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Rapid Replacement of Bayou Sara Bridge Swing Span

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MARRIOTT'S RENAISSANCE HOTEL AT SEAWORLD
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Introduction

As part of its ongoing program to upgrade and bring remote control capabilities to its inventory of 47 movable bridges, rehabilitation objectives are being addressed concurrently on many, including operational items and equipment, as well as structural repairs as needed. In some cases, replacement was the more prudent option, and this was true for the single-track Bayou Sara Bridge outside of Mobile, AL. The approach spans had been recently replaced, but the through girder swing span was fast approaching 90 years of age. Key objectives for the replacement were to minimize maintenance, and allow for remote operation. It was also crucial that the rail service interruption must be very minimal during the construction phase.

This paper is a synopsis of the change-out of the Bayou Sara Bridge Swing Span, including the adjustments made during construction to meet a rail service outage reduction from 48 to 14 hours. Summary of design aspects for the replacement are also covered.

Background

Bayou Sara Bridge is located at Mile Post 000 658.30, on the M&M Subdivision, northeast of Mobile, Alabama and southwest of Montgomery, Alabama (see Figure 1). The railroad bridge crosses Bayou Sara at the confluence of the Bayou and the Mobile River, adjacent to Twelve Mile Island, and accommodates up to 40 freight trains daily.

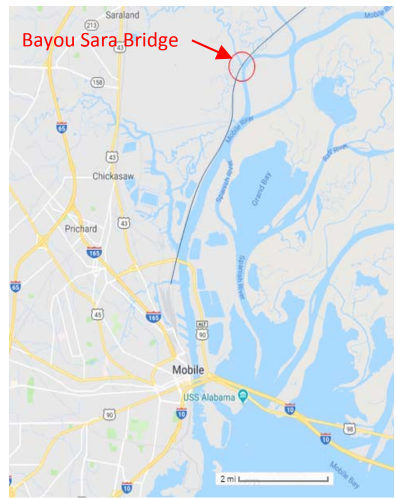

Figure 1 Bayou Sara Bridge Location

The Bayou Sara Railroad Bridge that was replaced is shown in Figure 2. Built in 1928, it comprised a 162’-2” long steel swing span consisting of built-up riveted steel through-girders, supported on the central concrete pier and two open-deck timber span approach structures of 110’-3” and 104’-2” long, respectively, supported by timber-pile trestles with concrete cap beams. The timber approaches were first replaced in 1958 with new timber approaches, and again in 2008 with concrete box-girder spans.

Figure 2 Bayou Sara Bridge to be Replaced – Built in 1928

Design Basis

As noted, the Bayou Sara swing span was reaching the end of its useful life, and so in 2014 the owner and operator CSXT, commissioned HDR to provide design services for the replacement of the entire swing span and construction of any necessary substructure.

It was determined that the replacement structure would be an open deck, steel through girder swing span designed in accordance with AREMA and CSXT Standards and clearance requirements. The design would make use of the existing substructure, with supplementation of the foundation as needed, the extent of which would be determined through soil investigation in the design phase. New mechanical systems would be hydraulically driven, including rail lifters, wedge actuators, and span drive system. System equipment such as drives and Hydraulic Power Unit (HPU) were to be located on the swing span, near the pivot center. Since there is a single navigation channel to the northeast of the pivot pier, an aerial cable was specified over the adjacent crossing, since vertical clearance is not a concern there. Finally, in keeping with CSXT's ongoing program for automation of their movable bridge operations, the replacement bridge was specified to be outfitted with remote operation capabilities.

Design Challenges

As noted above, it was decided to attempt to make use of the existing substructure in support of the replacement superstructure. This presented challenges in assessment of the reliability of the existing timber piles, the surrounding soil, and the concrete substructure elements. Another challenge with the Bayou Sara site is the low clearance from the bridge span down to water level (4.5 ft min. freeboard). Other challenges related to constructability were (1) site access; and (2) limited duration rail outage for span replacement.

Utilize Existing Foundations

Original boring logs from the 1928 contract plans were employed for initial foundation assessments (see Figure 3 for original foundation detail). These assessments concluded that the rest pier foundations were adequate for the replacement design as-is. However, the initial assessment for the pivot pier capacity was borderline, so a soil boring investigation was conducted, under a 24-hour United States Coast Guard (USCG) marine outage, and results indicated adequacy to support the replacement structure. In addition to the questions surrounding the timber piles and soil comprising the deep foundation, the pier concrete was surveyed for its viability under the effects of the new structure as well as the environment, for its anticipated life span. Since the pivot pier concrete near the top surface exhibited wear of both physical and chemical nature, and it was important to ensure the integrity of this critical machinery-mounted interface between the foundation and the replacement superstructure, the decision was made to remove the upper (3-odd ft.) portion of the pier cap, and replace this with a precast concrete cap element, with the rack, wedge seats, and pivot bearing preinstalled to accelerate the replacement. Ultimately, this precast concrete pier cap scheme devised during the design phase was superseded when it was requested in construction phase that the rail outage be reduced from 48 to 14 hours. The adaptation selected to achieve this acceleration is discussed in detail below.

Limited Freeboard

Low clearance below the superstructure to the surface of the brackish water below presents a challenge for durability of the structural steel and for the operating machinery and equipment. This was the driving force behind the use of hydraulics and associated limitation of open gearing. Likewise, the drive system and HPU were ultimately located more than 35 ft. above the (mean high) water level. Stainless steel enclosures (NEMA 4X rated), PVC-RGS conduits, and sub-sea connectors for proximity switches were incorporated to promote resiliency in the electrical system. Metallization and a two-coat epoxy paint system was selected as the structural steel's protective coating measure for low maintenance and maximized life-cycle.

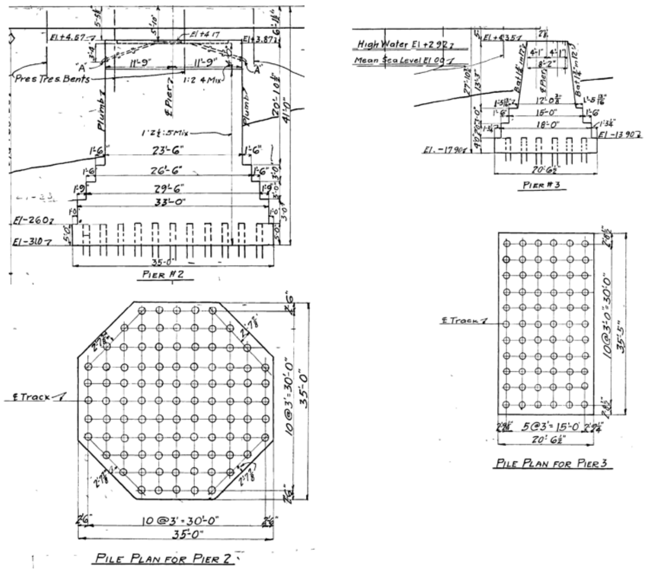

Figure 3 Existing Foundations

Site Access

There are some difficulties associated with the site of the Bayou Sara Bridge. The low-lying swampland extending for miles around the bridge site represents an obstruction against consideration for a roadway of any kind for vehicular access. Access to the bridge for local operation, maintenance, inspection, rehabilitation, construction – including material and equipment delivery – is thus limited to marine vessels, and rail-borne passage such as hy-rail vehicles, see Figure 4.

Figure 4 Site Limited Access

Limited Rail Outage for Span Swap-Out – Grillage

As mentioned above, the rail outage to be conceded by CSXT's freight rail operations was originally 48 hours, which is a challenging timeline for removal of an entire rotating freight-rail conveyance, and installation of a new one. Within the construction phase, Brasfield & Gorrie, General Contractors (B&G) developed a detailed plan to achieve the swap-out of bridges using the solutions detailed in the contract plans within this service outage duration. However, as the planned outage drew near, CSXT requested whether a reduction in the outage could be achieved, to avoid delaying their freight schedules. Options were considered, including temporary shoring to allow faster return to rail service. In the end, the collaborative efforts between the owner, contractor, and engineer concluded that the most cost-effective solution would be a structural steel support frame – or grillage – to be suspended from the new swing span with rack, wedges, and pivot bearing pre-mounted on it, allowing for a faster swap-out of the swing spans.

A schematic of the grillage from Steward Machine Company's (SMC) shop drawings is presented in Figure 5. The primary function of the grillage was to provide support for the new swing span under freight train loads, immediately after float-in. Sufficient rigidity for the direct support – and maintained relative alignment – of pivot bearing and wedge seats was therefore the first requirement. The outage for marine navigation was longer, allowing for time to cast the surrounding concrete in place after the float-in phase. However the schedule did demand that the rack be aligned upon float-in, leading to the second function of the grillage: mounting/support of the rack. The 'T-beam' shape, comprised of welded plates, was selected for the ring beam and the central 'spine' of the grillage, to provide the rigidity needed without a bottom flange which would interfere with concrete placement. At main support locations below the wedge seats and the pivot bearing, lower base plates are incorporated for immediate engagement on shim stacks and grout. Shims were similarly used around the perimeter in support of the rack support beam.

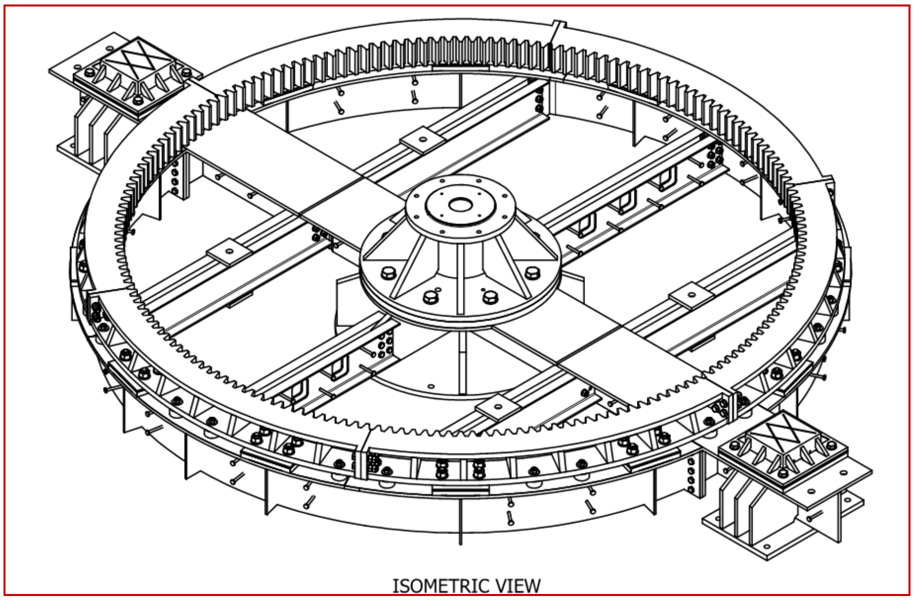

Figure 5 Structural steel grillage shop drawing rendering (Steward Machine)

As illustrated in Figure 5, double-channel bracing elements were incorporated in the grillage frame, transverse to the primary support 'spine' of the grillage, for maintaining the alignment of the frame in transport. These members were also used for engaging with the threaded bars suspended from the superstructure to hold the frame in place during transport. The four bracing beams used for this were removed after location of the span in place, and reinforcing steel cages were then installed. The two main bracing beams at center remained in place and were ultimately embedded in concrete. These were detailed with holes through the webs to promote flow of concrete, and studs to further integrate the steel grillage in the cast-in-place concrete pier cap.

Construction Initiation

The Bayou Sara Swing Span was constructed approximately 5 miles south of the bridge site at a rock storage yard along the Mobile River in Mobile, AL. B&G's construction team mobilized to the site in August 2017 to start site preparations for structural steel erection beginning shortly thereafter. This project posed several construction challenges including utilizing existing foundations, revised float-in duration, working on and around active rail, remote site access, and seasonal increased train traffic. In June 2017, prior to mobilizing, CSXT requested that B&G & HDR begin reviewing options to reduce the outage duration by more than half of the original allotted time. As noted earlier, the grillage concept was ultimately selected in September of 2017, approximately two months prior to the target float-in date of Thanksgiving.

Grillage Procurement

When the grillage concept was first discussed, B&G immediately contacted SMC to discuss constructability and material availability. SMC was able to provide feedback on what shapes were readily available and what fabricated sections would be most efficient to fabricate. The general shape and sections were first approved so that material could be released. Machining and specific anchoring requirements were developed during fabrication through several coordination calls between CSXT, HDR, B&G, and SMC. This collaborative effort facilitated expedited shop drawing development and engineering review and was crucial to procuring the grillage in time for installation prior to the float-in.

Float-In Plan Development

A comprehensive Float-In Plan noting the pre-float-in, float-in, and post float-in activities was developed by B&G to provide visibility on the overall scheme to remove and replace the existing bridge. This plan was submitted to CSXT and HDR for feedback and discussion during weekly coordination calls with respect to potential risks and abatement measures. It also served as a catalyst for discussions clarifying responsibilities between CSXT and B&G leading up to and during the float-in. The Float-In Plan included narratives of key activities, site logistics and staging diagrams (See Figure 6), activity scripts, and construction engineering documents relative to various aspects of the work. The activity scripts were utilized as a form of micro-scheduling. Each key activity was broken down into several tasks. The script included the field crew who would be performing the work, materials and equipment necessary, and a target duration of the activity. After the reviews and approval by all involved, the finalized plan was presented to the B&G field and operations team, CSXT, and HDR prior to the float-in. The presentation provided another opportunity for the entire team to provide feedback or ask questions about the plan.

Pre-Float-In

When internal B&G planning sessions began, the initial focus centered around determining what work could be completed or partially completed prior to the float-in to reduce the original outage duration. The two principal areas of focus were:

1. Existing Foundation Prep Work
2. New Bridge Machinery Prep Work

Within each group, several activities were derived and incorporated into a detailed completion list and tracked daily with the B&G field team to manage the work and track pre-float-in schedule.

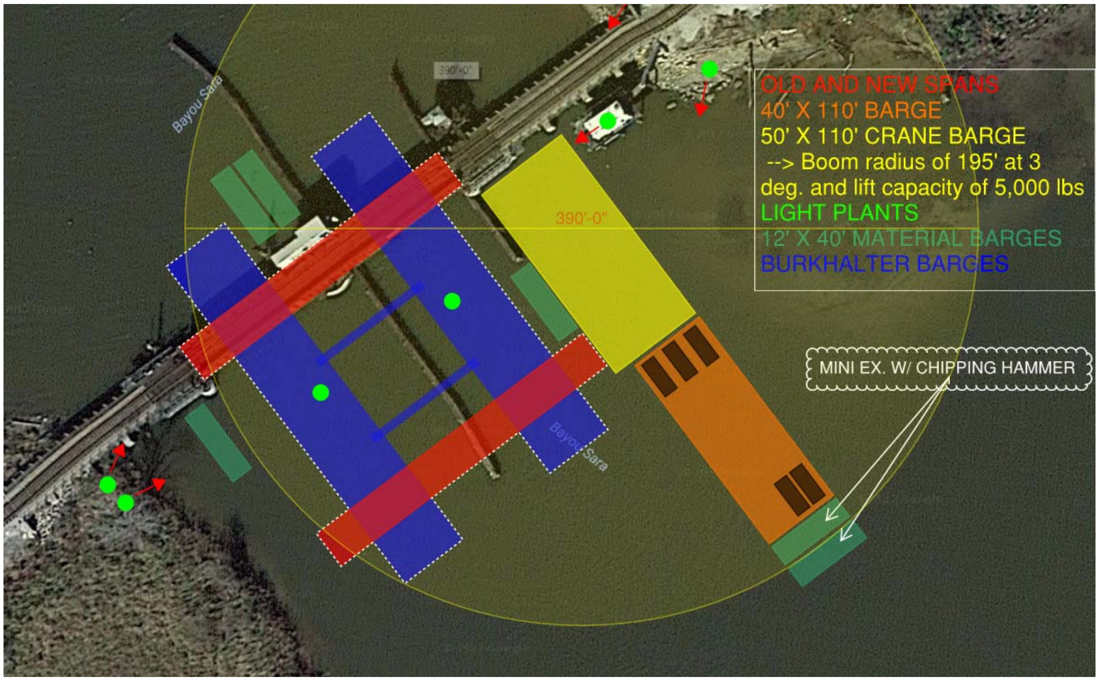

Figure 6 Site Logistics and Staging

Existing Foundation Prep Work

The existing center pier at Bayou Sara was the focal point in planning for the Float-In. A hybrid cofferdam was constructed around the center cap early in the project to provide a working platform 360 degrees about the pier. It utilized a two-stage installation, a synthetic membrane draping the sides, and a small 3" pump to keep water out of the work area as needed. As noted above, approximately 3ft of the existing pier needed to be removed and replaced with a new reinforced concrete cap. Having the ability to access the center pier at all times was crucial. Figure 7 shows the cofferdam setup.

The biggest unknown prior to the float-in was the condition of the center pier and its ability to be removed in one piece during the float-in. The original float-in scheme utilized a round-the-clock wire sawing operation during the first phase of the outage to separate the top portion of the pier. The wire sawing scheme was modified so that it took place prior to the rail outage window and could occur under live train traffic, which significantly reduced the outage window duration. The revised wire sawing scheme consisted of five (5) phases:

1. Core Pilot Holes to Run Wire Through Cap
2. Selective Demolition for Existing Span Jacking & Blocking Pockets
3. Wire Saw Outer Thirds of Cap
4. Jack and Block Bridge to Distribute Load to Rest Pier
5. Wire Saw Middle Third of Cap

While coring the pilot holes, the core samples were inspected. No steel reinforcing throughout the center pier cap was observed. The core samples were taken to a local testing lab to determine the compressive strength of the existing concrete cap. The results varied from 1500psi to 2800psi. The low compressive strengths and lack of reinforcing reconfirmed that the existing top of cap condition was poor and in need of replacement.

Figure 7 Center Pier Cofferdam

When the outer two thirds of the cap were wire sawed, two 100 ton jacks were used on either side of the blocking pockets to raise the bridge at each support location. Hard timber blocking and a 1” thick steel sole plate were used to support the bridge and lock the blocking in place. The jacking pockets were sealed and secured to prevent shifting under vibrations from live train traffic. The existing bridge was supported for five (5) days prior to the rail outage and monitored daily. This temporary support condition was reviewed by a third-party engineer prior to jacking and blocking the bridge to verify it would not have adverse effects on the existing span. The train speed was also reduced to 10mph during this time as an added safeguard. Figure 8 shows the timber blocking installed just after the span was jacked up incrementally and Figure 9 shows the blocking in its final condition prior to the outage. Note the saw cut line and pilot holes in Figure 9.

At the rest piers, the new wedge seat anchor bolt holes were cored prior to float-in as the new bridge was four feet wider than the existing bridge. The rest pier concrete at each wedge seat location was also chipped down and smoothed. Steel shim pack bases were installed and epoxied in to provide a level surface for installing supplemental shims up to the bottom of wedge seat elevation. To accelerate horizontal bridge alignment during the float-in, bridge stops were also installed at the back corners and a threaded extension plate was used to align the horizontal positions prior to float-in. Four bridge position stops were installed, but three were utilized, leaving room to float the bridge in and position into one corner (see Figure 10).

Figure 8 Timber Blocking in Pocket

Figure 9 Timber Blocking in Final Condition

Figure 10 Bridge Stops at one Corner

New Bridge Machinery Preparation Work

With incorporating the grillage concept, one major concern was machinery alignment and the ability to adjust after the bridge was set in place. B&G opted to perform an alignment check prior to float-in to verify rack flatness and the construction of the grillage frame. When the grillage arrived at the erection site, the bridge was positioned over the grillage using self-propelled modular transporters (SPMTs), which helped accelerate grillage installation. Threaded rods and a jacking frame on the trackside of the bridge (see Figure 11) was used to raise the frame into its initial position. A combination of porta-powers, come-alongs, and the jacking frame on the trackside was used to position the grillage and machinery rack in place. A third-party measurement company was used to check the rack flatness and horizontal alignment relative to the center of the bridge and pinion motors. Once the rack was in place, the jacking frame and threaded bars were locked into place, blocking was placed between the balance wheels and machinery rack, and several come-along and ratchet straps were used as cross bracing to limit the grillage movement during the span transport and float-in (see Figure 12).

Another key pre-float-in activity was the end wedge seat installation. These seats were over 800lbs and it was not feasible for a crane to set the seats during the float-in due to site logistic and time constraints. Installing the seats on the existing rest piers prior to the float-in was reviewed, but upon laying them out, the existing wedge seats conflicted with the new location by approximately 4 inches. It was then determined that the seats would need to be transported with the span during the float-in. The plan to achieve this was to secure the seats to their respective wedge locations using banding, come-alongs and a backup shackle and cable to secure the seat in the event it fell off prior to or during the float-in. Refer to Figure 13 for a typical configuration.

Figure 11 Grillage Jacking Frame

Figure 12 Grillage Frame and Machinery Aligned and Secured Prior to Float-In

Figure 13 End Wedge Installation Prior to Float-In

Float-In

The accelerated float-in scheme developed into the following general sequence of activities:

1.	Demo existing span utilities and machinery	Hour 0-2
2.	Secure existing center pier cap	Hour 0-2
3.	Raise up and float out existing span	Hour 2-3
4.	Center pier prep prior to float-in	Hour 3-6
5.	North and south pier prep work prior to float-in	Hour 3-6
6.	Float-In and new span alignment	Hour 6-8
7.	Lowering span	Hour 8-10
8.	Final alignment and secure span	Hour 10-12
9.	Grillage support frame removal	Hour 12-14

Breaking down the activities by the hour allowed the team to track progress consistently throughout the outage. The critical path of the outage ran through the center pier.

Secure Existing Center Pier Cap

Securing the top portion of the pier cap to the existing bridge was critical to shortening the outage duration. If the cap could not be removed with the existing bridge, a track-mounted chipping hammer would have been used to break up the cap and remove it from the center pier. This would have been time consuming and labor intensive. Several options were conceptualized including the use of cables as a basket, strong back beams with anchor plates tied to the cap (see Figure 14), and a threaded rod hanger system with epoxied dowels in the cap (see Figure 15). Consulting Engineer Heath & Lineback (H&L) provided concepts of each system with B&G's assistance. The basket option was ruled out quickly when B&G consulted with a local rigging company on the configuration. The rigging company advised that the sharp bends in the rigging, even with softeners, could be points of fatigue and cause the basket system to fail. Ultimately, the threaded rod system was used. This was primarily because most of the system could be installed prior to the float-in, with only a few small members to be installed when the outage commenced. The strong back beam option was procured and on hand to be used as a backup option in the event the threaded rod system failed.

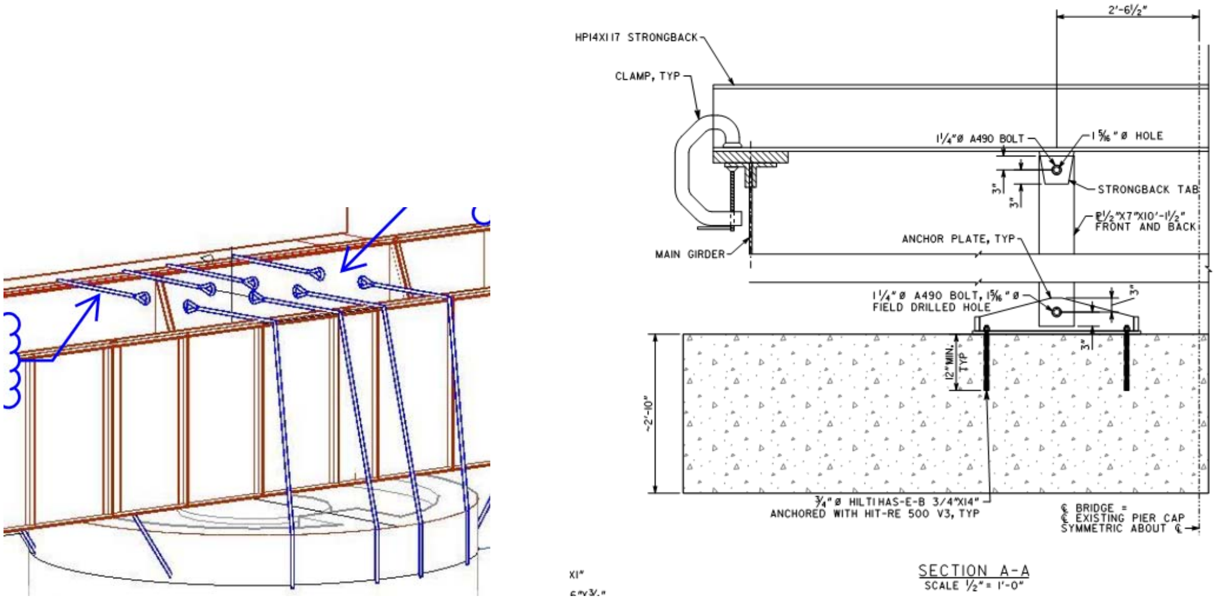

Figure 14 Conceptual Basket Hanger System (left) and Strong Back Beam and Anchor Plate System (right) – Heath & Lineback Engineers

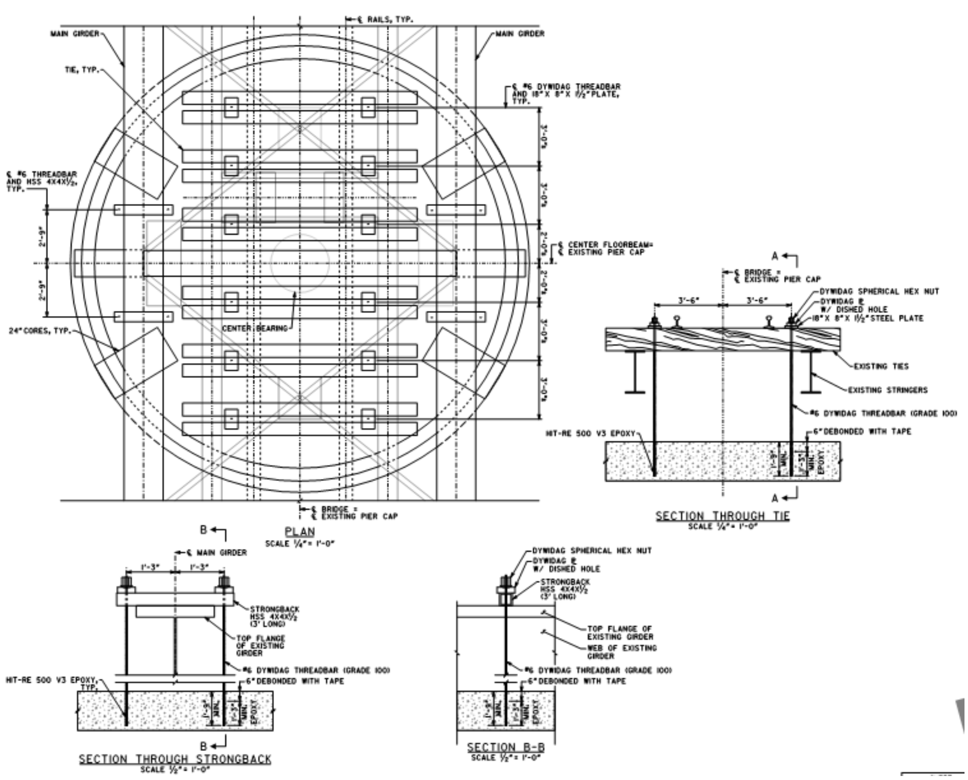

Figure 15 Threaded Rod Hanger System – Heath & Lineback Engineers

When the float-in began, the center pier crew installed the top support tube steel for the outer rods, coupled the threaded rods together, and welded the couplers in place to lock them in. Two large ratchet straps were also used to provide lateral inward pressure on the cap to help resist major fatigue cracking. As the existing span was raised, the existing cap rose with it in one piece as planned (see Figure 16).

Figure 16 Existing Center Pier Cap Removal

Center Pier Preparation Prior to Float-In

The concept of the grillage frame allowed the dead and live loads to be passed directly through the frame to the center pier. To achieve this, the grillage needed to be supported by steel shims to transfer the load. When the existing bridge and cap were removed, the B&G team immediately began to clean the center pier and prep for shim installation, as shown in Figure 17. A robotic survey instrument was utilized to quickly layout the grillage frame, anchor bolt, and rebar dowel locations on the pier relative the center of track. A level instrument was used to quickly verify elevations as shims were installed. Anchor bolt and rebar dowel holes were drilled during this time as overhead clearance would be limited after the span was set. Multiple hammer drills were used so that coring for dowels and anchors could be done simultaneously in each quadrant to minimize time spent on prep work. Shims were placed in the center pivot and center wedge seat footprints for the grillage to be set directly on them. Fast setting epoxy was used to secure the shims so that shifting would not occur while setting the bridge.

Lowering Span

When all anchor and rebar holes were drilled and shim elevations confirmed, the bridge was then floated over the piers – see Figure 18 and 19 – and water was pumped into the barges to lower the span. The pumps were controlled individually, and the span was lowered slowly. When the bridge was roughly aligned horizontally, come-alongs connecting the barge and rest pier on each rest pier side were used to move the span horizontally in lieu of using push boats. Multiple survey points were taken using the robotic survey equipment to verify placement periodically as the span was lowered. When the span was within ¼” of the final elevation, the horizontal alignment was checked at four locations and then lowered into place.

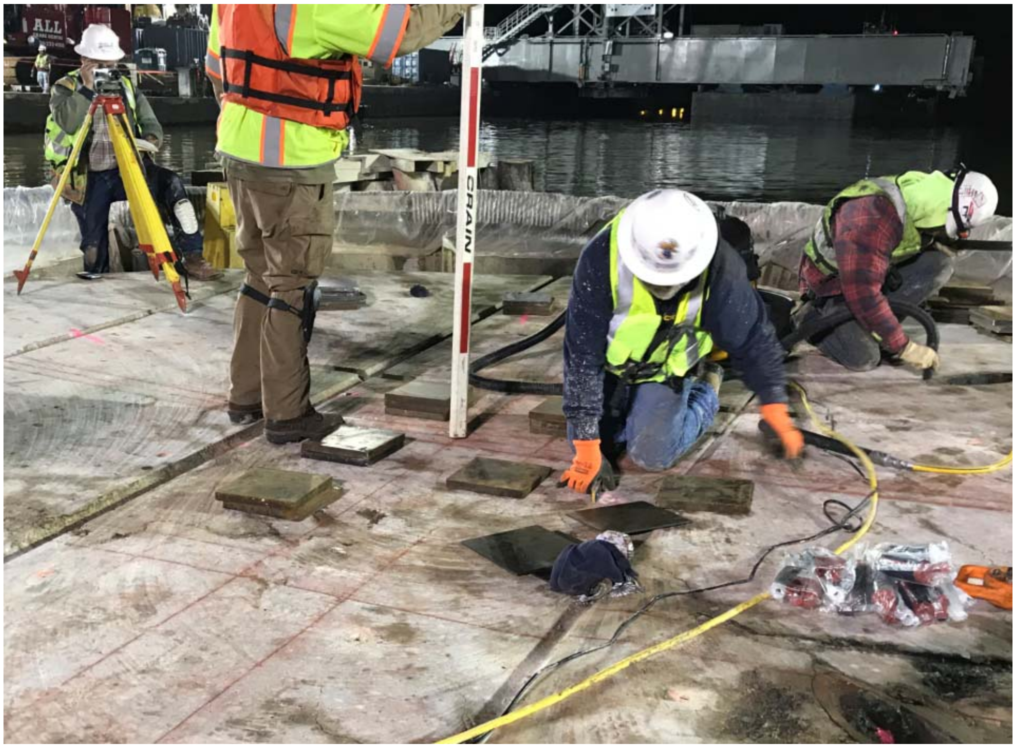

Figure 17 Center Pier Prep Work Prior to Float-In

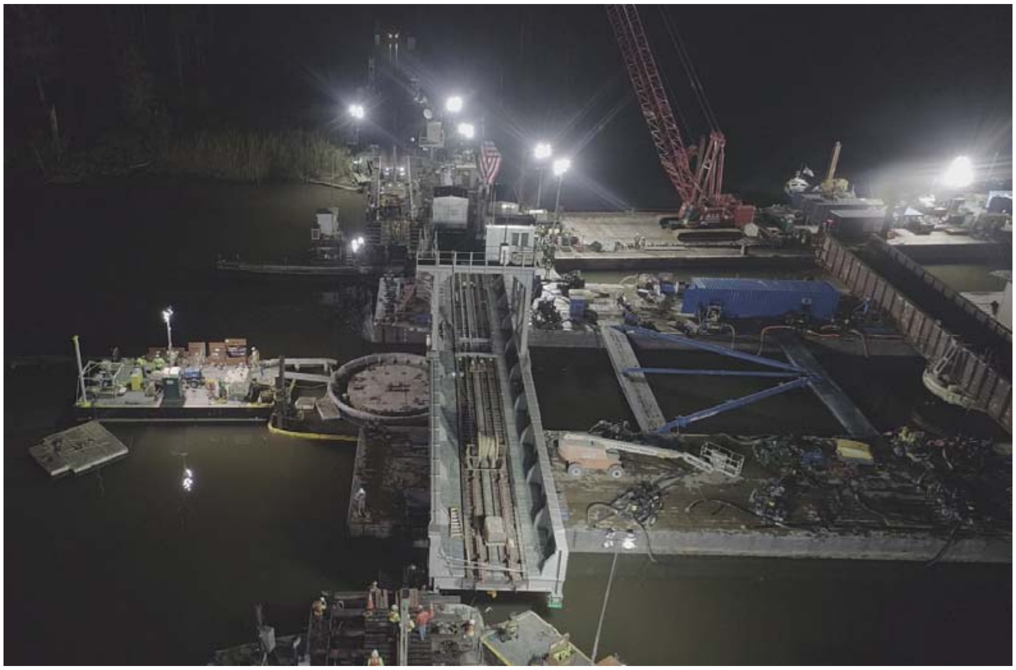

Figure 18 Bridge Float-In Over Existing Piers

Figure 19 Grillage Alignment Over Center Pier Shims

Final Alignment and Securing Span

When the bridge was resting on shims, the third-party measurement company was used again to verify machinery rack flatness and horizontal alignment relative to the bridge center and pinion motors. The rack measurements were nearly identical to the pre-float-in measurements taken and only minor adjustments needed to be made. Small porta-powers were used to make minor adjustments – see Figure 20 – and shims were placed directly below the grillage to lock the frame and machinery in place. Once the frame was properly shimmed, grout pads were poured beneath the center pivot and center wedges to secure the shims and grillage frame anchors. Heaters were then setup at the center, north, and south piers to accelerate the setup and cure time of the grout.

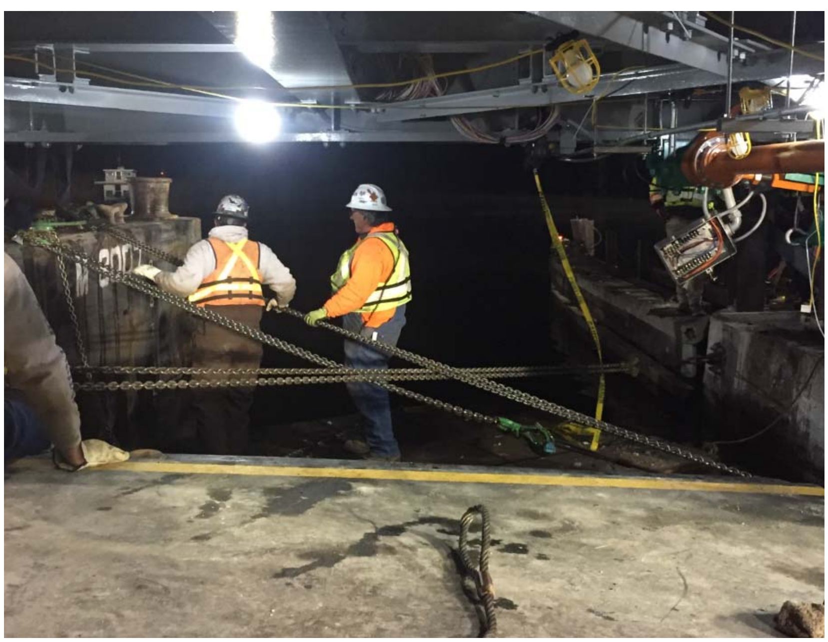

Figure 20 Come-Along Setup Used to Position the Bridge

Post-Float-In

After completing the outage, formwork and reinforcing installation began. Preparations were also made for loading concrete trucks at B&G's offsite erection yard. The pour was approximately 38 CY and the travel time from the plant to the bridge site was approximately one hour. Two barges were used, each holding two trucks and a line pump (refer to Figure 21). The concrete placement required another short rail outage to allow the concrete to setup and cure. CSXT also requested that the concrete mix be high early strength to allow train traffic to resume approximately 6-8 hours after concrete placement was completed. Prior to the pour, B&G had the concrete supplier develop a temperature curve correlating heat of hydration to compressive strength. The curves were then uploaded to a job specific database that could be accessed via a mobile phone app. Temperature sensors were installed within the pour to take real-time temperature readings. Within 3 hours of completing the concrete placement, the theoretical strength approached 1500psi. The 1-day cylinders for the first and second batches broke at 3,700psi and 2,450psi respectively. The temperature sensors indicated similar readings between 2,200psi and 3,200 psi. It should be noted, that the first batch of concrete used had a significant amount of accelerant which caused the mix to setup faster than expected and posed workability issues. The accelerant dosage in the second batch was reduced and workability was improved.

Conclusion

The successful Bayou Sara Bridge Swing Span replacement is depicted in Figure 22, with freight passing over the newly installed structure. At approximately two months prior to the target float-in date of Thanksgiving, modified pivot support scheme for reduction of the outage duration from 48 to 14 hours, posed a significant challenge. The design approach allowed for seamless construction thanks to the prefabricated grillage with pre-mounted mechanical components as well as a durable life cycle of the bridge using metalized structural steel. The grillage concept allowed for an efficient construction sequence utilizing existing foundations and revised pre-float-in preparations to accommodate a shorter rail outage. The structural steel grillage also played a crucial role in reducing the outage time tremendously as the pivot machinery was directly suspended from the new swing span during the float-in. Collaboration between the designer, owner, and contractor remains the key to a successful rapid swing span replacement.

Figure 21 Barge and Concrete Truck Setup

Figure 22 Bayou Sara Swing Bridge in service shortly after float-in

Acknowledgement

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