HEAVY MOVABLE STRUCTURES, INC.
NINETENTH BIENNIAL SYMPOSIUM

October 16-20, 2022

Rehabilitation to the trunnion and pinion supports at Monmouth County Bridge W-43 over the Shark River in the Boroughs of Belmar and Avon-by-the-Sea

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Abstract:

Monmouth County Bridge W-43 (The Shark River Bridge) is a dual leaf bascule span movable bridge which spans the Shark River. At 339 feet long, the bridge is owned and operated by Monmouth County serving as a vital link between the boroughs of Avon-by-the-Sea and Belmar, two popular summer tourist destinations along the Jersey Shore. Constructed in 1936, W-43 is now in its 85th year of service and has been the subject of several rehabilitation projects to maintain its serviceability to the motoring public. The bridge is also located at the mouth of the Shark River Inlet, making it a critical structure for navigable traffic.

In late 2019, the County along with the HNTB Corporation discovered that the outer trunnion supports were found to be in an advanced deteriorated state. Working closely with the County, HNTB developed a set of emergency rehabilitation plans which were implemented with the intent of repairing the trunnion and pinion supports ahead of the 2020 summer schedule. HNTB developed these documents in under a month and working closely with the contractor was able to open the bridge 2 months ahead of schedule. The purpose of this paper is to provide an overview of the design method utilized to successfully underpin the trunnion and pinion supports to serve as a case study and template for similar repairs. The paper also provides some of the challenges encountered during construction and identifies the original causation of the repair.

Introduction:

Monmouth County Bridge W-43 (Figure 1), or the Shark River Bridge, is located on County Route 18 (Ocean Avenue) and crosses the Shark River Inlet. The bridge is comprised of five spans with a total length of 339 feet and an overall width of approximately 57 feet. Its five spans consist of two reinforced concrete t-beam approach spans, followed by two concrete encased steel girder spans, with a dual leaf bascule span in the center. The bridge is founded on reinforced concrete piers and abutments and its foundation is comprised of timber piles.

Figure 1 - Bridge W-43 (Looking West)

Bridge W-43 serves as a vital link to the communities of Avon-by-the-Sea and Belmar. Given its location, the bridge is located at the mouth of the Shark River and is adjacent to the Atlantic Ocean (See Figure 2). It also serves as one of three main routes in and out of Belmar/Avon and is a popular route for those wishing to use the beaches. At the height of the summer, the bridge's ADT is well over 5,000 vehicles a day and is a popular route for pedestrian traffic as the area surrounding the bridge is mainly residential homes.

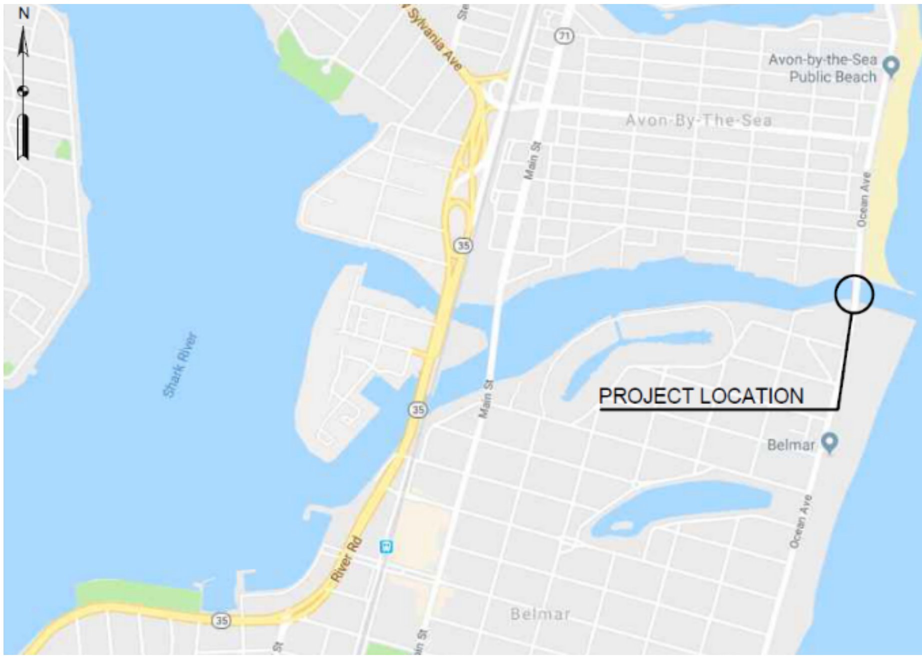

Figure 2 - Location of Bridge W-43

Bridge W-43 was originally constructed in 1936 and designed by the HNTB Corporation. At 85 years into its service life, it has been the subject of several rehabilitation contracts. In 1987, the dual leaf bascule span was removed entirely and replaced as it had reached the end of its service life. In 1997, the tender houses were rehabilitated providing an additional story which provided better observation of ongoing navigable vessels. This contract also included machinery and electrical system upgrades. On top of these projects, throughout its service life, W-43 has had its fender system replaced at least once; maintenance repairs done to both its substructure and superstructure; and replaced its barrier gates, live load anchors and span locks.

As the bridge is located directly adjacent to the Atlantic Ocean, it is subject to a highly corrosive environment, making it subject to frequent maintenance issues. Since the 1970's, the HNTB Corporation has assisted the County as the on-call engineer. Together with the County, HNTB has developed many of the rehabilitation projects outlined above. Additionally, HNTB and the County have developed proactive measures to ensure the bridge maintains its serviceability and achieves a total service life of 110 years when it is slated to be replaced entirely. This is achieved through frequent inspections, prioritized repairs, and utilizing the institutional knowledge of both the County and HNTB.

Discovering the Defect

During the 2019 NBIS inspection, it was noted that the supports to the pinions required repair. (See Figure 3). These elements were deemed critical and flagged as a priority repair as they assist the direct operation of opening and closing the bascule span. The pinions allow for the rotation of the main gear shaft which in turn opens and closes the bridge. These supports were each configured around the main-thru girder of the bascule leaf. As the On-Call Engineer, HNTB and the County performed a follow up inspection, to identify the area of repair and develop a plan for implementation. During this inspection, it was discovered that the four outer trunnion supports were also in an advanced deteriorated state, exhibiting signs of corrosion and section loss. Shown in figures 5 and 6, the outer trunnion support provides one of eight main supports to the bascule span.

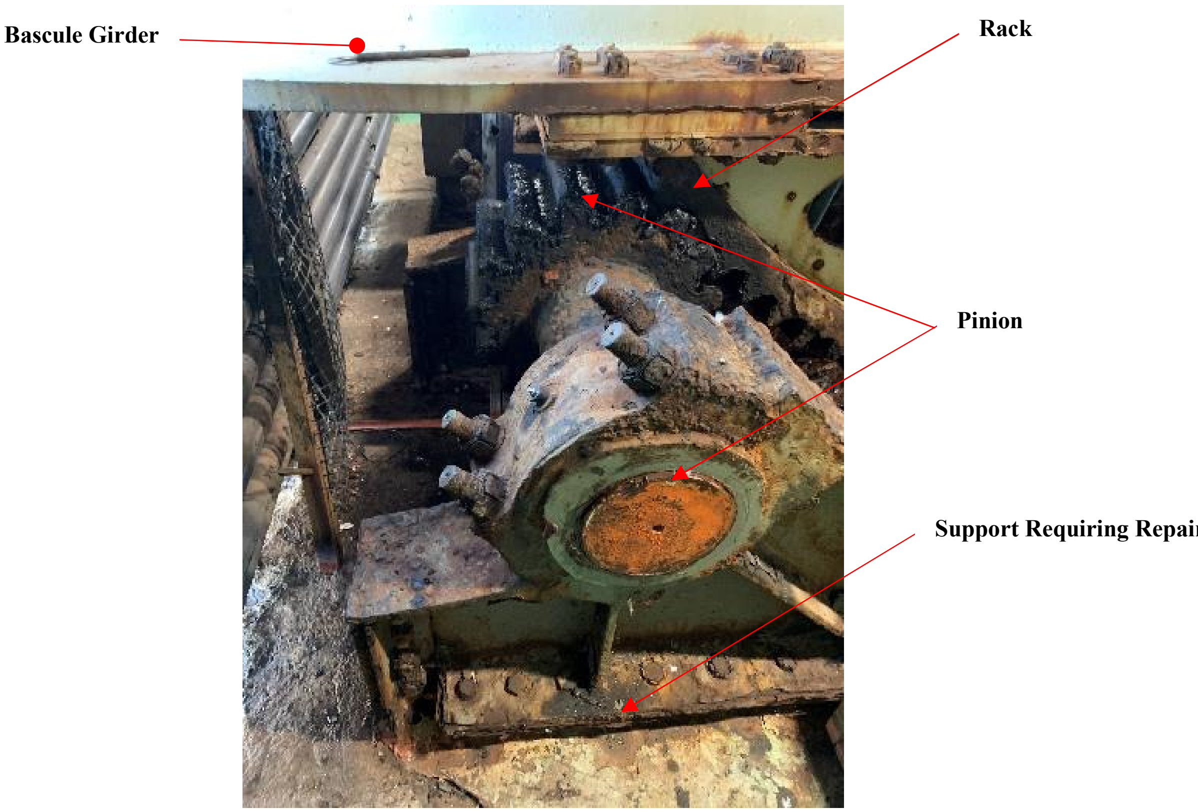

Figure 3 - W-43 Pinions (Northeast Corner)

Figure 4 - Pinion Support Area Requiring Repair

Figure 5 - Northeast Trunnion Support

Figure 6 - Trunnion Steel Support Requiring Repair

The trunnions provide structural support to the bascule span in both the open and closed positions. A bearing which supports the span sits on top allowing the movable leaf to rotate (See Figure 5). These outer supports (subject of this rehabilitation) are located in an exterior machine room and also incorporates the end of the fascia girder from the adjacent flanking/anchor span, with all elements encased in concrete. This main vertical column which supports the trunnion bearing and the flanking span ties directly into the bascule pier. Therefore, this outer trunnion is subjected to the loads created by the Bascule Span and the maximum shear forces from the anchor/flanking span.

Based on an evaluation of the existing as-builts and associated field inspection it was determined that the deterioration of these members is due to a combination of the corrosive environment in which Bridge W-43 is located, and the location of these supports. These supports also sit directly below the "Flower Box" (see Figure 7) an area of the deck that opens and closes due to the rotation of the bascule span. This "Flower Box" opening allows for infiltration of water and salt allowing it to pool underneath in the outer machine room, causing these supports to be highly susceptible to corrosive elements. This was further supported based on the fact to minimal deterioration was discovered to any of the supports located inside the inner machine room.

Figure 7 - Flowerbox Opening (Northeast Corner)

Given this information and the critical nature of the trunnion supports, the County tasked HNTB with two objectives. The first was evaluating the capacity of the support to ensure the bridge could remain open to vehicular traffic. The second task was to develop rehabilitation plans which could be implemented immediately utilizing the County's emergency procurement procedure.

Trunnion Support Evaluation

At the County's request, HNTB investigated the capacity of the trunnion to ensure no immediate action was required. HNTB performed Load Ratings in accordance with the 2018 Manual for Bridge Evaluation. Load Ratings were performed using the Load Resistance Factor Rating (LRFR) Method, and the Load Rating Factor (LFR) Method.

Determining the loading on the column required a less than traditional approach. After review of the as-built documents it was determined that the outer trunnion support was susceptible to loads from both the bascule span and adjacent flanking span. This was because the support not only accommodated the trunnion bearing, but also the end of the main thru girder which connected to the main flanking span. For dead load evaluation, it was determined that this column was subjected to a portion of the dead and live loads from the adjacent flanking span, which needed to be included in the evaluation calculations.

It was determined that the trunnion column was a 14" CB 158, and the beam's capacity was determined using the LRFD AASHTO Standards for Bridge Design. As the member was found to be in poor condition it was assigned a condition factor of 0.85, while its system factor given its non-redundant nature was also assigned a factor of 0.85. Using this information, the following results were determined:

Table 1 - W-43 Column Load Rating Results (LFR Method)

	LFR (Tons)		
	Loading	As-Built	As-Inspected
Inventory	HS-20 (36 Tons)	42.50	17.37
Operating	HS-20 (36 Tons)	70.93	29.00

Table 2 - Trunnion Column Load Rating Results (LRFR Method)

	LRFR (RF)		
	Loading	As-Built	As-Inspected
Inventory	HL-93	1.22	0.52
Operating	HL-93	1.58	0.67

As a result of this analysis, it was determined that based on the current condition of the trunnion supports, the bridge should be posted for 15 tons.

Trunnion Support Rehabilitation Design

Following the evaluation, HNTB began to prepare contract documents for repairs to both the trunnion and pinion supports. It was determined that for both supports, the members needed to be reinforced with steel plates and encased in high-strength concrete to restore the lost section and prevent further deterioration of the supports.

While the pinion supports proved to be straightforward in this approach, the trunnion supports approach was challenging. Given the level of deterioration, simply chipping concrete and reinforcing the member with steel plates could not be done, as exposing the beam could lead to localized buckling of the member. Therefore, to safely underpin the trunnion support a jacking scheme was required.

As discussed previously, jacking the load out of the trunnion column is challenging for several reasons. The first being that due to the navigable traffic traveling underneath the span, one span always needed to be left open to allow the boats to pass through. Therefore, to successfully jack a single span a jacking system which accommodated both the dead load and at the same time supported the counterweight would need to be designed. Secondly, this system would also need to incorporate loads from the flanking span. Therefore, an additional jacking scheme needed to be added which relieved this load out of the column as well.

Based on this information a jacking scheme for the bascule span was developed using a combination of a forward jack paired with a strong back system. The forward jack was placed within the machine room directly underneath the lower flange of the bascule span. While a strongback system was positioned around the counterweight to act as a saddle. This illustrated in figures 8 and 9.

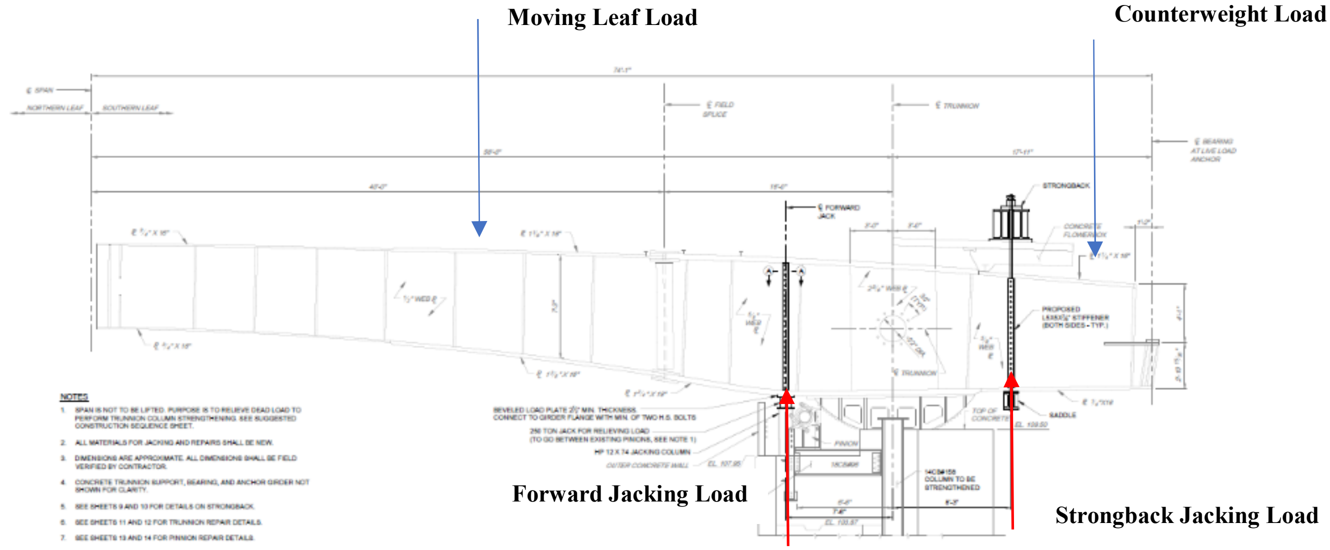

Figure 8 - Free Body Diagram for Bascule Span Jacking Scheme

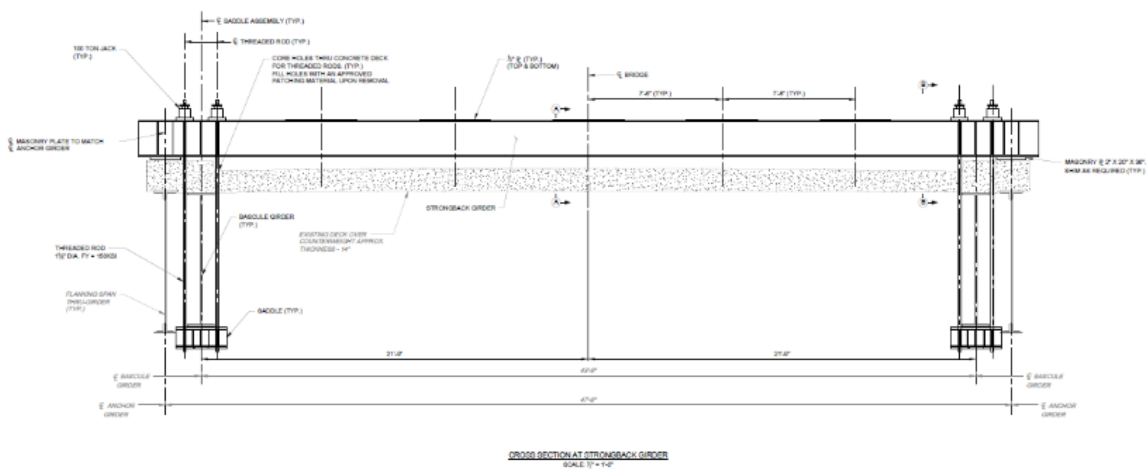

Figure 9 - Strong Back System Elevation View

As you can see from the above, a paramount challenge associated with the jacking scheme was ensuring the span was completely balanced so that the bridge could be lifted. Also, the purpose of the system was to not lift the span, but to instead redirect the load path out of the column and into the flanking span. To achieve this an additional jack was required which not only relieved the flanking span load out of the column, but also, redirected this jacking load as well.

As you can see from the free body diagram (figure 10), this jack was placed directly in between the trunnion column and the strongback system. Placement of this jack was critical, as it allowed for the load to be almost completely transferred back into the flanking span. Based on an analysis, it was determined that some dead load was still acting within the trunnion column. However, based on HNTB's analysis it was deemed that the column when fully exposed and could safely operate under this load.

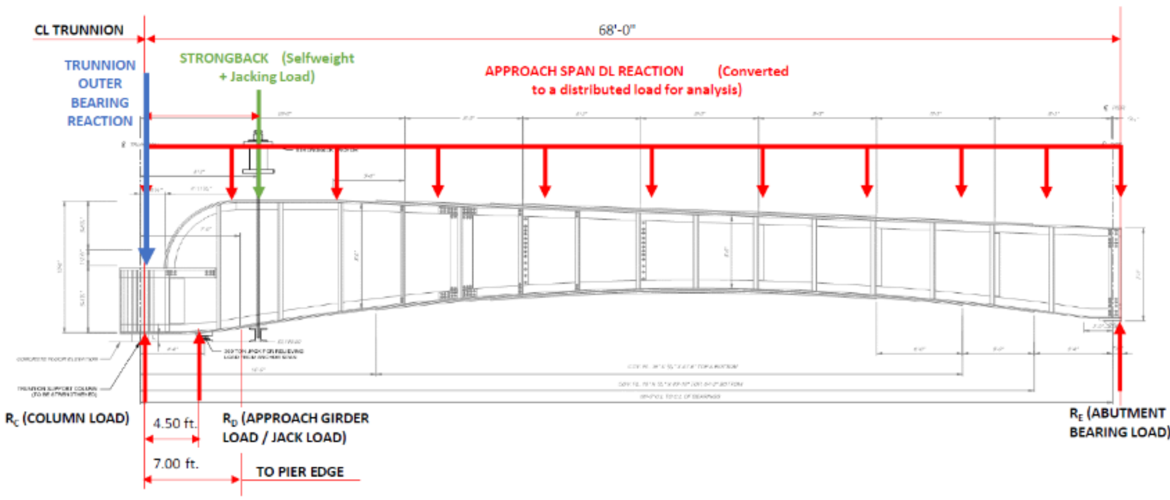

Figure 10 - Flanking Span Jacking Scheme

As the strongback system included a steel beam across the roadway, Bridge W-43 would need to be closed to traffic. This made analysis easier, as no live load would be acting on the bridge. However, a provision for construction loads was added in accordance with AASHTO Temporary works. Additionally, due to local buckling concerns from jacking forces angles were added directly above the jacks to support the webs of the bascule and flanking span fascia girders.

Based on HNTB's calculations, 250-ton jacks were designed for the forward column. While four 100-ton jacks were designed to be placed on top of the strongback beam. Finally, two 450-ton jacks were designed to be placed underneath the flanking span fascia girder. To avoid damage to the trunnion bearings, it was specified that the nuts be loosened on the bearings to account for any slight movement due to jacking.

Once the bridge was successfully jacked, the contractor would be allowed to proceed with the repairs, including removal of concrete up to 24 inches to completely expose the supporting trunnion column. Once exposed, the contractor would clean the column utilizing SSPC-SP3 methods for cleaning. SSPC-SP3 is a method of cleaning limited to hand tool cleaning, which allows for the removal of all mill scale, rust, paint and other contaminates on the member subject for repair. This method was chosen mainly due to the small space of the outer machine room.

Following cleaning of the column, it was reinforced using a series of 1/2 inch steel plates as shown in the below figure. Once the steel plates were installed rebar would be installed and the column would be completely encased in concrete. As the original bridge was constructed using 3,000 psi concrete, NJDOT Class A concrete with a compressive strength of 4,000 psi was selected. Additionally, to expedite the construction schedule, it was specified a high-early admixture be utilized to accelerate curing of the support.

As discussed above, the repair of the pinion supports was relatively straightforward. Based on HNTB's analysis it was determined that jacking was not required to underpin these supports. Therefore, these repairs could occur at any point during construction. The method of repair was identical to the trunnions in that, 1/2-inch steel plates were selected to reinforce the support. Following installation of the repair plates, rebar was installed, and Class A Concrete was poured to encase the supporting member. Similar to the trunnions a high-early admixture was also specified for this repair.

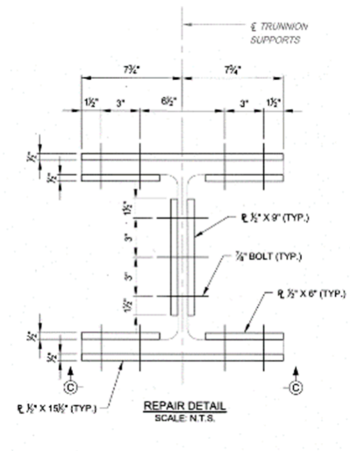

Figure 11 - Trunnion Column Repair Detail

Construction

Following the evaluation of the trunnion supports and given the load rating results, as well as, the critical nature of the repairs, HNTB recommended that the work be done ahead of the 2020 summer peak season due to the exceptionally high traffic across the bridge. Plans were developed over the month of December 2019, and the County utilizing their emergency procurement protocol arranged for a meeting with three selected contractors in early January 2020.

Based on a schedule developed by HNTB it was determined that the total construction duration for the project could be achieved within 120 Calendar Days. With the bridge needing to be reopened to traffic by May 18, 2020 ahead of the summer season. To expedite construction an incentive payment in the amount of $1,650 a day was offered for each day completed ahead of the May 18, 2020 deadline. Additionally, it was anticipated that the work would be done using a combination of cranes and barges, with temporary scaffolding to be installed along the back of the Bascule Pier. It was estimated that the work would be constructed for $1.5 Million.

Plans were offered at 75% to the three selected contractors and were completed prior to bid receipt on January 13, 2020. Plans were updated and finalized based off questions received from each of the three contractors, and modifications were made to the plans when appropriate. Given the timeframe the contractors only had ten days to put together bids. Final plans were transmitted to the contractor on January 9, 2020.

Bids were received on January 13, 2020 and were evaluated using two criteria, cost and schedule. Following the County's emergency procurement procedure, bids were received, and the apparent low bidder was Cornell and Company of Westville New Jersey with a bid of $494K. Additionally, Cornell offered the fastest timetable for completion with an expected substantial completion date of April 2, 2020.

Based on a meeting held on January 14, 2020 between the County, HNTB and Cornell it was discussed that Cornell expected to do the work without the use of any barges, utilizing only a small support crane to install the strongback beam. Additionally, Cornell did not expect the installation of any temporary scaffolding and would be able to get in the required materials utilizing the access via the tender house stairwell. Based on this discussion and given Cornell's reputation for completing complex steel repair work, the County made the contract award to Cornell.

Construction began on January 20, 2020 given the complex nature of the work, and following County protocol, HNTB oversaw all construction operations, providing design support when necessary, and daily inspection. This method had been employed previously by the County on these types of projects and proved extremely successful as it allowed for direct communication between the design team and the contractor, allowing for quick solutions as problems arose.

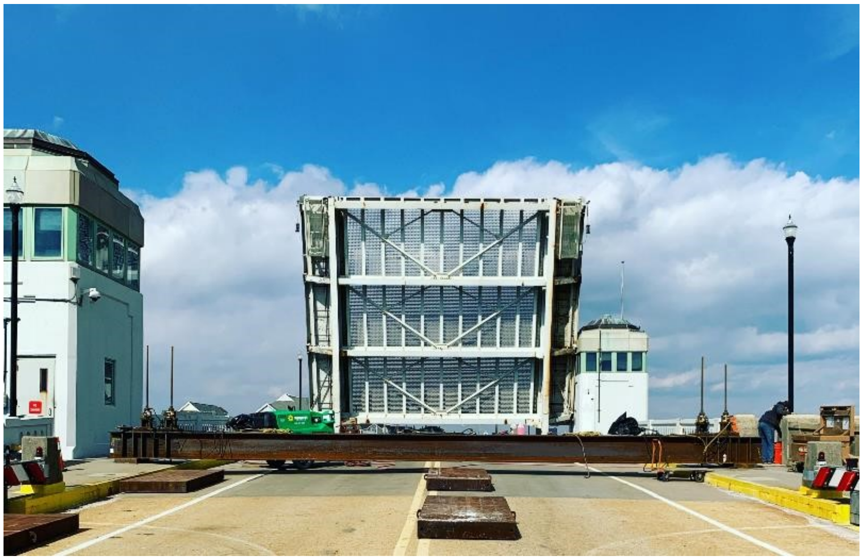

Figure 12 - Strongback Girder following Installation on Southern Span

During construction a total of 11 RFI's (Request for Information) were submitted by the contractor which resolved unforeseen field issues and assisted in expediting construction. In summary, the following pertinent RFI's were submitted which could be considered best practices for this type of work:

- In Lieu of Full-Length Angles, due to constraints within the machine room, partial length angles were analyzed and approved by HNTB for installation above the jack to counter act localized buckling of the web.
- The original design called for a single 450-ton jack to be placed underneath the anchor span. In lieu of this single jack, two identical 250-ton jacks with stiffeners were requested to be utilized instead. HNTB analyzed and approved the use of these series of jacks.
- For the pinion repairs, bent plates were utilized in lieu of single plates welded together to expedite construction and ease installation.
- During construction to expedite the project schedule, the contractor requested that the strongback girder and jacks be released prior to pouring concrete encasing the repaired members. After analysis of this temporary condition, this request was denied as it was deemed the unsupported of the column prior to pouring could become compromised under the dead load of the bascule span and anchor span.

In addition to the above RFI's following removal of the concrete and cleaning the trunnion supports it was revealed during construction that deterioration to these supports was worse than expected, specifically the northwest corner. As shown below, the northwest corner support suffered 100% section loss to the web compromising the support further. Given the direct lines of communication the HNTB worked quickly to resolve the issue, providing modifications to the initial detail to further reinforce the member. This was issued to the contractor via a field order. Given the quick work of HNTB, no extra cost or schedule impacts were incurred by the contractor.

Figure 13 - Northwest Trunnion Support with 100% Section Loss

Construction was subsequently completed on April 2, 2020 in line with the original construction schedule, and the bridge reopened to traffic. As the contractor completed the project ahead of the May 18, deadline an incentive payment of $89K was made to Cornell. Additionally, no claims for additional compensation nor extensions in contract time was requested, making the project a huge success for the County.

Best Practices and Lessons Learned Identified

As stated above, this project while an emergency was a great success to both the County of Monmouth and HNTB. There are aspects of this project which can be learned from and utilized on bridges of similar configuration, as well as, any project undergoing an emergency procurement process. These practices included the following:

- High Level Support: From the early onset, the County of Monmouth worked hand-in-hand with HNTB to make sure that construction continued without any setbacks. The County took an active role in coordinating with local officials, boaters and businesses to ensure the public was up to date regarding construction, answer any complaints and gather appropriate feedback for consideration into the final construction documents.
- Condensed Bid Process: Using the County's emergency bid protocol, HNTB was able to release drawings to the selected contractors during a 10-day bid process which under the normal bid procedure could add up to 2 months to the overall procurement process. Additionally, allowing HNTB to release 75% drawings allowed for valuable feedback from the three contractors which was incorporated into the final bid documents and possibly preventing or reducing costly Change Orders.
- County Emergency Process: By allowing HNTB to oversee all aspects of construction, it allowed for fast communication between all parties. This communication allowed for quick responses to contractor RFI's, and resolution to any key issues that may arise during construction.
- Quality Reviews: While documents were being finalized, the HNTB team utilizing its standard for quality, utilized a series of technical reviews to avoid any issues during construction. These

reviews included constructability, technical, and over-the-shoulder reviews provided by the County.

- Incentive Payment: The use of an incentive payment as a part of this project was a great success, as it encouraged the contractor to expedite construction ahead of the anticipated schedule.

Additionally, lessons learned as a result of this project include the following:

- Trunnion supports for all moveable bridges should be inspected regularly and evaluated as a part of the biennial NBIS Inspection. These evaluations should be included with the load ratings performed on other elements. Evaluations should be performed for both LRFR and LFR methodologies.
- Machine rooms should be inspected regularly to determine if any areas are susceptible to salt/water infiltration. These areas should be addressed as a preventative measure.
- Structural supports which provide direct support to the main bascule span should be coated and maintained to avoid deterioration.
- Bent plates should be recommended in lieu of single plates as a means for underpinning steel supports, especially in hard-to-access areas.
- Access to the supports proved to be less of a challenge than expected. While initially thought to be done using a series of barges and scaffolding supports, the work was achieved mainly using labor and a small support crane without any barges.

Model for Success

Together with the Monmouth County Department of Public Works and Engineering, Cornell and Company and the HNTB design/construction team, Monmouth County was able to develop a plan and implement repairs to the trunnion and pinion supports in under six months. Because of the County's expedited emergency bid process, the design team was able to develop repair plans and release them to bid two months ahead of schedule. Additionally, given the County's involvement and teamwork, the public was kept informed and up to date about the progress of this project while at the same time providing the necessary support needed to the design and construction teams. This emergency repair project serves not only as a model for success in communication and cooperation, but also serves as a good case study for defects that may be common within dual-leaf bascule span type bridges. It is the hopes that this project brings this issue to light for similar type bridges, and the method of repair serves as a template for success.

Acknowledgements

The completion of this paper could not have been possible if not for the support of the Monmouth County Department of Public Works and Engineering and assistance of those who made this project possible. Specifically, we would like to thank Joseph M. Ettore, PE, the County Engineer for his support and guidance in developing this paper. Additionally, we would like to thank Gabrielle Maggio for her support in reviewing this paper.