DESIGN AND LAUNCHING OF A REDUNDANT TRUSS OVER RAILROAD YARD
Existing Bridge

• 5 – ~107 ft long Warren Through Truss spans
• Built in 1925
• Owned by BNSF RR, maintained by City
Existing Bridge

- Geometrically deficient
  - Narrow Traffic Lanes
  - Low Vertical Clearance
- Structurally deficient
- Fracture Critical members
- Closed to traffic by City on May 30th, 2014
- Eligible for National Register of Historic Places
Project Criteria

- Located on “Grand Rounds Scenic Byway System”
  - Park system with Pedestrian and Bike traffic
  - Community favored truss over arch
- Structure Requirements
  - BNSF and MnDOT clearance and loading requirements
  - Redundant design – eliminate FCMs
- Railroad Requirements
  - Increase clearances for safety
  - Reduce number of piers in rail yard from 4 to 2
  - Minimize impacts to rail yard during construction
Truss Options

- Pratt Truss
  - Vertical compression
  - Diagonal tension
  - Multiple cable tension redundancy
  - Shorter compression elements
  - Large cable diameters result in specialized replacement

Fence
Truss Options

- **Warren Truss**
  - Diagonal tension & compression
  - Longer compression elements
  - Split member tension elements

- Uniform load path simplifies detailing
- Eliminates large cables
- Smaller vertical secondary members
- Aesthetically less “busy”
Selected Bridge Layout
Closed versus Open Sections

- **Closed box**
  - Small size required
  - Not easy to inspect
  - More difficult to fabricate

- **Open H or I**
  - Complete access
  - Easy to inspect
  - Easy to fabricate

- **Selected Open Section**
I versus H Section

- **I Section**
  - Does not trap water/debris
  - Eliminates gusset plates
  - Integral truss connection

- Discontinuous load path
- Stress concentrations
- Not load path redundant
I versus H Section

- **H Section**
  - Potential to trap water/debris
  - Eliminate gusset plates
  - Integral truss connection

- Continuous load path
- No stress concentrations
- Two redundant load paths through connections
- Slope chord to allow water to drain
Redundancy

- **Load Path Redundancy**
  - Traditionally – multiple parallel girders
  - Not “Fracture Critical”

- **Structural Redundancy**
  - Redistribution of loads to other elements by analysis
  - SRM – “System Redundant Member”

- **Internal Member Redundancy**
  - Built-up bolted member
  - Still “Fracture Critical”
  - Alternative and sufficient load path exists within the member itself
Redundancy

• Acceptable level of reduced load carrying capacity for damaged structure
  • Agree on reduced load factors for fracture design cases

• System Redundant Members (SRM)
  • Design and Fabrication Requirements of Fracture Critical
    • Use increased material properties and welding requirements
    • Grade 50WF3 Steel
  • Reduced Inspection Requirements
Fracture Design Criteria

• Loss of entire tension member or connection

• $1.1 \text{ DC} + 0.75 \text{ (LL+IM)} + 1.1 \text{ FDF}$
  - LL+IM is 2 lanes plus pedestrian
  - FDF is fracture dynamic force

• Extreme event limit state
  - Local yielding acceptable
  - Exhibit visible deformation
Tension Chord Redundancy

- More than two truss lines
  - Multiple longitudinal elements for redistribution of load
- Multiple chord members
  - Alternate load path within truss if one fails
- External post-tensioning
  - Secondary backup system
- Post-tensioned concrete
  - Pre-compressed
  - Not Fracture Critical
  - Multiple individual wires in tension
Tension Member Selection

- Post-tensioned bottom chord
  - Easier to inspect and maintain
  - More durable
  - Highly redundant
  - Successful prior experience in MN

- Split member tension verticals and diagonals
  - Direct alternate load path
  - Separate connections

- Eliminates FCM
  - Truss tension members designated SRM
Top Chord Connections
Top Chord Connections
Bottom Chord Member

• Steel U-shaped Shell
  • Tension during launching and erection only
  • Formwork for concrete
  • Connection from steel to concrete
  • Consistent steel facade

• Post-tensioned concrete
  • Poured after launching
  • Stressed before deck pour
  • Pre-compressed member
Bottom Chord Connections
Floor Beam Redundancy

- Span between bottom chords on skew (65 ft)
- Spaced at ~ 10 ft
- Deck integral to floor beams and bottom chord
  - Stay-in-place metal deck forms
- Shown to be “Structurally Redundant”
  - Remove entire floor beam
  - Deck spans two floor beams
  - Yield line analysis – deck is sufficient
  - SRM
Erection Constraints

- Midday 4 hour windows on mainline and runner/receiver tracks
- 10 day for yard tracks (4 at a time)
- Bridge out of service allows for in-line erection on approach embankment
Launching Concepts

- Remove existing trusses whole
  - Meet closure windows
  - Minimize equipment in rail yard
  - Contain asbestos and lead paint

- Use existing pier foundations
  - Steel column braced to pier supports launching girders

- Use new approach girders for launching
  - Option given to contractor

- Launch new truss steel skeleton
  - Steel shell for “temporary” bottom chord
  - Use SIP steel deck forms
Launching Concepts

- Suggested erection sequence and support schematic in design plans
- Vetted concept and obtained estimating support from Parsons Construction Group
Construction Bids

- 3 Bids Received – March 2015
  - Minnowa $22.0M
  - Kraemer NA $20.9M
  - Lunda $20.2M
- Winning Bid within 5% of Engineer’s Estimate
  - Structural Steel $2.60/lb
  - Bridge cost of $16M
- Construction began late summer 2015
- Opened to traffic in October 2017
Railroad Coordination

• Goal: Uninterrupted and safe operations of BNSF’s yard
• Weekly RR Coordination meetings
  • Review Contractor’s 4-week lookahead schedule
  • Review flagging needs
  • Request upcoming outages
• Review of construction documents
  • Parallel review of erection engineering documents/procedures by RR Engineering and EOR
Truss Removal
Launching Setup
Launching Setup
Launching Setup / Truss Removal
Truss Removal
Truss Removal
Truss Fabrication
Shop Assembly
Assembling New Truss
Assembling New Truss
New Truss Launch Setup
New Truss Launch
New Truss Launch
New Truss Launch
Set Truss on Bearings
Deck Pour
Summary

- Developed unique approach for steel truss redundancy
  - Eliminated FCMs
- Minimized maintenance & inspection
  - Reduce future work over rail yard
- Developed aesthetically pleasing truss
  - Supports community history and urban industrial feel
- Developed unique construction approach
  - Influenced by rail road site conditions
  - “It waddles like a truss, quacks like a truss, but it’s not a truss” in the traditional sense. –Jack Yuzna
Finished Project
Finished Project