Replacement of the TRRA Merchants Truss Spans – Face Lift for a 120-Year-Old Bridge

JOSH CRAIN, P.E., S.E, Genesis Structures Inc., Kansas City, MO, ROB NEVILLE, Walsh Construction, Chicago, IL, MATT BOBEN, Mammoet USA

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ABSTRACT: The Terminal Railroad Association of St. Louis' (TRRA) Merchants' Bridge is a railroad gateway between Missouri and Illinois, crossing the Mississippi River near downtown St Louis. Along with modifications to the existing approach structures, the project is highlighted by the replacement of the three original 4 million pound 517-foot pin-connected simple span main trusses and reinforcement of the limestone and granite masonry main river piers original constructed in 1890. The original twin-track truss spans are replaced with three 9-million-pound twin-track ballasted trusses. This presentation will focus on the accelerated bridge construction methods used on the project, most notably the assembly of the new trusses on a floating plant on the river and the gantry system and temporary foundations utilized for the removal of the existing trusses and installation of the new trusses.

INTRODUCTION AND PROJECT BACKGROUND

Span Replacement Method

The principal challenge for the Merchants Bridge team was keeping the existing bridge operational while the new bridge was under construction. The job is centered around completing the substructure work under single-track operation and replacing each truss span during a 10-day closure. Within the 10-day closure, the contractor had two 24-hour windows to close the channel and remove the existing span or install the new span.

The construction team reviewed several replacement options during the bid phase. The first option considered was building the truss on a fixed platform or barges at elevation similar to Figure 1. This would keep hoisting to a minimum but ultimately had too many issues. The truss would have needed to be built 80' in the air at normal low water. That lead to stability concerns on the barges and access issues during construction. With the strong current, the team was also concerned about securing the barges in the current to land the bridge precisely on the pier cap.

Figure 1 - Float-in Concept Developed by EOR

The chosen span replacement method was to install a gantry beam over each pier and utilize a strand lift and slide system to hoist or lower the truss to barges on the water. See Figure 2. Since this method allowed the truss to be constructed 5' off the barge deck, that allowed for better access, better stability and simplified the crane picks.

Figure 2 - Strand Jack Concept Developed by Construction Team

Original Bridge Construction

Construction of the Merchants Bridge began in late 1888 and was completed in early 1890, a total construction duration of about 18 months. By contrast, the construction of the new bridge has an anticipated construction duration of 38 months. The present-day construction team was limited to building a single span at a time under single track train traffic, but the original construction duration of 18 months is still impressive.

The bridge is founded on a timber caisson that was constructed on land, floated out to the pier location in the river and ballasted down to the riverbed as shown in Figure 3**.**

Figure 3 - Original Bridge Caisson Construction

Four river piers are constructed from granite from the timber caisson to the normal high-water level and limestone above the normal high-water level. The masonry blocks form the pier's perimeter, and the hollow interior is filled with concrete

The superstructure, shown under construction in Figure 4, is a 517′ 4-million-pound steel truss. During construction, a timber trestle was installed that blocked parts of the river as shoring. The timber piles survived under the riverbed for 130 years and ended up being major obstructions for the cofferdam work on the new bridge.

Figure 4 - Original Bridge Main Truss Span Construction

PREPARATION OF 120-YEAR-OLD BRIDGE STRUCTURE

Pier Strengthening

In addition to the total replacement of the main truss spans, another primary goal of the structural rehabilitation was to strengthen the four existing river piers to function during a seismic event and to withstand impacts due to vessel collisions. Strengthening of the 120-year-old masonry piers was achieved by adding a 3-ft thick concrete encasement. The new encasement was supported on a new concrete footing with micropiles. Dowel bars were drilled into the masonry to aid in transferring the shear forces from the new concrete to the existing stone.

During construction, the gantry system is supported on the existing pier on the upstream end and by new drilled shafts on the downstream end. The location of the upstream gantry tower fell outside the limits of the existing masonry cap and entirely on the newly encased portion of the pier cap, as shown in Figure 5. To ensure integrity of the pier during construction, two separate load paths were considered in the evaluation. The first load path assumed the gantry tower loads were supported fully by a reinforced concrete column section considering only the new concrete as being effective without shear-friction resistance from the drilled dowels. The capacity of this section was found to be adequate for the gantry tower loads. The second load path considered only the shear-friction resistance of the dowels drilled into existing stone. The size and quantity of drilled dowels was increased from the original design to provide additional capacity to transfer the gantry tower load into the existing pier. Two independent load paths capable of withstanding the gantry tower load provided the desired redundancy for this critical and unique operation.

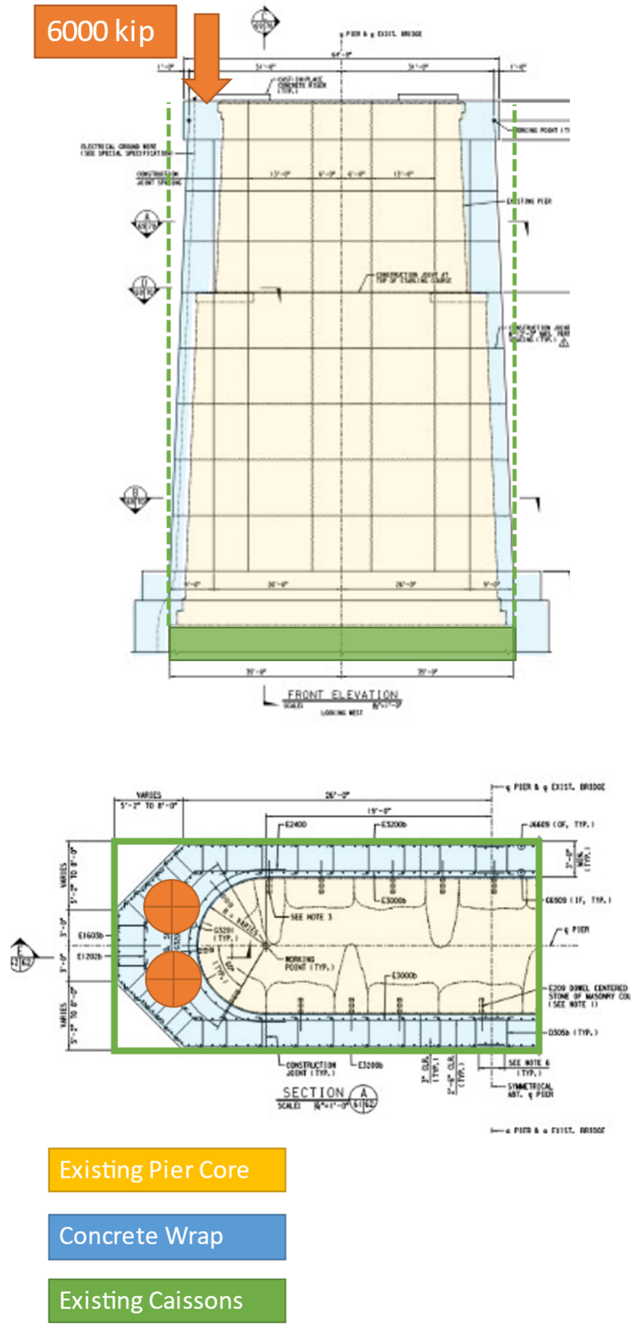

Figure 5 - Loadpath for truss falsework through strengthened pier

Existing Truss Strengthening

The method of removal of the existing 3,800,000-pound truss span required lifting lugs to be attached at the ends for connection to the strand jacks on the gantry system. The existing truss end connections are a pin connecting the tension bottom chord and compression diagonal. See Figure 6. The lifting lug utilized new gusset plates inserted through holes cut in the cover plate of the end diagonal and in between the bottom chord built-up members is shown in Figure 7. The gusset plate connected to the bottom chord and the end diagonal bypassing the pin connection. A lifting plate to connect the strand jacks was then bolted to the new gusset plates.

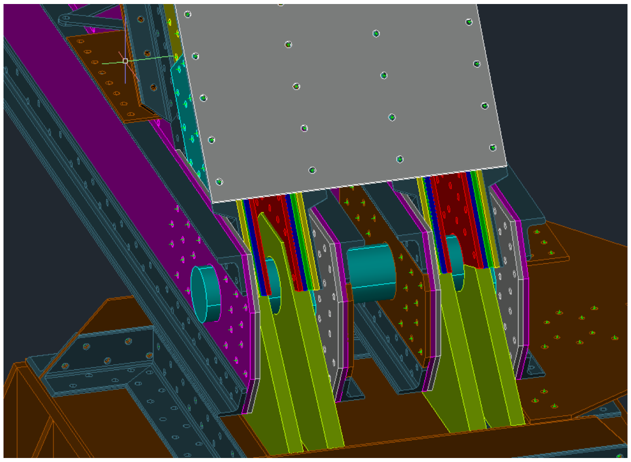

Figure 6 - 3D Rendering of existing L0 pin connection

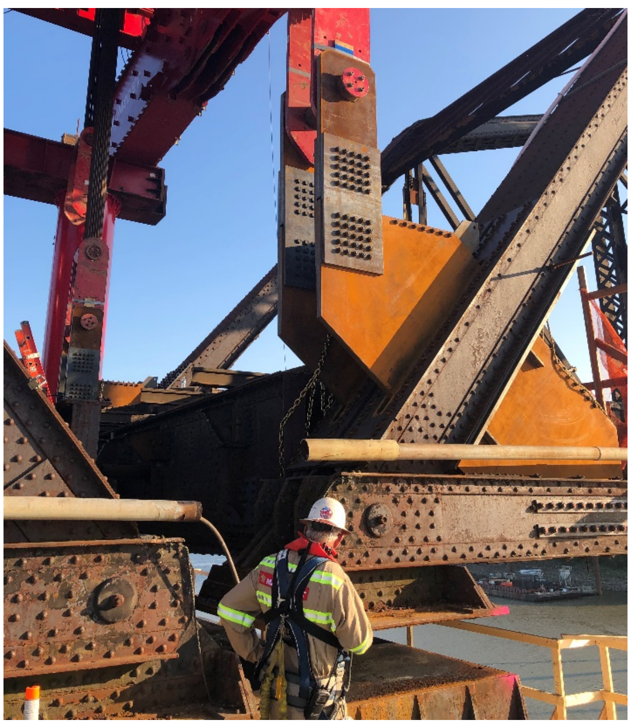

Figure 7 - Existing truss lifting gusset connection

TRUSS ERECTION

Erection Area / Mooring Facility

The truss was constructed on barges at a project-built mooring facility about 3,000′ downstream of the bridge. A lot of thought went into the assembly area to allow for efficient crane operation, protection from high and low water, and protection from extreme weather events. Deliveries arrived on the material trestle shown in Figure 8 and were set using a 4100 ringer crane.

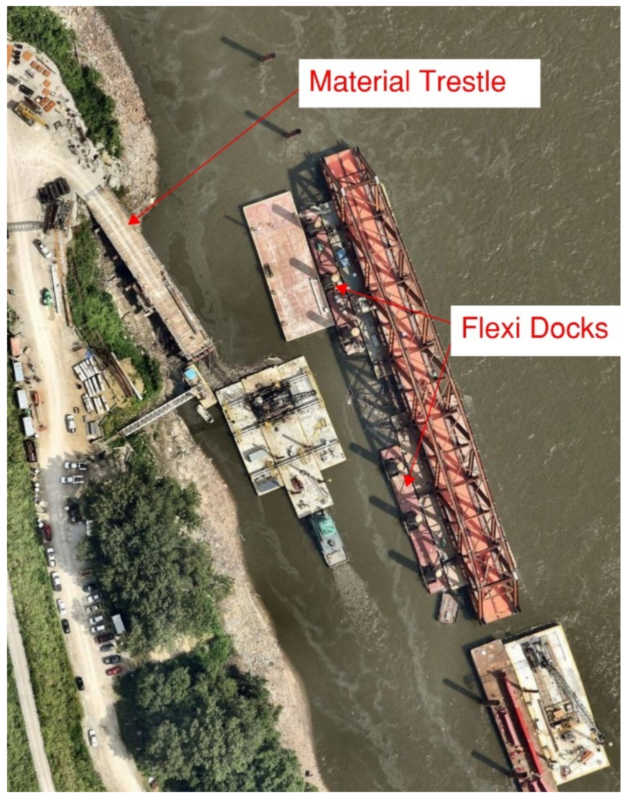

Figure 8 - Aerial Photo of Truss Erection Area and Mooring Facility

To secure the truss in a high wind event, 6 of the 10 piles are 9′ diameter piles drilled 20′ into rock. The large diameter pile and deep rock sockets were required because the Mississippi River experiences changes in river elevation of up to 65 feet and has very little overburden in this area.

A bathometric survey was also conducted in this area as shown in Figure 9. The project team used this to confirm the depth of the overburden compared to rock elevation and ensure the truss barges, drafting 9′, wouldn't bottom out on the river bed.

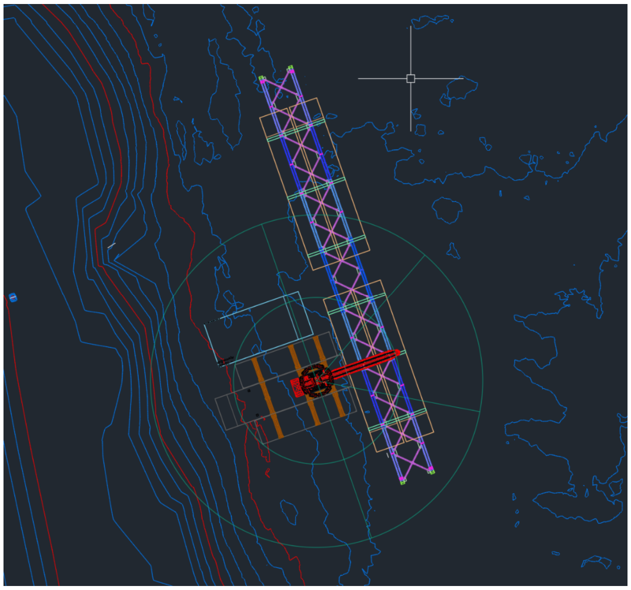

Figure 9 - Plan View with Contours of Truss Erection Area and Mooring Facility

Barge Grillage

The truss was constructed on 4, 35x195x10.5′ barges that were paired together using twin W40x503 spine beams. Reference Figure 10. In order to get the load from the weight of the 9-million-pound span in to the barges, the W40x503 beams were welded to the sides of the barge instead of the top to more efficiently deliver the load in to the barge's internal framing. This also required the construction team to send the barges to a local shipyard to strengthen the barges prior to loading.

Figure 10 - Barge Grillage used for Truss Erection

Phased Erection

The project team put a phased construction plan together to ensure the span sat level in the water and barges remained stable during erection. With individual members weighing up to 131,000 pounds, setting a single member would cause the barge to list noticeably.

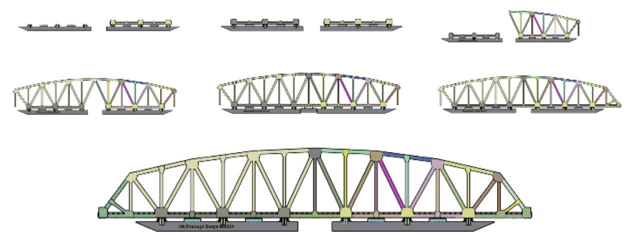

Figure 11 - Truss Erection Sequence

Little was needed in the way of temporary tiebacks or erection aides. The truss members were self-supporting for most stages of construction. The top and bottom chords have flanges that are up to 3-3/4″ thick.

With members that thick and up to 5 plys of steel coming together at one time, some of the 92,000 bolts in a span were up to 11″ long.

GANTRY SYSTEM USED FOR SPAN CHANGEOUT

Gantry System Overview

The main spans changeout gantries were comprised of two unique but similar systems. Mammoet worked with Walsh and Genesis for over three years before the first execution and came up with all the parameters all companies needed to achieve the installations. The downstream supports rested on two 9′ diameter shafts drilled into bed rock by Walsh. The downstream sides of both gantry systems used bases made up of W40 x 431 I beam to allow the MSG towers to be placed on top of the drilled shafts. The upstream side of the support came from custom-made pipe columns that put the load into the upgraded pier. This was achieved by using two 1420mm diameter pipe columns. This side also included a brace that provided stability to the two systems.
The difference between the two gantry systems

was in the main overhead gantry beams spanning between the upstream and downstream falsework. Differences between the overhead gantry beams are described below.

1. One gantry system was- built using an existing Mammoet beam system called the P55 beams. These beams were made from grade 100 plate. The original beams, designed in the early 2010's, were made to fit in standard 40' shipping containers with custom end caps to allow the beams to be made into a 40' container. To achieve the beam length and strengths requirements for this project, Mammoet designed new taller beams sections to be spliced together with the original 2010 beam. The new beams sections were located at midspan to handle the maximum bending forces. These new taller sections were also containerized, but were the max height of a container. See Figure 12 for a profile.

2. The second gantry system used beams called PDV. They were existing beams owned by former ALE. The PDV beams were fabricated from grade 50 material. Mammoet had to reinforce these two beams with over 70,000lbs of steel for the project. The reinforcement work was done in house in our Houston yard. These two beams are the ones discussed above with a weight of +350kips.

Figure 12 - New Larger Profile P55 on left connected to original P55 profile.

Pre-assembly of major components

Another unique aspect of this project was the preassembly work that Mammoet performed before the equipment got to the site. A large number of items were pre-assembled. Below is a list of the largest and most unique items.

1. The PDV beams. With a total length of 154'-2", the beams were reinforced and bolted together at the Mammoet yard in Rosharon, Texas. The beams were then loaded onto dolly load 16-line GH and truck pulled from Mammoet yard in Rosharon, Texas to Freeport, Texas to be loaded onto awaiting deck barges. See Figure 13 & Figure 14.

Figure 13 - PDV beams transported using SMPTs

Figure 14 - PDV beam being loaded onto deck barge

2. Two additional items that were pre-assembled for shipment were the MJS tower and the pipe columns. The MJS towers were fully assembled in the Mammoet yard and trucked down to the barging location. The pipe columns had to be shipped in pieces down to freeport and assembled on site since these were too wide to ship economically. This can be seen in Figure 15.

Figure 15 - Completed components loaded onto deck barge for transport to St. Louis

3. The last major component preassembled is the strandjack assembly seen below in Figure 16. The strandjacks had this individual wire put into the jacks and the re-coilers. This way all the work of stabbing the wire into the jacks could be done prior to the jacks being shipped. Once down at the Freeport loading site, the skid beams and support beams were flown onto the barge, and then the strandjacks with the re-coilers were flown onto the system to make it complete.

Figure 16 - Strandjack assembly with protective tarps

Overall, two barges full of equipment were shipped up to St. Louis, Missouri from Freeport, Texas. The deck barge sizes used for transport were 200′ x 35′ x 10′-6″.

Gantry Falsework Assembly

The Mammoet gantry falsework was installed in the months leading up to the changeout. Walsh Construction built the drilled shafts and rock sockets, and then Mammoet and Walsh worked together to assemble the falsework components. Because of the multiple span changeouts, an East and West gantry systems were fabricated that could be jumped from the first location to the 3rd and second location to the 4th location. Erecting the gantry falsework was a challenge because the size (overhead gantry beams weighed more than 350 kips each) and location (picks were performed with ringer cranes located in the middle of the Mississippi). The most significant challenges of the gantry assembly included:

1. Erection of the taller downstream tower. During truss installation, the stability of the downstream tower was provided by the pipe brace secured to the gantry beam and the existing pier. Prior to erecting the overhead gantry beams, the stabilizing pipe brace was installed to provide the necessary adjustment / stability in the system to allow the beams to stay withing dimensional tolerances. This brace can be seen Figure 17**.**

2. Installation of the 350-kip gantry beams 100-ft in the air. Due to reach limitations with the ringer cranes, the 350-kip gantry beams had to be rigged and set back down multiple times so the ringers could be repositioned. This was achieved by using two legs of the J&R 700ton Gantry system. The two legs were clipped and chained down to the top of the pier. Once the beams were set down, it allowed the ringer crane to be repositioned to finish the installation of the gantry beams. One advantage to using the J&R gantry system is it allowed the gantry beams to be set down and leveled with the hydraulics if needed prior to shimming at the final supports.

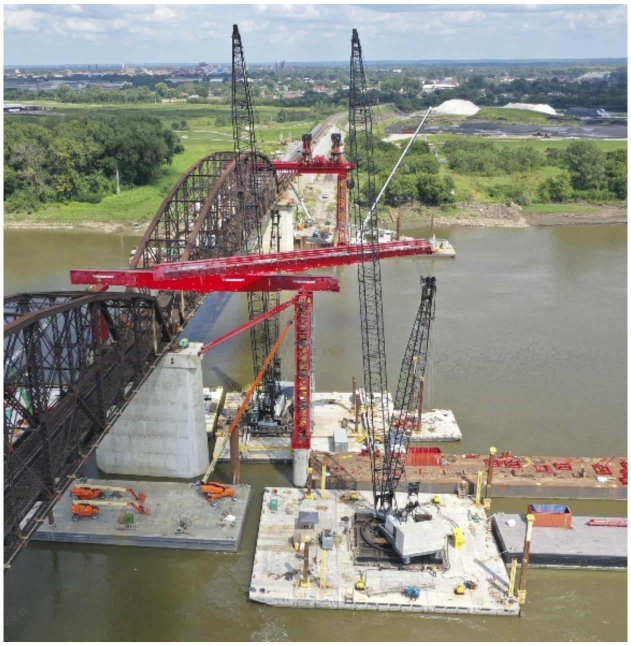

Figure 17 - Installation of Mammoet Gantry Beams. Downstream Falsework Temporarily Braced

3. As with the downstream tower, the upstream pipe supports could also be adjusted using hydraulic jacks under specially designed wings into the pipe column bases. See Figure 18**.** Providing adjustability in the upstream and downstream towers helped ensure the system behaved as predicted in the computer simulation modules.

Figure 18 - Jacks used to help level upstream pier side columns.

4. The last unique and challenging piece to install on the system was the strandjack assembly. The preassembly of the pairs of 900Ton strandjacks will be discussed further down in the article. The unique challenge of the strandjack pairs was determining the C.o.G of the entire assembly. The overall C.o.G of the system was calculated with all the weights and then the below rigging was chosen for the lift. Using a standard Tandemloc bar with side stability "safety rigging" to allow for a successful installation and take down of the 4 total strandjack assembly. The rigging and strandjack assemblies can be seen in Figure 19**.**

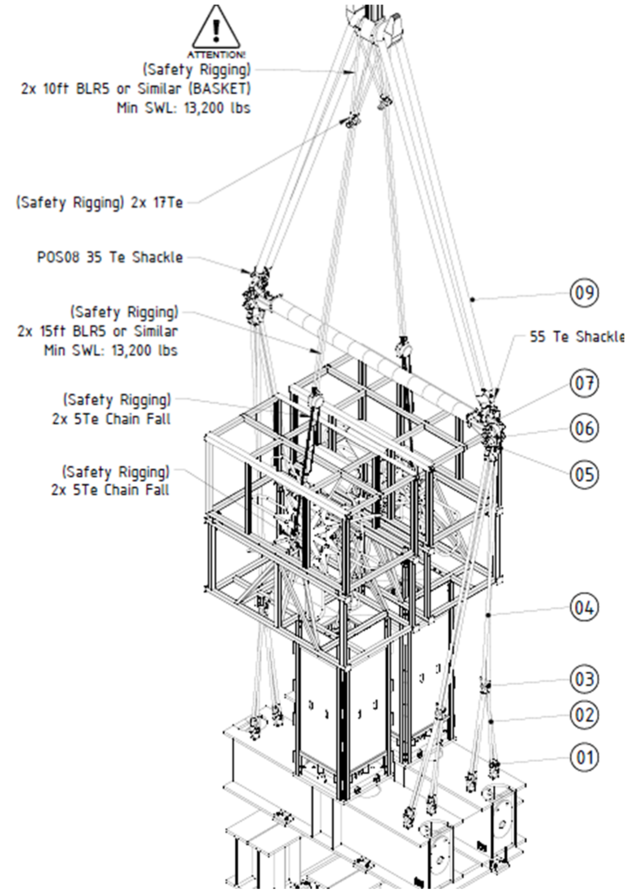

Figure 19 - Strandjack assembly rigging scheme.

SPAN CHANGE OUT

Overview of Schedule

An overview of the changeout schedule is summarized below. So far, the first two spans have been successfully installed within the planned closured plan shown below.

- Close track and channel
- Day 1 – Attach Existing Span Demo Lugs to Gantry & De-Energize the Bridge
- Day 2-4 – Lower Old Truss and Pour New Risers on Pier
- Day 5 – Float in New Truss and Weld Bearings
- Day 6-7 – Install Closure Plates and Track. Re-Energize Bridge.
- Reopen track

Positioning of Barges – Stream Flow Challenges

With the challenges of installing the Mammoet falsework gantry system completed before the changeout, the biggest obstacle now was combating the streamflow at the two spans outside the navigation channel. The large streamflow forces resulted from two conditions: 1) the peak streamflow velocity around the piers was as high as +/-13fps, and 2) the new truss barges were drafting 8 feet and sitting crossways in the river, creating a larger surface for the streamflow to collect. See Figure 20 for a photo of the fully erected new truss at the truss assembly area. Like wind forces, streamflow forces are a function of velocity squared. The stream flows under span 1 in the main navigable channel were recorded at 2-3 fps. The spans outside the navigation channel would generate +/-20 times the streamflow forces if considering the 13-fps peak velocities.

Figure 20 - New Truss Completed on Assembly / Float-in Barges – 2.5-ft of Freeboard Remaining

The Contractor was not permitted to install infrastructure in the channels ahead of the 10-day outages. For this reason, the truss positioning plan had to utilize infrastructure either outside of the main navigation channel or by use of tug boats. Ultimately, the Contractor selected tug boats as the primary system to control the tow of the float-in and float-out barges during positioning between the gantry towers. Even with an 8-fps design streamflow, installing the second span required 14,000 horsepower of tug boats to control the tow, see Figure 21. In addition to the primary control by tug power, a secondary winch system was provided as a backup. The winch system could also be used more effectively than the tugs for the final fine-tuning position of the trusses before being set down. Winches were anchored to separate barges secured to temporary mooring piles anchored in rock.

The Contractor wanted to verify that the 14,000 horsepower was sufficient for handling the new truss before removing the existing. A test push was performed with the float-out barges ballasted down to similar free boards, see Figure 22.

Figure 21 - New Span 2 Barges Controlled with Tugboats Prior to Lifting with Gantry System

Figure 22 - Float-Out Barges Ballasted Down for Test Push with Tugboats

CONCLUSIONS

At the time of writing, all pier reinforcing wraps are completed. The existing 120-year-old piers are now rated to resist vessel impact and seismic forces. Two of the three main river truss spans have been installed. The third is currently being assembled and planned to be installed by the end of 2022.

Given the project constraints of large streamflow forces and pier heights 60-ft above normal pool elevation, the decision to go with a gantry/strand jack installation proved to be very effective. Walsh's concept at bid time, Mammoet's ability to innovatively reuse existing inventory, and the collaborative construction engineering efforts of Mammoet and Genesis were key contributors to the success of the strand jack solution.

The first two spans have been installed within the 10-day track outage. The third span will present similar stream flow challenges seen during the second span installation.