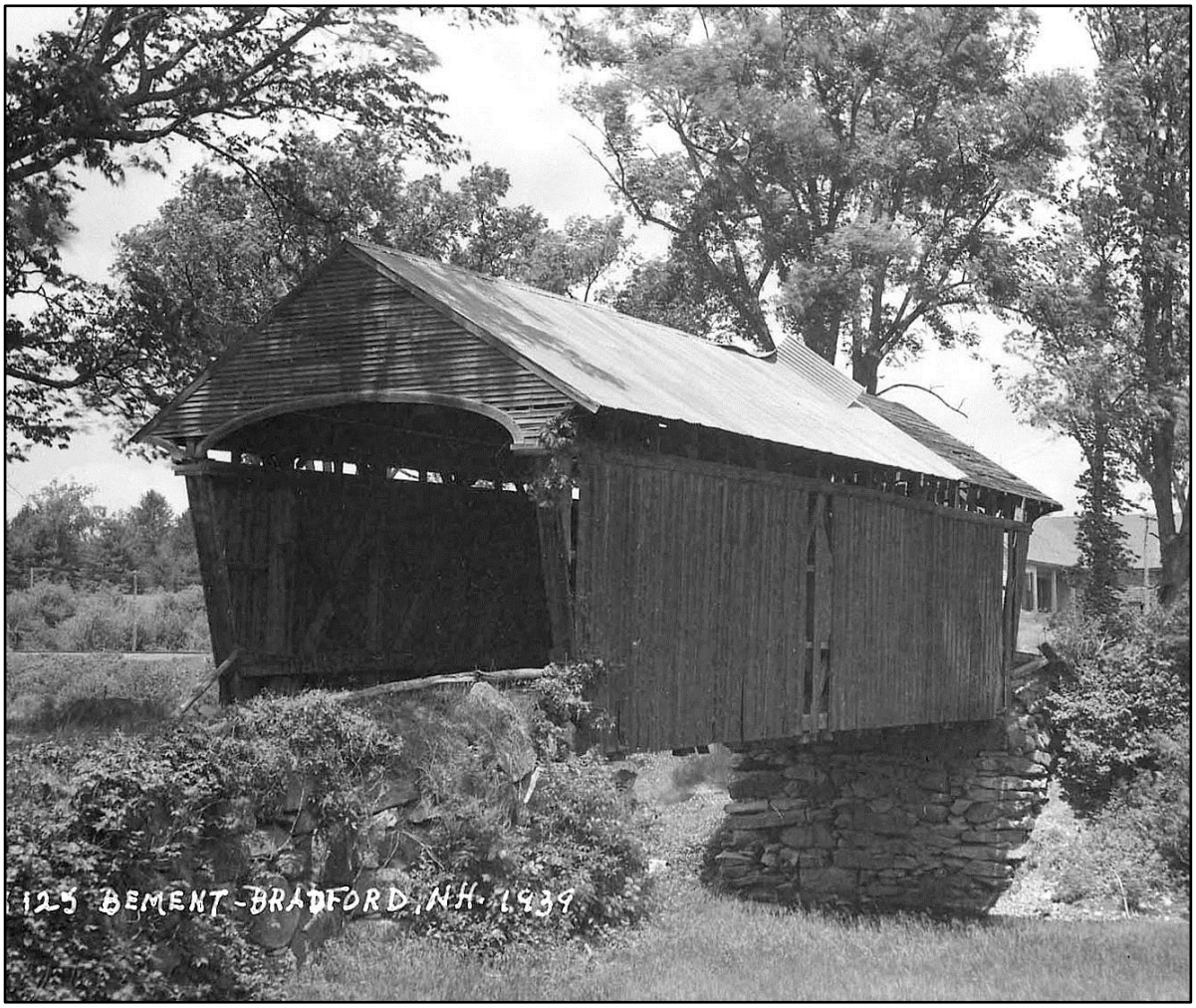
Bement Covered Bridge, Bradford, New Hampshire
Rehabilitation & Preservation Plan



Bement Bridge in 1939, showing damage evidently from 1938 hurricane.

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for

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Manchester, New Hampshire

and

Town of Bradford, New Hampshire\

February 2018

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1.0 PURPOSE & SCOPE

This report arises from National Historic Preservation Act Section 106 Consultation meetings and discussions between the Town of Bradford, owners of Bement Covered Bridge in conjunction with their consulting engineer, Hoyle Tanner & Associates, (HTA), the New Hampshire Department of Transportation (NHDOT), and the New Hampshire Division of Historical Resources (NHDHR), hereafter collectively referred to as the Parties, regarding proposed Section 106 reporting requirements pertaining to the rehabilitation of the Bement Covered Bridge[1], a historic property listed on the National Register of Historic Places on November 21, 1974.

The rehabilitation work proposed by the Town as designed by HTA will involve replacement of non-original members, the replacement "in-kind" of other members that may or may not be original but are rotted or damaged to the extent that they lack historical integrity, and the addition of reversible structural reinforcing members. [2]

Recognizing that this type of rehabilitation work can be conducted in accordance with the Secretary of the Interior's Standards for the Treatment of Historic Properties (Standards), the Parties have proposed that this *Rehabilitation and Preservation Plan* (*Plan*) be prepared by a 36CFR61-qualified architectural historian to identify the work to be done and how the work will comply with the Standards by not altering any aspects of the property's historic integrity or character-defining features that make it eligible for the National Register.

This *Plan* includes the following sections: history of the bridge; description of past repairs and alterations; list of character defining features and their integrity with reference to accompanying photographs of current conditions; table of proposed rehabilitation work items with reference to accompanying construction drawings that highlight individual members to be repaired; discussion of how the work item complies with the Standards and recommendations for maintenance of the bridge to preserve the integrity of its character defining features.

2.0 HISTORY OF CONSTRUCTION, REPAIRS & ALTERATIONS

2.1 Date of construction: 1854

The present Bement Bridge was preceded by two bridges according to the town's bicentennial history.[3] The first bridge on the site was erected by the town in 1800 and financed by a so-called Penny-Tax, of one penny per acre of land. The second bridge was built in 1818 when the town voted to build a new bridge "near Samuel Bement's." No additional information regarding the nature of these earlier structures or the circumstances leading to the building of the second bridge was obtained. In 1854 the town voted to build a new single span covered bridge of the Long Truss design which was erected at a cost of $500.[4]

2.2 Architect/Engineer: Not known.

The truss type is considered a variant of the Long Truss, patented by Major Stephen H. Long (1784-1864) of the United States Army March 6, 1830. Long was a native of Hopkinton New Hampshire and a graduate of Dartmouth College. He was made a Colonel of U.S. Corps of Topographical Engineers in 1861. The truss follows the general pattern of the Long Truss design with posts, main braces and counter braces, but varies in a number of important details indicating it was not built in accordance with the original patent, or

[1] NHDOT Project Bradford X-A002(722)

[2] According to the Secretary of the Interior's Standards for the Treatment of Historic Properties (Standards), when damage or deterioration of a member precludes repair, as in the case of certain types of structural members, and when the essential form and detailing of the member is still evident, replacement should be made "in kind," meaning of the same material, form and detail. When in kind replacement is not technically or economically feasible, the Standards allow the consideration of compatible substitute replacement materials.

[3] Bradford History and Bicentennial Committee. *Two hundred plus, Bradford, New Hampshire in retrospect.* Canaan, New Hampshire: Phoenix Publishing, 1976.

[4] Ibid.

Long's later patents of 1836 or 1839 (see Figure 1 discussion). Most importantly the truss lacks the wedge blocks inserted at the top of the counterbraces and driven to pre-stress the truss, a core claim of the patent.

2.3 Builder/Contractor/Supplier: Not known.

No records of the original (1854) construction are known to exist. The National Register Nomination for the bridge prepared in 1974 notes that "the bridge has a tradition of having been built by Stephen H. Long and constructed entirely of hemlock although no evidence was found to support or dispute the claim."[5] More recent research and writing about Long and Bement Bridge show that Col. Stephen Long was fully occupied with important Army engineering work in the west from 1840 until his death in Alton Illinois in 1864.[6] There is no evidence that he took leave to return to New Hampshire to build a covered bridge. William Truax, a modern covered bridge builder from New Hampshire who inspected Bement Bridge for the town in 2012 notes how the bridge varies in a number of details from the Long design and postulates that it may have been built by Horace Childs, a covered truss bridge builder from nearby Henniker who was active in the region at the time.[7] This theory is supported by the fact that Horace Childs, along with his brothers Enoch and Warren, were nephews of Col. Stephen Long and were appointed by Long as "sub-agents" in 1832 to promote the building of his patent bridge.[8] In 1834 Horace Childs built a Long Patent bridge over the Contoocook River in nearby Henniker (destroyed 1852). He formed the bridge building concern, Horace Childs & Co., that at times employed his two brothers, as well as Frederick Whitney, Dutton Woods and Thomas Livingston. Many dozens if not hundreds of bridges built for the state's early railroads and highways from the 1840s to the 1860s can be attributed to these men either individually, working in partnerships or in other collaborative arrangements.[9]

2.4 Original plans, design, materials and construction: Not known.

Original plans or construction records are not known to exist for the Bement Bridge. Twentieth century photographs of the bridge (presented in figures below), very limited documentary information, and current conditions, provide the only evidence pointing to the original makeup of the bridge.

2.5 Current Conditions: Bement Bridge consists of two seven panel timber trusses, approximately 12'-6" tall measured between upper and lower chord centers, spaced roughly 17'-6" on center (see Figures 1-5). Including the gable roof, the overall height of the bridge from sill to ridge is approximately 22'-0". The panels have single verticals (posts) typically measuring 6-¾" x 7-¾" in cross section, single diagonal braces measuring 6-¾" x 6-$^{7}/_{8}$" or 7-0" x 5-$^{7}/_{8}$", and double-member counter braces measuring 2-$^{7}/_{8}$" x 7-¼", 3-¼" x 8-0", and 2-$^{7}/_{8}$" x 5-$^{7}/_{8}$" plus others with slight variations of those dimensions.[10] [Note: all timber dimensions given are for member cross section].

The upper chords consists of four members, the two interior measuring 4-0" x 7-$^{7}/_{8}$" and the two exterior measuring 3-½" x 7-$^{7}/_{8}$". The lower chords consists of four members, the two interior measuring 4-0" x 9-¾" and the two exterior measuring 3-0" x 9-¾". The lower chords were replaced by the NH Highway Department in 1947, and reportedly repaired again during the 1968-1969 rehab of the bridge, described below.

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[5] Brian R. Pfeiffer, "Bement Covered Bridge National Register Nomination Form" 1974, quote from Floyd L. Avery, "Report of Covered Bridges in New Hampshire," Concord, NH: NH Department of Public Works and Highways, 1965, p. 6.

[6] See "Stephen Harriman Long" at: https://www.nps.gov/fosm/learn/historyculture/long.htm.

[7] See web article by William Truax on Bement Bridge at: https://bridgewright.wordpress.com/2014/09/30/a-theme-and-its-variations/. See also "Structural Condition Assessment" [for Bement Bridge] undated manuscript located in Town of Bradford survey files, New Hampshire Division of Historical Resources, Concord.

[8] See Dario Gasparini, et.al. "The Development of the American Truss," in Justine Christianson and Chrsitopher H. Marston, Eds., *Covered Bridges and the Birth of American Engineering*, Washington, D.C. National Park Service, 2015, pp. 130-135.

[9] Leander W. Cogswell, *History of the Town of Henniker 1735 to 1880.* Concord, NH: Republican Press Assoc., 1880, pp. 246-247, 259, 372-374.

[10] The Bement Bridge trusses differ from the Patent Long Truss: the Long Truss has double posts, double braces and single counter braces.

The posts extend approximately 24" above the upper chord to carry 6-0" x 7-0" overhead cross beams that join the two trusses together at their upper panel points. The cross beams are braced to the posts with 2-¼" x 3-⅝" knee brace members. The cross beams are braced to one another with cross braces, 5-¾" x 4-¾", morticed into the top of ties about 12" in from the post connections and ship-lapped at their intersection. The cross beams and cross braces together form the upper lateral bracing system.

There are two rafters per panel, measuring approximately 3-0" x 6-0" located over each post and at the mid-point of each –panel. The rafters rest on a separate retrofitted longitudinal beam or plate, nailed to the top of the posts and to short jack-posts resting on the top chord to carry the load of the intermediate or "mid-panel" rafters. The entire roof system framing was replaced in the 1968-1969 rehab of the bridge, described below.

The floor system consists of floor beams, decking, lower lateral bracing and tie-rods. None of these members can be assumed to be original to the bridge. The floor beams are of two sizes, 3½" x 11-0" and 5¼" x 11-0". The timber decking runs lengthwise, perpendicular to the floor beams and consists of 3" x 8" rough planks. The deck boards are nailed directly to the floor beams with square butted side and end joints. The lower lateral bracing consists of four sets (eight total) of 6" x 3" timbers running diagonally between the lower chords. Steel ties rods consisting of ½" reinforcing rod run perpendicular to the lower chords to draw the chords tight against the lower lateral bracing.

The substructure consists of two dry-laid stone abutments, north and south, both with U-type stone wing walls. The north abutment appears to be original to the bridge and is primitively constructed of random rubble and uncoursed fieldstone of widely varying size and shape. The downstream (east) half of the north abutment has been replaced with a poured concrete abutment, evidently encasing some portions of the original stonework. The south abutment is of distinctly different materials and workmanship compared to the north abutment, consisting of large quarry-split granite blocks of relatively uniform rectangular size and shape, laid in courses with headers. Wing walls are all of dry laid random rubble and uncoursed fieldstone.

2.6 Repairs & Alterations: Bement Bridge has undergone numerous and extensive repairs over the course of its 164 year history. Some repairs undoubtedly occurred in the 19th century as a result of normal wear and tear, floods and storms, but no records or information pertaining to such work was located.[11] The south abutment, based on the nature of its materials and workmanship was likely constructed in the late 19th or early 20th century. The Annual Reports of the Town of Bradford repeatedly list sizable expenditures for "work on bridge", "bridge stringers", "shingling bridge", "bridge plank", without attributing the expense to a specific bridge.

The first documentary evidence of a specific repair is found on the New Hampshire Highway Department (NHHD) bridge inventory card for Bement Bridge (state bridge number Bement 140/144) onto which is penciled "Lower Chord Replaced By State 1947." Four photographs from 1939 owned by the Town (Figures 6-9) as well as two taken in 1942 by the NHHD and attached to the bridge inventory card (Figures 10-11), provide good visual information on what were likely original or at least much earlier conditions of the bridge. For example, the portal was previously an elliptically-arched opening as opposed to the present squared opening that was constructed during roof and siding repairs made by the Town in 1954. The remodeled bridge appeared on the cover of the Town's 1955 *Annual Report* (see Figure 12). The 1939 photos show damage including missing sheet metal roofing and vertical siding boards that was likely caused by the 1938 hurricane and flood that tore through the state. The 1942 photos show repairs to those features as well as a major concrete repair to the north abutment. These repairs were evidently made by the Town under their general bridge maintenance budget.

[11] The entire collection of Bradford Town Annual Reports at the NH State Library from 1890 to 1978 were examined for expenditures on Bement Bridge.

The 1954 repairs that altered the portal opening also replaced the corrugated galvanized metal roof that was probably originally installed in the early 20th century, to an asphalt shingle roof (Figures 12, 13).

Substantial repairs were made to the bridge in 1968-1969 by the state highway department's covered bridge repair crew. For a detailed discussion of that work please refer to the captions accompanying Figures 14-17). In 2012 the wood shingle roof installed during the 1968-69 rehab was replaced with a standing seam metal roof.

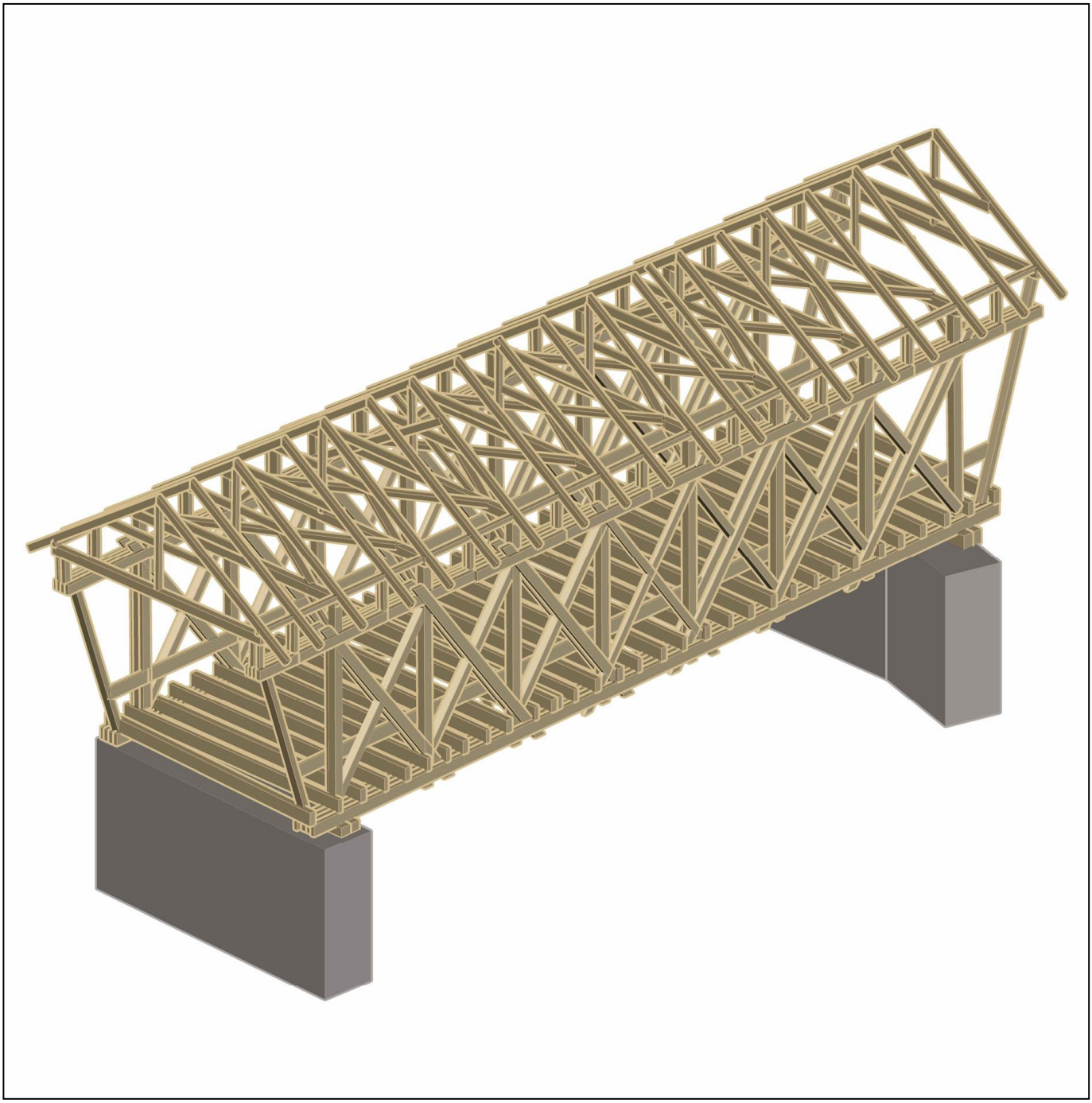


FIGURE 1: Bement Bridge, Isometric scale drawing from 3D laser field scanning August 2016, showing framing arrangement. The patented Long Truss design utilized paired posts, paired diagonal braces with single counter-brace running between the braces, and three-part top and bottom chords. The Bement bridge consists of single posts, single diagonal braces running between double counter-braces, and four-part top and bottom chords. Most importantly, the Long Truss utilized wedge blocks inserted at the top of the counterbraces and driven to pre-stress the truss, a core claim of the patent and a feature missing from the Bement Bridge (Illustration by Doucet Survey, Inc. for Hoyle Tanner Associates 2016).

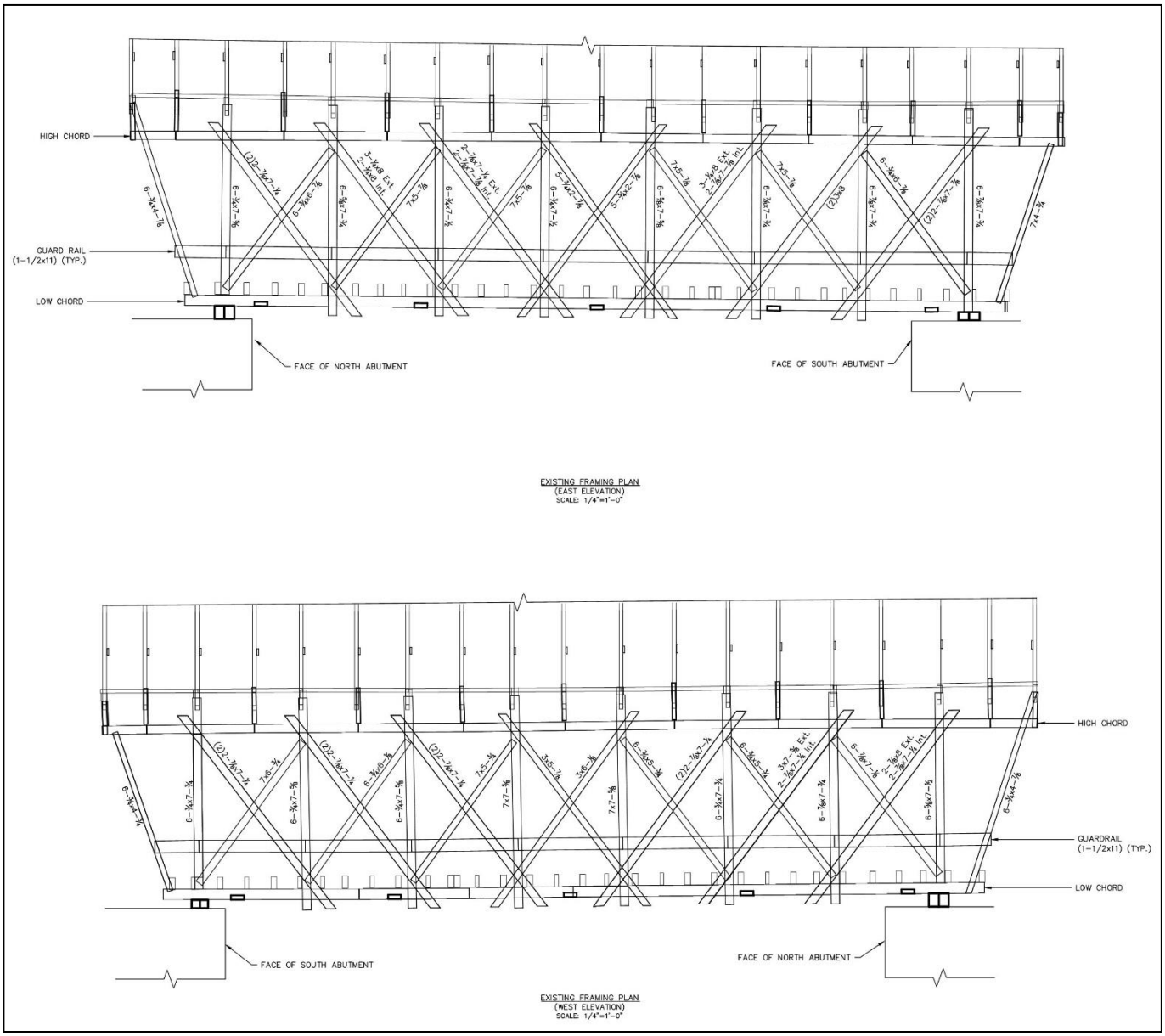


FIGURE 2: Bement Bridge, current conditions scale drawing from 3D laser field scanning August 2016, showing east and west truss vertical and diagonal members. Note shorter single diagonal braces wedged into notches in vertical posts and longer paired diagonal counter-braces extending beyond and joined to the top and bottom chords (Doucet Survey, Inc. for Hoyle Tanner Associates 2016).

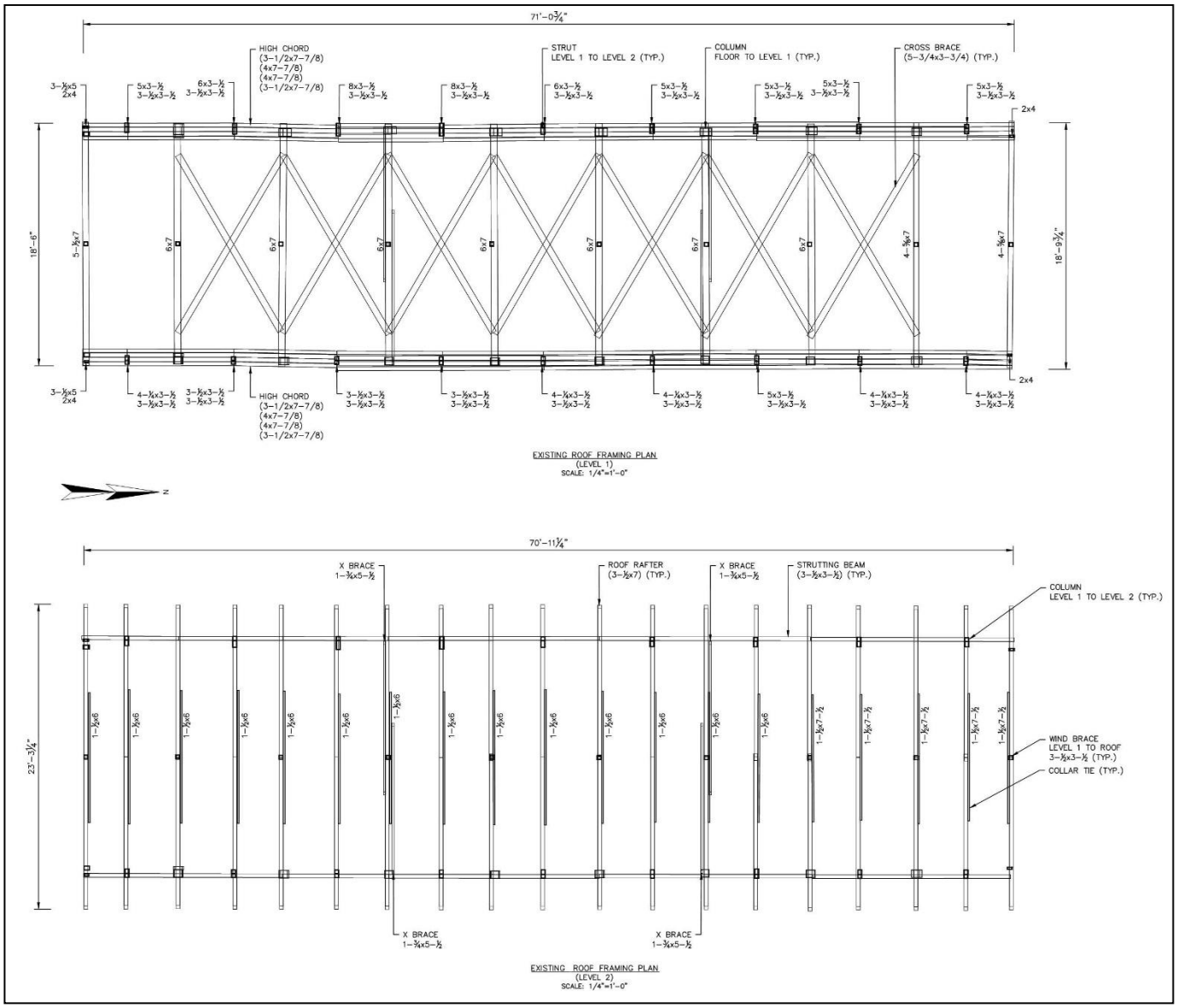


FIGURE 3: Bement Bridge, current conditions scale drawing from 3D laser field scanning August 2016, showing upper chord members, cross beams and lateral cross-bracing (top figure) and roof framing (bottom figure) showing rafters, collar ties and wind bracing (Doucet Survey, Inc. for Hoyle Tanner Associates 2016).

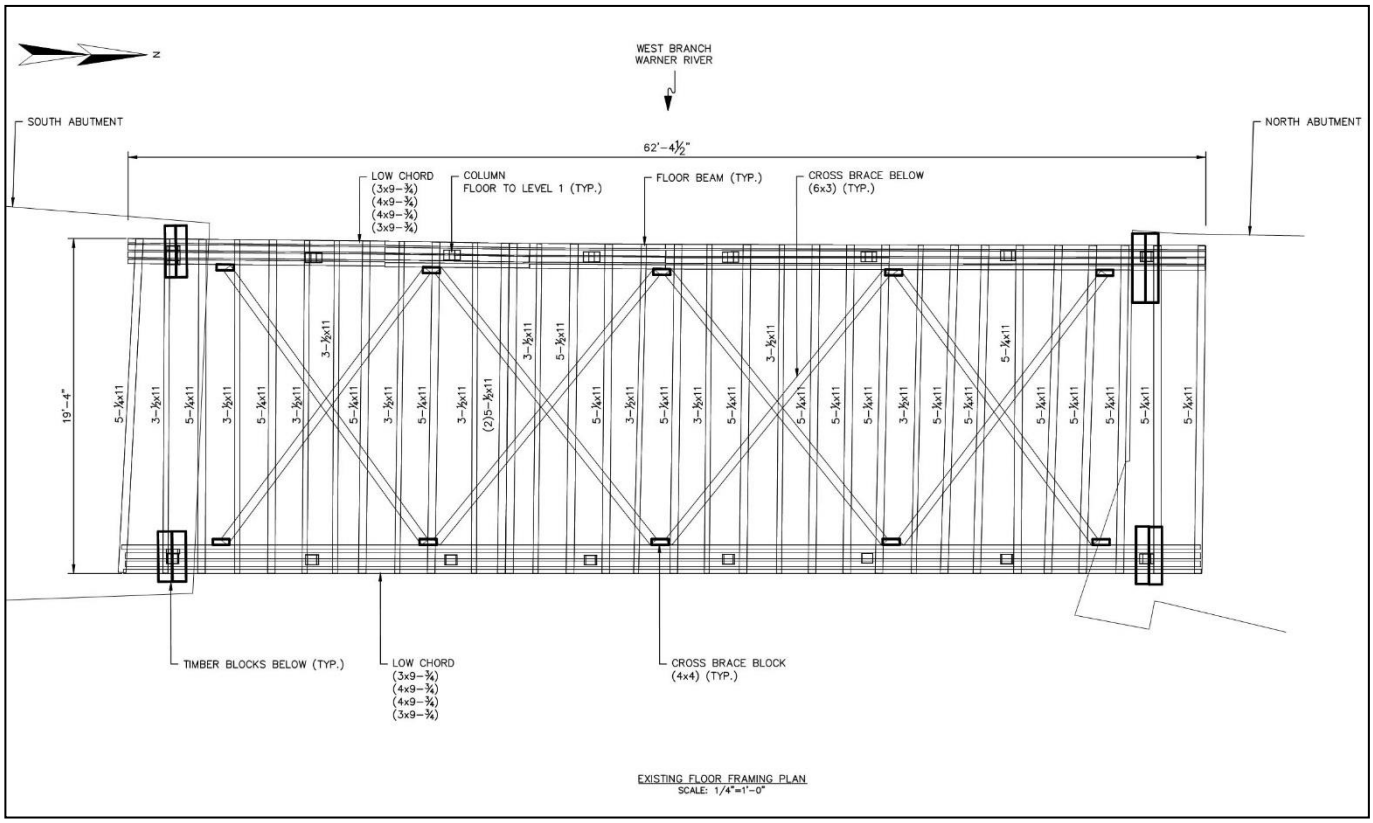


FIGURE 4: Bement Bridge, current conditions scale drawing from 3D laser field scanning August 2016, showing lower chord members, floor beams and lower lateral cross-bracing (Doucet Survey, Inc. for Hoyle Tanner Associates 2016).

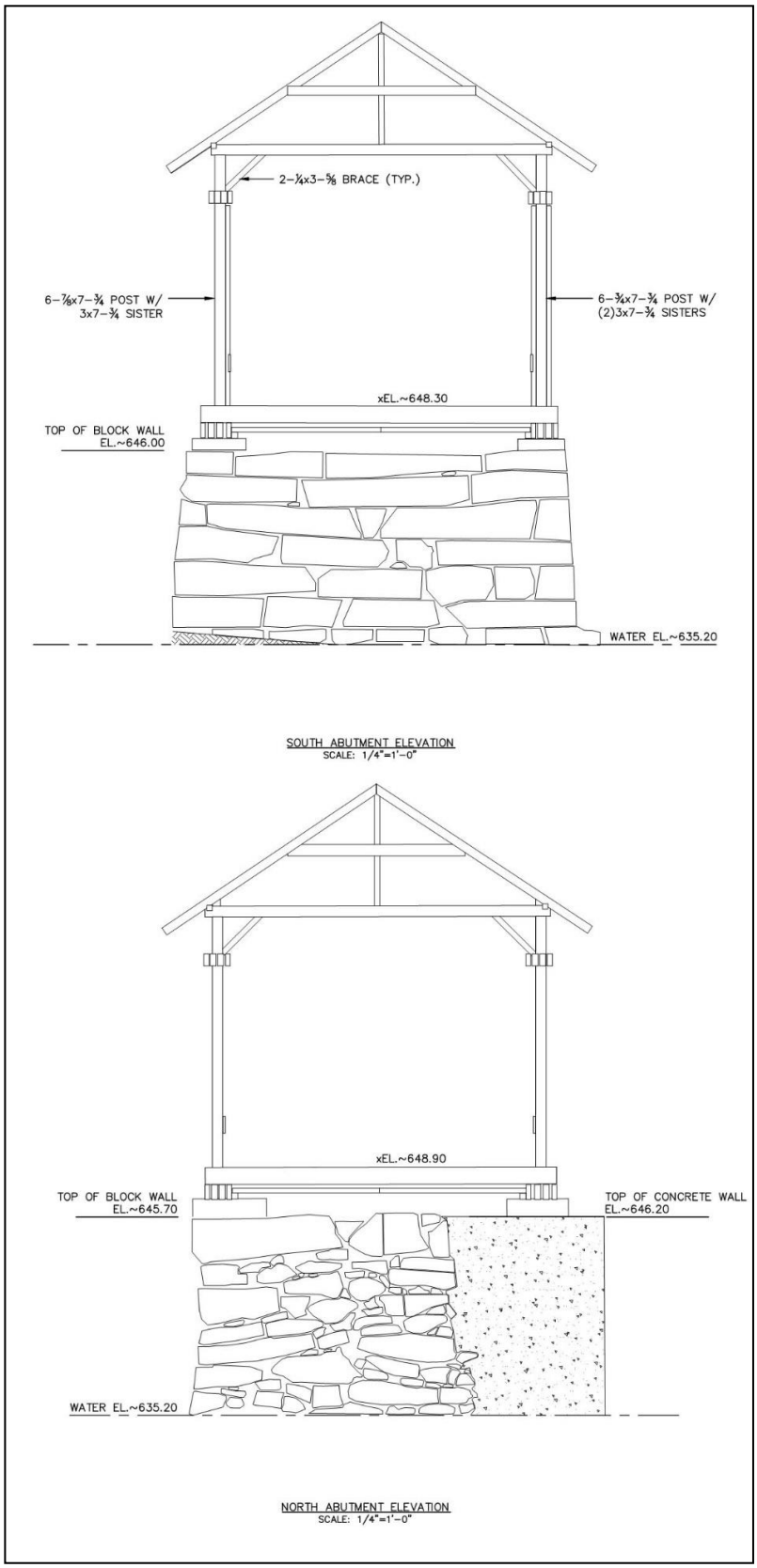


FIGURE 5: Bement Bridge, current conditions scale drawing from 3D laser field scanning August 2016, showing south and north abutments and section through respective portal framing. Note differences in stonework of abutments: the south abutment is assumed to be a later replacement; the north abutment is of more primitive construction with a large concrete repair made between 1939 and 1942 (Doucet Survey, Inc. for Hoyle Tanner Associates 2016)

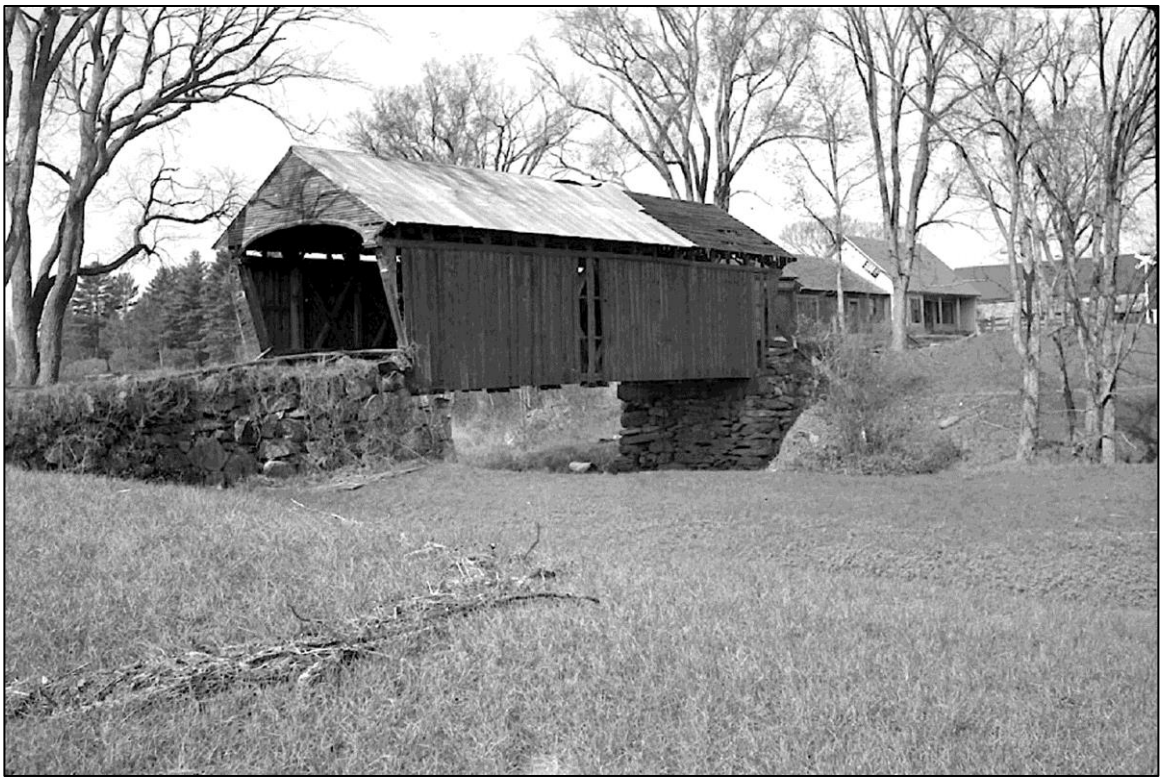


FIGURE 6: Bement Bridge, south portal and downstream (east) side, 1939, showing damage evidently from 1938 hurricane & flood. Note existing concrete repair to north abutment not present (source: Town of Bradford).

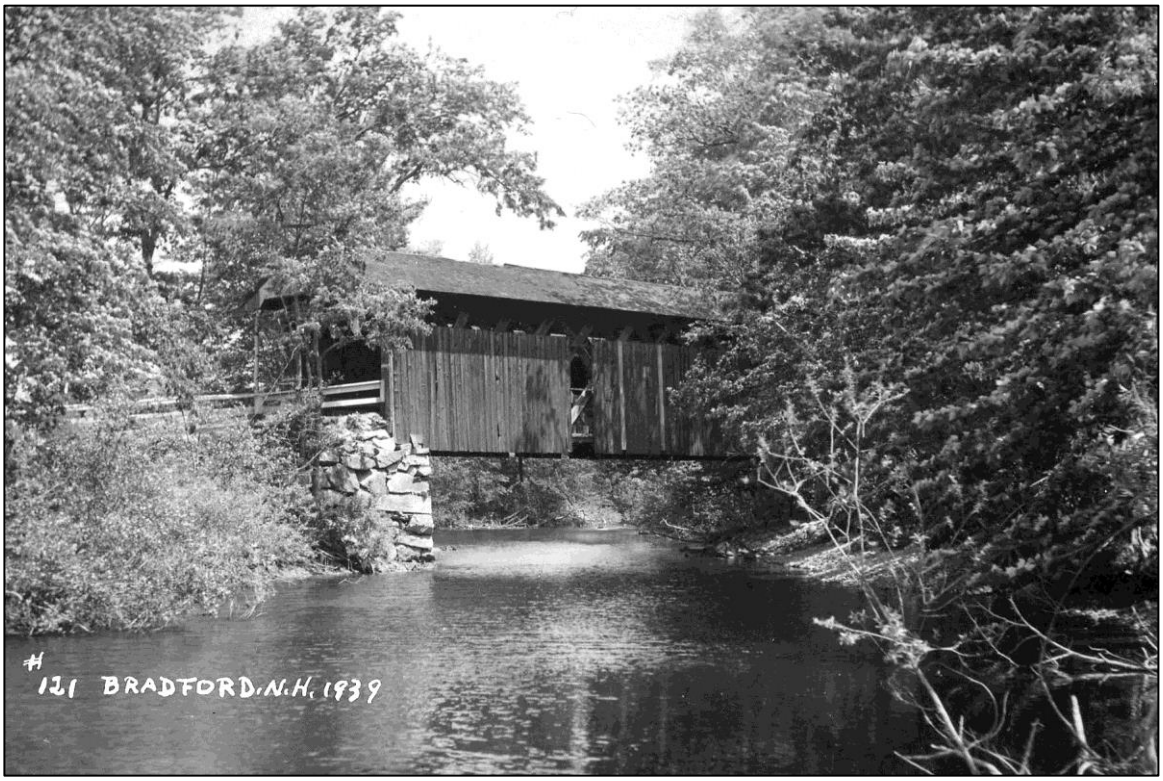


FIGURE 7: Bement Bridge, north end and upstream (west) side, 1939 (source: Town of Bradford).

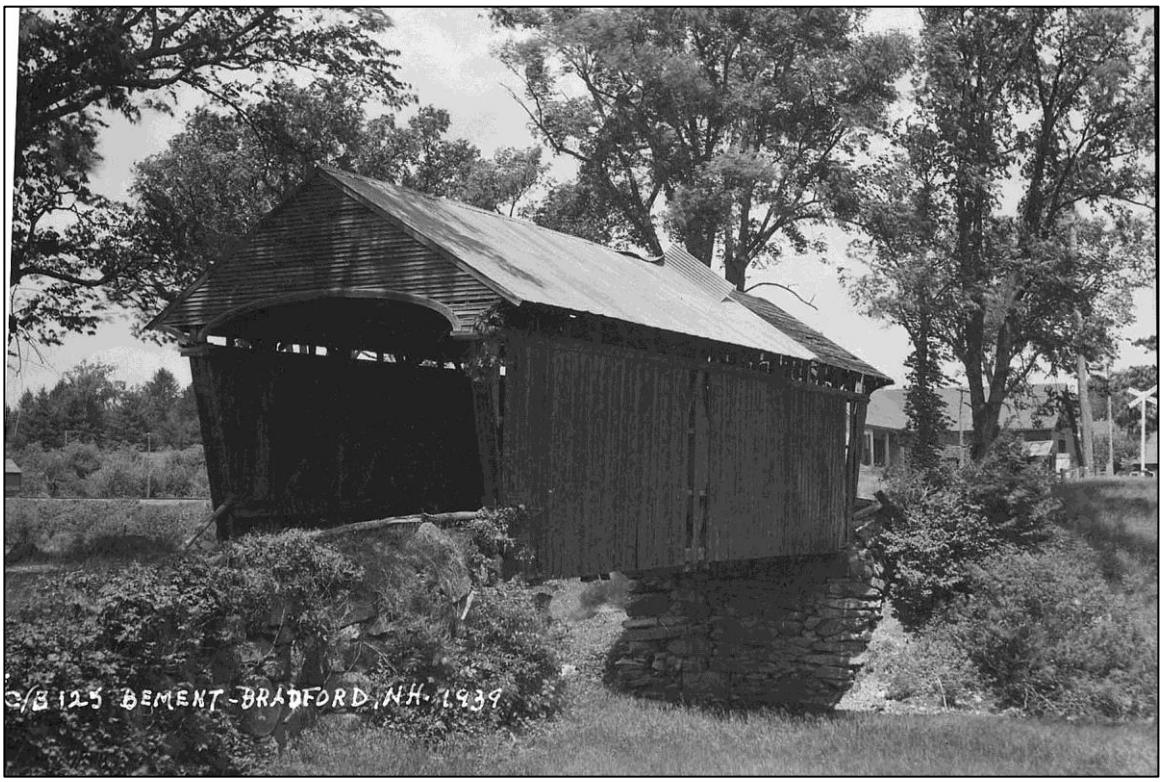


FIGURE 8: Bement Bridge, south portal and downstream (east) side, 1939, showing original elliptical arch shaped portal opening (source: Town of Bradford).

FIGURE 9: Bement Bridge, interior, looking out north portal, 1939. Note roofing missing and also former Boston & Maine Railroad right-of-way crossing Center Road just north of the bridge, now occupied by NH Route 103 (source: Town of Bradford).

FIGURE 10: Bement Bridge, south portal and downstream (east) side, 1942, showing north abutment repaired with cast-in-place concrete, repairs to wood siding and to corrugated sheet metal roof (NHHD Bridge Inventory Card 5/20/1942).

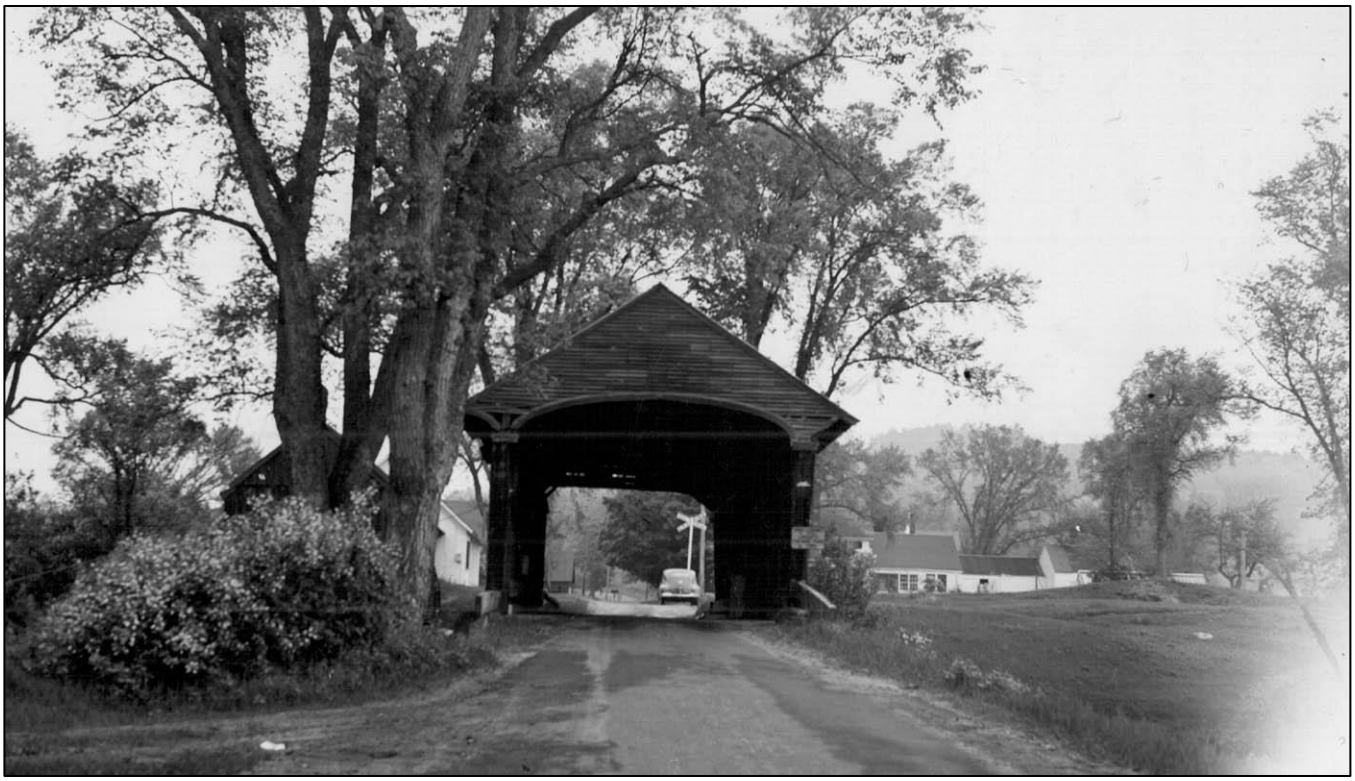


FIGURE 11: Bement Bridge, approach to south portal, 1942, showing original arched portal opening (NHHD Bridge Inventory Card 5/20/1942).

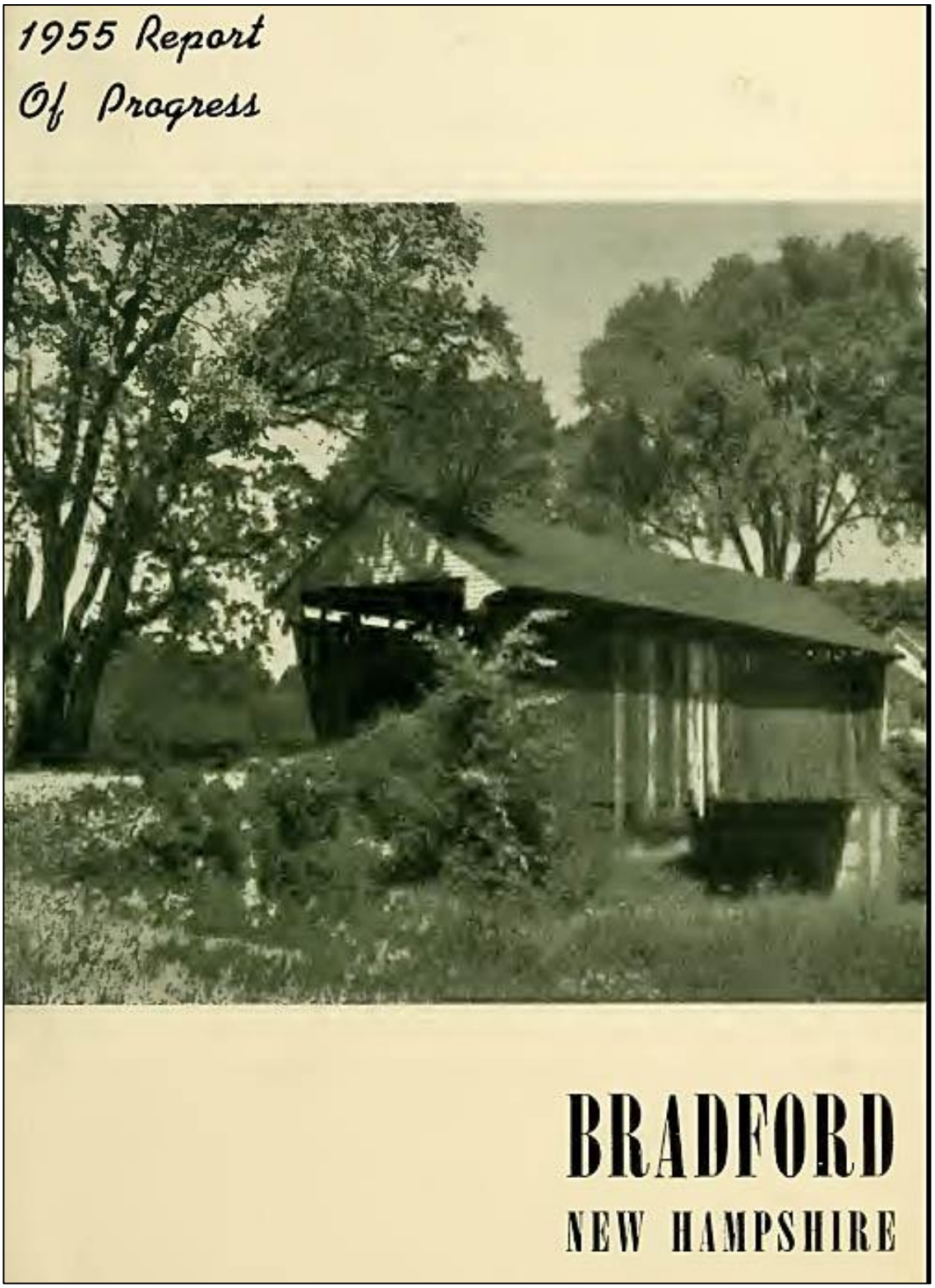


FIGURE 12: Bement Bridge on cover of Bradford Annual Report for year ending 1955 showing south portal and downstream (east) side. Note prior corrugated metal roofing replaced with asphalt shingles and portal rebuilt with it present squared opening. The work was done by the Town under the general bridge maintenance account in 1954. Photo is credited to Don Sieburg, New Hampshire State Planning & Development Commission.

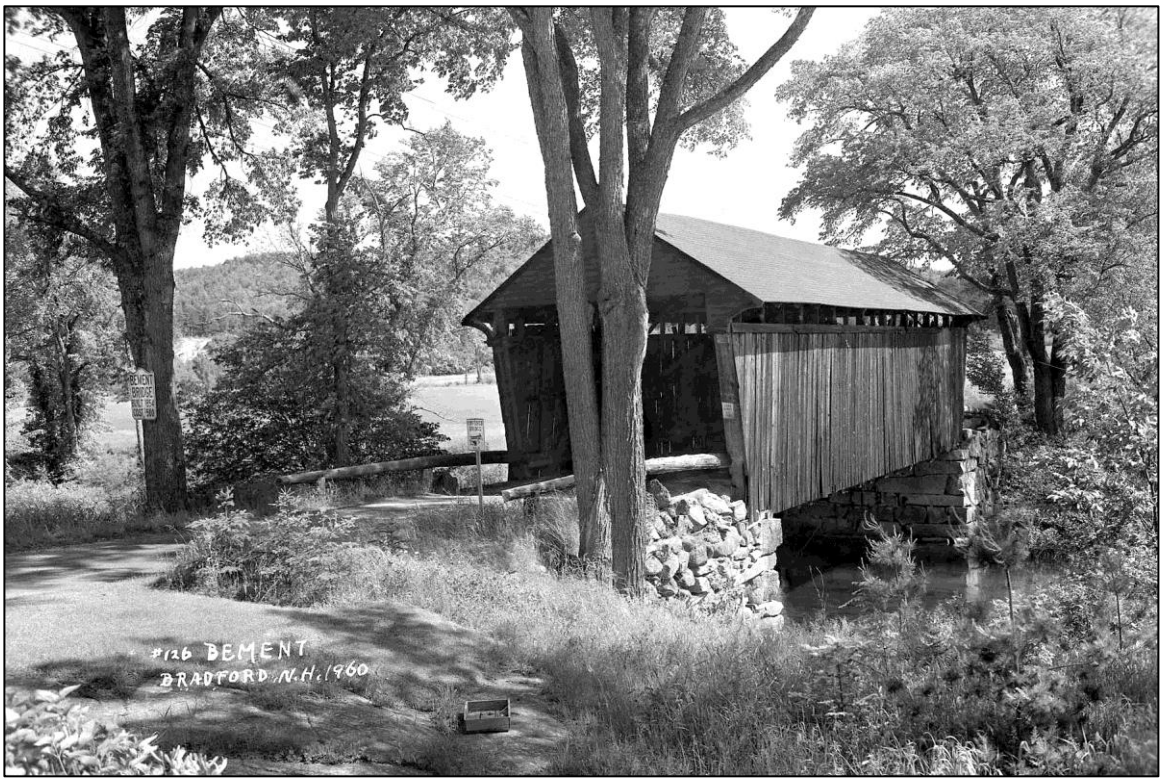


FIGURE 13: Bement Bridge, north portal and upstream side in 1960, showing new asphalt roof and alteration of portal made in 1954 (source: Town of Bradford).

FIGURE 14: In 1968 the Town of Bradford determined Bement Bridge to be unsafe, confirmed by an inspection by bridge engineers from the state highway department. The state agreed to pay two-thirds of the rehab costs and provide their expert covered bridge repair team out of New Hampton to do the work. The project got underway late in 1968, continued through the winter and wrapped up in May 1969 (source: Whitney 1971, p. 18).

FIGURE 15: The State Highway Department's crack covered bridge team shown at work in winter 1968, included Superintendent Eugene "Slim" Philbrick, Foreman Melvin Garland, and worker/carpenters Norman Bishop, Henry Eastman, Armand Riel, Emery Rule and Ralph Thoroughgood (source: Whitney 1971, p. 18).

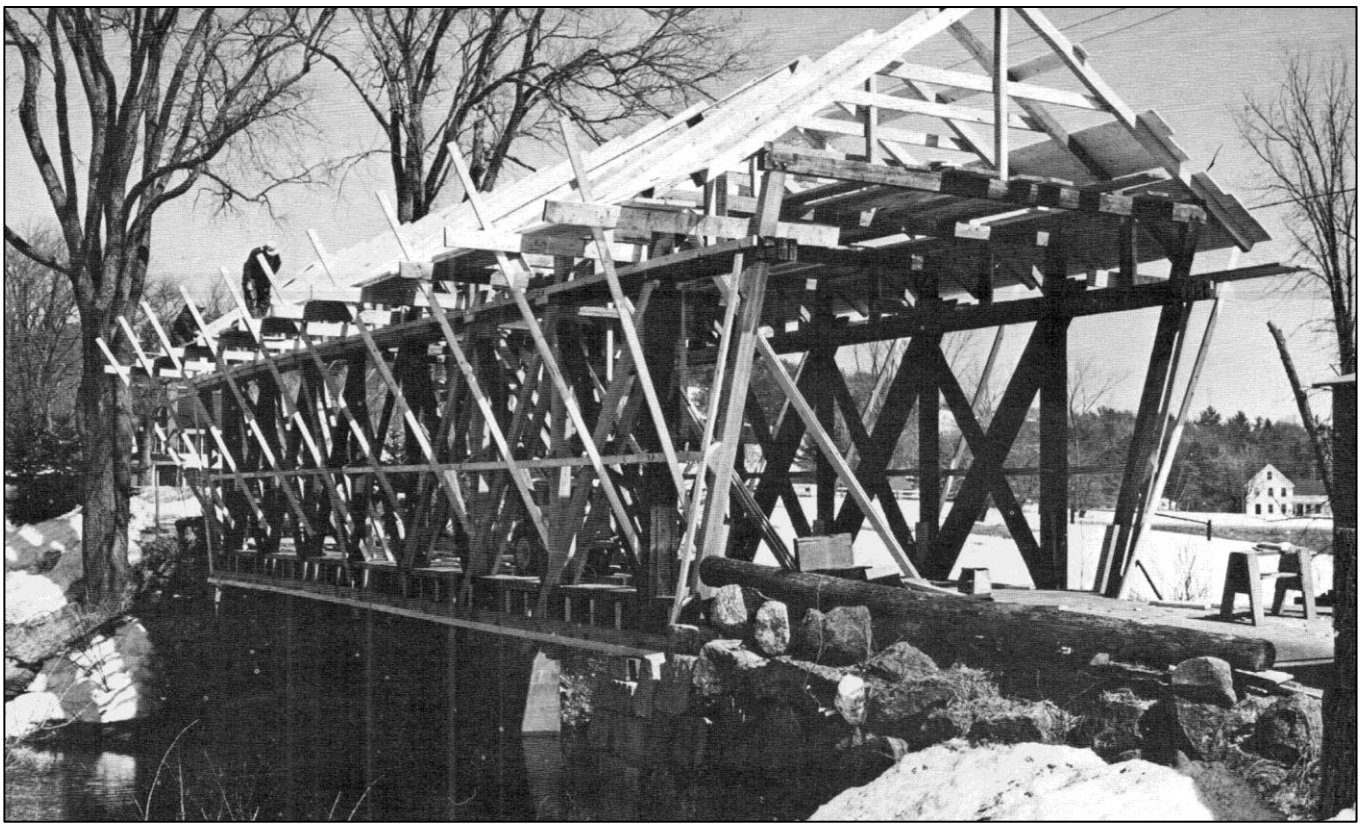


FIGURE 16: The 1968-69 repairs included a new roof system and replacement of many structural members but an exact report of the work done was not located. The total cost of the work as reported in the Town Annual Report for 1969 was $24,478.14, of which the town's share was $8,159.38 (source: Whitney 1971, p. 18).

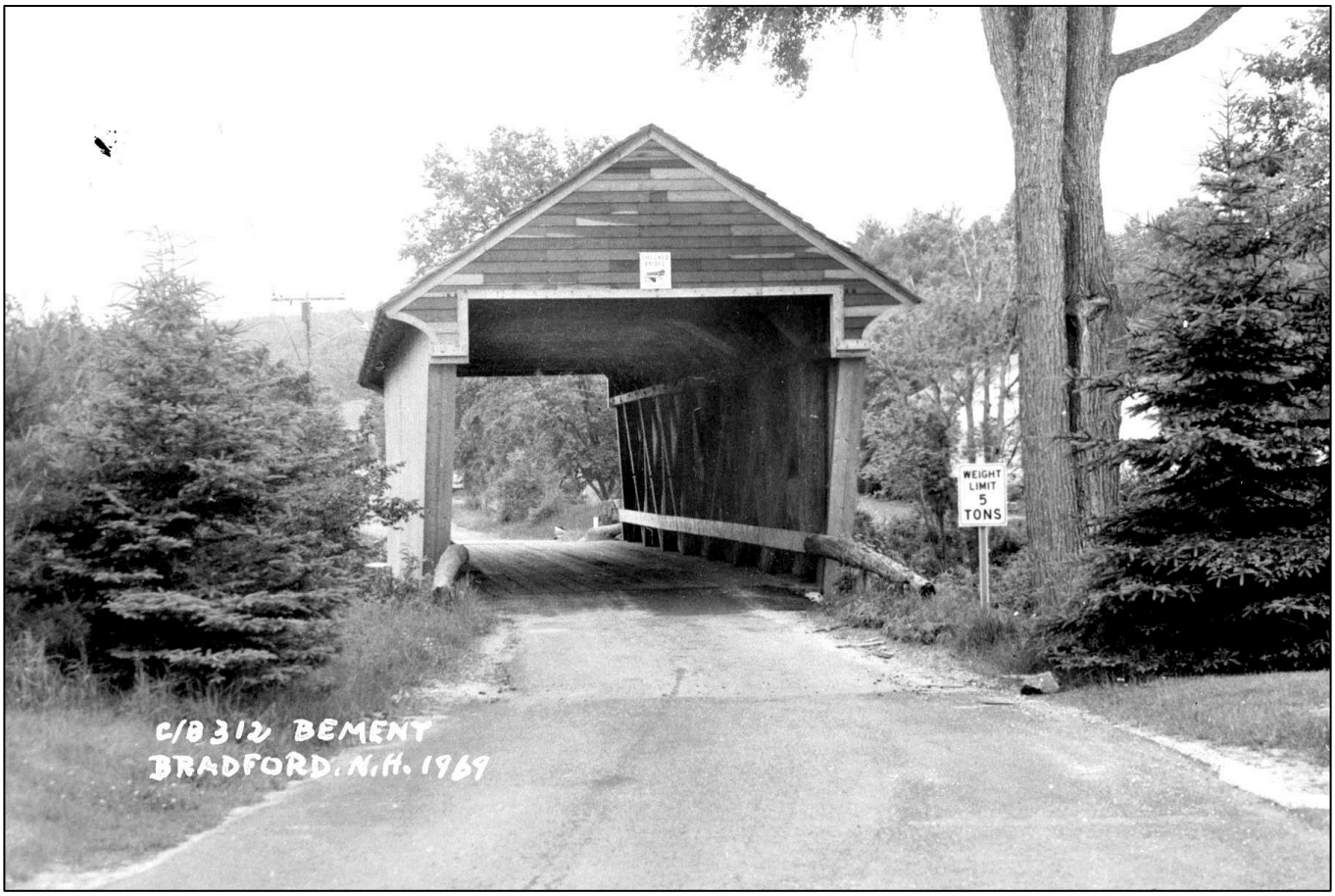


FIGURE 17: The north portal in 1969 after completion of repairs by the State Highway Department. Note what appears to be all new siding visible on the east (downstream) side. Also note use of recycled clapboards on the portal wall evidently dating from the 1954 rehab by the Town. A few new clapboards can be seen patched in (source: Town of Bradford).

3.0- BRIDGE FEATURE TREATMENTS

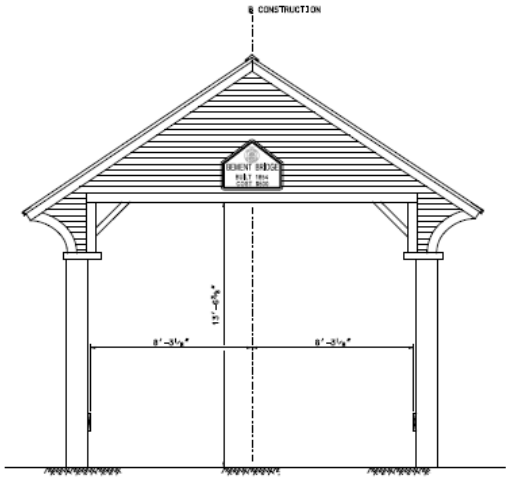
3.1 Portal			
Date(s):	1969	**Source:**	Town records & other records of repairs, 1968-1969.
Description:	Portal consists of wood framing and siding that encloses the gable ends of the bridge to a point equal or below the height of the overhead cross ties to establish the vertical clearance and keep out weather.		
Condition:	The portal siding is generally in fair to good condition but exhibiting severe weathering and splitting particularly on the south portal.		
Describe Work:	Replace opening framing, siding and trim of both portals in-kind as needed (see Plan Sheet 7 – Existing and Proposed Portal Elevations, shown in part below). Rebuild portal opening shape to original arched opening shown in historic photos (see Figures 6, 8-11).		
Project Need:	Present siding and trim near end of service life; bridge owner seeks to restore portals to original appearance.		
Impacts:	Work complies with Secretary's Standards for Rehabilitation, *Design for the Replacement of Missing Historic Features*. Materials to be replaced are not original to bridge; replacement materials and features based on historic photos.		

South Portal

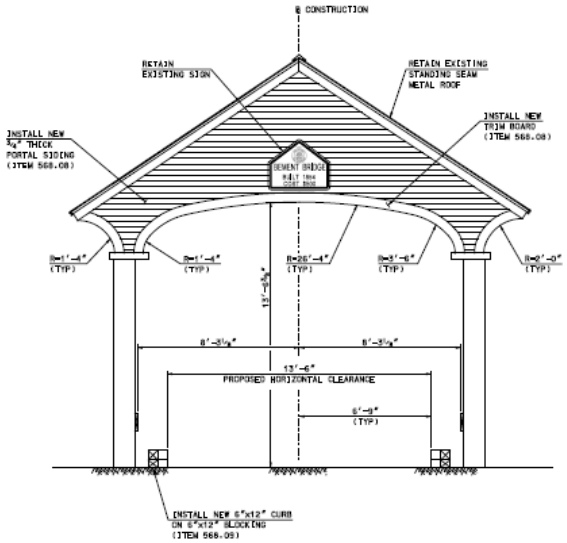
North Portal

South Portal detail


North Portal inside



EXISTING PORTAL ELEVATION
(SOUTH PORTAL SHOWN, NORTH PORTAL SIMILAR)
(LOOKING NORTH)
SCALE: 3/8" = 1'-0"



PROPOSED PORTAL ELEVATION
(SOUTH PORTAL SHOWN, NORTH PORTAL SIMILAR)
(LOOKING NORTH)
SCALE: 3/8" = 1'-0"

Plan Reference: Sheet 7	Existing and Proposed Portal Elevations

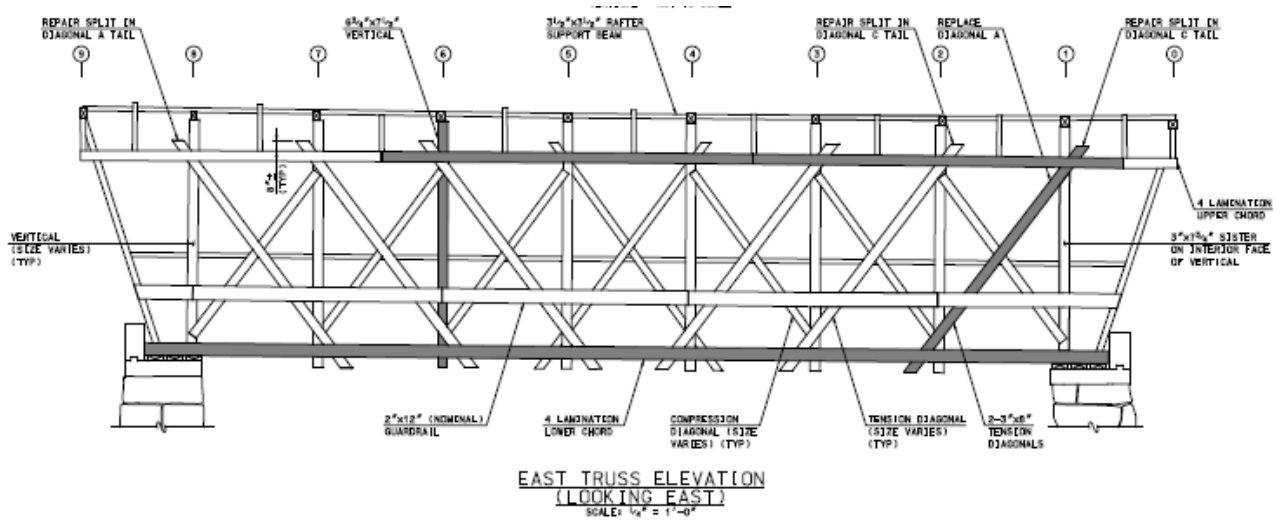
3.2 Truss Vertical Members (Posts)			
Date(s):	1854, 1947?, 1968-9?	**Source:**	Town records & other records of repairs, 1947, 1968-1969. Exact date of specific members has not been ascertained.
Description:	Vertical members (posts) typically measure 6-¾" x 7-¾" in cross section and roughly 16' long, with tails extending about 2' above the upper chord and 1' below the lower chord. Posts are mortice joined to the chords and intersecting cross members.		
Condition:	One post identified during inspection has a broken lower tail. Chord replacement during rehabilitation (see Feature 3.4, 3.5) may reveal additional posts with structural deficiencies.		
Describe Work:	Bridge will be jacked and braced during rehabilitation as required to straighten, release stresses, plumb and re-align the trusses. Special care shall be taken to avoid damage to members that are to remain and to avoid movement of the truss that could result in distortion or misalignment of the truss and its joints. All joints in replaced members shall match the existing joint, including all nails, bolts or screws required unless noted otherwise. Vertical members shown to be replaced are to be replaced "in-kind" with new members identical in dimensions and configurations as the members originally used in the bridge (see Plan Sheet 30 - East Truss Plan and Elevation, shown in part below, and Plan Sheet 31 - West Truss Plan and Elevation).		
Project Need:	Posts are primary structural members of the truss and critical to the structural integrity of the bridge. Tails of post members assist in holding the chords in place vertically; local collapse of the floor is possible if lower tails are broken. The member to be replaced does not possess the required structural integrity.		
Impacts:	One of sixteen posts is specified for replacement (~ 6% of the total). Member to be replaced will be replaced "in-kind" with wood members of the same size and workmanship based on field measurements upon removal of damaged member. Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features*.		

Oblique view of west truss with eight posts

Rectified view of posts of west truss, north end

Post w/ broken tail at Node 6 to be replaced.

Critical lower chord splice joints adjacent to Node 6 post.

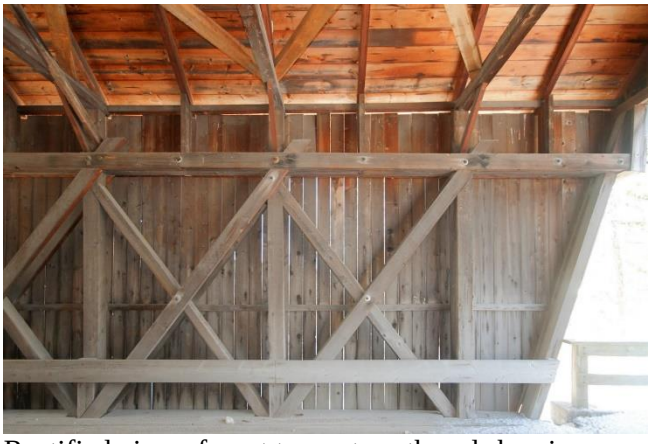


EAST TRUSS ELEVATION
(LOOKING EAST)
SCALE: 1/4" = 1'-0"

Plan Reference: Sheet 30	One post (shaded) on East Truss at Node 6 to be replaced.

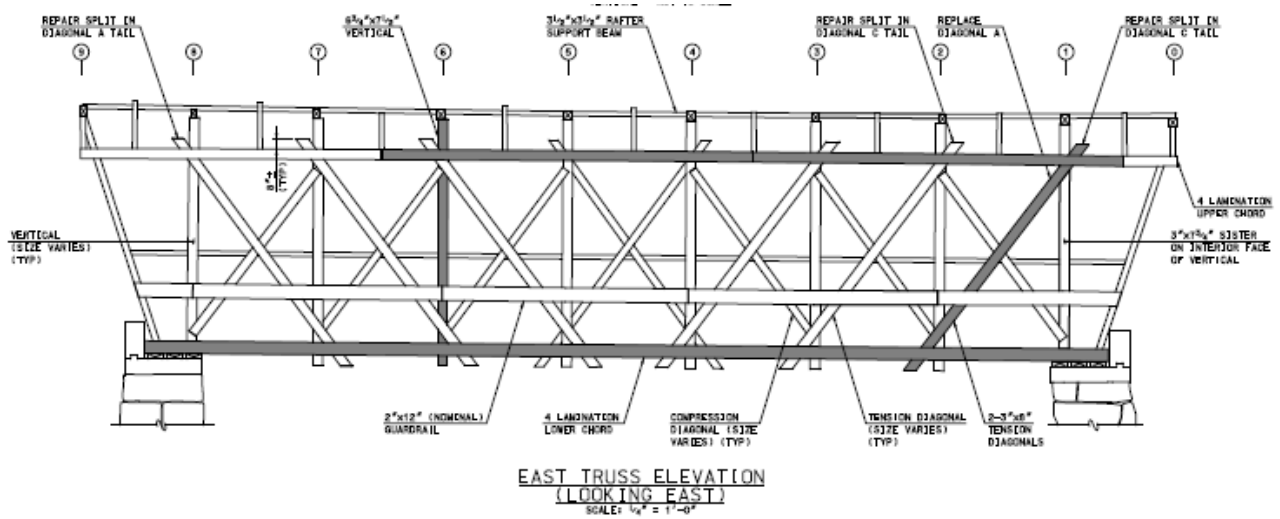
3.3 Truss Diagonal Members (Braces & Counter Braces)			
Date(s):	1854, 1947?, 1968-9?	**Source:**	Town records & other records of repairs, 1947, 1968-1969. Exact date of specific members has not been ascertained.
Description:	Two types of diagonals are present within the truss, compression diagonals known as braces and tension diagonals known as counter-braces. Brace diagonals are single members and measure 6-¾" x 6-$^{7}/_{8}$" or 7-0" x 5-$^{7}/_{8}$". Counter-brace diagonals are double members and measure 2-$^{7}/_{8}$" x 7-¼", 3-¼" x 8-0", and 2-$^{7}/_{8}$" x 5-$^{7}/_{8}$" with minor variations. Braces are morticed into the posts; counter braces are bolted to the outside of the posts and morticed into the top and bottom chords with tails extending beyond the chords.		
Condition:	One counter-diagonal identified during inspection has a broken lower tail.		
Describe Work:	Bridge will be jacked and braced during rehabilitation as required to straighten, release stresses, plumb and re-align the trusses. Special care shall be taken to avoid damage to members that are to remain and to avoid movement of the truss that could result in distortion or misalignment of the truss and its joints. All joints in replaced members shall match the existing joint, including all nails, bolts or screws required unless noted otherwise. Diagonal members shown to be replaced are to be replaced "in-kind" with new members identical in dimensions and configurations as the members originally used in the bridge (see Plan Sheet 30 - East Truss Plan and Elevation, shown in part below, and Plan Sheet 31 - West Truss Plan and Elevation).		
Project Need:	Diagonals are primary structural members of the truss critical to the structural integrity of the bridge. Tails of the counter braces assist in joining the diagonals to the chords and distributing loads to other truss members. Distortion or collapse of the truss is possible if counter-brace tails are broken. The member to be replaced does not possess the required structural integrity.		
Impacts:	One of the sixteen counter diagonals is specified for replacement (~ 3% of the total diagonals). Member to be replaced will be replaced "in-kind" with wood members of the same size and workmanship based on field measurements upon removal of damaged member. Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features*.		

Oblique view of west truss showing braces and counter braces in X between posts.



Rectified view of west truss at north end showing braces and counter braces between posts.

 Counter brace with w/ structural split at Node 1 to be replaced.	 Detail of brace between double counter brace and tails extending above upper chord.



EAST TRUSS ELEVATION
(LOOKING EAST)
SCALE: 1/4" = 1'-0"

Plan Reference: Sheet 30	One counter diagonal (shaded) on East Truss at Node 1 to be replaced.

3.4 Upper Chord Members

Date(s):	1854, 1968-9?	**Source:**	Town records & other records of repairs, 1968-1969. Physical and photographic evidence suggest member has been replaced in part at various times.

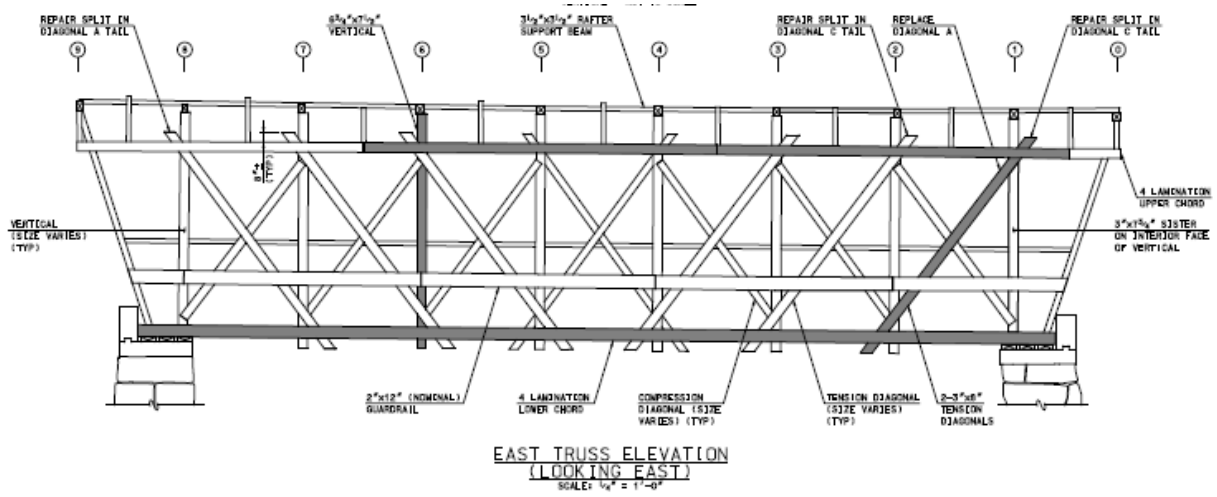
Description:	Upper chords are laminated assemblies consisting of four members, the two interior measuring 4-0" x 7-$^{7}/_{8}$" and the two exterior measuring 3-½" x 7-$^{7}/_{8}$". The members are joined to one another with bolts and mortised shear blocks that provide an air gap, and joined to posts and diagonals with morticed joints, tree nails and bolts. Some bolts may be original and others added later for reinforcement.
Condition:	Identified members have splits at the connection to the vertical and diagonals. Due to the built-up laminated construction of the upper chord, it is impossible to inspect all sections of the chord members without disassembly. Additional structural deficiencies may be discovered during rehabilitation.
Describe Work:	Bridge will be jacked and braced during rehabilitation as required to straighten, release stresses, plumb and re-align the trusses. Special care shall be taken to avoid damage to members that are to remain and to avoid movement of the truss that could result in distortion or misalignment of the truss and its joints. All joints in replaced members shall match the existing joint, including all nails, bolts or screws required unless noted otherwise. Members shown to be replaced are to be replaced "in-kind" with new members identical in dimensions and configurations as the members originally used in the bridge (see Plan Sheet 30 - East Truss Plan and Elevation, and Plan Sheet 31 - West Truss Plan and Elevation, with Upper Chord Plan details, shown in part below,
Project Need:	The chords are primary structural members of the truss that carry the live and dead loads. The members to be replaced do not possess the required structural integrity.
Impacts:	Approximately 10 percent of the total number of upper chord members require replacement. Member to be replaced will be replaced "in-kind" with wood members of the same size and workmanship based on field measurements upon removal of damaged member. Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features*.

Front view of upper chord showing thru-bolted connections to posts and diagonals.

Underside view of upper chord showing 4 laminated beam assembly, shear block, end splice, spacing and thru-bolt.

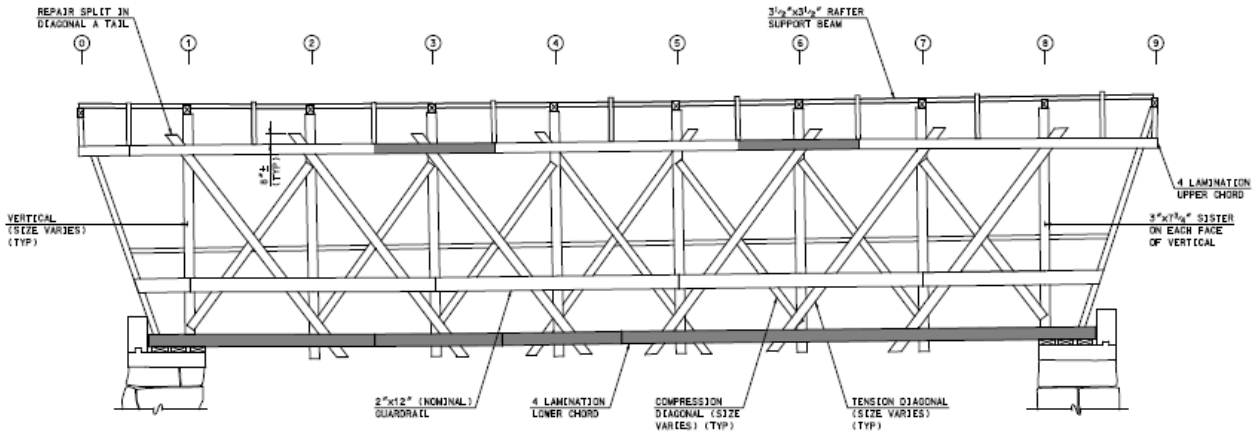
Crack in upper chord at Node 3. Note added vertical thru bolt reinforcement.

Crack and deterioration in upper chord at Node 6.



EAST TRUSS ELEVATION
(LOOKING EAST)
SCALE: ¼" = 1'-0"

Plan Reference: Sheet 30	Approximately 48' out of 272' of chord member (shaded) on East Truss to be replaced.



WEST TRUSS ELEVATION
(LOOKING WEST)
SCALE: ¼" = 1'-0"

Plan Reference: Sheet 31	Approximately 16' out of 272' of chord member (shaded) on West Truss to be replaced.

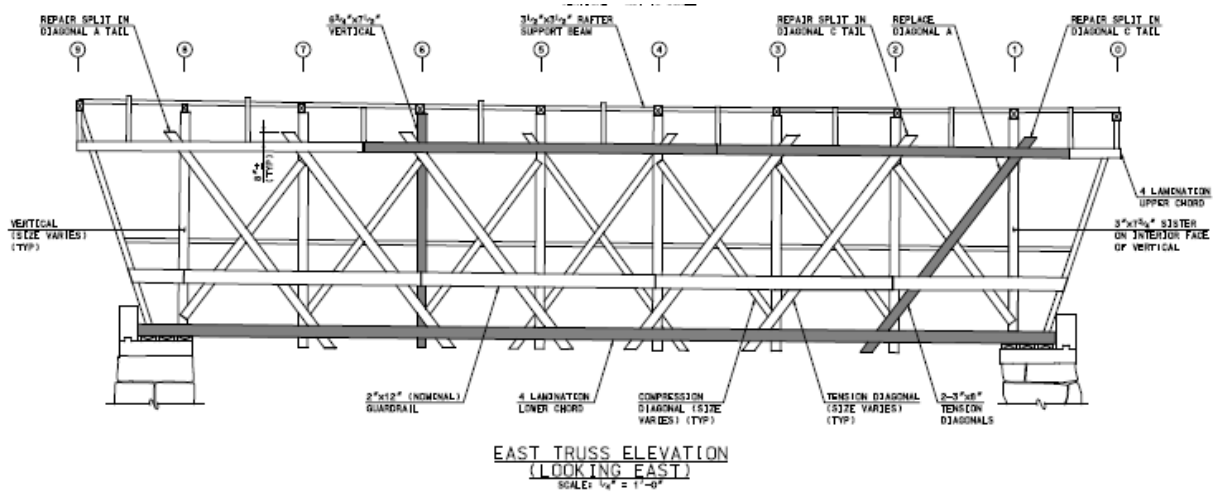
3.5 Lower Chord Members

Date(s):	1947; 1968-9	**Source:**	NHHD records; Town records & other records of repairs, 1968-1969.

Description:	Lower chords are laminated assemblies like the upper chords consisting of four members, the two interior measuring 4-0" x 9-¾" and the two exterior measuring 3-0" x 9-¾". The members are joined to one another with bolts and mortised shear blocks that provide an air gap, and joined to posts and diagonals with morticed joints, tree nails and bolts. Some bolts may be original and others added later for reinforcement.
Condition:	The entire bottom chord was replaced in 1947 by the NH Highway Department and replaced again during the 1968-1969 rehabilitation. Several pressure treated members are incorporated into the chord. Based on experience with similar structures and our structural analysis, the joint configuration of the lower chord is not structurally adequate to support the design loading. This chord is in tension which means that at joint locations the force in the chord ply leaf must be transferred between adjacent members using bolts and shear blocks. Typically, these joints are staggered since multiple rows of connection hardware are required to transfer member forces. In this bridge, two of the four ply leaves have joints at the same location and a third ply leaf joint is located one panel away. This configuration greatly reduces the capacity of the chord as the strength of the chord is controlled by the connection hardware and not the large timber member. Due to the built-up laminated construction of the upper chord, it is impossible to inspect all sections of the chord members without disassembly. Additional structural deficiencies may be discovered during rehabilitation.
Describe Work:	Bridge will be jacked and braced during rehabilitation as required to straighten, release stresses, plumb and re-align the trusses. Special care shall be taken to avoid damage to members that are to remain and to avoid movement of the truss that could result in distortion or misalignment of the truss and its joints. All joints in replaced members shall match the existing joint, including all nails, bolts or screws required unless noted otherwise. Members shown to be replaced are to be replaced “in-kind” with new members identical in dimensions and configurations as the members originally used in the bridge (see Plan Sheet 30 - East Truss Plan and Elevation, and Plan Sheet 31 - West Truss Plan and Elevation, with Upper Chord Plan details, shown in part below,
Project Need:	The chords are primary structural members of the truss that carry the live and dead loads. The lower chord as constructed does not possess the required structural capacity.
Impacts:	A complete replacement of the non-original lower chord is required. Member to be replaced will be replaced "in-kind" with wood members of the same size and workmanship but with less joints and longer members like what would have been originally used. Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features*.

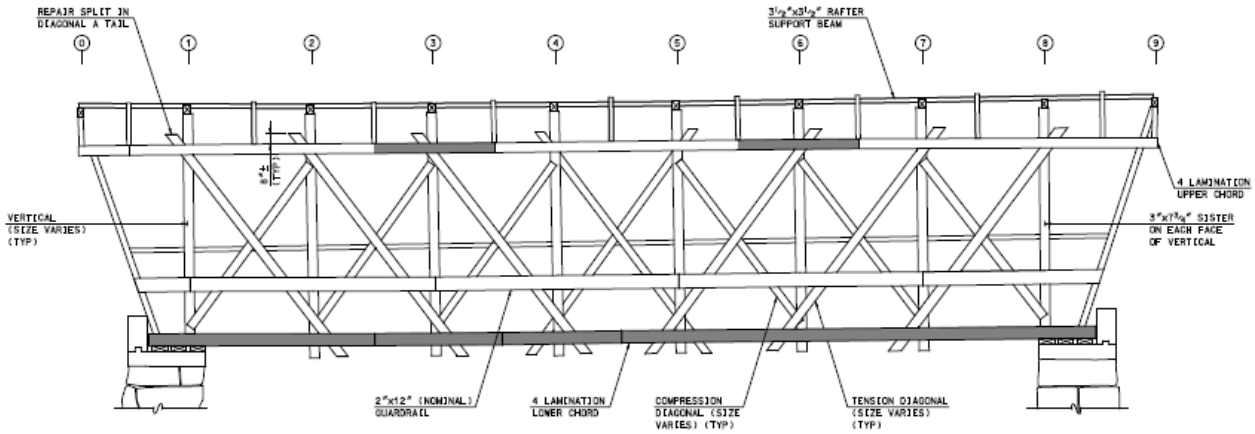
Lower chord showing tails of post and diagonals morticed between laminations joined with thru-bolting.

Lower chord showing two adjacent ply splices and shear blocks.



EAST TRUSS ELEVATION
(LOOKING EAST)
SCALE: ⅛" = 1'-0"

Plan Reference: Sheet 30	Entire lower chord member (shaded) on East Truss to be replaced.



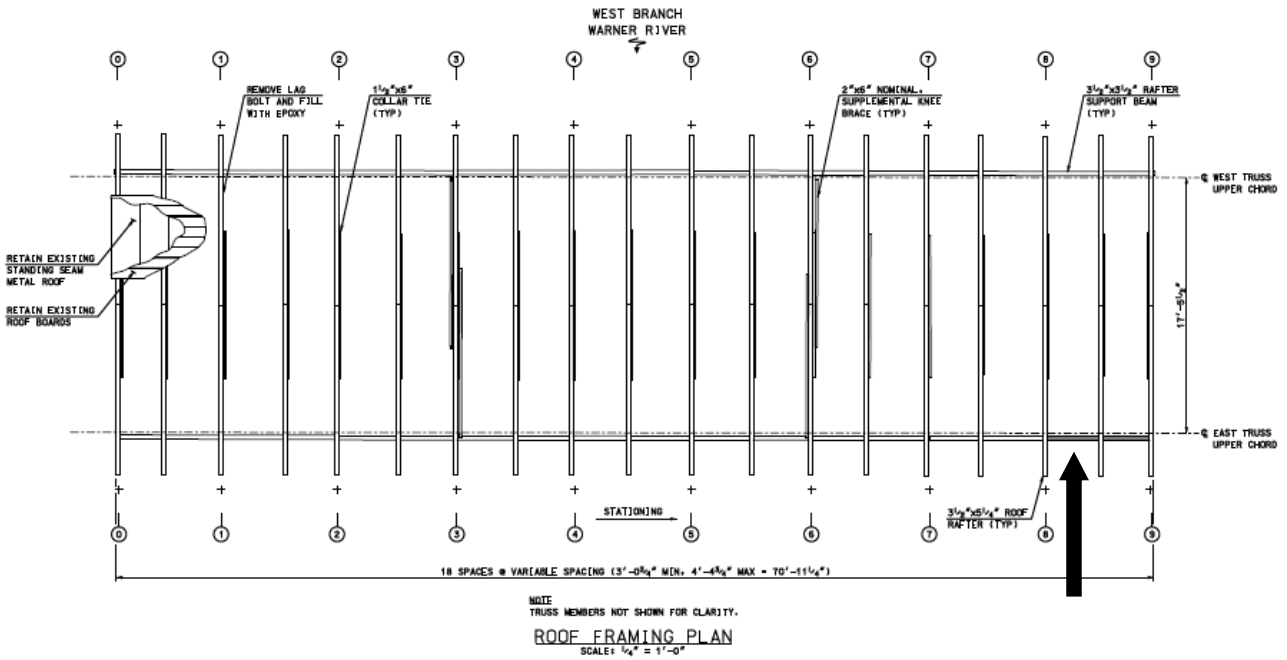
WEST TRUSS ELEVATION
(LOOKING WEST)
SCALE: ⅛" = 1'-0"

Plan Reference: Sheet 31	Entire lower chord member (shaded) on West Truss to be replaced.

3.6 Rafter Support Beams			
Date(s):	1968-9	**Source:**	Town records & other records of repairs, 1968-1969.
Description:	The rafter support beam is a single solid member measuring 3-½" x 3-½" x 71' long that was retrofitted during the 1968-69 replacement of the entire roof framing assembly. The beam was apparently added to simply new rafter alignment and framing by providing a continuous straight horizontal member to which the rafter could be seated with a conventional "bird-mouth" notch and nails.		
Condition:	Identified members have splits, checks and distortion along the length of the member,		
Describe Work:	Temporarily support the roof rafters that bear on the rafter support beam. All joints in replaced members shall match the existing joint, including all nails, bolts or screws required unless noted otherwise. Members shown to be replaced are to be replaced “in-kind” with new members identical in dimensions and configurations as the members originally used in the bridge (see Plan Sheet 28 – Roof Framing Plan and Details, shown in part below,		
Project Need:	The rafter support beams transfer the load carried by the roof rafters into the truss. Failure of the rafter support beam can cause a partial collapse of the roof.		
Impacts:	Approximately 5 percent of the total length of rafter support beam require replacement. Member to be replaced will be replaced "in-kind" with wood members of the same size and workmanship based on field measurements upon removal of damaged member. Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features*.		

Rafter support beam carried on end of crossbeams and jack posts, not an original feature.

Detail of split in rafter support beams at Node 8.



Plan Reference: Sheet 28	Approximately 8' out of 142' of rafter support beam (shaded) on East Truss to be replaced.

3.7 Cross Beams			
Date(s):	1854?	**Source:**	Town records. Some members may be original to bridge; exact date of specific members has not been ascertained.
Description:	The cross beams and the cross braces joining them together form the upper lateral bracing system. Eight cross beams span over the roadway to connect the two trusses at the top of each post. They measure 6-0" x 7-0" by about 17'-9" long.		
Condition:	Identified members have splits, breaks and twisting at the connection to the vertical members.		
Describe Work:	Bridge will be jacked and braced during rehabilitation as required to straighten, release stresses, plumb and re-align the trusses. Special care shall be taken to avoid damage to members that are to remain and to avoid movement of the truss that could result in distortion or misalignment of the truss and its joints. All joints in replaced members shall match the existing joint, including all nails, bolts or screws required unless noted otherwise. Cross beams shown to be replaced are to be replaced "in-kind" with new members identical in dimensions and configurations as the members originally used in the bridge (see Plan Sheet 29 – Upper Lateral Bracing Plan shown in part below).		
Project Need:	The cross beams are a component of the upper lateral bracing system that stiffens the bridge and transfers lateral loads (primarily wind loads) across the bridge without creating racking or other distortions in the truss. The members to be replaced do not possess the required structural integrity.		
Impacts:	Portions of two cross beams totaling about 18 feet of cross beam, equaling approximately 13 percent of the total cross beams, require replacement. Members to be replaced will be replaced "in-kind" with wood members of the same size and workmanship. Member deficiencies are located at the end of the member; therefore, it is proposed to salvage half of the existing cross beam by providing a scarf joint at the center of the beam. Replacement member will be "in-kind" and of the same size and workmanship based on field measurements upon removal of damaged member. Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features*.		

Cross beams connect the two trusses at the tops of each post.

Cracked cross beam end at Node 7, west truss.

Cracked cross beam end at Node 1, west truss.

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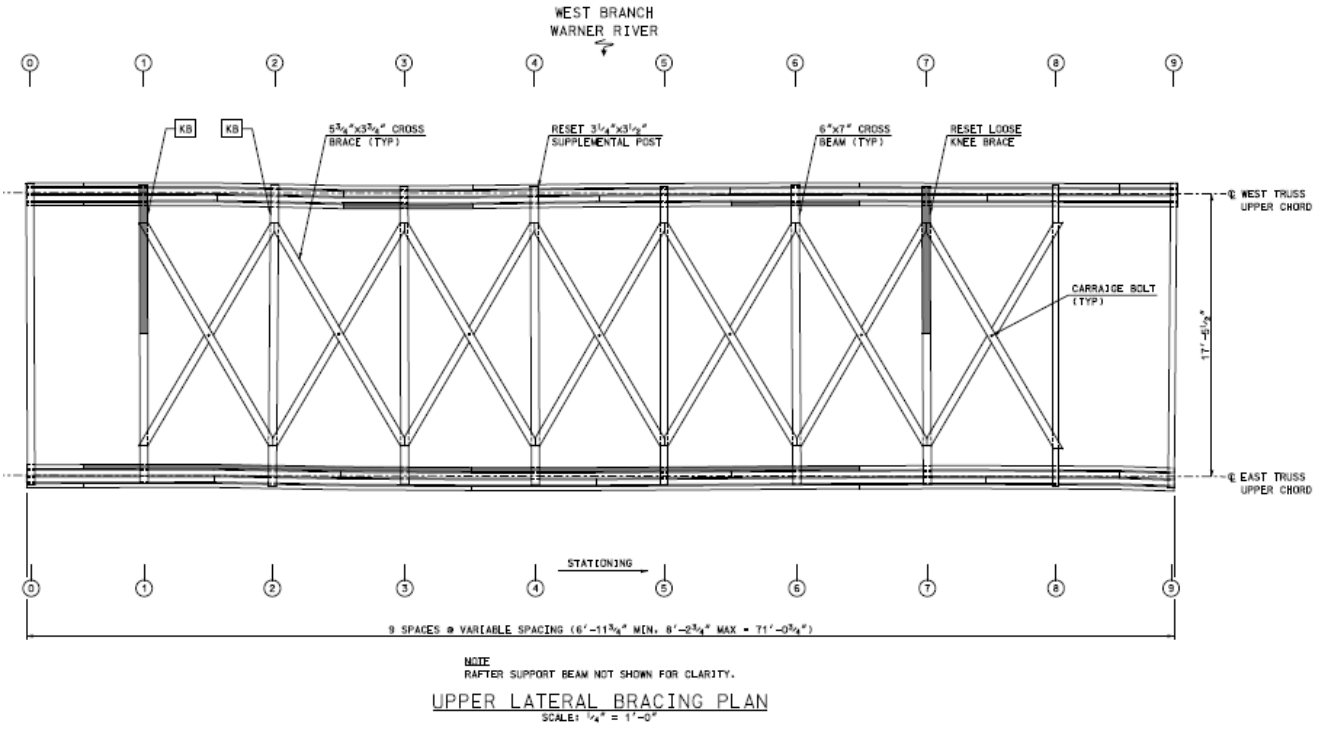


Plan Reference: Sheet 29	Sections of two cross beams (shaded) to be replaced at Node 1 and Node 7, west truss.

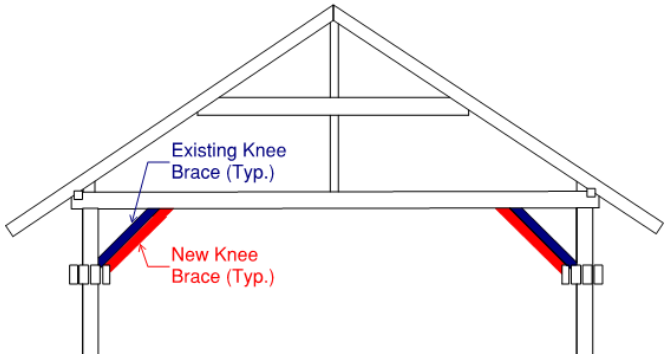
3.8 Knee Braces

Date(s):	1854; 1968-9?	**Source:**	Town records & other records of repairs. Some members may be original to bridge; exact date of specific members has not been ascertained.

Description:	Knee braces brace the cross beams to the posts and consist of single timbers 2-$^{1}/_{4}$" x 3-$^{5}/_{8}$" by about 3' long.
Condition:	There is a single 2¼"x3⅝" knee brace that extends from the truss vertical to the cross beam. Knee braces are toe nailed to the top face of the upper chord and to the underside of the cross beams. This configuration does not provide adequate lateral stiffness of the truss upper chord as sweep was observed during field investigations.
Describe Work:	Install new supplemental knee braces to mitigate future racking and longevity of the bridge. See the graphic below for the proposed configuration and Plan Sheet 29 – Upper Lateral Bracing Plan.
Project Need:	The knee braces, also called sway braces help stiffen the bridge and transfer lateral loads (primarily wind loads) across the bridge without creating racking or other distortions in the truss. The existing members do not possess the required structural sufficiency.
Impacts:	Sixteen supplemental knee brace members will be sistered to existing members. New members will be compatible in size and material to the original members, effectively doubling their strength and preventing damage to the original members by over stressing. Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features*.

Oblique view of west truss showing braces and counter braces in X between posts.

Rectified view of west truss at north end showing braces and counter braces between posts.



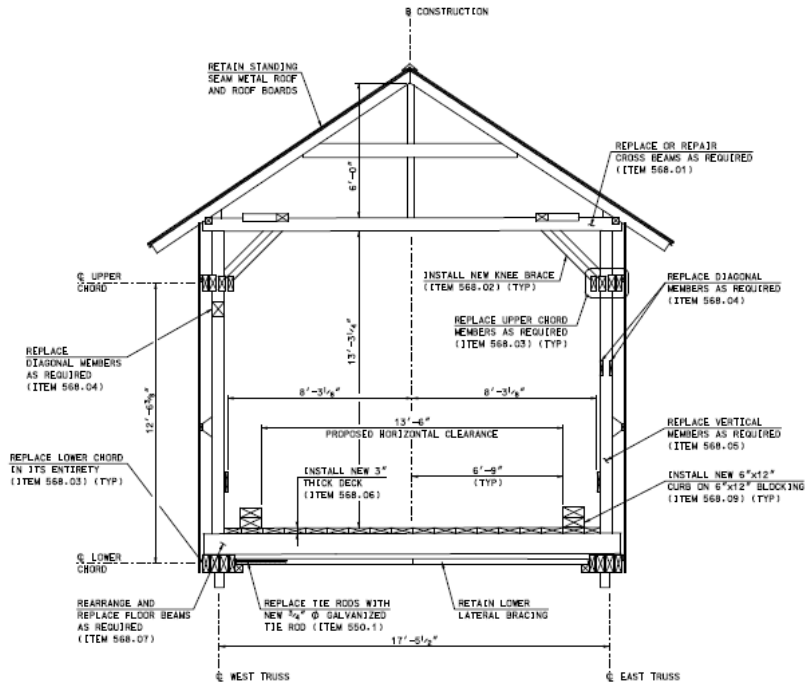
Plan Reference: Sheet 29	New knee braces to sistered to existing knee braces.

3.9 Floor Beams			
Date(s):	Unknown	**Source:**	Some members may be original to bridge but unlikely; exact date of specific members has not been ascertained

Description:	Floor beams are carried on the lower chords and run transversely between the trusses. The decking or floor boards are nailed to the floor beams. The floor beams are of two sizes, 3½" x 11-0" and 5¼" x 11-0". It is unlikely that any of these members are original to the bridge but no records regarding their specific replacement were located.
Condition:	The floor beams vary in condition from good to poor. However, their size is insufficient to carry the required 6-ton design live loading at the current spacing.
Describe Work:	Remove the existing eleven 3½" x 11-0" floor beams and replace with new 5¼" x 11-0" floor beams. Re-arrange the remaining existing 5¼" x 11-0" floor beams and supplement with the new 5½" x 11-0" floor beams to provide a uniform spacing. Remove and replace the broken 5½" x 11-0" floor beam between nodes 3 and 4. See Plan Sheet 8 – Existing and Proposed Typical Bridge Sections.
Project Need:	An adequate floor beam system is required in order to achieve the required 6-ton live load capacity of the bridge. Certain existing members and present configuration does not provide the required structural sufficiency.
Impacts:	The new floor beam members will be compatible in size and material to the existing larger members. Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features*.

Floor beams span between lower chords.

Broken Floor Beam between Node 3 and 4



PROPOSED BRIDGE SECTION

SCALE: ⅜" = 1'-0"

Plan Reference: Sheet 8	Rearrange and replace floor beams as required.

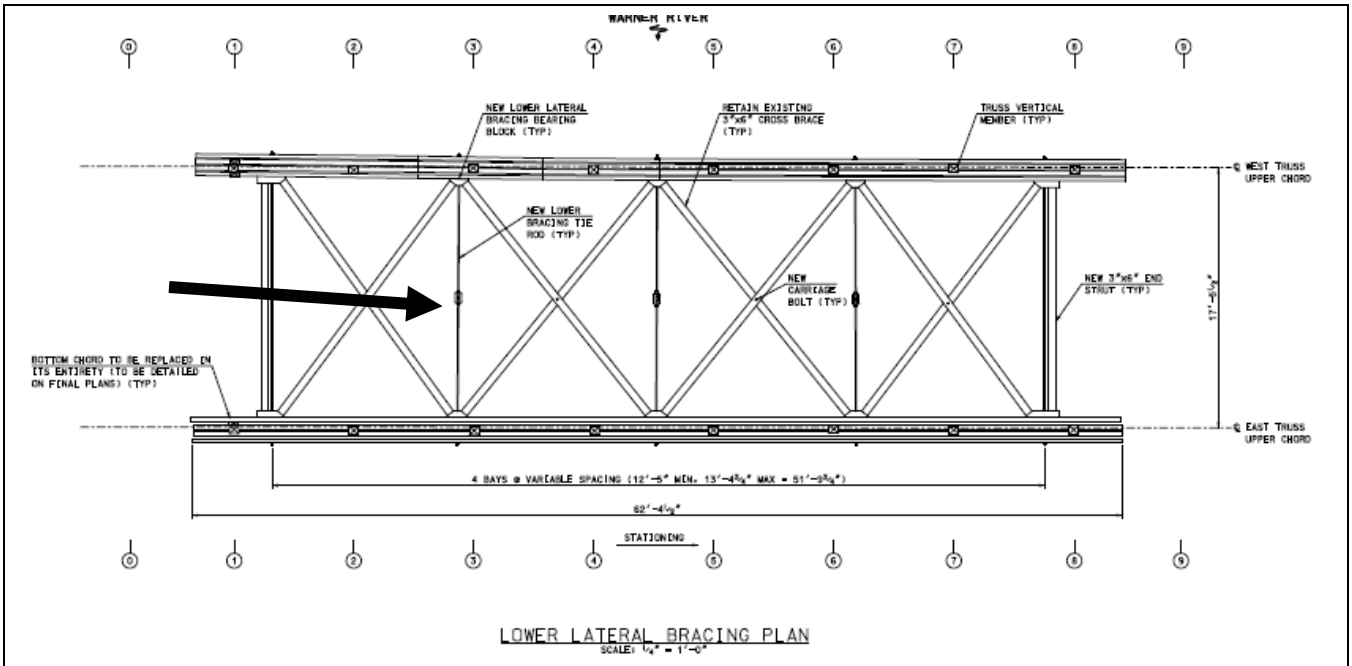
3.10 Lower Lateral Bracing Tie Rods

Date(s):	20th c.; 1947?	**Source:**	Physical evidence; NHHD records.

Description:	The lower lateral bracing tie rods are retrofitted tension members comprised of steel reinforcing rods that run across the width of the bridge parallel to the floor beams to tie together the lower chords. They act as long bolts that compress the chords together tightly against the lower lateral cross bracing. The rods are spirally deformed indicating they date from the mid-20th century and were evidently installed with the replacement of the bottom chords in 1947 or 1968.
Condition:	The lower lateral bracing tie rods are unprotected steel and exhibit significant corrosion with advanced section loss. The ends of the cross braces are not well connected to the bottom chord with only a few toenails and a support block which due to loss of tension in the tie rods are loose and structurally deficient.
Describe Work:	Bridge shall be jacked and braced as required to straighten, release stresses, plumb and re-align the trusses. Special care shall be taken to avoid damage to members that are to remain and to avoid movement of the truss that could result in distortion or misalignment of the truss and its joints. All lower lateral bracing tie rods will be removed and replaced with new galvanized steel rods. New bearing blocks are proposed to be installed at ends of lower braces in order to sufficiently connect the lower bracing members to the bottom chord. Two new struts (one at each end of the bridge) are also proposed to keep the ends of the bridge square. See Plan Sheet 33–Lower Lateral Bracing Plan.
Project Need:	The lower lateral bracing helps to stiffen the bridge and to transfer lateral loads across the bridge without creating racking or other distortions in the truss. Failure of the existing deteriorated tie rods and bracing member connections to the bottom chord would compromise the structural integrity of the lower lateral bracing system and the stability of the bridge.
Impacts:	All five tie rods are to be replaced. New bearing blocks and two new struts are also proposed to strengthen the connection of the lower bracing members to the bottom chord. The new ties rods, blocking and struts will be compatible in size and material to the members replaced. Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features*.

Steel tie rod running across bridge below floor beams to join lower chords of each truss.

Tie rod connection to lower chord at lower lateral cross bracing bearing point.



LOWER LATERAL BRACING PLAN
SCALE: 1/4" = 1'-0"

Plan Reference: Sheet 33	Replace all lower lateral bracing tie rods with new galvanized steel tie rods.

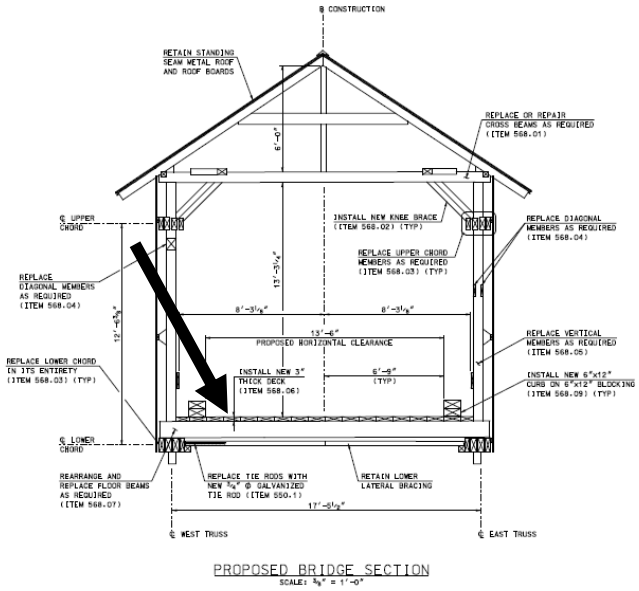
3.11 Decking

Date(s):	1968-9	**Source:**	Town records & other records of repairs, 1968-1969. Members are assumed not original to bridge but exact date of specific members has not been ascertained. Members date to various repair events..

Description:	Longitudinal timber decking consists of 3" x 8" rough planks, nailed directly to the floor beams with butted side and end joints.
Condition:	The plank deck is in poor condition with many loose or broken pieces and is heavily worn.
Describe Work:	Replace deck on its entirety with new 3" thick deck. See Plan Sheet 8 – Existing and Proposed Typical Bridge Sections.
Project Need:	An adequate floor decking system is required in order to achieve the required 6-ton live load capacity of the bridge. The existing deck is at the end of its service life.
Impacts:	New decking will be compatible in size and material to the existing members. Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features.*

Decking is split, rotted and loose and has reached end of practical service life.

Detail of deck failure and deterioration.



Plan Reference: Sheet 8	Replace 3" wood decking with same.

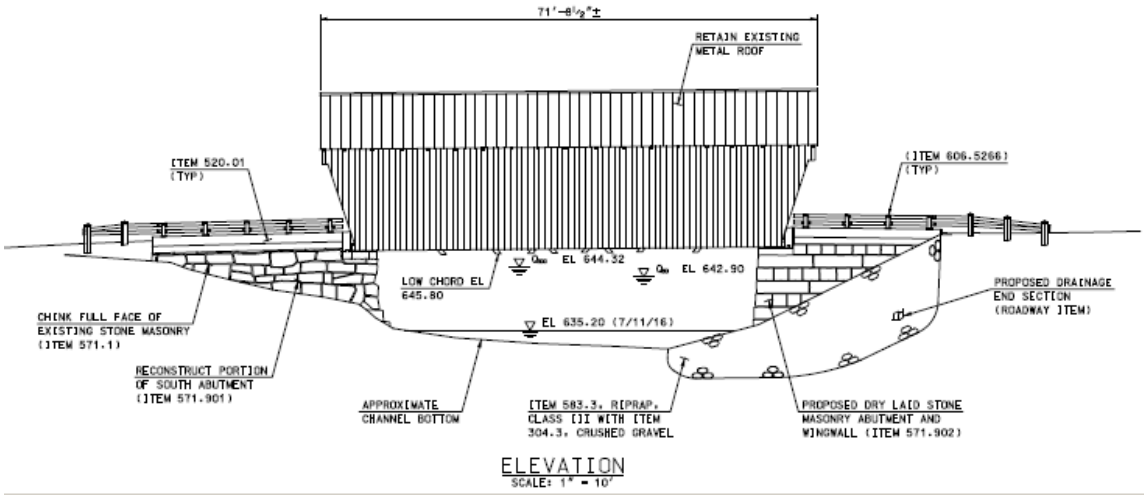
3.12 Substructure			
Date(s):	1854; c.1890?; c.1940	**Source:**	Physical and photographic evidence.
Description:	The substructure consists of two dry-laid stone abutments, north and south, both with U-type stone wing walls. The downstream (east) half of the north abutment has been replaced with a poured concrete abutment, a repair believed to have been made shortly after 1938 hurricane and flood.		
Condition:	The bridge substructure is in serious condition at the north abutment and fair condition at the south abutment. The south abutment exhibits bulges in the wingwalls with evidence of significant movement. The backwall has signs of movement and heavy leakage, loss of backfill material which is accumulating to the bridge truss seats. This condition is contributing to the deterioration of the bedding timbers at the bearings and ends of the bridge. The north abutment stem wall, including the returns to the wingwalls (corners), has deteriorated sufficiently and is considered to be in serious condition. The construction of the north stem wall exhibits a lower level of skill than its southern counterpart and was built using a poorer selection of lower-quality stone. There is a long running joint in the center of the stem; it appears that some lateral spreading may have occurred in this area. The portion of the stem that is not encased in concrete is clearly bulging outward. The use of stones of disparate size (very large stones alongside much smaller material), together with poor construction technique, has resulted in inadequate tying-back of the stem wall into the wing walls. This has resulted in weakness in the wing walls immediately to the north of the stem; this is most visible in the return to the west wing wall. A number of the larger stones have cracked, possibly a result of pre-existing flaws or equally likely caused by uneven distribution of forces within the abutment due to poor construction methods. The wing walls of the north abutment are poorly built using smaller stone than their south side counterparts. There is also some evidence of outward settling/bulging.		
Describe Work:	*North Abutment:* Completely remove and replace the abutment and wingwalls dictated by observed deficient structural conditions and the deficiencies noted in the size and quality of existing stones. *South Abutment:* Reconstruct portions of the east and west wingwalls to stabilize, remove bulges and prevent continued deterioration. Partially rechink and wedge abutment stemwall using compatible stonework. Construct a new concrete backwall and concrete cap to provide required structural bridge and approach foundation; concrete to be at ground level and largely concealed from the view. See Plan Sheets 20-27 – Substructure Modifications.		
Project Need:	Substructure is structurally deficient and in need of rehabilitation to provide a safe supporting structure for the bridge..		
Impacts:	Work complies with Secretary's Standards for Rehabilitation, *Replacing Deteriorated Historic Materials and Features*.		

North Abutment showing loose stone work and concrete repair c.1939.

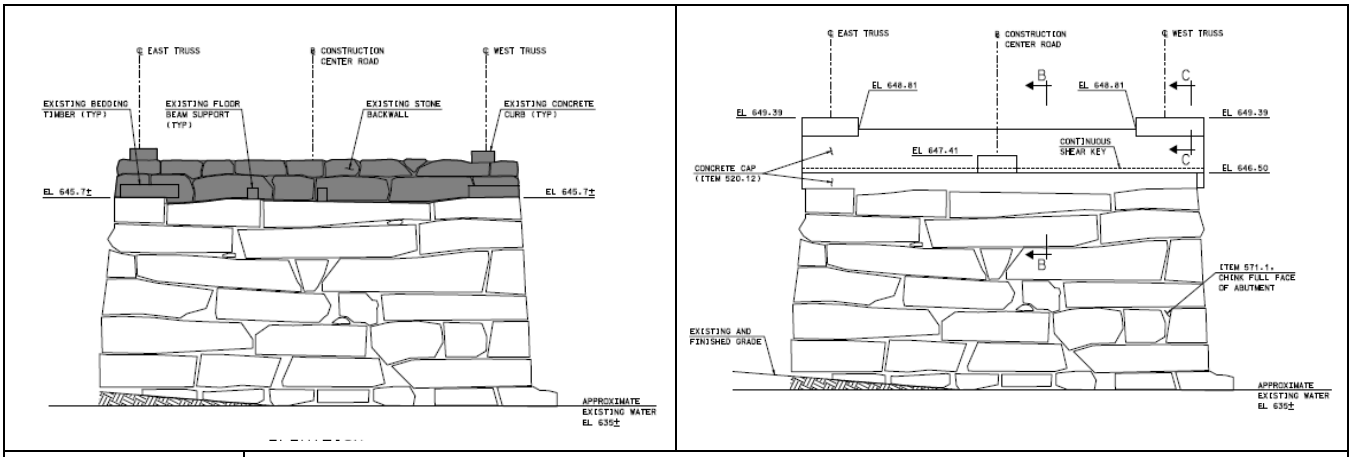
North Abutment, showing concrete repair and upstream side.

South abutment.

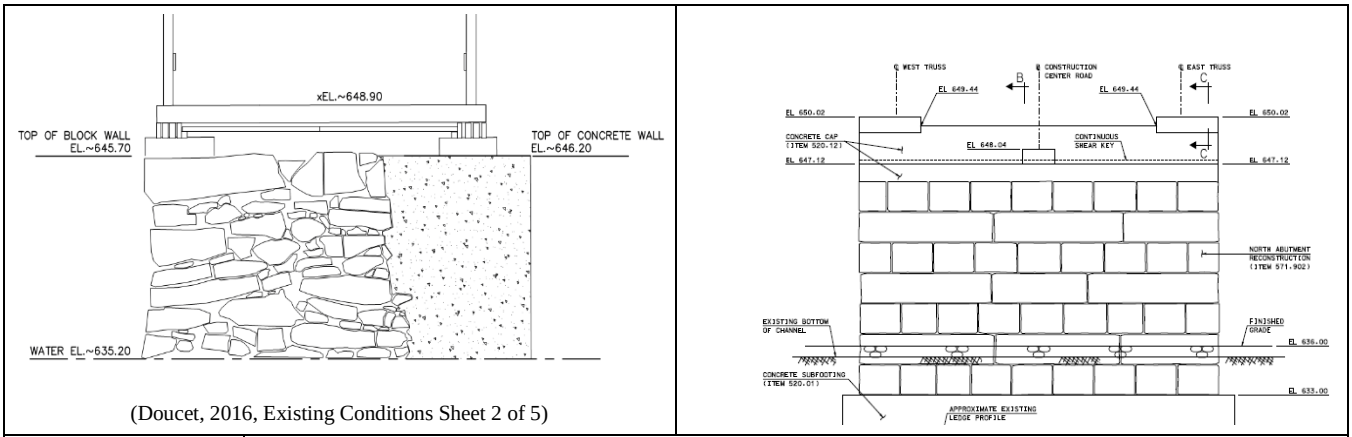
South abutment, downstream side at left; north abutment visible across river.



Plan Reference: Sheet 16	Appearance of proposed rehabilitated south abutment (left) and new dry-laid stone north abutment (right).



Plan Reference: Sheet 20, 21	South abutment: Existing (left); Repair design (right).



(Doucet, 2016, Existing Conditions Sheet 2 of 5)

Plan Reference: Sheet 22	Nouth abutment: Existing (left) showing loose and displaced collapsing stones (laser scan) and concrete repair; Proposed new dry laid cut stone abutment, (right).

4.0 TREATMENT SUMMARY

The designed rehabilitation work is proposed to restore Bement Covered Bridge to a legally required load capacity of 6 tons. In its present condition the functional capacity of the bridge is limited by the floor beams to 2.2 tons and by the trusses to 2.0 tons.

The proposed work will be conducted in accordance with the Rehabilitation Standards within the *Secretary of the Interior's Standards for the Treatment of Historic Properties (36CFR68.3(b))* (Standards):

> According to the Standards, "*Rehabilitation* means the act or process of making possible an efficient compatible use for a property through repair, alterations and additions while preserving those portions or features that convey its historical, cultural or architectural values" (36CFR68.2(b)).

The proposed work has been designed to be fully compliant with the spirit and intent of the Rehabilitation Standards as summarized in the Table of Standards Compliance below.

The proposed work has also been designed with consideration of the Standard's *Guidelines for Rehabilitating Historic Buildings* to the extent that they are applicable to a historic covered bridge which possesses features common to buildings. The applicable guidelines include:

- *Repair Historic Material and Features*
- *Replacing Deteriorated Historic Materials and Features*
- *Design for the Replacement of Missing Historic Features*

The vast majority of the work encompasses the repair and/or replacement of deteriorated materials and features. While few if any of the members scheduled for replacement are likely to date from the original 1854 construction of the bridge and constitute later replacement members, such members are considered historic in their own right since they have in most cases been replaced "in-kind" 50 or more years ago. The proposed work maintains the prudent tradition of "in-kind" replacement and will match the new member with the old in design and material to the full extent possible. Tension members are typically not suitable for splice repairs however the predicted loads on the overhead cross ties will allow for repair with a new section joined to the old with a scarf joint thereby retaining a portion of the historic material. The design for the missing original portal feature that was removed in 1954 is based on historic photographs and measurements of remaining trim elements that were a part of the missing feature. Design of the new stone north abutment similarly will draw on the remaining elements of the existing feature which due to deterioration and an incompatible concrete repair lacks integrity of design and materials but still provides information for a compatible yet distinguishable replacement. Further discussion of the compatibility of the proposed work to the Standards in presented in the following table.

TABLE OF STANDARDS COMPLIANCE

Rehabilitation Standard (36CFR68.3(b))	**Project Compliance**
(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.	YES. Property will be used as it was historically.
(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.	YES. Removal of square portal alteration, although a feature over 50 years of age, its construction in 1954 removed an original and important character defining feature (see Standard (6) below).

Rehabilitation Standard (36CFR68.3(b))	**Project Compliance**
(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.	YES. Historically false changes or conjectural features are not proposed.
(4) Changes to a property that have acquired historic significance in their own right will be retained and preserved.	YES. Proposed work is limited to deteriorated features and will not remove prior changes except portal alteration (see Standards 2 and 6).
(5) Distinctive materials, features, finishes and construction techniques or examples of craftsmanship that characterize a property will be preserved.	YES. Proposed work is limited to deteriorated features and will not remove entire distinctive characteristics or elements.
(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.	YES. Proposed work is limited to repair rather than replace where structural engineering calculations allow. Replacement features will be "in-kind" (matching old in design, color, texture and materials). Replacement of missing original portal feature will be based on historic photographic evidence.
(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.	YES. No treatments that cause damage to historic materials will be used. A transparent fireproof coating will be applied to wood members. A fire alarm system will be mounted to members using least invasive methods and reversible fastening.
(8) Archeological resources will be protected and preserved in place. If such resources must be disturbed, mitigation measures will be undertaken.	YES. Archeological issues have been addressed in a Phase 1A report.
(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.	YES. New additions are not proposed. Exterior alteration of the portal complies with Standard 4 & 6. Reconstruction of the north abutment is compatible in materials, features, size, scale, proportion, and massing to original and to south abutment. The work will be differentiated from the old and a product of its own time.
(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.	YES. All work, if removed in the future, will not impair the essential form, integrity or environment of the property.

5.0 PRESERVATION RECOMMENDATIONS

Maintain

Routine maintenance of a historic structure is the cost-effective form of conservation. It is typically coupled with routine inspections to catch problems while they can be inexpensively remedied. Since the bridge will be undergoing a major rehabilitation and will continue under the protection of a relatively new standing seam metal roof (2012) with an estimated life of 40 years, recommended maintenance actions are of a general preventive nature as opposed to specifically targeted to areas of deficiencies. Further recommendations may be identified by the project engineer following rehabilitation of the structure.

- Remove moisture-trapping debris such as leaves, litter, and road sand accumulated along the edges of the deck up against and in between truss members. Debris traps moisture, fosters fungus grown and accelerates the rotting of wood and corrosion of metals. The use of pressurized air or vacuum is recommended; high pressure water is not recommended. Perform yearly or as needed to eliminate trapped moisture and prevent mold and fungus growth.

- Clean beam seats and abutments, cross beams and other under-deck members that typically accumulate debris. Perform every two years and after high water events that may have deposited debris.

- Perform a cursory inspection of the bridge every two years to check status of new repair work (tighten bolt-up and tie-rod connections, timber checks and splits, evidence of substructure movements, etc.) and determine if additional maintenance work is required.

6.0 SOURCES (see footnote citations)

Bement Covered Bridge files at New Hampshire Division of Historical Resources, Concord. Files include the National Register Nomination Form (1974), correspondence and other information relating to the bridge.

Bradford, Town of, Annual Reports. 1890 to 1970. Accessible at NH State Library, Concord.

New Hampshire Highway Department (NHHD) bridge inventory card for Bement Bridge (state bridge number Bement 140/144). Located at NHDOT, Concord.

Whitney, Stephen T. "Common Sense and Bement Bridge," *New Hampshire Profiles,* March 1971, pp. 16-19.

36 CFR 68 (The Secretary of The Interior's Standards for the Treatment of Historic Properties). Online at: https://www.gpo.gov/fdsys/granule/CFR-2012-title36-vol1/CFR-2012-title36-vol1-part68