moved to a nearby farm by the county where they were stacked outside on wood blocks and covered by tarps.

Professional engineer Matt Reckard of J. A. Barker Engineering performed the engineering appraisal of the bridge members. With the help of two county highway workers and a fork lift, Reckard inspected, measured, and assessed each timber, and made sketches that recorded and graphically illustrated his recommendations. Metal tags were nailed to each timber to correlate the notes with the timbers. The work took over a month since about 210 major truss timbers had been salvaged. Gradually, it became possible to distinguish which span a particular timber came from. Since the spans had slightly different panel



Figure C9.7 Sorting arch timbers and trying to determine the original positions. Matthew Reckard, J.A. Barker Engineering, Inc., 2008.

lengths, the chords, diagonals, and lateral bracing timbers had different details or lengths. The arch timbers had different radii. Only the floor beams and upper cross timbers seemed to be identical for the two spans, so it was decided that it did not matter where those were put back.

While the timber “trriage” was going on, the structural analysis was being performed. A finite element program was used to model the primary truss systems. This is an especially useful tool for Burr-arch trusses, where two dissimilar structural systems, the arch ribs and the multiple-kingpost truss, are harnessed to work together to carry the loads. To speed the work, a two-dimensional model was used, with wind forces being hand calculated and manually added to the gravity forces in the chords. A project objective was to achieve a 10-ton posted load limit – the same load limit that the bridge had before the tornado.

One complication was that some of the new wood was of lower quality than the original timbers, which were old-growth eastern white pine from Michigan. Furthermore, insufficient eastern white pine was available in the state forests, so yellow poplar was used as well. (Since the wood was donated, it was difficult to decline it even if the quality was lower than the original.) Luckily, the structural analysis showed that the compression members were adequate with an extra margin of safety, so, the white pine could be used there. Poplar was used for the new tension members, because its greater shear strength than white pine would be useful in the tension connections.

Somewhat late in the rebuilding process, when county officials resisted lowering the load limit, two other changes were made to further compensate for designing/engineering concerns about the quality of the timber. The two-layer oak deck had been salvaged for reuse. Analyses showed that the bottom layer could be switched to white pine and still provide adequate strength. Seasoned oak weighs about 45 pounds per cubic foot, compared to 27 pounds for white pine. Since there was enough slash and left-over smaller pieces of white pine to supply the bottom layer, the change was made, thus reducing the dead weight of each span by about 10,000 pounds.³

A second modification was to reinforce the tension connections in the lower chord. These were originally made with wood fish plates, but almost all had broken over the years and had been reinforced with steel rods in 1989. The steel

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rods and anchor plates were not saved after the tornado and were deemed too expensive to replicate. Instead, a different, non-original treatment was used to meet the desired load limit within the budget. Two 2" x 1/2" steel bars were inlaid into the side of each spliced lower chord timber a few feet from its end, and the bars were connected by a horizontal strap going across the tension connection. It is a simple detail used by competing covered bridge builder J.J. Daniels, but not by Kennedy. Thus, although not a treatment actually used on this bridge originally, it is an historic treatment that brought the bridge into compliance with increased vehicle weights and speeds.

Plan preparation started as soon as the structural analysis was finished. It was soon clear that drawings would have to be prepared showing the bridge curved to the desired camber, and not idealistically, but incorrectly, pretending (as most plan sets do) that the chords are straight lines. Only by drawing the chords as curves could timber dimensions and notching be determined well enough to fit properly. Reusing the salvaged timbers, and fitting in new timbers to re-make a coherent structure proved more difficult than designing an all-new Burr-arch truss to the same overall dimensions.

The timber arches varied slightly in depth along their length, being least deep at midspan. By paying attention to that variation, along with bolt hole locations, notching angles, and other details, a best-fit location was determined for each surviving arch timber. It was time consuming but rewarding detective work. Plans had to show the dimensions and fabricating details of each new timber because the builder was going to cut the new timbers at his yard, long before he took them to the bridge site to see if they fit with the surviving timbers. There was little extra wood to cover for mistakes, so it was crucial that they were cut correctly on the first try. During this time the designer also decided on the nature of repairs needed to the damaged, but reusable, timbers, and prepared specifications and drawings for those repairs.

Where there was a choice, original timbers were placed where they would be most visible. For instance, all surviving lateral bracing timbers were placed overhead where pedestrians on the bridge could see them. The lateral bracing under the deck is entirely new.



Figure C9.8 Start of framing for one span; blocking provides camber. Double notching visible at tops of posts. Arthur Gatewood, 2010.

The rebuilding was truly a team effort. Rush County repaired the abutments, which had been damaged during the collapse. The county and Moscow residents were active and productive in fundraising. Numerous people and organizations contributed, and a donation of \$355,000 by the Eli Lilly Foundation was critical to achieving \$520,000 total cash contributions. This was enough, augmented by donated materials and services and help from the county, to complete the project.

The Indiana Department of Natural Resources harvested the trees, hauled them out of the forest, cut logs to approximate length based on the designer's preliminary direction, and delivered them to the builder. The Indiana-Kentucky Regional Council of Carpenters donated many hours of skilled labor installing the siding and roof.

The builder, Square and Level Construction of Bridgeton, Indiana, proved to be highly skilled. Within a month of the tornado Square and Level had quoted their price for the project, even before plans had been prepared, had it accepted, and had started to plan their operations. For a while, they waited for plans to be finished and for the logging to start. But as soon as the logs arrived at their shop,

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Figure C9.9 Start of framing for one span; blocking provides camber. Double notching visible at tops of posts. Arthur Gatewood, 2010.

they started to cut the timbers to size since the cut pieces would season more quickly than entire logs. The stockpile of timbers grew through the summer and into the fall of 2009, and in February 2010 activity moved to the bridge site. The first step was to level and stone the construction area, which had been donated for that purpose. Cribbing was placed at intervals and adjusted in elevation to match the camber called for by the drawings. Then the lower chord timbers were laid on the cribbing, and truss verticals were placed and temporarily braced in the upright position. Upper chord timbers were next, followed by the diagonal timbers. Chord pieces were cross bolted, clamping the verticals in place. Then, cross timbers were laid between the upper chords, and the upper lateral bracing, 5" x 5" diagonal timbers, were inserted and wedged tight. Floor beams and their lateral bracing were added to the lower chords. Most of the diagonal timbers are original, as are a few of the vertical posts, but all the chords are entirely new wood.

After the basic truss configuration had been rebuilt, the arch ribs were added. This took some field adjusting, but Square and Level Construction eventually produced an excellent fit. The fact that the trusses could support their own



Figure C9.10 Slightly darker color and "battle scarred" surface distinguish 1886 timbers from those cut in 2009. Tony Dillon, 2010.

weight without help from the arches was very useful during lifting.

Each span was weighed using a portable scale and then placed on dollies. The spans were then rolled to the repaired substructure and lifted into place using large cranes. The weighing ensured that the crane operators were prepared for the weight they would lift.⁴ After each span was set, the end pieces of the arch ribs were measured and cut for exact fit to the irregular stone bearing surfaces. Most of the stringers had survived the collapse, so they were reused, and the deck was secured to the stringers. Rafters were cut and installed. Then came lathes and a new metal roof. Girts to hold the siding were installed, and then the siding. Windows were built, and the original lattice windows were reproduced. The portals were sided and trimmed as Kennedy originally had done. His vine decorations, roof brackets, and elliptical opening had long ago been traced from another Kennedy-built bridge. The bridge was painted in the original Kennedy white. Bridge railing was added, as well as some off-structure guardrail. Then it was ready for a ribbon cutting.

Several hundred people came for the opening, where flags, food vendors, a color guard, and a high school band contributed to the festive atmosphere.

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Figure C9.11 Lifting the first (shorter) span into place. Arthur Gatewood, 2010.



Figure C9.13 Steel strap and inlays reinforce a lower chord splice in the rebuilt bridge. James Barker, VS Engineering, Inc., 2014.



Figure C9.12 Bridge interior in 2011. Compare with Figures 3 and 4; all three were taken from the same place and looking in the same direction. Arthur Gatewood, 2011.

Analysis of Treatment and Standards That Have Been Applied

The bridge continues in its historic use, carrying one lane of traffic over the Flatrock River. Despite the catastrophic damage, the rebuilt bridge retains its character-defining features and spatial relationships, and a significant amount of its original material. The timber trusses continue to carry the load. This project satisfies many of the individual Standards for Rehabilitation.

Section 106 Compliance Information

This project was funded by private donations, so Section 106 procedures were not applicable.

Lessons Learned

Very severe damage or deterioration can be repaired if the local community wants it bad enough. To some extent, it is a question of will. Without determined, energetic advocacy by the local community, the range of damage that is

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“feasible” to repair is circumscribed. With active, united, determined community support, a historic covered bridge can be brought back from severe damage or deterioration.

Funding the project without federal aid saved much time and reduced the work load for everyone except the fundraisers. Decisions were made at the local level, sometimes with a single meeting. There was no second guessing or worrying about the many steps in Section 106 compliance and environmental studies. A Rush County Commissioner handled the land acquisition. Support from the highest levels of state government was crucial to the effort. Although no state funding was proffered, timber was provided, which signified the importance of the project. A number of fundraisers worked minor miracles, and donors were recognized on a plaque mounted on the bridge’s interior.

Teamwork is essential. A wide variety of people, with different skills, made crucial contributions to the project.

Having an engineer and timber framer who care about preservation is important. The quality of the design and the professional time spent on it cannot be precisely defined in a contract. The quality of the built structure cannot be precisely defined by the plans and specifications. The highest quality covered bridge and bridge plans will probably be produced by people who care the most about the deeper, long-term benefits of historic preservation. Because federal aid was not used for the project, the county commissioners were free to choose the engineer and contractor who they thought would do the best job. The results speak to the validity of this idea.

During design, it was important to draw the bridge with the desired camber. If this is not done, the lengths of certain timbers will be wrong, and the notch locations for the connections will be out of position. Such refinement takes more time than drawing the chords straight, but the engineer is supposed to do things right, not quick. For minor repairs this recommendation does not apply.

Modern structural analysis tools such as “finite element” computer programs are very useful. They increase the reliability of answers while reducing the workload and are especially advantageous when analyzing a statically indeterminate structure such as a Burr-arch truss.

The Burr-arch truss has many attributes, but also has an oddity that can cause trouble. The Burr-arch combines the truss form and arch form in a symbiotic relationship. The truss stiffens the arch and prevents local deformation as a heavy load crosses the bridge. In return, the arch adds strength to the truss and usually carries more than half of the total load. However, whereas other trusses (Long, Howe, Town, etc.) have a single bearing point at each corner, the Burr-arch has two: one where the truss rests on the bearing seat ledge, and a second where the arch ribs press against the abutment several feet lower. If the timbers at the truss bearing decay then the arch ribs support everything, which is a bit like a bridge on stilts and not necessarily stable. Therefore, at the Moscow Bridge the engineer added blocks at the truss bearing seats to prevent the lower chords from moving to either side. The blocks are anchored into the abutment masonry.

Historic bridge preservation matters to people, a lot. The stories of how people reacted to the apparent loss of the Moscow Bridge surprised both the engineer and the timber framer. The bridge touched people more than most things in their environment, or at least in their public works environment. When the first span was placed on the piers, several bystanders teared up. The engineer said he had designed more than a hundred bridges, requiring many hundreds of beams, and had never seen or heard of that happening when a concrete beam was set into place.

When a long, difficult journey is completed, celebrate.

Project Particulars

Rehabilitation Project Team

Owner: Rush County, Indiana, Board of County Commissioners

Builder: Square and Level Construction, General Contractor
Dan Collom, Chief Timber Framer

Engineer: James Barker, P.E., Project Engineer, J. A. Barker Engineering, Inc.

Timber Supplier: Indiana Department of Natural Resources, Division of Forestry

Fundraising: Indiana Landmarks, CSO Architects, and the Moscow Bridge Rehabilitation Committee

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Date of Project

Sept. 2008 (start design) – Sept. 2010 (finish rehabilitation)

Cost for Treatment Project

Approximately \$600,000 actual cash outlay; about \$1,100,000 including estimated value of donated materials and services.

Case Study Team

This report was prepared by James Barker, P.E., J. A. Barker Engineering, Inc., Bloomington, Indiana, 2013. Matthew Reckard, P.E., Project Engineer for J.A. Barker Engineering, Inc.; and Mary E. Kennedy, Indiana Department of Transportation, provided comments.

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Footnotes

¹ Ball State University architecture students produced measured drawings in the 1970s as part of a survey of Indiana covered bridges. While the Moscow Bridge drawings were not transmitted to the HABS/HAER/HALS Collection, they have been catalogued at the Ball State University Architecture Library: Collection number HD 71.022. 3 sheets by Mark Mattox, ca. 1971: <https://ballstate.app.box.com/s/wrc-bohigcg4hywft1fjdp3yp4ikayygc>, accessed March 23, 2016.

² During the 1986 repair, the design engineer phoned the contractor to ask if he had any trouble removing the arch ends. When the contractor replied it had been easy because he “blew them out,” the engineer became agitated and started yelling over the phone. The contractor calmed the designer down by explaining that he blew out the wood using compressed air. Such is the deterioration that is occasionally found in “structural timbers.”

³ There was enough left-over material that the needed boards could be cut from the left-overs.

⁴ The span placements turned out to be popular events, with lawn chairs and refreshments aplenty. One woman even came back from Florida to see a span go up. She explained that her husband had proposed to her on the bridge, and her son had proposed to his wife there, and she was not going to miss that moment for anything.

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10. Pulp Mill Covered Bridge Addison County, Vermont



Figure C10.1 General view of west portal showing north side, view to southeast. Martin Stupich, 2015.

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10. Pulp Mill Covered Bridge

Addison County, Vermont

By Josif Bicja and Sean T. James

Administrative Data

Bridge Name

Pulp Mill Covered Bridge

Bridge Structure Type

Double-barrel multiple-kingpost with Burr-arches; 180' clear span from abutment to abutment

Date of Original Construction

1853

Original Builder

Unknown

Bridge Owner/ Client

Towns of Middlebury and Weybridge, Vermont; each town owns half the structure

FWHA Project Identification Number

BHO 1445(33)

World Guide Number

45-01-04

Structure Number

VT Covered Bridge No. 1

HABS/HAER/HALS Number

HAER VT-31

National Register Number and Date

NRIS 74000200; listed September 10, 1974

Description of Location

The bridge spans Otter Creek between the towns of Middlebury and Weybridge in Addison County, Vermont. The bridge is located on Town Highway Nos. 3 and 5 beginning approximately 0.34 miles east of the intersection with VT Route 23.

Description of Setting

The bridge is located in a rural area in the northeast quadrant of the town of Middlebury, Vermont, approximately 0.90 miles northwest of the downtown area and in the southwest quadrant of the town of Weybridge, Vermont.

Historical Background and Context

The water power provided by Otter Creek encouraged settlement in this area, with development first occurring on the Weybridge side. Around 1793-95, Solomon Bell and his sons built a sawmill. Later, a carding mill, fulling mill, and clothier's works were added. By 1800, Dennis Bell, who is variously mentioned as Solomon's brother and his son, was operating the sawmill. At one time, Bell owned land on both sides of the falls except the area where a trip hammer and a paper mill were built. Guy Woodworth, a manufacturer of scythes, established the trip hammer shop in 1804 and later operated a blacksmith shop.

A series of paper mills gave the area and the covered bridge across the Otter Creek their names. The first paper mill was built in 1817, and one was still operating as late as 1860. A linseed oil mill was built in 1817 and also operated as late as 1860. The same building also housed a grist mill for grinding feed and a candlewick and cotton batting factory. Development on the Middlebury side began in 1826 when the Wainwright foundry burned, and the Wainwrights rebuilt on the Middlebury side of Paper Mills falls, north of the bridge.¹ The foundry operated until about 1866. An 1870 business directory noted that there were several unoccupied mill privileges on Otter Creek. In 1886 none of the enterprises were in operation, but the old trip hammer building was reportedly still standing near the covered bridge.² In 1917, the Hortonia Power Company purchased the land water rights and established hydroelectric facilities.

The Pulp Mill Covered Bridge (also known as the Paper Mill Covered Bridge) is frequently cited as dating from 1805 and 1820.³ According to Vermont Agency of Transportation (VAOT) records, the Pulp Mill Covered Bridge was built much later, in 1853.⁴ The bridge is located over Otter Creek between the towns of Middlebury and Weybridge and is one of five surviving double-barrel covered bridges in the country and the oldest double-barrel covered bridge in the State of Vermont that carries vehicular traffic. Due to its historic and national significance, the Pulp Mill Covered Bridge is listed in the National Register of Historic Places.

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The bridge is an important part of the local roadway network, which currently carries an Annual Average Daily Traffic (AADT) volume of approximately 1,900 vehicles. It was originally built as a 180' single clear span timber superstructure utilizing double-barrel, multiple-kingpost Burr-arch trusses.⁵ Shortly after it was built, extensive sagging and structural problems were evidenced. In 1859-60, local bridge builder David E. Boyce added secondary nail-laminated wood arches to strengthen the trusses. The next attempt to prevent the structural failure of the bridge involved constructing two stone masonry piers with timber cribbing on top to provide support under the bottom chords of the trusses in order to shorten the overall span length. The piers were both skewed in reverse directions, which created unequal spans at each truss. The exact date of the construction of the piers is not known but presumably they were built in the late nineteenth century.

During 1979-80, the bridge underwent a major rehabilitation. The project included encasing the stone masonry piers in concrete and replacing the timber cribbing on top of the piers with new pressure-treated timber cribbing. Portions of the nail-laminated wood arches and truss bottom chords were replaced. One 6" x 12" pressure-treated timber ply was added on the inside fascia of the north and south truss bottom chords, and two 6" x 12" pressure-treated timber plies were installed on the interior truss bottom chord. New 7/8"-diameter steel hanger rods were added to connect the nail-laminated wood arches to the inner ply of bottom chord at each panel point. Finally, new 6" x 6" pressure-treated lower lateral braces were installed.

In 1991, Jan Lewandoski rehabilitated and strengthened the north truss and north arch in the western span. Lewandoski rehabilitated the interior truss and interior arches of the eastern span in 2002. A glue-laminated (glulam) pedestrian bridge was constructed in the mid-1990s on the south (upstream) side of the Pulp Mill Covered Bridge. Two cantilevered glulam floor beams, independent of the covered bridge and fitted between the timber cribbing and bolted down over the concrete portion of the piers, support the pedestrian bridge. Hoyle, Tanner & Associates, Inc. (Hoyle, Tanner) was assigned, through a retainer contract with the VAOT, the task of preparing an engineering study for the rehabilitation of the Pulp Mill Covered Bridge. The project's Priority of Uses as defined by the Vermont Historic Covered Bridge Preservation Plan is "Special Use on Roads." This use allows the bridge to remain in service but limits use

to very light traffic, primarily cars. Completed in March 2008, the engineering study reported that the bridge was in poor condition with significant structural problems. Per the recommendations provided in the report the bridge was posted with signs on each approach for only one vehicle to cross the bridge at a time in each barrel.

The Hoyle, Tanner design team completed the final design phase of the project in November 2011. VAOT awarded the project through a qualified bid process in December 2011 to Alpine Construction, LLC of Schuylerville, New York. Rehabilitation work commenced at Pulp Mill Covered Bridge in January 2012 to replace, repair, and/or strengthen deteriorated and inadequate structural capacity truss members in order to support an H4 (4-ton) live load. The project was completed in November 2012, with an official ribbon cutting held in November 9, 2012.

Physical Description of Bridge

Pulp Mill Covered Bridge is a three span continuous structure with an overall length of 199' and a clear span of approximately 180'. The spans vary at each truss and are as follows: 51'-10" (west span), 62'-4" (center span) and 66'-1" (east span) for the north truss; 53'-5" (west span), 60'-5" (center span) and 66'-6" (east span) for the center truss; and 55'-4" (west span), 57'-8" (center span), and 67'-6" (east span) for the south truss. The two piers are stone encased in concrete with timber cribbing on top of them. Both abutments are also stone encased in concrete. The bridge is approximately 26'-0" wide with a minimum horizontal clearance width of 9'-5" from face of arch to face of arch at each barrel and a minimum curb to curb width of 8'-10" in the westbound barrel and 8'-5" in the eastbound barrel.

Trusses and Arches

Pulp Mill Covered Bridge has several key structural components. The south multiple-kingpost truss has one laminated arch that consists of nine 2 1/4" x 6" planks. The north multiple-kingpost truss has one arch that consists of ten 2" x 6" planks. The interior center multiple-kingpost truss has two arches that each are comprised of ten 2" x 6" planks. Prior to the rehabilitation, each arch was bolted to the inside of each truss vertical member with two 3/4"-diameter steel through bolts. In addition, the arches had 7/8"-diameter steel hanger rods connected to the inner ply of bottom chord at each panel point. Prior to the

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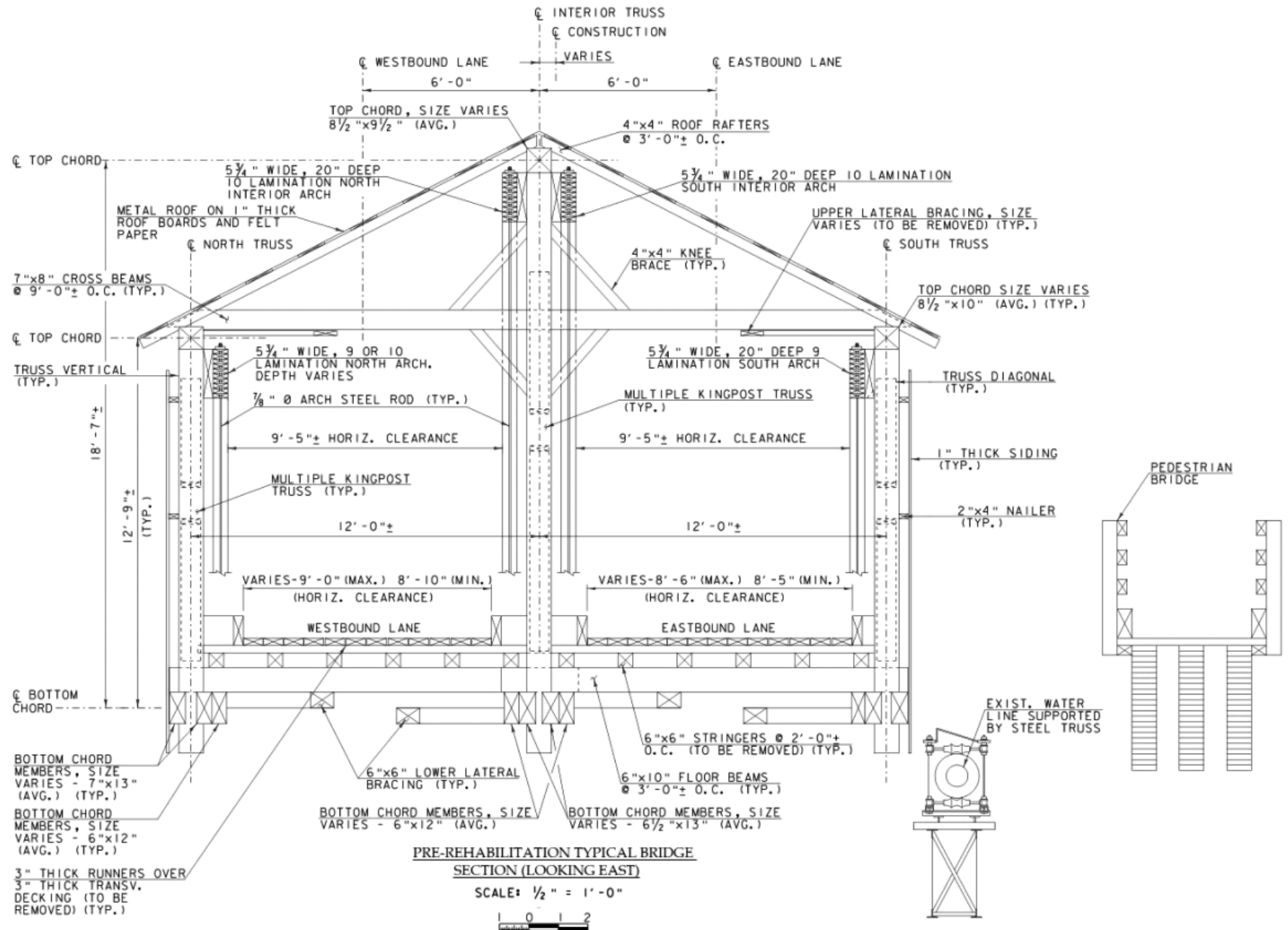


Figure C10.2 Pre-rehabilitation typical bridge section, looking east. Drawing by Hoyle, Tanner.

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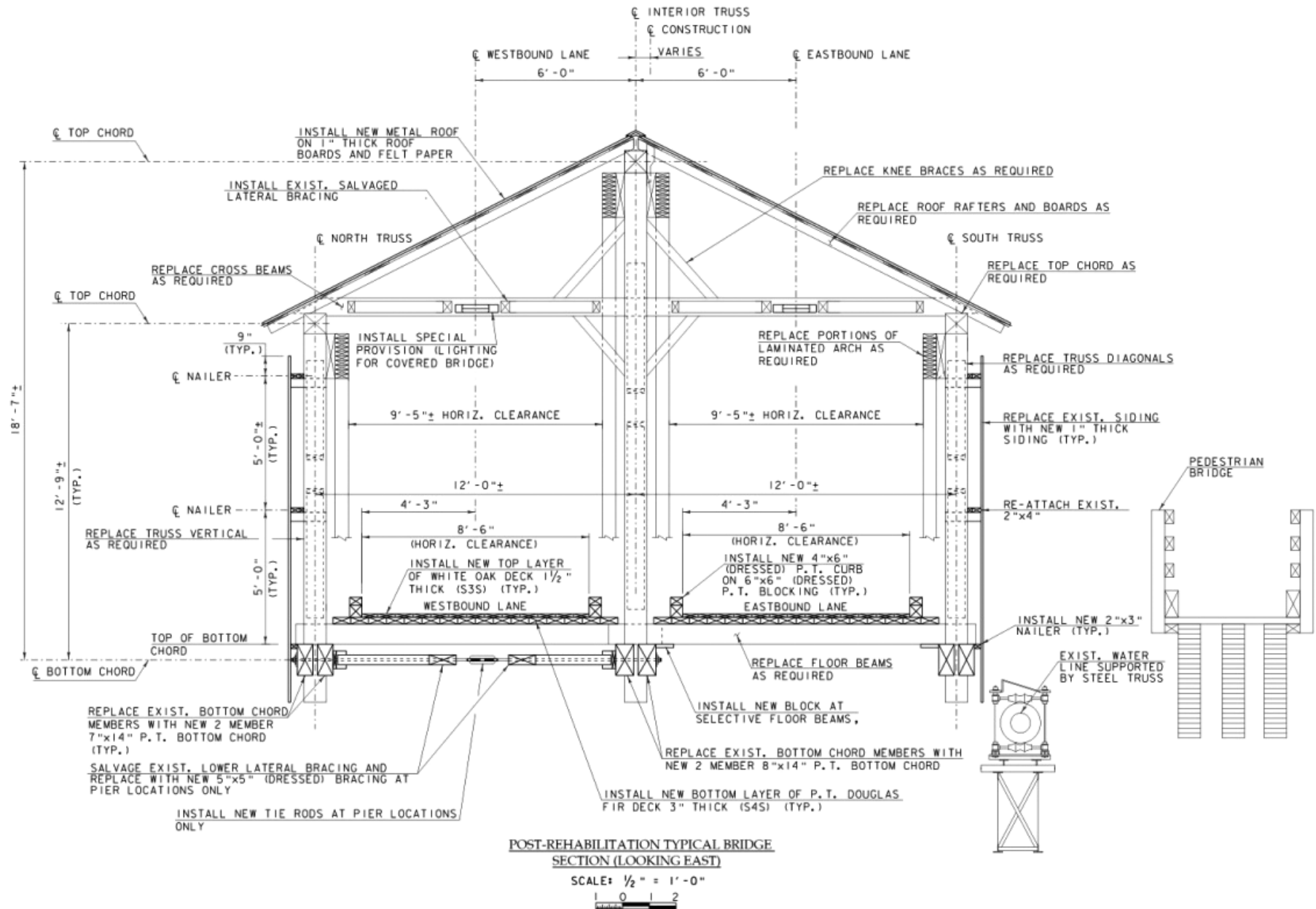


Figure C10.3 Post-rehabilitation typical bridge section, looking east. Drawing by Hoyle, Tanner.

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Figure C10.4 Buckling of west end of the south arch. Sean T. James, November 2006.

rehabilitation, the east end of the north arch and the east and west ends of the south arch had deformed considerably and exhibited significant snap through buckling. At a few locations above the deck, the arches had been damaged due to vehicle collision impact. The interior arches were in good condition with very few small knots and splits.

All four laminated arches span 180' with the ends supported at the front faces of both abutments. The north and south arches rise about 18' while two interior arches rise about 24' nearly to the top of the upper interior truss chord. On each multiple-kingpost truss there are twenty-two panels spaced at approximately 9'-0" on center. The upper chord of each truss consists of a single 8 1/2" x 10" timber. The upper chord was decayed at several areas due to water penetrating through the roof system. Prior to the rehabilitation, the bottom chords of the north and south trusses consisted of two 7" x 13" timbers and one 6" x 12" pressure-treated timber while the interior truss consisted of two 6 1/2" x 13" timbers and two 6" x 12" pressure-treated timbers.



Figure C10.5 Severely corroded splice plate of interior truss at west span. Josif Bicja, August 2007.

The bottom chord members were butt spliced with galvanized-steel plates and bolts during the 1979-80 repair work. Years of exposure to roadway de-icing agents had caused deterioration of the bottom chord galvanized-steel plates, bolts, and ends of the arch and truss rods. At many locations along the bottom chords, several inches of roadway sand and debris had collected and contributed to the deterioration of the adjacent galvanized-steel plates, bolts, and steel rods. The steel members were severely deteriorated and beyond repair.

The truss vertical members are approximately 8 1/2" x 10" through the middle section and shouldered on the top and bottom to receive the truss vertical members. During previous rehabilitations, timber shoulders were added and bolted at some of the verticals. The verticals were tenoned into the top chord and several of these connections had failed prior to the rehabilitation. In the lower ends of the verticals the timber is notched to a thickness that varies from 2 1/2" to 4 1/2".

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Figure C10.6 Truss vertical to top chord with failed connection at interior truss. Sean T. James, July 2007.

Prior to the rehabilitation, the bottom chord laminae were not notched to receive and “lock” in place the lower ends of the verticals. In a few locations, there were timber blocks behind the verticals that were either bolted or notched in between the bottom chord members, but in the majority of the lower ends of the verticals, there were no members to prevent movement along the span of the bridge. This poor craftsmanship of the connections significantly reduced the notched timber thickness needed to prevent shearing off the lower ends of the verticals.

The truss diagonal members consist of 4” x 10” timbers supported at the shoulders of the verticals. When the bridge was subdivided into three spans, the direction of half the diagonals was reversed, and additional diagonals were added to X-brace the ones that would be primarily in compression.

Before the rehabilitation, the sag of the bridge was a maximum of approximately 6” on the eastern span. The trusses were bearing on bedding timber and the timber cribbing that rested on the two piers. Several butt splices of the old bottom chords over the piers had dislodged vertically due to insufficient through bolting and high applied forces and moments.



Figure C10.7 Typical split tail end of verticals at Node N12 (north truss). Josif Bicja, August 2007.



Figure C10.8 Notched end of vertical at connection with bottom chord at Node N4 (north truss).

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Figure C10.9 Downstream elevation, looking east. Note sag in east and center span. Sean T. James, November 2006.

Roof Framing

The roof framing consists of metal roofing attached to $\frac{7}{8}$ " to 1"-thick roof boards supported by 4" x 4" roof rafters spaced at approximately 3'-0" on center. The roof rafters are notched into the 8 ½" x 10" top chord members. Prior to the rehabilitation the roof framing was in good condition, with very minor knots, checks, and splits observed during the in-depth inspections.

Upper Lateral Bracing

The upper lateral bracing consists of 4" x 4" knee braces and 7" x 8" cross beams bearing on the top faces of the top chords of the north and south trusses and notched at the truss vertical members of the interior truss. There are transverse steel tie rods and wooden sway braces between the cross beams and the vertical truss members. The 4" x 4" knee braces connect the tops and bottoms of the cross beams with a mortise and tenon connection to the truss vertical members of the interior truss. Due to the sag of the existing trusses, a gap of up to 2 ½" had opened up in approximately nine cross beams bearing



Figure C10.10 Twisted cross beam and bracing to top chord connection near Node N14.



Figure C10.11 2 ½" gap between cross beam and top chord of exterior truss at Node N19. Josif Bicja, July 2007.

on top of the top chord members. At these locations the cross beam had been "stapled" with $\frac{1}{4}$ "-square steel rods. In the majority of these cross beams, the downward forces from the trusses had caused twisting due to eccentric connections of the steel rods.

Prior to the rehabilitation, the upper lateral braces consisted of 2" x 7" members, which were butt-spliced and toe nailed to the top chords of the existing trusses. These members were not original to the covered bridge. The toe nail connection between the braces and the top chord truss members consisted of one or two nails with a very low lateral capacity.

Floor Beams, Stringers, Decking and Lower Lateral Bracing

The floor system consists of 6" x 10" transverse floor beams that are spaced at approximately 3'-0" on center. Prior to the rehabilitation the floor beams used to support 6" x 6" longitudinal stringers were spaced at approximately 2'-0" on center.

The deck consisted of two layers of 3" planks running transversely and longitudinally. The longitudinal deck planks had significant wear and were considered to be in poor condition. The transverse layer of the deck, floor beams, and the stringers were in fair to good condition with some rot, large knots, and splits. There was considerable sand and debris buildup on the decking. The existing 6" x 6" lower lateral braces were lag screwed to the truss bottom chords of the existing trusses at the panel points. This meant that only those braces that were loaded in compression were effective, while the others had very low tension capacity. At the intersection of the lateral X braces there was a through

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Figure C10.12 East portal, looking west, ca. 1930. Collection of the Henry Sheldon Museum of Vermont History, Middlebury, Vermont.

vertical steel bolt to reduce the unbraced length of the member and to ensure flush and in-plane fit. There were transverse steel tie rods, but not at every panel point.

Abutments and Piers

Both abutments and piers were originally constructed out of large dry stacked stones, and the exact depth of the abutments is not known. All substructure units had been encased in concrete and new concrete backwalls had been constructed at both abutments in the 1979-80 rehabilitation. The abutments and piers were in good condition with some cracking and minor spalling noted. During the in-depth inspections, two areas of local scour were observed at the east pier. All of the existing wingwalls were in good condition.

Chronology of Development and Use

Only six years after the Pulp Mill Bridge was constructed, secondary nail-laminated wood arches were added to strengthen the trusses in 1859-60. At some point in the late nineteenth century, two stone masonry piers were added to

shorten the overall span length of the bridge. Major repairs were undertaken from 1979-80. Jan Lewandoski repaired the north truss and arch in 1991, followed by the interior truss and arches of the eastern span in 2002. The other major alteration to the bridge during this period was the construction of a glue-laminated pedestrian bridge on the south (upstream) side of the bridge in the mid-1990s. Finally, Hoyle, Tanner and Alpine Construction, LLC undertook a major rehabilitation of the bridge in 2012, and it reopened for use by 4-ton live load traffic on November 9, 2012.

The bridge has been used by very light traffic, primarily cars weighing 8,000 pounds or less. From 2007 until the covered bridge was fully rehabilitated, the bridge was posted with signs on each approach for only one vehicle to cross the bridge at a time in each barrel. The rehabilitated bridge is currently posted with 8,000 pounds load limit on each approach.

Description of Most Recent Rehabilitation Project

The goals of the 2012 rehabilitation were to address structural deficiencies and safety concerns associated with the Pulp Mill Covered Bridge and to ensure its continued use by future generations for light vehicular traffic.

Hoyle, Tanner first prepared an engineering study to determine the feasibility of rehabilitating the Pulp Mill Covered Bridge. The design team initially performed in-depth and hands-on structural inspections of the bridge that included field measuring and collecting field data in order to have an accurate assessment of the condition of the bridge. The bridge was load rated to determine its current load carrying capacity as well as its capacity to support an H4 (4-ton) live load. Although the H8 (8-ton) live load was also evaluated, it was not the preferred alternative since it required replacement or strengthening of over half of the truss members. If the deteriorated and inadequate truss members were replaced and/or strengthened as recommended in the study, the rehabilitated truss would have a controlling live load capacity of approximately H4 (4-ton) at inventory level limited by the truss vertical and bottom chord members' capacity.⁶ Repair, strengthening, and replacement methods were evaluated in order to minimize harm to the historic resource and preserve the historic fabric.

The design process and tasks that were completed to determine the structural adequacy of each bridge component included the following.

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Wood Species Identification

Eleven small wood samples were taken from deteriorated members that the project team expected would be replaced during the course of the bridge rehabilitation or from non-critical sections of members for the purpose of species identification. Doug Gardner, Ph.D., a professor of Wood Science and Technology at the University of Maine at Orono identified the samples. His analysis determined that the old floor beams, stringers, transverse layer of the deck, and truss members were eastern spruce, while the arches and the replacement top chord members of the interior truss were southern pine. Finally, the new floor beams and roof rafters were eastern hemlock. The growth rates ranged from six to thirty rings per inch. The species evaluation was consistent with historical records that indicate native and local wood was used during original construction.

Structural Analysis

A structural analysis was performed of all key members of the bridge superstructure. The Service Load (Allowable Stress) design method was used for all members. Allowable stress values for wood members were based on the 2005 National Design Specification for Wood Construction and Supplement. The wood species used in the superstructure was identified through testing by Doug Gardner. The grade assigned to each member was based on a visual examination of knots, checks, slope of grain of the wood, and the growth-rate characteristics of the wood.

Live Loading

The scope of work included load rating of the covered bridge for an H4 (4-ton) and H8 (8-ton) live load. Several vehicles heavier than an H4 truck, such as ambulances, fuel delivery trucks, and three axle flatbed trucks, were considered in the load rating of the bridge members for the H8 live load. The width of such vehicles varies from 7'-6" to 8'-6", while the minimum width of the covered bridge is 8'-10" in the westbound lane and 8'-5" in the eastbound lane at the curb line. The horizontal clear distance between arches at each barrel is about 9'-5". It was not desirable to have heavier vehicles crossing the bridge—despite the fact they might fit with very small horizontal and/or vertical clearances to the main structural truss members—in order to prevent the possibility of collision impact to arches, knee braces, cross beams, and other bridge members.

Rehabilitating the bridge for an H8 live load would have required extensive replacement of members. Therefore, the team concluded that an H8 live load would not be practical for this covered bridge, and that it would be posted for a live load of H4, which was approximately the truss capacity after the recommended rehabilitation.

The live load model used in analyzing the truss members (chord and web members), arches, stringers, floor beams, and decking was an AASHTO Standard design truck or design lane loading, which was assumed to occupy a width of 10' based on the AASHTO Standard Specifications.⁷ However, each barrel of the Pulp Mill Covered Bridge has a minimum travel way clearance of much less than 10'. Clearly, the available width of the travel way is substandard, but vehicular traffic is allowed to cross the bridge.

For long span and/or multiple span bridges such as the Pulp Mill Covered Bridge, AASHTO Standard Specifications of equivalent uniformly distributed lane load and concentrated point loads often control the load rating of truss members (chord and web members) and arches, while the standard design truck controls the load rating of floor beams, stringers, and decking.

The lane load is an equivalent load developed to simplify the truck train of variable weights and certain axle and truck spacing. The simplification was done for ease of calculations to determine the worst effects on conventional type bridges, while minimizing the variability in the final results. The Pulp Mill Covered Bridge is a very rare and unique three span continuous structure and as such it does not have the characteristics of a conventional bridge. The lane load simplification of the truck train will not necessarily yield the maximum effects at any given truss member. For the analysis of the Pulp Mill Covered Bridge, several truck train load cases were considered for H4 live loading in the computer model.

The live load in the computer model was moved along the span of the bridge in small increments for each load case, and the worst effects at all the members were determined. For the floor system (floor beams, stringers, and decking) the inventory rating was determined by combining the maximum effects of live load with the dead load effects, while the operating rating was determined by combining the maximum effects of live load with the dead load and compared to higher operating stress.⁸

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To determine the live load capacity of all truss and arch members for the inventory rating, the maximum effects of the live load were combined with the dead load effects. For the operating rating, the maximum effects of live load were combined with the snow and dead loads to determine the worst effects.

Trusses and Arches Analysis



Figure C10.13 Three-dimensional computer simulation of the Pulp Mill Covered Bridge. Hoyle, Tanner & Associates, Inc.

The trusses and arches were analyzed to determine their current live load capacity. A 3-D full bridge computer model was utilized for the structural analysis.

As discussed above, two through steel bolts were used to connect the arches to the vertical truss members prior to the rehabilitation. This means that the load sharing between the arches and the trusses is mainly dependent upon the capacity of this connection. For the vertical loads to be distributed to the arches, the bolts must resist a vertical shear force that is proportionally derived due to the relative stiffness of the arches to the trusses. Each arch and each truss was modeled in 3-D in the STAAD PRO Structural Analysis program and the stiffness of each component was found due to a unit load. Once the stiffness of each component was derived, the load that is transferred to the arches was proportioned to the relative stiffness of each component in consideration. The transferred vertical load was less than the calculated allowable capacity of the through bolts. During field inspections, it was observed that the through bolts were not distorted, bent, or failing, reinforcing the findings in the structural analysis. At only one location the through bolts were bent due to what appeared

to be a vehicle side mirror collision to the exterior south arch. After a careful review of the existing conditions and the relative stiffness of arches to trusses investigations, the load sharing between the arches and the trusses was determined. Additional load distribution to the arches was transferred from the steel hanger rods used to connect the arches to the bottom chord. A portion of the live load was also distributed to the steel arch hanger rods and into the arches. The majority of the steel arch hanger rods over the piers were zero force members, meaning they did not carry load, because the bottom chord was in compression and the steel arch hanger rods were tension only members due to the slenderness of the rods and the method of connections. All hanger rods were removed, and the connections of the arches to the truss vertical members were strengthened during the rehabilitation work.

To determine the current live load capacity of all truss and arch members, full dead and live loads were applied and compared to allowable inventory stress levels, while full dead, live, and snow loads were applied and compared to the higher operating stress levels. Several live load cases were considered. The controlling load case, to approximate the worst effects, was different for each member under consideration. In general, the live load stresses accounted for 30 to 40 percent of dead load stresses. The live load stresses of the single truck load case were typically only about 10 percent lower than that of the controlling load case. For the majority of the members, the single truck load case did not have a significant effect on the load rating results.

Trusses and Arches Repairs

The portions of the trusses above the bottom chord were in good condition except for some of the verticals, diagonals, and top chord members where rot and several large splits were found. Epoxy injection into the larger splits of a few members was done to lessen further splitting and insect damage in those areas. The east end of the north exterior arch, and the east and west ends of the south exterior arch had gone out of shape and were rebuilt.

The arch hanger rods used to get hit regularly by the vehicular traffic. The majority of the steel arch hanger rods over the piers were zero force members. All arch hanger rods were removed and the connections of the arches to the truss vertical members were strengthened during the rehabilitation work.

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Figure C10.14 Downstream bridge elevation shored during construction, looking south. Two steel beams were installed on the underside of the bridge and fitted between timber cribbing at the piers. Josif Bicja, July 2012.



Figure C10.15 Temporary shoring system, looking south. Josif Bicja, April 2012.



Figure C10.16 Temporary shoring system inside the bridge, looking east on eastbound barrel. Josif Bicja, July 2012.

The existing bottom chord laminae were not notched to receive and lock in place the lower ends of the verticals as explained above. Many attempts to repair the bottom chord had been made, but it was still showing signs of distress prior to the rehabilitation. The poor craftsmanship of the connections of the truss vertical members to the bottom chord significantly reduced the notched timber thickness, which is much needed to prevent the shearing off of the lower ends of the verticals. Two 7" x 14" pressure-treated timbers on the north and south trusses replaced the entire bottom chord, while the interior truss consisted of two 8" x 14" pressure-treated timbers. New bottom chord laminae consisted of scarfed joints.

In order to minimize the applied moments at the upper shoulders of the interior truss vertical members, 1/2"-diameter horizontal galvanized-steel rods were installed at the intersection of the diagonals to the verticals and in the areas that the top would be in tension. In the areas where the top chord would be in compression, 5" x 5" compression strut timbers were installed with mortise and tenon connections into the truss vertical members. Such members are not readily visible as they are above the upper bracing members. These changes minimized interior truss member replacements for the required live load capacity of 4 tons, and they are also reversible.

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Figure C10.17 New bottom chord with scarfed joints. Josif Bicja, April 2012.



Figure C10.19 Replaced portion of north arch, east end. Josif Bicja, July 2012.



Figure C10.18 Typical sistered roof rafters. Josif Bicja, July 2012.

Roof Framing Repairs

The roof rafters and roof boards were analyzed for dead load, wind load (18.3 PSF), and a ground snow load of 50 PSF (29.8 PSF roof applied) per the 2005 Vermont Fire and Building Safety Code snow load and the 2006 International Building Code. The roof rafters and roof boards were found to be adequate for the applied dead, wind, and snow loads. The existing standing seam metal roof was in fair condition; however, during the rehabilitation the existing metal roof was even more damaged by the removal of certain truss and roof members. It was replaced with a new standing seam metal roof. Fourteen rafters and approximately 40 percent of the existing roof boards were replaced in kind during the project. Several other rafters were sistered in order to preserve as much as possible of the historic fabric.

Upper Lateral Bracing Repairs

The existing upper lateral bracing was analyzed for wind loading in conformance with 2006 International Building Code. It was in poor condition and was not

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Figure C10.20 Typical top chord scarfed joint. Josif Bicja, July 2012.

adequate to resist code required wind loads. The bridge trusses were racked between 5" and 7", depending upon the location, which provided evidence of this deficiency. The expected lateral deflections could damage the covered bridge by way of truss misalignment and broken or deformed members. Due to the poor capacity of the upper lateral bracing, the existing bracing was replaced with horizontal 4" x 4" X bracing between the existing cross beams.

The knee braces in the bridge were in good condition with the exception of a few knee braces that had collision damage from oversized vehicles. There were eight locations where knee braces were replaced in kind, and eight locations where cross beams were replaced in kind. Of these, one had suffered collision damage, and seven were replaced because of twisting, checks, and splits.

Floor Beams, Stringers, Decking and Lower Lateral Bracing Repairs

All stringers were removed during the work to reduce the dead load on the trusses. The removal of stringers required raising the existing covered bridge superstructure



Figure C10.21 New upper lateral bracing and arches on eastbound barrel. William Caswell, September 2012.

by installing larger timber blocking and sleeper beams at the bearing seats, which also increased the hydraulic opening under the bridge.

The existing deck was replaced with two new layers of planks running longitudinally to the span. The top layer of the deck consists of 1 ½"-thick white oak planks that serve as a sacrificial wearing surface. The bottom layer of deck consists of 3"-thick pressure treated Douglas fir planks.

All existing 6" x 6" lower lateral braces, which were poorly connected to the truss bottom chords of the existing trusses at the panel points, were removed to reduce the dead load of the bridge. New 5" x 5" Douglas fir lateral braces were only added in bottom chord compression areas over the piers.

In addition, a new wood curb was added to the bridge to help keep vehicles from damaging the trusses and arches.

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Figure C10.22 Newly grouted and sealed concrete abutment supporting the new lower chord, consisting of two 7" x 14" pressure-treated timbers. Josif Bicja, July 2012.

Abutments and Piers Rehabilitation

Repairs to the bridge's substructure included minor, partial depth concrete repairs to all existing substructure elements, and grouting and sealing the concrete cracks in both abutments and piers and all four wingwalls. Grout bags were installed in the areas of scour at the east pier. The exposed concrete surfaces were also stained and sealed.

Fire Detection/Protection

The following fire detection protection systems were added to the rehabilitated covered bridge:

Intumescent or fire retardant coatings (NOCHAR/POLASEAL) are water-based, water repellent treatments that are specifically designed to protect exterior and interior wood surfaces but not affect the strength of the wood. They pene-

trate the wood and then cure by reaction with air to lock into the pore structure of the wood. These coatings work by raising the flashpoint of the wood, thereby making it difficult a fire to start. The fire-retardant coatings contain a fire retardant to reduce flame spread in the event of a fire, and a blend of special preservatives to fight against decay. The coatings, which are available in colored and clear versions, are applied to the wood by brush or spray. In addition to the fire-retardant coating, fungicide was applied to the bridge members to prevent fungal growth. Infestation by fungi causes wood to rot, lowering the capacity of affected members.

If a fire starts, it is important the local fire department be notified as soon as possible, so a fire detection system was installed. "Protectowire" is a proprietary system that consists of a small wire run through key locations in the bridge. The sensor cable is comprised of steel conductors individually insulated with a heat sensitive polymer. The insulated conductors are twisted together to impose a spring pressure between them and wrapped with a protective tape. If a rapid rise in temperature is detected or if a wire is cut, the system alerts the fire department. This advanced warning can greatly reduce fire damage to a bridge and prevent the fire from destroying the bridge.

Analysis of Treatment and Standards That Have Been Applied

1. A property will be used as it was historically or be given a new use that requires minimal changes to its distinctive materials, features, spaces, and spatial relationships.

The bridge was rehabilitated for continuing use with minimal repairs to its original substructure units, and the majority of the historic fabric on the superstructure was also retained. Wood members were replaced in kind where too deteriorated to repair. A secondary top chord was added on the interior truss for necessary support. The wood trusses are able to support all dead, snow, wind, and live loads without the addition of non-traditional materials.

2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alterations of features, spaces, and spatial relationships that characterize a property will be avoided.

The visual character of the covered bridge was retained and preserved. The

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geometry of the bridge (portal opening, panel spacing, member sizes, and span lengths) was retained. Each historic feature of the bridge was carefully inspected and retained if no deficiencies were noted. If there were deficiencies, the members were repaired and, where necessary, strengthened and replaced only as a last result. Features that were too deteriorated to repair were replaced to match the original deteriorated features.

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.

No changes were made to the covered bridge that would create a false sense of historical development.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

Changes, such as the addition of bottom chord plies and arch hanger rods, that had been made to the covered bridge after its original construction date were determined not to contribute to the historic significance and were not considered character-defining, so they were removed.

5. Distinctive materials, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

The majority of the trusses and arches were preserved. New members were replaced in kind to match the original, with the exception of the new bottom chord. The original bottom chord was not properly constructed, and it did not match the conventional framing of a multiple-kingpost truss. Thus, it was replaced with a more appropriate feature.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.

Each member of the bridge was carefully inspected and retained if no deficiencies were noted. Those members with noted deficiencies were first evaluated for potential repair, then strengthened and replaced as a last

resort. Repair work was completed with in-kind materials and traditional craftsmanship techniques.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

Chemical treatments were used below the deck level with non-toxic chemicals.

8. Archaeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

The abutments were repaired and preserved. No archeological disturbance took place.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

A secondary top chord was added on the interior truss. It is compatible with the historic features and material of the bridge. In fact, by eliminating the need to replace the truss members, its addition actually protected the integrity of the bridge by retaining more historic materials.

10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

A secondary top chord was added on the interior truss, but this change is easily reversible and does not destroy the historic character of the bridge.

Section 106 Compliance Information

Hoyle, Tanner presented the proposed project at the Vermont Historic Covered Bridge Committee meeting on February 27, 2007, and consensus was reached on the rehabilitation specifics. The Vermont Agency of Transportation reviewed this undertaking according to the standards and procedures detailed in the April 5, 1999, Programmatic Agreement (PA) to implement the Federal-Aid Highway Program in Vermont and the PA Manual of Standards and Guidelines.

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10. Pulp Mill Covered Bridge

Project review consisted of identifying the project’s potential impacts to historic buildings, structures, historic districts, historic landscapes, and settings, and to known or potential archeological resources. VAOT Officers findings supported the determination of no adverse effect for the project. Completion of the no adverse effect memo document evidenced that FHWA had satisfied its obligations under Section 106 for this undertaking.

Lessons Learned

A thorough in-depth and hands-on inspection of a covered bridge is a critical part of the rehabilitative process. Proper detailing and use of materials during rehabilitation projects, as well as regular maintenance, are also very important factors in preserving covered bridges.

Project Particulars

Rehabilitation Project Team

Mark D. Sargent, P.E., Project Manager, VAOT
John H. Weaver, P.E., VAOT

Date of Project

January 2012 – November 2012

Cost for Treatment Project

\$1,638,629.00

Case Study Team

Prepared by Josif Bicja, P.E., Project Engineer, Hoyle, Tanner & Associates Inc.
Advised by Sean T. James, P.E., Project Manager, Hoyle, Tanner & Associates, Inc., 2013.

Footnotes

¹Phase 1 Archaeological Site Identification Survey, Consulting Archaeology Program at University of Vermont, 1997.

²H. P. Smith, *History of Addison County, Vermont* (Syracuse, NY: D. Mason and Co., 1886).

³Glenn Andres, *A Walking Tour of Middlebury* (Middlebury Bicentennial Committee, Middlebury, Vermont, 1975); Curtis B. Johnson, *The Historic Architecture of Addison County, Vermont* (Montpelier: Vermont Division for Historic Preservation, 1992).

⁴Lola Bennett, “Pulp Mill Bridge,” HAER No. VT-31, *Historic American Engineering Record* (HAER), National Park Service, U.S. Department of the Interior, 2003.

⁵Herbert W. Congden, *The Covered Bridge* (Middlebury, VT: Vermont Books, 1959).

⁶The inventory rating is defined as a vehicle live load that can safely pass over the bridge an infinite number of times without any detrimental effects to the bridge.

⁷The live load model consists of either a design truck or a uniformly distributed load with concentrated loads that was developed as a notional representation of shear and moment produced by a group of vehicles routinely permitted on highways. The load is referred to as “notional” because it does not represent any particular truck.

⁸The inventory rating is defined as a vehicle live load that can safely pass over the bridge an infinite number of times without any detrimental effects to the bridge. Operating rating is defined as the maximum permissible vehicle live load to which the structure may be subjected. Allowing unlimited numbers of vehicles to use the bridge at the operating level may shorten the life of the bridge.

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10. Pulp Mill Covered Bridge

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11. Swann Covered Bridge

Blount County, Alabama

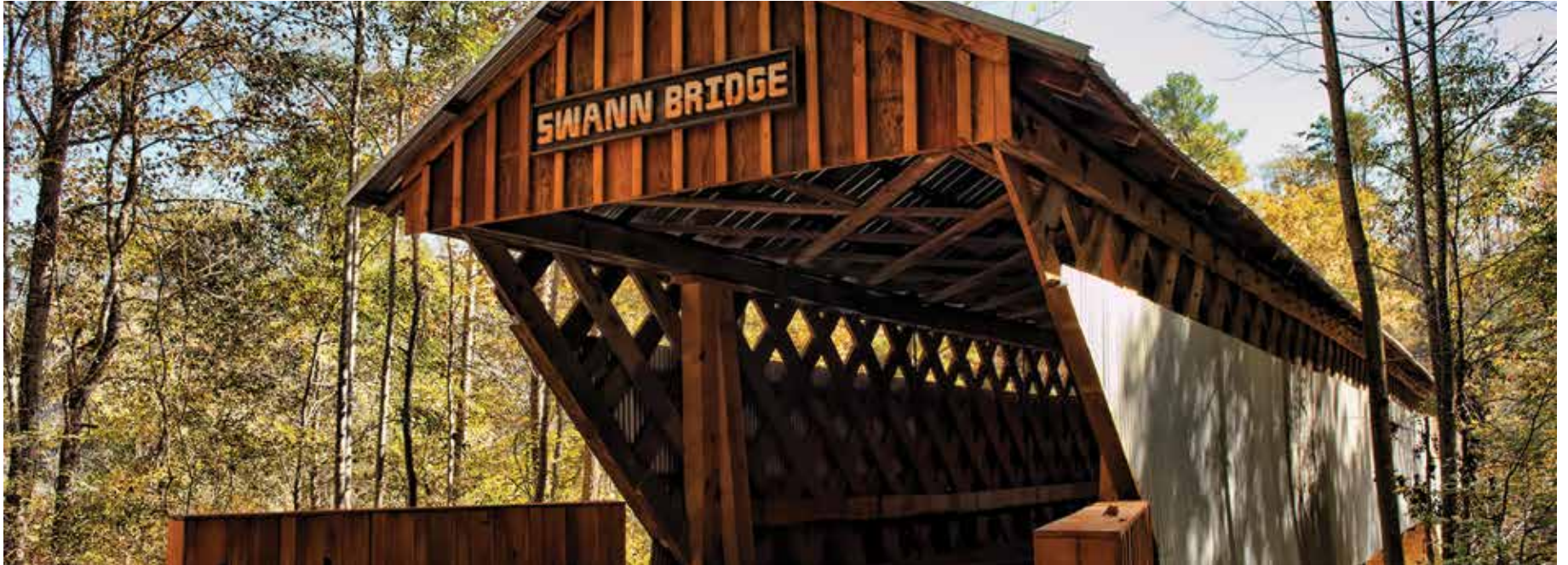


Figure C11.1 Rehabilitated Swann Covered Bridge. Susan Johnson, 2012.

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11. Swann Covered Bridge

Blount County, Alabama

By Winston Sitton, Manjeet H. Ahluwalia, Evan C. Lowell

Administrative Data

Bridge Name

Swann Covered Bridge (also known as Joy Covered Bridge)

Bridge Structure Type

Three span Town lattice truss, approximately 304' long with inclined end portals

Date of Original Construction

1933

Original Builder

Zelma C. Tidwell

Bridge Owner/ Client

Blount County, Alabama

World Guide Number

01-05-05

Structure Number

O CO0123 05 0000019Z 00; BIN 001644

HABS/HAER/HALS Number

HAER AL-201

National Register Number and Date

NRIS 81000123; August 20, 1981

Description of Location

Located in unincorporated Blount County, Alabama, near the town of Cleveland, the bridge carries Swann Bridge Road over the Locust Fork of the Black Warrior River and is located approximately 1.1 miles from Alabama Highway 79.

Description of Setting

The bridge is situated in a rural setting that is being actively used for agricultural purposes.

Historical Background and Context

The Blount County bridge crew built the Swann Covered Bridge in 1933 under the direction of Zelma (Zelmer) Tidwell and his uncle Forrest Tidwell. Workers erected the bridge using ropes to hoist the timbers and materials off the ground. Julius McCay, a worker, lost his footing and fell from the top of the structure during construction. He lay unconscious for several hours but later returned to work. Mr. Tidwell remembered, "I'll never forget when we finished building it; the people in the community were so proud to have it they gave us a big supper."

Swann Covered Bridge was built to connect the Blount County communities of Cleveland and Joy. Since it was located on property owned by Swann Farms, it was generally called Swann Bridge, although some residents also called it the Joy Bridge because it was on the road leading to Joy. The bridge rises 28' above the water and is the longest surviving covered bridge in Alabama. In June 2009, Swann Covered Bridge was closed to traffic, but it was reopened on October 22, 2012, and remains open to vehicular traffic with a 3-ton weight limit.

In August 2003, the Blount County Commission applied for \$134,570 in Transportation Enhancement (TE) funds to replace the roofs and to carry out some cosmetic repairs to Blount County's three remaining covered bridges. The commission received funding in early 2004, but in March 2006, the FHWA wrote a letter to the Alabama Department of Transportation (ALDOT) stating the TE funds could not be spent until minimum safety standards were met. ALDOT forwarded the letter to Blount County in May 2006. FHWA listed three options for the county: 1) make repairs after performing a structural load analysis; 2) close the bridge to vehicular traffic and only allow pedestrian use, which required a structural load analysis; or 3) replace the bridges using replacement funds. The county chose to hire a professionally-licensed structural engineer per the National Bridge Inspection Standards to perform an in-depth inspection and load rating (via analysis) and then make the necessary repairs. The structural analysis of all three bridges cost \$134,000.

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Other funding sources had to be found because TE funds could not be used for structural analysis. The Blount County Commission applied for National Historic Covered Bridge Preservation Program (NHCBP) funds with the help of ALDOT in July 2006. The NHCBP funds were to be awarded in September 2006, and since the TE funds were set to expire before this date, a six month extension was granted. Due to congressional difficulties the NHCBP funds were not awarded, so the county returned the TE funds in January 2007.

FHWA awarded \$25,878.75 (the full amount requested) in NHCBP funding (25 percent county match) to Blount County in August 2007. The commission then decided the project should be a rehabilitation project, not just roof replacement and cosmetic repairs. The Blount County Commission then reapplied for TE funds and was awarded \$249,000 (25 percent county match) in May 2008. The TE funding agreement was signed on September 25, 2008.

In February 2008, Blount County obtained cost estimates for in-depth structural analyses of all three of the county's historic covered bridges. Then in May 2008 the county submitted a letter to ALDOT to select a consultant from the on-call list. ALDOT approved the county's request to select TranSystems as a consultant and to enter an agreement with them for the structural load rating analysis. TranSystems began work in February 2009 and submitted the preliminary structural analyses reports for all three bridges to ALDOT in December of that same year. The ALDOT Bridge Bureau approved the reports on February 23, 2010.

The bridge plans were then submitted to ALDOT for review on April 21, 2010, and authorization was given on August 24, 2011. Bob Smith Construction, Inc. was the only bidder and was awarded the contract. Work began on the bridge in November 2011 and had been completed by September 2012. The bridge was open to vehicle traffic at a ribbon-cutting ceremony the following month. The project was made possible by the tireless work of Richard Spraggins, Blount County Engineer at the time. The total estimated project cost for all three covered bridges was \$539,476.50.

Physical Description of Bridge

Swann Covered Bridge is a three-span structure comprised of two timber Town lattice trusses measuring approximately 304' long, with inclined end portals. The bridge span lengths are 102'-1", 98'-8", and 103'-2", west to east. The abutments, piers, and wingwalls are gravity concrete placed on a stone outcropping. The bridge carries a single roadway with a minimum width of 10'-1". The timber truss utilizes a lateral timber cross bracing for the top chord. The lower lateral bracing system consists of diagonally placed lateral steel eye loop end round bars, with turnbuckles, that connect to the vertical steel bars supporting the floor beams. Sway bracing is provided at each truss end and over each bent. The bridge has a "Weight Limit 3 Tons" posting sign on each approach.

The timber Town lattice truss configuration consists of six timber elements, an interior chord (four 2" x 10" members) and an exterior chord (two 2" x 10") along both the bottom and top of the truss. The chords are made continuous with butt splices approximately 3'-6" apart. There is 9'-11" +/- clear distance between the top and bottom chords. The interior chords are through bolted to the 1-1/8" vertical steel rods and are spaced apart 12'-1" center to center. The 2" x 10" timber lattice members are sandwiched in between the interior and exterior chords and through bolted from the exterior to the interior chord with two vertically spaced bolts at the intersection of each lattice member. The timber lattice members are inclined at 45 degrees, spaced apart at approximately 2'-2" center to center, with opposing intersecting members bolted together with one or two horizontally placed bolts at intersections. There are additional timber frames at the ends of the structure and at several locations between the abutments, including the piers. The frames consist of various-sized vertical posts located between the top and bottom chords of the trusses.

The floor system consists of timber floor beams, stringers, and deck planking. Vertical steel rods at each end support the 6" x 10" timber floor beams. The steel rods pass through the truss bottom and top chords (via a drilled hole with support washers) and through the intersecting top chord lateral bracing members. The floor beams have variable spacing, from 11'-10" to 15'-5". The beams support four timber stringers, each consisting of three 2" x 10" timber elements made continuous with offset butt splices. The exterior stringers are located 2'-5" from the center of the interior chords; the remaining interior

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11. Swann Covered Bridge

stringers are conservatively estimated to be spaced 2'-5" center to center. The stringers support four layers of deck planking. The bottom layer of timber deck planking consists of 2" x 8" diagonal planks across the stringers, spaced approximately 1'-6" center to center. The second deck planking layer is placed transversely and has adjacent 2" x 8" planks. The third deck planking layer consists of longitudinally placed 2" x 8" planks with butt splices. The top deck planking layer is nearly similar to the third layer and has 2" x 8" runners which are longitudinally placed along the wheel lines only, for most of the bridge length, and along the full roadway width at the ends of the bridge.

The timber roof system consists of alternating 2" x 4" rafters, spaced at 3'-0" center to center, and supported by a 2" x 6" timber sill plate on each truss. The rafters meet at the center with no ridge beam. The rafters support four 2" x 4" timber purlins on each side of the roof, which carry the sheet metal roofing. Vertical wood siding covers the roof system portal ends. The truss siding is partial height and consists of corrugated sheet metal supported by longitudinal wood members attached to the trusses.



Figure C11.2 South elevation, looking northwest. TranSystems, 2009.



Figure C11.3 General underside view, looking west. TranSystems, 2009.



Figure C11.4 General view, looking west. TranSystems, 2009.

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Figure C11.5 General view of interior, looking east. TranSystems, 2009.

Chronology of Development and Use

The known bridge repairs occurred in 1979, 1997, and 1998. During the summer of 1979, the county commission repaired the bridge's abutments and portals. In the spring of 1997, county forces sprayed the bridge with Nochar's Fire Preventer, manufactured by Nochar, Inc., of Indianapolis. The fire retardant was applied as a preventative measure after the Nectar Covered Bridge in Blount County burned down in 1993. In December 1998, the county commission repaired a scour hole at the pier located in the river and placed an additional footing around the pier located near the riverbank. At some point timber bents were placed close to the abutments at each approach to provide extra support. Both bents are currently in place.

Description of Most Recent Rehabilitation Project

TranSystems made a site visit to the structure on February 4, 2009, to verify member sizes and spacing and observe conditions that could potentially affect the structural capacity. The field visit revealed variations in floor beam and rafter spacing from the provided plan and elevation views. Additional vertical posts were noted at the bridge ends and at pier locations. No significant deterioration of the timber members in the trusses was noted during the fieldwork.

In addition, based on the structural analysis results, TranSystems observed the bottom chord, truss members, and stringers had adequate capacity for an H3 (3-ton) vehicle. The bottom chord member had insufficient capacity at the pier and required strengthening for one bay on either side of the pier. The floor beams had insufficient capacity to carry an H3 vehicle and required strengthening. As a result, TranSystems recommended strengthening the floor beams by building them up with 4" high x 10" vertical timbers on either side of the existing floor beams. TranSystems also recommended similarly strengthening the truss bottom chord through the addition of two 2" x 10" members for one bay on either side of the pier. The sizes for the members were based on using Southern Pine Select Structural No. 2 timber.



Figure C11.6 Floor, runners, and rail removed. TranSystems, 2012.

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11. Swann Covered Bridge

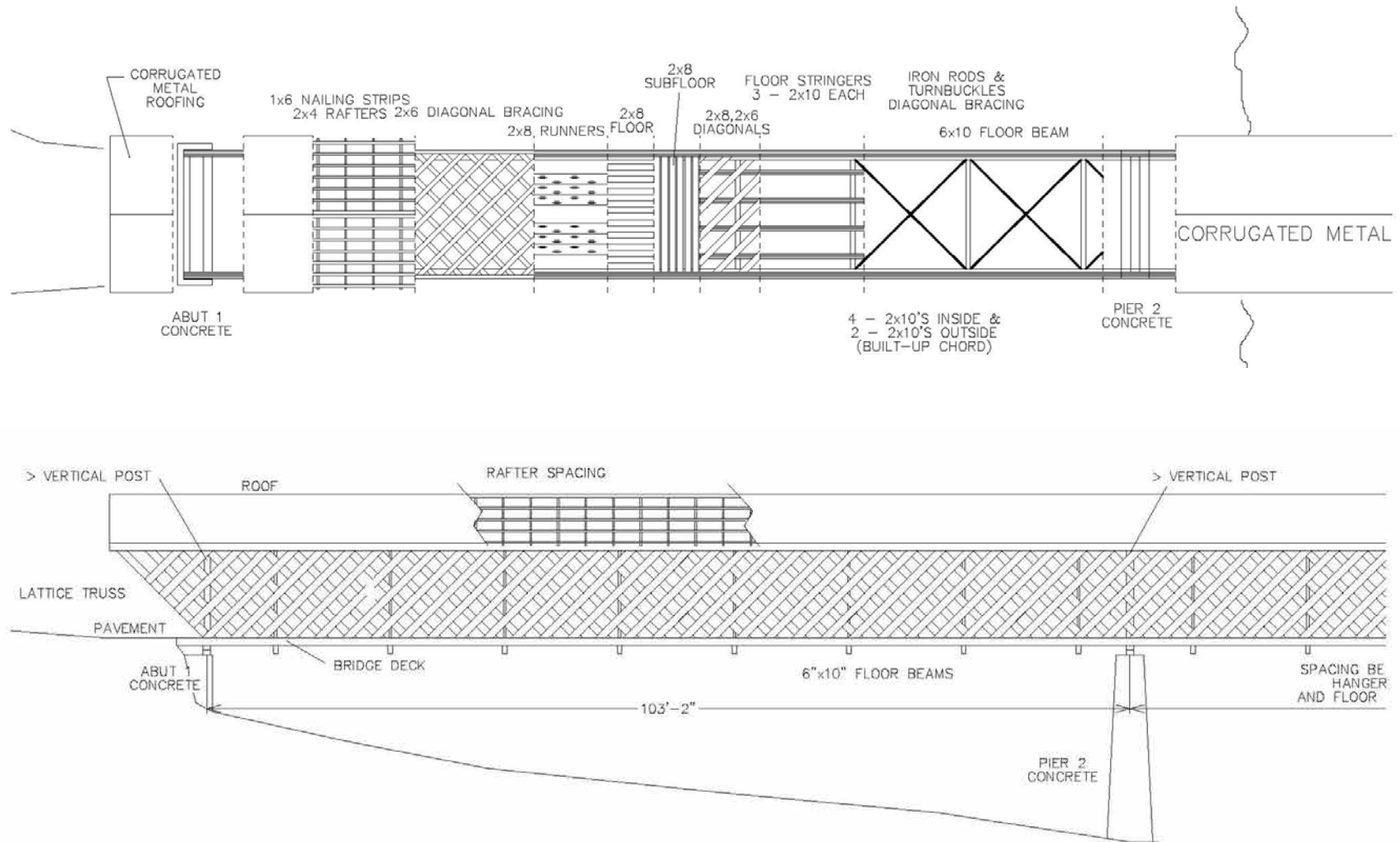


Figure C11.7 Detail and overall plan and elevation of Swann Bridge. TranSystems, 2009.

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Figure C11.8 Abutment 1 showing gable with missing boards. TranSystems, 2012.



Figure C11.9 Span 1, near floor beam 2, showing separation between stringer 4 boards. TranSystems, 2012.

Bob Smith Construction, Inc. started construction in November 2011. The first step was to build a steel grate cross drain at the approach on the eastern side to divert drainage away from the entrance to prevent rot. The next step was to remove the rails and part of the floor system to further inspect the stringers and floor beams. After the floor and runners were removed, Bob Smith Construction used compressed air to clean the bridge for inspection.

TranSystems conducted another field visit on January 10, 2012, to examine the exposed timber elements and inspect the condition of the floor system and truss members that had previously been hidden. The inspection revealed deteriorating or rotting stringers and posts, split floor beams, a wide crack in a breastwall, debris accumulation on the upstream end of pier 2, and bent hanger rods.

After the inspection, construction began anew with replacing and strengthening floor beams by attaching 4" x 10" timbers to each side of the new beams with 3/4"-diameter threaded rod. Replacement hanger rods were also installed at this time. No temporary supports were used. Instead, a chain hoist temporarily secured a floor beam to the top of the truss, allowing for stabilization and adjustment as floor beams and hangers were removed and installed. A telescopic boom lift was required to access the sections over water.

Once all the floor beams and hangers had been replaced, the rest of the floor system was removed and the stringers were repaired. The abutment timber caps were replaced at this time. Damaged and rotted stringers were replaced at approximately the first 30' at each end of the bridge. The remaining stringers were replaced as needed. Because the existing stringer timbers had separated over time, the joints were cleaned and the timbers were pulled together. The stringer timbers were secured with 3/4"-diameter threaded rods and nuts plus nails. The bottom chords of the truss were also strengthened by the addition of two 2" x 10" members attached by nails and 3/4"-diameter threaded rods.

A structural analysis was performed of all key members of the bridge superstructure. The Service Load (Allowable Stress) design method was used for all members. Allowable stress values for wood members were based on the 2005 National Design Specification for Wood Construction and Supplement. The wood species used in the superstructure was identified through testing by Doug Gardner. The grade assigned to each member was based on a visual examination of knots, checks, slope of grain of the wood, and the growth-rate characteristics of the wood.

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Figure C11.10 Vertical post at Pier 2 revealed deterioration on south side. TranSystems, 2012.



Figure C11.12 Abutment 4 showing deteriorated ends of stringers. TranSystems, 2012.



Figure C11.11 Span 3, south (right) side with bent hanger rod 1. Condition also observed at north hanger rod at floor beams 5 and 6. TranSystems, 2012.



Figure C11.13 Right vertical post is rotted at abutment 4. TranSystems, 2012.

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Figure C11.14 Wide crack in abutment 4 breastwall. TranSystems, 2012.

The diagonals, subfloor, and floor were then replaced with new material. While approximately 95 percent of the lattice truss was retained, the runners and rails had to be entirely replaced with new material. Most of the roof timbers were retained, but the metal roofing had to be entirely replaced. Nochar Fire Preventer was applied as a fire retardant about a month after construction was completed. This allowed the timber treatment to dry enough for the Nochar to soak into the timbers.

Along with the grate drain, a concrete approach was added at each entrance to direct water away from the bridge entrance. New timber rails that are compatible with the historic character of the bridge were also added at each entrance. The existing timber bents, which were not part of the original construction, were left in place to provide support at the approaches. They may be removed at a future time.

Analysis of Treatment and Standards That Have Been Applied

1. A property will be used as it was historically or be given a new use that requires minimal changes to its distinctive materials, features, spaces, and spatial relationships.

The bridge is on its original abutments and continues to function as a self-supporting wood truss, with non-original timber piles providing additional support to one span. The bridge still serves as a vehicular crossing.

2. The historic character of a property will be retained and preserved. The removal of distinctive materials or alterations of features, spaces, and spatial relationships that characterize a property will be avoided.

The visual character of the bridge was not compromised, and all character defining features were retained. The geometry of the bridge (camber, panel spacing) remains. Every member of the truss was carefully examined and retained if possible. Materials which were replaced match in kind the material they replaced or a historical antecedent.

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, such as adding conjectural features or elements from other historic properties, will not be undertaken.

No changes were made that would create a false sense of historical development. All character-defining features were respected as products of their time within the period of significance.

4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.

Changes that had been made to the bridge after its original construction date were determined to not contribute to the historic significance and were not considered character-defining features.

5. Distinctive materials, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved.

The most important members of the truss were preserved. Replacement members, where necessary, were made from in-kind material using craftsmanship that replicated historic construction methods. Other character-defining features were retained and/ or replaced in kind with traditional materials and methods.

6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture, and, where possible,

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11. Swann Covered Bridge

materials. Replacement of missing features will be substantiated by documentary and physical evidence.

Repair work and replacement work was done using in-kind materials and traditional craftsmanship techniques.

7. Chemical or physical treatments, if appropriate, will be undertaken using the gentlest means possible. Treatments that cause damage to historic materials will not be used.

Chemical treatments were used sparingly, and non-toxic chemicals were chosen when possible.

8. Archaeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.

The abutments remained in place. Archeological disturbance did not take place.

9. New additions, exterior alterations, or related new construction will not destroy historic materials, features, and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.

There were no additions, and the repair work conducted was sensitive to the character of the bridge. In-kind replacement materials were used to maintain the structure's integrity.

10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

There were no additions or adjacent new construction.

Section 106 Compliance Information

The project was determined to have no adverse effect

Project Particulars

Rehabilitation Project Team

Richard Spraggins, P.E., Blount County, County Engineer (retired 2012)

Winston Sitton, P.E., Blount County, County Engineer

Gary White, Blount County, Bridge Inspector

TranSystems, Structural Analysis

Bob Smith Construction, Inc., John Friedberg, Project Manager

Eric Nordgren, Superintendent

Date of Project

November 2011 to October 2012

Note: The length of project also includes rehabilitation of Easley Covered Bridge by the same crew, which took place concurrently

Cost for Treatment Project

\$194,623.00

Case Study Team

Prepared by Winston Sitton, County Engineer, Blount County; advised by

Manjeet H. Ahluwalia, P.E., and Evan C. Lowell, P.E., TranSystems, 2013.

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EDITOR BIOGRAPHIES

Christopher H. Marston has been an architect with the U.S. National Park Service's Historic American Engineering Record since 1989, serving as the project leader of the HAER National Covered Bridge Recording Project from 2002-2019. Under his leadership, HAER documented 100 bridges, produced a Smithsonian-sponsored traveling exhibition, hosted two national conferences, and designated seven bridges as National Historic Landmarks. He was co-executive editor (with Justine Christianson) of *Covered Bridges and the Birth of American Engineering* (Historic American Engineering Record, 2015). He also served as co-editor of the award-winning *America's National Park Roads and Parkways: Drawings from the Historic American Engineering Record* (Johns Hopkins University Press, 2004). Christopher has presented on his work at HAER at a variety of professional conferences, and serves as an active member of several preservation organizations, including the Society for Industrial Archeology (President, 2018-2020), Preserving the Historic Road, and the Transportation Research Board's Committee on Historic and Archaeological Preservation in Transportation (ADC50).

Thomas A. Vitanza is the Senior Historical Architect for the U.S. National Park Service's Historic Preservation Training Center. He and his office provide planning, design, documentation, and construction services to National Park units and many other federal, state and local government entities as well as qualifying non-profits who wish to preserve National Register structures. Tom has completed hundreds of projects for scores of NPS clients including preservation of National Landmark structures at Arlington National Cemetery. Tom is a licensed professional architect in Maryland and carries the National Council of Architectural Registration Boards certification. Tom is currently a Director at Large for the Association of Preservation Technology International Washington, D.C. chapter (APT-DC) and a 10-year veteran member of the U.S. Department of State Technical Review Committee for the Ambassadors Fund for Cultural Preservation.

