LANGLEY COVERED BRIDGE REHABILITATION: Practical Solutions for Rehabilitation of a Historic Covered Bridge

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Langley Covered Bridge
Centreville, Michigan
OUTLINE

- Project background, history of bridge
- Assessment of rehabilitation needs, findings of structural analysis
- Rehabilitation construction process, lessons learned
BACKGROUND

- Project began 2005, completed 2009
- Project participants:
  - St Joseph County Road Commission
  - Preservation architect
  - Structural/preservation engineer
  - MDOT historian
  - Contractor
Significance of Langley Bridge

- Constructed 1887, timber Howe trusses
- One of four remaining historic covered bridges in Michigan
- One of the longest historic covered bridges in US
- Forms part of local identity
- Still in active use as county road
The Langley bridge 1887
Raising the bridge for dam 1910
New causeway to connect bridge across floodplain
Later changes: deck, piers and abutments replaced 1950s
Sway bracing modifications
The fishing window
The Structure

Heavy timber Howe through trusses
The Howe trusses here are the historically significant feature.
The Langley Bridge trusses

- Each truss 94 ft long, 16 ft tall, h/L = 6
- 10 panels per span, 9’-2 3/4” each
- Diagonals slope 60
Trusses built up from sawed timber, three laminations at chords

- **(3) 5" x 9"**
- **(2) Rods, Ø varies**
- **(3) 5" x 12"**
- **Tension diagonal 6" x 6"**
- **Compression diagonals, size varies**
Iron castings at nodes, tension rod bearing directly on chords
ASSESSING REHABILITATION NEEDS; FINDINGS OF STRUCTURAL ANALYSIS
Issues

- Bridge was posted for 3T load limit
- Load and speed limits regularly ignored
- Last major repairs and maintenance 1970’s
- Previous modifications and repairs addressed functional requirements only, little regard for historic preservation
Recent Vehicle Impact
Issues with roof: framing and covering
Issues with siding: rot, lead paint peeling into the river
1950s steel deck framing, corroded, lead paint peeling
Truss bottom chord reinforcing corroded, south span sagging
Low clearance an advantage during condition audit
Hands on, piece by piece
Rotting of bottom chord

Raccoon (Deceased)
Rotting and crushing of compression diagonals
Crushing of tension rod bearings, at top chord...
And bottom
Purpose and Need: Defining the Loads

- We recommended public meetings held to discuss conversion to pedestrian and bicycle use only.
- That idea not endorsed by community.
- Community wanted to maintain crossing over river as a county road.
Loads

Modern loads per AASHTO vs horse-drawn carriages and wagons: 30,000# vs 7,000#
Structural analysis to assess repair and strengthening needs

- We examined roof framing, deck framing, trusses, girders and substructure, no work below the waterline
- Want to discuss here three issues:
  - Tension capacity of bottom chords
  - Load transfer at castings
  - Role of counterbraces in Howe trusses
Findings

- Timbers stresses within reasonable limits for No. 1 white pine, though at high end
- Tension rods also well within allowable stresses, ok for fatigue
Findings (cont)

- Max bottom chord tension on gross area of timbers appeared acceptable
- But tension chord members were spliced in original construction
Bottom chord splice locations
Fishplate detail
Bottom chord splices

- Evaluate tension on net area and shear parallel to grain in the timbers and fishplates, and compression on the bearing surfaces.
- To support wagon loads, need 13,000# of load transfer through each fishplate if we rely on them alone to do the job.
Assessing bottom chord tension capacity

- Per current code limits on bearing stress, bottom chord fishplate capacity is 5,200#, not adequate even to carry self weight of bridge.
- Might then assume all tension carried by remaining two laminations (ref S. Patrick Sparks, APT Journal 2005), but they too are spliced.
- Need to consider development of tension capacity of bottom chord as a whole, all three laminations.
The weak links
Fishplates, keys, bolts acting
Fishplates, keys, bolts acting
Tension capacity using keys and fishplates

- Four bearing surfaces and one or two bolts in single shear at critical path
- Total capacity = 26,000 # per current NDS, including $C_d$ and 0.75 $F'_c$ limit
  (or 33,000# per pre-2001 NDS)
- Acceptable for wagon loads, not H15 on trusses with deteriorated and cobbled chords
Bottom chord strengthening

- Steel channels each side of each chord, hidden by siding
- Provided good bearing for deck beams and tension rods
Bolting pattern to develop tension in steel channels, not to splice wood lams
Load paths at castings

- Max vertical = 31k, fc = 200 psi (wagons)
- Max horizontal component = 18k
- fc// on lug bearing surface = 1950 psi! but F'c// for EWP SS P&T = 834 psi
Force transfer at castings

- In recent times, max horizontal load carried may have been $= 28k$, so $f_{c'//} = 3000$ psi
- Tension rods don’t bear on wood, no dowel bearing to help out
- Friction?
- Is $C_D$ of 1.15 too conservative?
- Confined $F'c'// = 3000$ psi, $\geq 800$ psi?
No action taken

- Had supported higher loads in the past without damage
- Ductile failure mode
THE REPAIR PROCESS
After lead abatement
Braced internally
Accessing the exterior
Replaced all tension rods and bearing plates
Repaired bottom chord bearing
Replaced and supplemented tension chord reinforcing
Spacers between wood and steel to promote durability
Compression diagonals at fishing window
Compression diagonal repairs

EXIST. (2) 6 x 8, 6 x 7 OR 6 x 6 COMPRESSION DIAGS. W/ (1) 6 x 8 BLOCKING, REMOVE & REINSTALL BLOCKING AS REQ'D

NEW 6 x FULL DIM. WH. PINE NO. 1 OR BETTER AT EA. DAMAGED COMPR. DIAG. HALF LAP W/ EXISTING TIMBER W/ ALL BRG. SURFACES TIGHT W/ (4) 3/8" Ø THRU BOLTS, NUTS, WASHERS, GALV

WOOD DECK

W12 DECK BM.

EXIST. TENSION RODS

EXIST 6 x 6 DIAG. BRAC

EXIST. BRG. CASTING TO REMAIN

SEE DETAIL 6/A-7

EXIST. 6X COMPR. DIAGS.

EXIST 6X BLOCKING REM. & REINSTALL, CUT RECESSES FOR NUTS, WASHERS

SEE DETAIL 2/A-7

IMPEL RODS, SEE DETAIL 8/A-7

NOTCH AROUND TENSION RODS AS REQ'D

BRG. CASTING TO REM.
Reused timber washers
Maintenance painting of steel
Completed 2009
Sag didn’t get removed
How to camber a Howe
Effect of tightening rods alone
Function of the counter braces?

Was prestressing the original concept? Can it practically be maintained?

We found almost all to be loose; they don’t brace the compression diagonals out of plane.

Assembly requirement only?
Overall Satisfaction