Bridge within a Bridge
Rehabilitation of CN Bridge 182.0 over Mississippi River, Dubuque, IA

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Abstract:
Due to the increased capacity and traffic demand on its mainline, CN committed to upgrading the 1535' Mississippi River Bridge near Dubuque, Iowa. This paper presents the challenges encountered and the creative solutions provided by the owner, the designer, and the contractor during the design and construction of CN Dubuque Mississippi River bridge rehabilitation project.

Strengthening of pin connected eyebars and pinned joints presented design, detailing and erection difficulties. A unique joint connection system using spidering gussets at the lower joints and butting gussets at the top chords was developed to avoid additional loading of the pins and provide an alternate load path around the pin for the built-up strengthening members. Special joints in the middle of the diagonal strengthening members serve as a transition for the members with different built-up arrangements and orientations. Reversed hairpins were used to provide redundancy for
the floorbeam hangers in the swing span. The existing frozen roller nest expansion bearings were replaced with PTFE/SS sliding bearings to prevent excessive secondary stress in the stiffened bottom chords after strengthening member installation. Emphasis was placed on effective design, proper detailing, minimal interruption to rail and marine traffic, and ease of construction.

Rehabilitation of the Dubuque Bridge with creative retrofit measures and efficient construction provides a cost effective way to upgrade the load carrying capacity, extend the lifespan of the bridge for the increased rail traffic, and minimize the disruption of railroad and navigation operations during the construction. Structural rehabilitation construction commenced in July 2011 and was completed in April 2014.

1.0 INTRODUCTION

Bridge 182.0 is part of the Dubuque Subdivision, and spans the Mississippi River near Dubuque, IA on Canadian National Railway (CN) single mainline track that runs east/west from Chicago to Sioux City and Omaha (Figure 1). The line currently carries 4 to 6 trains per day and roughly 10 MGTM. The bridge includes a fully operational swing span operated locally by CN Bridges and Structures forces during navigation season, during which the swing span is mostly in the open position.

Figure 1 – CN Partial System Map and Bridge Location
The current 6-truss, 1535’ long bridge was built in the 1890s for the Illinois Central Railroad by American Bridge Works, as a replacement for a prior bridge completed in 1868 for the Dunleith & Dubuque Bridge Company by Andrew Carnegie. The single track crossing consists of one 360’ swing truss span, two flanking 250’ truss spans, and three 225’ approach truss spans. All spans are of pin-connected Pratt through truss type with sloping top chords. Diagonals and most bottom chords are comprised of slender eyebars. The original floor system consisted of built-up floorbeams spaced at 24’ - 25’ centers and stringers spaced on 5’ centers with safety stringers 2’ from the live load stringers on each side. The substructure consists of concrete-jacketed stone masonry piers and abutments founded on driven timber piling. The pivot pier is protected by a timber fender system and steel sheet pile end cells. Figure 2 shows the original bridge prior to the rehabilitation.

![Bridge Looking East and Upstream](image)

Figure 2 – Bridge Looking East and Upstream

Due to the increased capacity and traffic demand on its mainline, CN committed to upgrading the mainline capacity to 315K at 25MPH, and, in May 2010, commissioned Modjeski and Masters, Inc. (MM) to perform a feasibility study of bridge strengthening based on CN’s rating and inspection reports. MM concluded that there were no critical deficiencies in the truss members based on the bridge condition assessment and strengthening was a viable option. MM also developed conceptual retrofit schemes and cost estimates in its August 2010 report “Evaluation of Potential for Bridge Strengthening for Dubuque Bridge, M.P. 182.00”. In January 2011, MM was awarded the structural engineering contracts for the strengthening of all six trusses, expansion bearing replacement, and swing span floor system replacement. Alfred Benesch & Company was awarded the engineering contract for the replacement of the fixed span floor systems. Bid solicitations were extended and subsequently awarded in three separate contracts: fixed span floor system replacement, fixed span truss strengthening and swing span floor system replacement/truss strengthening. Osmose Railroad Services, Inc., the successful bidder for all three contracts, started the structural rehabilitation work in July 2011, and completed the work in April 2014. The construction was conducted in the following stages: fixed span floor system replacement, fixed span truss strengthening, expansion bearing replacement, swing span floor system replacement.
replacement, and swing span truss strengthening. New steel installed is approximately 2.7 million pounds while existing steel removed is approximately 1.2 million pounds resulting in a net addition of 1.5 million pounds. The total cost of structural rehabilitation including engineering is approximately 17.5 million dollars. The bridge rehabilitation also included mechanical/electrical upgrades and in-kind replacement of the pivot pier north fender system, which are not part of this paper or the aforesaid cost.

2.0 RETROFIT DESIGN AND DETAILS

2.1 Extent of Strengthening

The extent of strengthening was based on a holistic approach taking into consideration information from CN’s capacity analysis, detailed bridge condition inspection reports, field stress measurements, field ultrasonic test results, fatigue and redundancy considerations, extent of corrosion, history of repairs and observed behavior under traffic. It was determined that the following major components would be part of the capacity upgrade:

- Floor System – Stringer and Floorbeams
- Bottom Lateral System
- Traction Bracing for Fixed Spans
- Hip Hangers of Fixed Spans
- Eyebear Diagonals for Fixed Spans and Swing Span
- Eyebear Bottom Chords for Fixed Spans
- Upper and Lower Truss Joints
- Expansion Bearings for Fixed Spans

Figure 3 indicates the members that require strengthening.

![Figure 3 – Strengthening Members](image)

2.2 Retrofit Design Criteria

- **Design Loading**
  - 315K Unit Cars with GF543a locomotives
  - 25 MPH maximum speed
  - 50-60 year life extension
• **Material**
  - Structural Steel: A709 Grade 50W (unpainted)
  - Bolts: A325 Type 3

• **Built-up Members**
  - Welded member fabrication
  - Bolted connections

• **Joint and Member Strengthening**
  - Avoid additional pin loading by bypassing the pins
  - Provide alternative load path around the pin
  - Provide redundancy
  - Ease of construction

• **Rail and Marine Traffic**
  - Scheme that will minimize rail traffic interruptions
  - Least impact to marine traffic when working on the swing span

### 2.3 Retrofit Schemes

Based on the member types and joint geometry, constructability, access, and design requirements, various schemes were developed for the member retrofitting, including replacement, addition of strengthening members, additional gussets, and reinforcing plates. Table 1 summarizes the schemes used for retrofitting various major components. Figure 4 shows truss geometry and strengthening for each span type.

**TABLE 1 – Retrofit Schemes**

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<td>Floorbeams</td>
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<td>Additional Hairpin Plates for Redundancy</td>
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<td>New Spidering Gussets Bypassing Pins</td>
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<td>Replacement</td>
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<tr>
<td>Traction Bracings</td>
<td>Addition</td>
<td>Rolled Sections (L)</td>
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2.4 Retrofit Details

2.4.1 Floor Systems

The strength, fatigue, and poor condition rating of the existing floor system clearly pointed towards the need for replacement. The existing system consisted of a pair of live load carrying main stringers spaced at 5' with a pair of safety stringers 2' from each main stringer. The replacement floor systems use a stringer and floorbeam arrangement and details that provide equal live load distribution, including four main stringers spaced at 2'-6".

A typical floor system for the fixed spans, as shown in Figure 5, consists of 4 stringers (W24x162) framed into welded built-up floorbeams with knee brackets at the ends. Traction frames were added and new truss laterals were installed with the floor system.
At Lower Joint L1, the reinforcing plates for the hip hanger retrofit were also installed with the floorbeam prior to the strengthening work for the hip hangers.

![Figure 5 – Typical Floor System for Fixed Spans](image)

The floor system for the swing span, as shown in Figure 6, is below the bottom chords, supported by the hanger plates on the lower pins with 4 stringers (W33x118) sitting on top of the welded built-up floorbeams. It was very difficult to provide redundancy for the floorbeam hangers. After extensive study, a creative solution was developed that employs reversed hairpin connection plates connected to the posts at the top and the hanger plate at the bottom, as shown in Figure 7.

![Figure 6 – Typical Interior Floor System for Swing Spans](image)

It should be noted that the hanging floorbeams are used at the interior joints only, while the end floorbeams are different as shown in Figure 8. Also, the existing stringers in the two panels adjacent to the pivot panel remain in place because they were installed in 1997. The new bottom laterals were installed along with the replacement floorbeams.
2.4.2 Hip Hangers

The existing hip hanger for the fixed spans was a riveted built-up section of laced double channels. The hip hanger strengthening consisted of new cover plates replacing existing lacings bolted to flanges of the existing channels using the existing rivet holes and newly drilled holes, as shown in Figure 9. Reinforcing plates attached to the channel webs at both ends provide connections to the gussets at the upper and lower joints, the transitions to cover plates, and the additional flexural capacity. The reinforcing plates were installed with the floorbeams before the hanger strengthening work.
2.4.3 Upper Joints

Upper joint strengthening included installation of the butting gussets connecting to the webs of the existing top chords. The gussets serve two primary functions:
- Add stability to the pin joint.
- Provide alternative load path for the eyebar strengthening members.

Figure 10 shows a typical gusset arrangement for Upper Joint U1. A splice was used to facilitate installation and provide adjustment for field variances in geometry and alignment. Additional holes in the existing members were required, as well as the removal of some lacings and installation of new stay plates.

![Figure 10 – Typical Fixed Upper Joint U1 Strengthening](image)

Figure 11 shows a typical gusset arrangement for an upper joint that connects a single diagonal, while Figure 12 shows an upper joint that connects double diagonals. The
The gusset was detailed to clear the sway frame. The single diagonal joint has a side bracket connected to the bottom of the chord.

**Figure 11** – Typical Single Diagonal Upper Joint Strengthening

**Figure 12** – Typical Double Diagonal Upper Joint Strengthening
2.4.4 Lower Joints

Lower joints for fixed spans are pinned joints connecting eyebar members. Strengthening pinned joints presented significant design and detailing challenges as well as erection difficulties. Avoiding additional loading of the pins and providing an alternate load path around the pins was the most critical element of the design. The retrofit scheme developed for the pinned joints employed overlapping spidering gussets that could transfer loads from diagonal strengthening members directly to the verticals and the strengthened bottom chord members without the load having to pass through the pins. This innovative solution achieved several major goals: strengthening the pinned joints, providing an alternative load path and redundancy for the eyebar strengthening members, and allowing for ease of construction and minimal interruption to the rail traffic.

Figure 13 shows typical Joint L2 where one chord is a box member and the other chord is an eyebar pack. Connection beams were needed to connect the spidering gussets to the webs of the box member.

Figure 13 – Typical Lower L2 Joint Strengthening
Figure 14 shows typical pinned joint strengthening where all diagonals and bottom chords are eyebars. Overlapping spidering gussets were used here.

![Figure 14](image1)

**Figure 14 – Typical Lower Pinned Joint Strengthening**

2.4.5 **Eyebar Bottom Chord**

Eyebar bottom chord strengthening included two welded built-up channels connecting to the new gussets at the lower joints. The strengthening members have independent load paths and the capacity to take full live load and impact. The two channels are between the existing eyebars and connected by the stay plates, as shown in Figure 15.

![Figure 15](image2)

**Figure 15 – Typical Eyebar Bottom Chord Strengthening**
2.4.6 Eyebar Diagonals

The eyebar diagonal strengthening also consisted of two built-up channels with stay plates. Depending on the gusset arrangement, the placement of the channels could be one of the following three cases:

- between the eyebars (Figure 16a)
- outside the eyebars (Figure 16b)
- above and below the eyebars (Figure 16c)

![Figure 16 – Typical Eyebar Diagonal Strengthening](image)

2.4.7 Mid Joints

Because of the different channel placement and orientation for the diagonal strengthening members, there is a need to add a mid joint to accommodate the transition. Figure 17 shows a mid joint that has all three cases of diagonal strengthening channel placement and the transition gusset at mid joint.

![Figure 17 – Typical Mid Joints](image)
2.4.8 Expansion Bearings

The existing truss expansion bearings were frozen, some in a fully displaced condition. Because the original bottom chords of the trusses included eyebar members that could not transmit compression forces, the frozen condition of the expansion bearings did not induce excessive stresses in the bearings and truss members. However, this would change when the bottom chord eyebar members were strengthened with sections that could also resist compression. Therefore, bearing repairs were part of the truss strengthening work. After investigating several options, the decision was made to replace all expansion bearings with polytetrafluoroethylene/stainless steel (PTFE/SS) sliding bearings. The use of this bearing type was feasible because of the presence of the pinned truss end joint, which provides the required rotation capability for the bearing. The replacement bearing assembly consists of a base plate that includes an embedded PTFE plate and a sole plate with stainless steel plate attached, as shown in Figure 18. This low profile bearing sits on a polymer concrete pad and allows for easy installation with minimal jacking and elevation adjustments.

![Figure 18 – PTFE/SS Sliding Bearings](image)

3.0 CONSTRUCTION

The online construction of a rehabilitation project of this complexity and magnitude required good planning, coordination, and execution. There were many challenges during the construction phase, and Osmose found solutions to various issues encountered and successfully completed the structural rehabilitation.
3.1 Construction Related Issues

3.1.1 Field Verifications

Field verification of the existing truss geometry, member details and dimensions, and site conditions was critically important to the fabrication and installation of the strengthening metal work. Prior to fabrication, a hi-rail bucket truck was used to access all points to verify dimensions on the design and original plans. Joint U1 locations on the swing span had to be modified to account for reinforcing work previously done. Gusset plates and reinforcing channel spacing had to be modified to provide clearance around the turnbuckles on the fixed span eyebars.

3.1.2 Logistical Concerns

The work involved a long, single track structure over a navigational channel. During the construction, rail (CN and BNSF) and navigation traffic had to be maintained. The bridge is also in close proximity to a BNSF interlocking and insulated joint. There is a BNSF diamond off the east end of the bridge. The bridge signal system and track time are controlled by the BNSF dispatcher. The heavily-travelled waterway required the bridge to be open for large periods of the day. With all these constraints, Osmose had to work closely with CN’s bridge tenders and BNSF dispatchers to obtain track time to ensure minimal interruption to the rail traffic.

3.1.3 Accessing Work Locations/Staging

Floor system replacement required access to the entire underside of the spans. Logistics for material handling required the under-bridge access to be movable during outages. Access was also needed at large areas near upper truss pin locations while not obstructing the railroad clearance envelope. The pivot pier fender was utilized for access to the floor system on the swing span in the open position. In anticipation of swing span rehabilitation, north fender system repairs included a complete steel grating walkway and a steel handrail system.

3.1.4 Material Handling

With both the tie deck and floor system of a single bay being replaced in an outage, barges were used below the span to accept the removed steel and tie deck material as well as stage the new steel material for the fixed spans. Where the water level or ice did not allow use of a barge, a hi-rail Geismar 360 Crane was used to allow pick and carry handling of the material from the end of the bridge. Material for the swing span was staged on the pier protection to limit time in the navigation channel. The tie deck was prebuilt in panels and installed from the track level. Truss reinforcing material was kept in a local warehouse due to high theft rates and brought to the site as needed for installation.
3.1.5 Field Installation Challenges

Clearances at pin locations were extremely tight. Where eye bars had shifted and twisted over time, they had to be re-centered prior to installation of the gussets and strengthening members. With the number of pieces that went into some joints, an exact sequence had to be followed to allow installation and bolting. With some locations having up to 11" of steel to bolt through, extra-long reamer bits and drift pins were required to facilitate the bolt installations. The majority of the swing span work had to be performed in the open position, so material was brought out by barge and staged on the pier protection fender. The swing span work on each side of the pivot had to progress equally out from the center to keep the operating span balanced. To account for the additional sag in the structure due to the added material weight, the upper eye bars were flame shortened at the center tower of the swing span. Temporary stringer brackets/saddles were installed at new floorbeams to support existing stringers.

3.1.6 Surface Preparation

Existing steel surface preparation between contact surfaces followed SSPC-SP 11 “Power Tool Cleaning to Bare Metal” with SSPC Class 3P containment. Power tool cleaning was limited to vacuum-shrouded power tools. Any faying surface that was not sealed between new steel was metalized for corrosion protection. Hazardous waste handling was per OSHA regulations.

3.1.7 Other Issues

There were many other issues that had to be resolved during the course of construction.

- Weather: precipitation (rain and snow), wind, cold and heat.
- CN power relocation.
- BNSF signal relocation coordination.
- North fender system barge collision (during project) and subsequent fender system replacement.
- Coordination with CN Forces who installed new 136# CWR.

3.2 Construction Time

- Fixed truss floor system replacement:
  - 8 hours: end floorbeam/adjacent stringer/tie deck
  - 12 hours: initial interior floorbeam/stringer bay/tie deck
  - 5± hours: subsequent interior floorbeam/stringer bay/tie deck due to Osmose’s proficiency
- Swing span floor system replacement:
  - 8 hours: end floorbeam/stringer bay/tie deck and pivot panel stringer bay
  - 6 hours: interior floorbeam/stringer bay/tie deck
• Fixed Span Truss Strengthening:
  o Lower joints installed under traffic in small time blocks
  o Upper joints-main plate installations done in windows of 2-3 hours per side
  o Diagonal members installed under traffic in small time blocks
• Swing Span Truss Strengthening:
  o Lower joints installed under traffic in small time blocks
  o Upper joints-main plate installations done in windows of 2-3 hours per side
  o Diagonal members installed under traffic in small time blocks
• Expansion Bearing Replacement:
  o 6-8 hours per pair of bearings

3.3 Construction Activities

3.3.1 Staging

Figure 19 shows staging for the fixed spans on a barge and for the swing span on the north end of the pivot pier fender.

![Figure 19 – Staging for Floor System Replacement](image)

3.3.2 Material Handling

Figure 20 shows the material delivery from a barge and a hi-rail Geismar 360 Crane.

![Figure 20 – Material Delivery](image)
3.3.3 Scaffolds

Figure 21 shows the scaffolds for upper and lower joint strengthening.

![Scaffolding for Upper and Lower Joints](image)

Figure 21 – Scaffolding for Upper and Lower Joints

3.3.4 Surface Preparation

Figure 22 shows the surface preparation and hazardous material handling.

![Surface Preparation and Hazardous Material Handling](image)

Figure 22 – Surface Preparation and Hazardous Material Handling
3.3.5 Floor Systems

Figure 23 shows the floor system replacement in a typical fixed span panel, while Figure 24 shows the swing span. Because the existing stringers have different spacings from the replacement stringers, temporary stringer support brackets were used to accommodate the spacing differences.

Figure 23 – Fixed Span Floor System Replacement

Figure 24 – Swing Span Floor System Replacement
3.3.6 Lower Joints

Figures 25 and 26 show strengthening activities at fixed and swing span lower joints.

![Figure 25 – Lower Joint Strengthening – Fixed Span](image)

![Figure 26 – Lower Joint Strengthening – Swing Span](image)

3.3.7 Upper Joints

Figure 27 shows strengthening activities at Swing Span upper joints.

![Figure 27 – Upper Joint Strengthening – Swing Span](image)
Figure 28 shows strengthening activities at Upper Joint U1, while Figure 29 shows a typical interior upper joint.

Figure 28 – Upper Joint U1 Strengthening

3.3.8 Members

Figures 30 and 31 show installation of fixed and swing span strengthening members.

Figure 30 – Strengthening Member Installation – Fixed Span
3.3.9 Expansion Bearings

Figure 32 shows new expansion bearing installation.

4.0 FIELD TESTING

CN Forces performed field testing of Span 6 before and after strengthening to validate the results of the rehabilitation work. The data shows that the live load stresses in the existing members have been reduced, which indicates that the newly installed members provide stress relief and thus increase the load carrying capacity of the bridge. Figure 33 shows the strain gages on the original truss members prior to the strengthening work and on the original and new truss members afterwards.
Figure 34 shows the original and the completed fixed span, while Figure 35 shows the swing span prior to and after rehabilitations.
5.0 CONCLUSION

Rehabilitation of the Dubuque Bridge with creative retrofit measures provided a cost effective way to upgrade the load carrying capacity and extend the lifespan of this 125 year old bridge to meet the increased capacity and traffic demand on the CN’s mainline. Strengthening of these pin-connected Pratt through-truss spans presented design, detailing, and erection difficulties, especially for the eyebar members and pinned joints. The owner, the designer and the contractor worked together to find solutions to the challenges which resulted in an efficiently strengthened structure with a redundant load path for most of the critical truss members, like a bridge within a bridge.

6.0 ACKNOWLEDGEMENTS

The authors would like to acknowledge the entire project team for the success of this rehabilitation work, especially Sandro Scola, Mike McDermott and Aneesh Bethi of CN, Zolan Prucz, Jeremy Martin, Josh Moore and Greg Taravella of MM and Dave Gates of Osmose.
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Mark Paull
CN

Rick Floyd, PE
Osmose
**Bridge Rehabilitation**

- **Increased Bridge Capacity Demand**
- **Rehabilitation Feasibility Study**
- **Design**
- **Structural Retrofit**
- **Electrical / Mechanical Upgrade**
- **Fender Replacement**

**Participants**

- **Owner:**
  - CN Railway
- **Engineering:**
  - Modjeski and Masters, Inc.
  - Alfred Benesch & Company
  - URS Corporation
  - ESCA Consultants, Inc.
  - Golder Associates, Inc.
- **Construction:**
  - Osmose Railroad Services, Inc.
  - J. F. Brennan Company, Inc.
  - CN Engineering (Maintenance of Way)
- **Material:**
  - LeJeune Steel Company
  - Capitol Steel Corporation
  - Goodco Z-Tech
**Important Timeline**

- Purchase Order
- Rolled Stringers
- Fixed Truss
- Floor System Replacement
- Exp. Bearing Replacement
- Swing CWR Replacement
- SWU Upgrade
- Exp. Bearing Replacement
- Swing CWR Replacement
- Floor System Replacement
- M/E Upgrade
- Structural Steel
- New Steel Installed: 2.7 million pounds
- Existing Steel Removed: 1.2 million pounds
- Total Cost – $20,000,000
  - Structural Rehab (incl. Tie Deck & Rail): $16,600,000
  - North Fender Replacement: $1,000,000
  - Engineering (excl. M/E): $900,000
  - Mech/Elec Upgrade (incl. engineering): $1,500,000

**Structural Rehabilitations**

- Upgrade Capacity
  - 315K cars
  - 25 mph
- Provide Redundancy
- Extend Service Life 50+ Years

**Existing Structure**

- West Approach
- East Approach

**Existing Fixed Spans**

- Eyebar Bottom Chords
- Eyebar Diagonals
- Pin Joints

**Existing Swing Span**

- Hanging Floorbeams
- Eyebar Diagonals
- Eyebar Top Chords over the Pivot

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**Existing Condition**

From Inspections, Ratings, Condition Assessment, Field Testing and Feasibility Study:

- Overall Condition: Good
- Rehabilitation: Feasible
- Strengthening: Required

**Required Retrofit**

- Floor System
- Bottom Lateral System
- Hip Hangers of Fixed Spans

- Eyebar Diagonals
- Eyebar Bottom Chords
- Pin Joints
- Expansion Bearings

**Strengthening Criteria**

- **Design Loading**
  - 315K Unit Cars with 25 MPH Speed
- **Material**
  - Structural Steel: A709 Grade 50W (unpainted)
  - Bolts: A325 Type 3
- **Members and Connections**
  - Welded fabrication
  - Bolted connections

**Challenges**

- **Strengthening Pin-Connected Joints and Eyebar Members**
  - Avoid additional pin loading by bypassing the pins
  - Provide alternative load path for strengthening members
  - Provide redundancy
  - Facilitate construction
  - Minimize rail and marine traffic interruptions

**Development of Retrofit Schemes**

- **Considerations:**
  - member type
  - joint geometry
  - space availability
  - access
  - constructability

- **Schemes:**
  - replacement
  - reinforcing
  - auxiliary members
  - new gussets
  - additional joints

**Retrofit Schemes**

- **Schemes**
  - Replacement
  - Strengthening w/ Parallel Members
  - Additional Gussets
  - Reinforcing Plates
  - Additional Plates for Redundancy

- **Based on**
  - Member Type
  - Joint Geometry
  - Constructability
  - Access
  - Design Requirement
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**Fixed Span Floor System Replacement**
- 4 - W24x162 Stringers
- Built-up Floorbeam
- Knee Brackets
- Intermediate Diaphragms (W18x86)
- Traction Frame
- New Bottom Laterals
- Design by Alfred Benesch

**Swing Span Floor System Replacement**
- 4 - W33x118 Stringers
- Built-up Floorbeam
- Hanger connecting to pin
- Intermediate Diaphragms (W27x94)
- New Bottom Laterals

**Swing Span Floorbeam Hanger**
- Reversed Hairpin Connection Plate Provides Redundancy
- Hanger PL
**Hip Hanger Strengthening**

- Reinforcing Plates
  - replace lacings
  - add axial capacity
- Connection Plates
  - provide transitions and connections to gussets at top and FB at bottom
  - add out-of-plane bending capacity

**Fixed Span Upper Hip Joint U1**

- Add Joint Stability
- Provide Alternative Load Pass
- Butting Gussets
- Splices
- Existing Hairpin
- Access
- Lacings and Stays

**Fixed Span Single Diagonal Upper Joint**

- Add Joint Stability
- Provide Alternative Load Pass
- Butting Gussets
- Bracket
- Sway Frame

**Fixed Span Double Diagonal Upper Joint**

- Add Joint Stability
- Provide Alternative Load Pass
- Butting Gussets
- Splice

**Fixed Span Lower Joint L2**

- Alter. Load Pass
- Spidering Gussets
- Bracket
- Spacer Beam
- Connections

**Typical Fixed Span Lower Joints**

- Alternative Load Pass
- Spidering Gussets
- Vertical Connections
- Eyebar Spacers
Typical Fixed Span Bottom Chord
- Provide Strengthening and Redundancy
- Built-up Channels
- Alternative Load Path
- Connection to Gussets
- Between Eyebars
- Stay Plates

Typical Fixed Span Diagonal
- Auxiliary Member - Built-up Channels
- Alternative Load Path through Gussets

Mid Joint
- Provide transition for various arrangements of diagonal strengthening members

Expansion Bearing Replacement
- Frozen
- Build-up stress in Bottom Chords
- Pin
- PTFE/SS Sliding Bearing
- Low profile
- Minimal Jacking

Field Testing
- Verify Results of Strengthening

Before and After – Fixed Span
Before and After – Swing Span

Construction

• Field Verifications
• Logistical Concerns
• Accessing Work Locations/Staging
• Material Handling
• Field Installation Challenges
• Surface Preparation
• Weather
• Coordination with CN and BNSF

Construction Time

• Fixed truss floor system replacement:
  – 8 hours: end floorbeam/adjacent stringer/tie deck
  – 12 hours: initial interior floorbeam/stringer bay/tie deck
  – 5± hours: subsequent interior floorbeam/stringer bay/tie deck
• Swing span floor system replacement:
  – 8 hours: end floorbeam/stringer bay/tie deck and pivot panel stringer bay
  – 6 hours: interior floorbeam/stringer bay/tie deck

Construction Activities

• Staging
  – on barge
  – on pivot fender

• Material Delivery
  – barge
  – hi-rail Geismar 360 Crane

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Construction Activities

1. Surface Preparation
   • Scaffolding
     – Upper Joints
     – Lower Joints – Traveling Platform

2. Surface Preparation
   • Hazardous Material

3. Surface Preparation
   • Fixed Span
     – Floorbeam
     – Stringers

4. Swing Span
   – Hangers
   – Floorbeam
   – Stringers

5. Swing Span
   – Hip / Mid
   – Strut

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Construction Activities

- Lower Joints
  - Fixed Span
  - Swing

- Member Installation

- Bearing Replacement

Maintenance of Traffic

- CN and BNSF Rail Traffic
- Marine Traffic

Safety

- Excellent safety results: Osmose > 64,000 Man-hours.
- FRA site visit December 2012 – no exceptions noted.
- Monthly safety audits.
- Incidents: 4 each all non-reportable.

Summary

- Cost Effective Capacity Upgrade
- Creative Rehabilitation Design and Detailing
- Good Planning, Preparation and Execution in the Field
- Minimal Interruption to Rail and Marine Traffic
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