Rehabilitation of a Two-Lane Covered Bridge

Presented to:
Second National Covered Bridge Conference
June 6, 2013

Presented by:
Sean T. James, P.E. – Project Manager
(sjames@hoyletanner.com)
Josif Bicja, P.E. – Project Engineer
(jbicja@hoyletanner.com)

Hoyle, Tanner & Associates, Inc.
Manchester, NH USA
Presentation Outline

• Background
• Bridge Description
• Project Purpose and Need
• Structural Analysis
  ▪ Geometric Limitations / Load Cases / Live Load Selection
  ▪ Computer Model
  ▪ Arch Interaction
  ▪ Observations & Results
  ▪ Proposed Modifications
• Rehabilitation Project
Background

Project Location
Background

• 5 Remaining Double Barrel Covered Bridges
  ▪ Roberts Covered Bridge, Eaton OH, 1829, 79’ Long Single Span, Multiple Kingpost w/Arches, Pedestrian Only.
  ▪ Ramp Creek Covered Bridge, Nashville IN, 1838, 96’ Long Single Span, Multiple Kingpost w/Arches, Vehicular.
  ▪ Philippi Covered Bridge, Philippi WV, 1852, 286’ Long Four Span, Long Truss, Vehicular.
  ▪ Shelburne Museum Covered Bridge, Shelburne VT, 1845, 168’ Long Single Span, Multiple Kingpost w/Arches, Pedestrian Only.
  ▪ Pulp Mill Covered Bridge, Middlebury/Weybridge VT, 1853, 200’ Long Three Span, Multiple Kingpost w/Arches, Vehicular.
Background

- Pulp Mill Covered Bridge
- Frequently Cited Built From 1805 and 1820
- VTrans Record Built in 1853
- National Register of Historic Places in Sept. 10, 1974
- AADT Volume of 1,900 Vehicles
- Originally Built as 180’ Single Clear Span, Extensive Sagging
- Nail Laminated Wood Arches Added in 1859-60
- Two Stone Masonry Piers with Timber Cribbing in Late 19th Century
Background

• Major Rehabilitation in 1979-80
  ▪ Stone Masonry Piers Encased in Concrete
  ▪ New Concrete Facing of Abutments and New Backwalls
  ▪ Portions of Arches and Truss Bottom Chords Replaced
  ▪ New Steel Hanger Rods Added to Connect the Arches to the Bottom Chord at Each Panel Point
  ▪ New 6” x 6” Pressure Treated Lower Lateral Braces Installed
• North Truss and Arch (West Span) Rehabilitated in 1991
• Interior Truss and Arch (East Span) Rehabilitated in 2002
• A Pedestrian Bridge Constructed in Mid-1990’s
Bridge Description

- 200’, 3 Span Continuous, over Otter Creek
- M. Kingpost Trusses w/Arches
  - 3 Trusses, 4 Arches
- 2 Lanes, 8’-6” Wide Curb-Curb, 26’ Out-Out
- 10’-6” Vertical Clearance
- 4 Tons Live Load Capacity Goal
Bridge Description

Upstream Elevation

Downstream Elevation
Bridge Description

West Approach

East Approach
Bridge Description

Roof Framing
Bridge Description

Upstream Barrel

Downstream Barrel
Bridge Description

Bridge East Pier & Floor Framing
Project Purpose and Need

• Bridge in Poor Condition
  ▪ Broken, Rotted, Impact Damaged Members
  ▪ Truss Vertical Member Issues
  ▪ Previous Repairs
  ▪ Sag in Truss Spans
  ▪ Snap Through Buckling of Arches

• Preserve Historic Covered Bridge
• Critical Link Between Towns
Project Purpose and Need

Rot

Break

Break
Project Purpose and Need

Broken Tenon – Truss Vertical
Project Purpose and Need

Undersized Verticals At Notch
Project Purpose and Need

Split Verticals
Project Purpose and Need

Previous Repairs
Structural Analysis

• Geometric Limitations
  ▪ Lane Width of 8’-6”
  ▪ Vertical Clearance – 10’-6” @ Center, 8’-0” @ Edge

• Allowable Stress Rating and Design

• Load Cases
  ▪ Dead + Live @ Inventory
  ▪ Dead + Live + Snow @ Operating
Structural Analysis

• Live Load
  ▪ Lane Load Evaluated
  ▪ H4 (4 Tons)
  ▪ Truck Train
  ▪ 5 Load Cases, Both Lanes Loaded
  ▪ 3D Computer Model
 Structural Analysis

H4 Load Cases

LOAD CASE NO.1 - 1 TRUCK

LOAD CASE NO.2 - 2 TRUCKS

LOAD CASE NO.3 - 3 TRUCKS

LOAD CASE NO.4 - 4 TRUCKS

LOAD CASE NO.5 - 5 TRUCKS

Three-Dimensional Computer Simulation of the Pulp Mill Covered Bridge - Unloaded
Structural Analysis

Arch Interaction / Condition
Structural Analysis

• Observations & Results
  ▪ Poor Connection Capacity of Vertical to Chord
  ▪ 3 Span Configuration Results in Member Stress Reversals
  ▪ Load Sharing of Trusses and Arches Critical
    ▪ Relative Stiffness Determined to Share Load
    ▪ Limited by Bolted Connection
  ▪ Live Load Stresses Approx. 30-40% of Dead Load Stresses
  ▪ Most Members Controlled by Multiple Truck Load Case
Structural Analysis

Proposed Modifications to the Interior Truss

Legend:
- 5”x5” Timber
- ½” Steel Rod
- Solid Blocking
Rehabilitation Project

- Three Ends of Arches Rebuilt
- Several Truss Member Replaced or Repaired due to Strength & Condition
- All Arch Hanger Rods Removed
- Connections of Arches to Verticals Strengthened
- Bottom Chord Replaced
- Reversible Modification to Interior Truss
- Several Roof Rafters Replaced In-Kind or Sistered
Rehabilitation Project

- New Upper Lateral Bracing Installed
- Several Knee Braces and Cross Beams Replaced In-Kind
- All Stringers Removed
- Several Floor Beams Replaced In-Kind
- Existing Decking Replaced
- Limited New Lateral Bracing Installed
- New Wood Curb Installed
Rehabilitation Project

- Trusses and Arches Realigned
- Protectowire and Lighting Installed
- Fire Retardant/Insecticide Coatings Applied
- Minor Approach Work
- Minor Repairs to Existing Substructure
- Total Construction Cost $1.7 Million
Rehabilitation Project

Temporary Shoring System Above the Deck

Temporary Shoring System Below the Bridge
Rehabilitation Project

New Bottom Chord

New Truss Verticals
Rehabilitation Project

Sistered Roof Rafters

Rebuilt East End of North Arch
Rehabilitation Project

Fire Detection Wires
Underside of Bridge

Typical Floor Framing at Arch Locations
Rehabilitation Project

Ribbon Cutting Ceremony
November 9, 2012

1St Car to Cross the Bridge
November 9, 2012
Rehabilitation Project

Question & Answer

Sean T. James, P.E. (sjames@hoyletanner.com)

Josif Bicja, P.E. (jbicja@hoyletanner.com)

150 Dow Street
Manchester, NH 03101