BEN SAWYER BRIDGE REHABILITATION: OUT WITH THE OLD, IN WITH THE NEW

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BIOGRAPHY

Timothy J. Noles, PE is a Partner of Hardesty & Hanover, LLP. Tim is a graduate of the University of Tennessee with a Bachelor of Science in Civil Engineering and has been with H&H since his graduation in 1984. Tim is responsible for overseeing the Southeast Region United States in regards to business development, project management, bridge engineering design and client satisfaction. He has also been responsible for the inspection, design and rehabilitation of major highway and railway bridge projects across the United States comprising of hundreds of major steel and concrete bridge structures with expertise in movable span bridges (vertical lift, swing and bascule). Notable structures during Tim's 27 year career include the Ben Sawyer Bridge, Sanibel Island Causeway in Fort Myers Florida, the 5th Street Bridge in Miami, FL and the Tomlinson Vertical Lift Bridge in New Haven, CT.

SUMMARY

The Ben Sawyer rehabilitation is one of the most unique superstructure replacements in bridge history and truly an engineering and construction feat. The project required a combine effort of design and construction engineering teamwork in order to replace a 13 span structure in 11 days, including commissioning the operation of the new movable span. The degree of difficulty was raised even higher when, uncharacteristic for South Carolina, cold temperatures, gale force winds, rain, and snow challenged the construction workers and engineers to finish on time. Projects such as these are truly remarkable engineering feats and a testament to the American steelworker.

Abstract

The Ben Sawyer Bridge spans the Intracoastal Waterway between Mt. Pleasant and Sullivan's Island near Charleston, South Carolina comprising of 12 steel plate girder approach spans and a swing span over the navigation channel. The original bridge was constructed in 1941 and was rapidly deteriorating due to the corrosive coastal environment.

The rehabilitation project consisted of the replacement of the existing steel superstructure on the existing substructure. The local community recognized the old bridge as an historical landmark and requested that the new bridge design incorporate distinctive features of the existing bridge:

- Swing span Pratt truss
- Cantilevered bracket and steel girder approach spans
- Concrete post and steel picket bridge rail
- Octagonal Control House

Improvements to the bridge included:

- Widened deck (increased from 24 to 28 feet) to accommodate bicyclists
- 5 foot sidewalk
- Crash tested bridge rail (TL-3).
- Designed to 2007 AASHTO LRFD
- Seismic retrofit

With the requirement of reuse of the existing substructure a detour for vehicular traffic would be required. The community would not support a lengthy detour due to the economic impacts to businesses. Therefore the SCDOT required that the closure must not exceed 10 days. The Design/Build Team was required to use innovative ABC (accelerated bridge construction) methods to minimize the closure period.

This Design-Build project required complete superstructure replacement in 10 days. The new approach spans were constructed adjacent to the existing on a temporary structure. The new and existing spans were jacked onto rollers which allowed the structures to be translated as required in a 24 hour period.

The swing span was erected at a staging yard to completion and placed onto a barge hat floated out to the site to remove the existing swing span and place the new swing span on the existing pivot pier using the rise and fall of the tide.

REHABILITATION OF THE BEN SAWYER SWING BRIDGE: OUT WITH THE OLD, IN WITH THE NEW

Introduction

The Ben Sawyer Bridge (SC 703) named after the South Carolina Highway Commissioner and Executive Director (1926-1940), spans the Atlantic Intracoastal Waterway between Mt. Pleasant and Sullivan's Island just south east of Charleston, South Carolina (Figure 1). The original bridge consisted of 12 steel girder approach spans, (6 per side) and a Warren Truss swing span over the navigation channel supported on reinforced concrete piers founded on timber piles. The swing span provided a 45 foot vertical clearance in the closed position and infinite clearance in the open position for navigation vessels. The original bridge provided a 12 foot lane of traffic in each direction in addition to 2'-6" safety curbs on each side of the roadway.

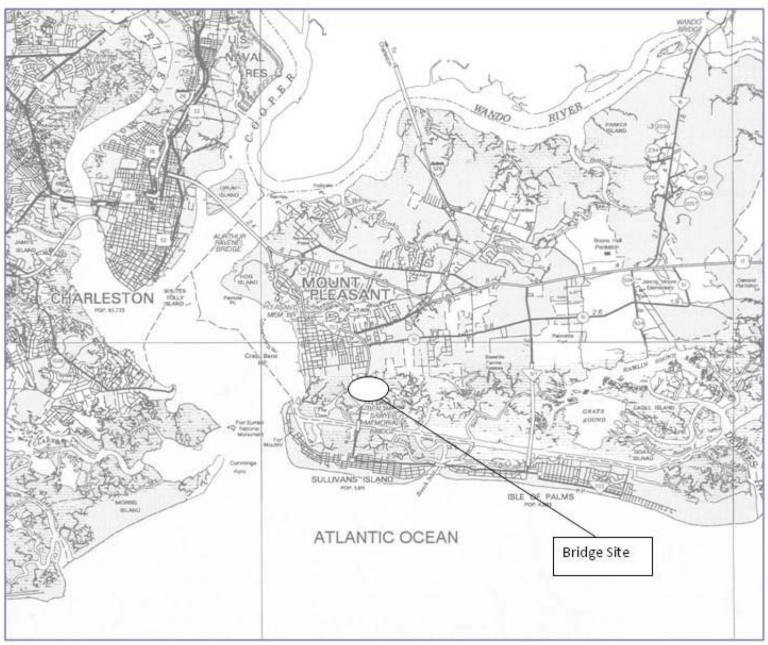

Figure 1: Location Map

The bridge provided the only access to Sullivan's Island, a barrier island and summer resort community of over 2000 residents, until the Isle of Palm connector was constructed in 1992 after Hurricane Hugo. This bridge became nationally renowned when the swing span was blown from its center bearing during the Category 5 Hurricane (Hugo) in 1989 (Figure 2). The span was eventually placed back on the pivot pier bearing after the hurricane and provided 22 more years of service. However, a replacement bridge was eventually necessary due to the coastal salt air environment was taking a toll on the steel superstructure. The bridge railings and concrete deck were also severely corroded. The deterioration of the superstructure required the bridge to be posted to limit truck weight to a maximum of 20 tons.

A study initiative to replace the bridge was initiated up by the South Carolina Department of Transportation (SCDOT) as recently as 2006 and was taken to the local communities for their input. The SCDOT favored a high level fixed bridge; however the local community was in favor of restoring the signature bridge. The engineering study determined that the substructure was in good condition and could be reused in rehabilitation but the superstructure was in poor condition due to severe corrosion to the swing span trusses and floor system and fatigue cracks were found on the approach span steel stringers.

Figure 2: Ben Sawyer Bridge after Hurricane Hugo.

Figure 3: Ben Sawyer Bridge prior to the rehabilitation.

The local community consisting of residents from the surrounding communities of Mt. Pleasant, Isle of Palms, and Sullivan's Island recognized the Ben Sawyer Bridge as a historical landmark and symbol of the charm and tradition of the community and requested that the bridge be replicated or restored as much as possible. The community favored a new bridge with the condition that the design incorporates the following distinctive features of the old bridge:

- Cantilevered brackets on approach span plate girders
- Concrete post and steel picket railing
- Swing span consisting of a Warren Truss with mid-truss brace
- Maintain existing vertical profile geometry
- Octagonal shape control house mounted on the swing span above the roadway

Improvements required by the SCDOT in their Request for Proposal included:

– Widened roadway deck (increased from 24 to 28 feet) to accommodate bicyclists

– Sidewalk (5'-6") on west side of roadway for pedestrians

– Bridge Railing Post meeting (TL-3) strength requirements

– AASHTO LRFD Movable Bridge Code compliant operating system

– AASHTO LRFD Bridge Code compliant structure including the existing substructure

With the reuse of the existing substructure, a lengthy detour of over 10 miles to the Isle of Palms Bridge would be required using conventional construction practices. The local community would not support a lengthy detour due to the economic impacts to the local businesses on both sides of the bridge along Ben Sawyer Blvd. Therefore the SCDOT required that the bridge closure must not exceed 10 days!

To promote innovative and unique construction techniques and engineering during all phases of the project and to ensure qualified bidders, the SCDOT advertised the project as a Design-Build (D-B) contract in May of 2008. The D-B team was required to use innovative accelerated bridge construction (ABC) methods to meet the bridge closure requirement of 10 days.

Figure 4: Rendering of new bridge elevation.

The Team

PCL Civil Constructors, Inc. (PCL) assembled a proven Team to provide Design-Build services to the SCDOT. The PCL staff proposed for this project is considered industry experts in both movable bridge and bridge replacement projects. The design team consisted of the lead bridge designer Hardesty and Hanover, LLP (H&H), with over 120 years of design experience in movable and fixed bridges and Florence and Hutcheson, Inc. (F&H), with over 20 years of experience with SCDOT. F&H supported H&H and PCL with permitting, civil, geotechnical, utility, and MOT design services. Civic Communications, a local Charleston, South Carolina Public Relations firm, managed community relations and public information distribution. The team also included key subcontractors and suppliers who were critical to the success of this project. Many of these team members have long-standing relationships with PCL and H&H on numerous previous bridge rehabilitation/replacement projects.

Figure 5: Rendering of new wider roadway deck with west sidewalk.

The Project

Delivery and Approach

A D-B Request for Proposal was advertised by the SCDOT for solicitation in May of 2008. The D/B Team with the lowest adjusted score (bid amount/technical proposal score) would be the selected contractor. PCL with the highest technical score and the lowest bid amount of $32.5 million dollars was awarded the contract all paid in federal dollars by the Federal Highway Administration (FHWA).

The technical proposal summarized the overall design and approach to the Ben Sawyer Replacement Project which took into account the following key criteria:

- Maintain similar appearance of the existing bridge
- Maintain existing vertical geometric profile
- On-going active community relations
- Adherence to schedule and bridge closure requirements
- Innovative and environmentally sensitive construction plan

Bridge Design

This Project consisted of the replacement of the existing superstructure. The new bridge superstructure was designed in accordance with the requirements of the RFP, Technical Specifications, Special Provisions, SCDOT Bridge Design Memorandums, SCDOT Design Guidelines, and AASHTO LRFD Code in the listed order of authority.

The dead load of the replacement superstructure was minimized as much as practical since it was to be supported on an existing substructure with additional loading requirements not provided for in the original design. New structural steel components with increased strength (ASTM A790 Grade 50) and lightweight concrete (116 lbs/ft3) were utilized for this purpose.

Substructure/Seismic Design

The substructure is in remarkably good condition with no signs of deterioration. Concrete cores were obtained during the development of the RFP which showed compression strengths of up to 9,000 psi. A preliminary seismic analysis was also performed prior to the RFP to determine the seismic event the bridge is capable of resisting. The D/B contract required the Engineer of Record (EOR) to perform a substructure foundation analysis including seismic analysis. The timber pile foundation was required to meet AASHTO LRFD code for the heavier superstructure with the use of isolation bearings or a substructure retrofit would be required.

Seismic analysis of the bridge was performed in accordance with the technical specifications provided in the RFP and followed all applicable codes. The bridge is classified as an Essential Bridge (IC = II) with a seismic performance category of SPC B based on long period acceleration which equal to = 0.1 g but less than 0.3g. The desired performance required in the RFP was a 500 year return period Functional Evaluation Earthquake. No live load was used for any of the seismic load combinations. Pile and footing elements were explicitly modeled with the appropriate representation of the effect of the nonlinear soil-structure interaction.

A 3-D model of the bridge from abutment to abutment was created using SAP2000 software and was analyzed using the seismic input loading specified in the technical specifications. This included a Response Spectrum Analysis (RSA) as well as a Time History. It was determined with the utilization of isolation bearings that the existing substructure was adequate for the prescribed seismic event. Some of the struts of the piers showed inelastic response, however there were no catastrophic failures of the substructure. It was also required that the swing span lateral displacement was not to collide into with the approach superstructure during an earthquake event. The swing span pivot bearing was designed to resist the seismic load of over 350 kips.

Figure 6: Typical Approach Span Isolation Bearing.

Pile driving data and soil borings from the original bridge construction were utilized to estimate load capacities of each pile using wave equation analysis so that it could be determined if the foundations satisfied AASHTO LRFD Code requirements. Although the foundations overall provided adequate capacity, group pile analysis showed pile resistance factors between 0.3 and 0.51. The resistance factors for the north rest pier individual piles were between 0.4 and 0.6. Although the piles exhibit a factor of safety, it was above the LRFD resistance factor of 0.4 for new bridges. However, AASHTO allows a resistance factor of 0.6 if PDA load testing is utilized. Therefore timber test piles were driven similar to the original construction pile data adjacent to the rest pier to obtain PDA data, to determine if a 0.6 resistance factor could be utilized. Resistant factors above 0.6 were found on individual piles of the north abutment. The SCDOT required that additional piles be driven to support the abutments to mitigate the additional loads placed on the abutments due to the approach slab and the additional dead and live load from the new superstructure. The abutment footings were extended on each side of the abutment and two additional piles were driven.

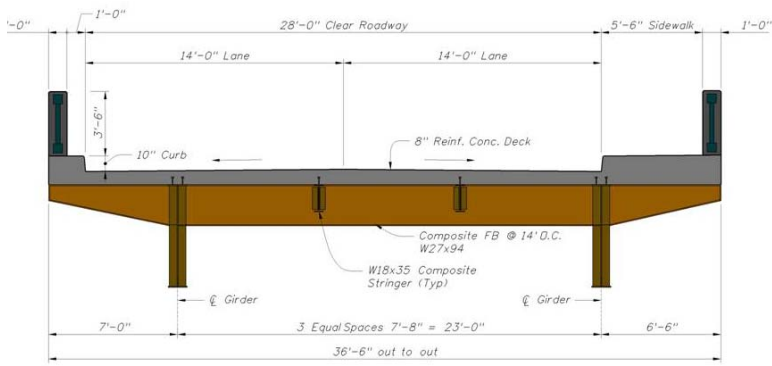

Figure 7: Approach Span Typical Section.

Substructure repairs and modifications included:

– *Approach span modifications* - Removed existing steel rocker bearings and replaced with new neoprene rubber/lead core isolation bearings with steel shim packs in between the bearing and the bottom flange of the new girders, and epoxy grout below the bearing to account for the height differential (Figure 6).

– *Pivot Pier Modifications* – Repaired large hole in the top of the pivot pier cap from Hurricane Hugo knocking the swing span off the pivot bearing.

– *Rest pier modifications* - Furnished and installed a new swing span lock assembly (wind shear key), new end lifts to align swing span deck with the approach span deck, and hurricane tie-downs consisting of eye bolts anchored to the top of the pier cap which are connected to the swing span end floorbeams to resist hurricane force winds to prevent a reoccurrence of the event during Hurricane Hugo.

– *Crack injection and spall repair* – Completed 600 LF of crack injection and 10 CF of spall repairs was accomplished on the pivot pier.

Approach Span Superstructure

The new approach span superstructure consists of four (4) three span continuous steel plate girder units (70-86-70 feet), supported on rubber isolation bearings anchored to the existing concrete piers. The replacement spans utilize 5 feet 6 inch deep welded plate girders supporting rolled steel floorbeams (W24x76) spaced at 14 feet and rolled steel stringers (W18x46) spaced in between the main load carrying girders. Brackets at each floorbeam cantilever from the girders to support the outer 6 feet of the concrete deck and sidewalk. The framing is similar to the old bridge (Figure 7) however, a change was made to the stringer floorbeam connection. The stringers now frame into the floorbeam webs with connection angles in lieu of connecting to the top flange of the floorbeam. This connection change prevents out of plane bending which caused cracking of the stringer web/flange interface in the old bridge. In addition the steel framing members are now composite with the 8 inch reinforced concrete deck for additional bending strength. The approach spans total weight is approximately 15% heavier than the previous bridge due to the RFP requirement of an increased concrete deck thickness (from 7 to 8 inches) and additional roadway width and sidewalk. The structural configuration was similar to the existing using a girder/floorbeam/stringer framing configuration. Other configurations were analyzed and determined to not be as efficient as a two girder system. The structural steel weight was similar to the existing with increased capacity for live load due to the use of light weight concrete composite with the Grade 50 structural steel. The original bridge was designed for an H-20-44 truck for each lane of traffic as per the 1940 AASHO Bridge Design Manual. The new bridge is designed for a HL-93 truck and lane loading which is approximately 25% heavier than the H-20.

The bridge railing posts are designed to resist a TL-3 railing load and match the appearance of the existing railing, consisting of steel pickets in between concrete posts, however the barrier is not crash tested.

Figure 8: Rendering of new swing span.

Swing Span Superstructure

The swing span, spanning 247 feet from rest pier to rest pier with a pivot pier in the center, spans the Intracoastal Waterway navigation channel of 94 feet (Figure 8). The span was analyzed per AASHTO LRFD requirements as a 2-span continuous structure in the closed position, and a cantilevered structure for dead load in the open position to determine maximum stresses. Erection stresses were also calculated for when the swing span was mounted on the float-in barge as a simple span cantilevered at both ends. A SAP-3D structural analysis model of the truss was created to assist in determining maximum loads for each component of the truss.

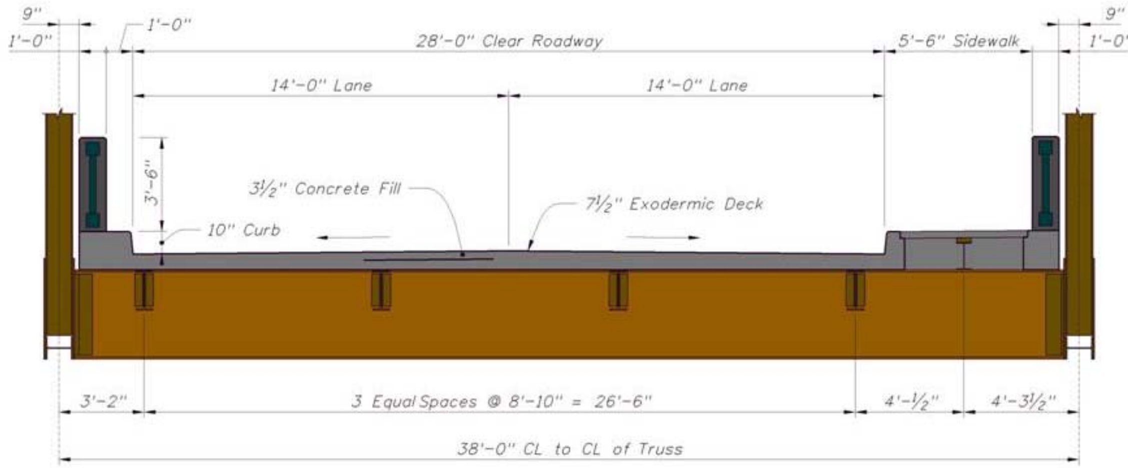

Figure 9: Swing Span Typical Section

The swing span superstructure is a center-pivot modified Warren through truss. The appearance matches the original swing span with the exception of the roadway widening, vertical clearance of the portal raised to 16 feet, and the addition of the new wider sidewalk. Although not required structurally, except at the portal, a mid-height brace of the truss was provided to match the existing swing span appearance.

The elevation of the bottom and top chords match the elevation of the old truss chords to ensure the existing appearance and navigational clearance of the channel was maintained. High strength ASTM A325 TC bolts were specified for all field and shop bolted connections to provide a riveted connection appearance of an historic structure. New steel components match the existing as closely as practical utilizing current steel design, and fabrication techniques. Wide flange rolled beams and HP rolled sections were used in lieu of latticed channel members due to their improved resistance to corrosion. An exodermic deck system utilizing lightweight concrete and steel grating minimized the span weight by requiring less stringers than a concrete filled grating system. Planing or grinding of the swing span concrete deck was performed to meet rideability requirements, and the deck was also grooved to improve roadway skid resistance. The sidewalk consists of aluminum grating panels and the steel railing system to minimize weight on the movable span. The railing system was entirely made of steel to minimize the weight of the railing. To meet the TL-3 resistance requirement an extensive bracing system underneath the sidewalk was required (Figure 9).

Control House

The control house is located above the roadway in the interior of the trusses inside the sway bracing. The control house is octagonal, similar to the existing, enlarged slightly to maximize view corridors of the waterway and roadway for the bridge tender and to meet necessary additional space requirements for the new electrical equipment (as per NEC code) and the bathroom. The bathroom is now located inside the control house with storage tanks in the ceiling and the floor for a working water supply and sewer system. Figures 10 and 11 shows the elevation view along with a floor plan of the control house.

Figure 10: Control House at mid-span above the roadway.

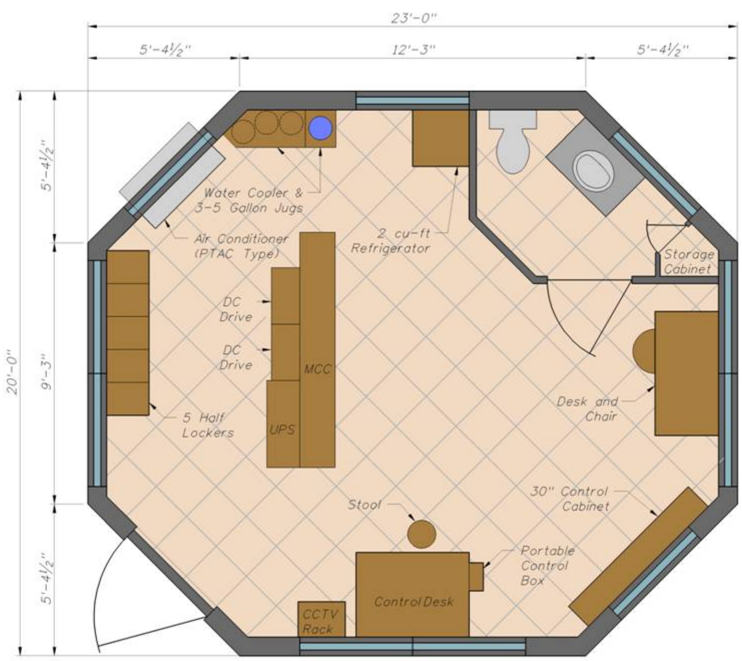

Figure 11: Control house floor plan.

Mechanical Systems

The mechanical systems of the swing span to open and close the bridge for the navigation channel are categorized as follows: 1) span drive machinery, 2) span support machinery and 3) span lock machinery. All mechanical systems and components were designed, fabricated, and erected as per the requirements of

AASHTO LRFD Movable Highway Bridge Design Specifications, 2nd Edition. PCL, H&H, and Steward Machine utilized our past experiences to assist in designing the details of the mechanical components.

1. ***Span Drive Machinery***

The span drive machinery consists of two independent drives, each capable of operating the swing span in the event of motor failure which provides a redundant system (Figure 12). The machinery is located on a machinery platform on the swing span above the pivot pier below the roadway deck. The platform spans between the pivot girder and a pinion girder on either side of the pivot. Each independent machinery system consists of a 10 HP motor which drives a closed reduction gear box. The reducer drives a pinion/bull gear set mounted to the pinion girder which drives the main pinion that engages with the rack mounted to the pivot pier to rotate the span 90 degrees about the center pivot bearing.

An extended input shaft at each right angle gearbox is accessible through the roadway deck. In the event of a power failure or loss of both motors, a capstan T-bar was provided which will engage the extended shafts for manual rotation of the span.

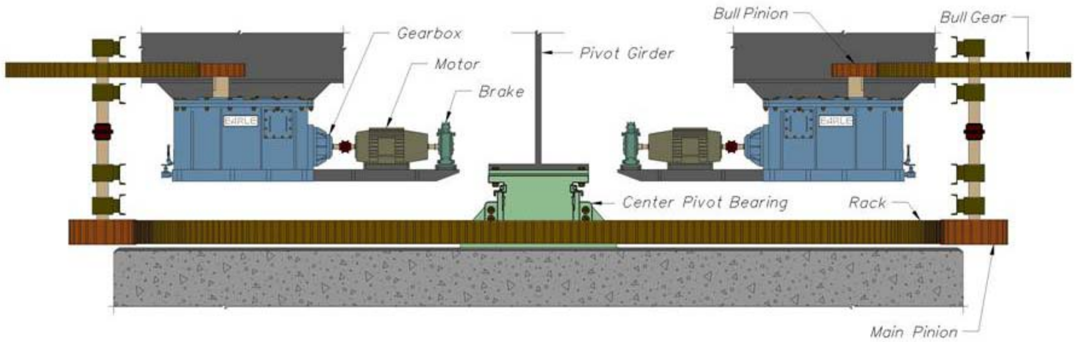

Figure 12: Elevation of operating machinery.

2. Span Support Machinery

The span support machinery consists of the following components: a) center pivot bearing, b) end eccentric lifters (in lieu of end wedges), c) center rollers d) balance wheels. The swing span rotates about the center pivot bearing (Figure 13). The bearing is a bronze/steel disc type contained in a steel box containing an oil lubricant bath. The bearing supports the entire weight of the swing span in the open position in addition to lateral loads induced by the swing span during a seismic event (approximately 350 kips) and live load from vehicular traffic.

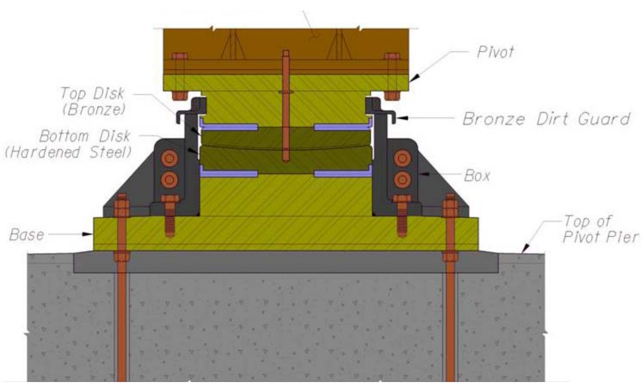

Figure 13: Cross section of pivot bearing.

End Lifters

The end lifters were used in lieu of an end wedge system to minimize weight on the span and provide easier access for maintenance. The eccentric rollers driven by an electric motor and worm drive gear box are mounted to the end floorbeam for easy access. The eccentric rollers partially remove the dead load deflection out of the swing span in the closed position to meet the approach roadway deck elevation.

Center Rollers

Two center rollers are provided at the pivot pier (Figure 14). The function of the center rollers is to resist vehicular live load and impact. The primary benefit of using center rollers in lieu of center wedges as per the technical specification is the elimination of actuation machinery. This innovation has the advantage of no associated actuation machinery or electrical equipment required. The only routine maintenance associated with this type of live load support is lubrication of the bearings.

Balance Wheels

As per AASHTO specification eight balance wheels were provided to counter overturning moments induced by wind loads during operation (Figure 14). A combination of shims at the connection with the superstructure and wheel bearings provided the proper clearance at installation and allow for future adjustments.

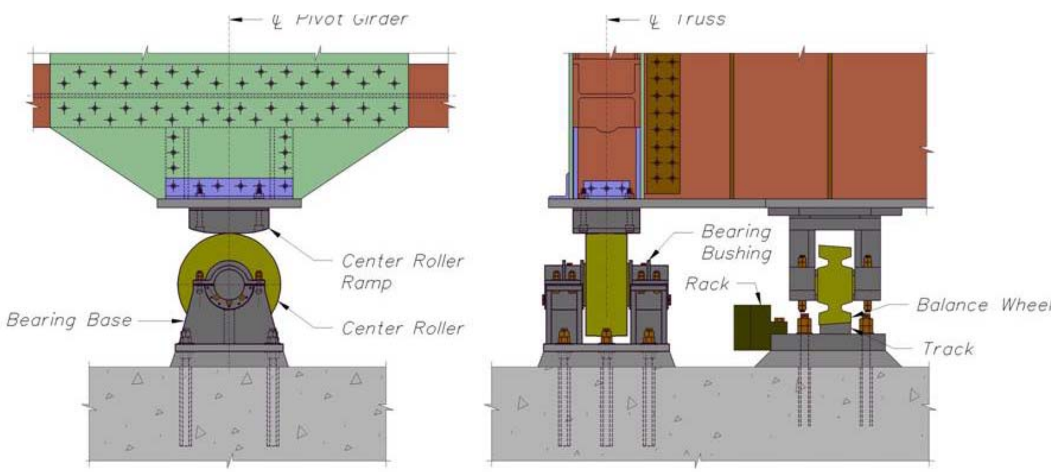

Figure 14: Center roller elevations.

Span Lock Machinery

Span locks are provided at each of the swing span at the centerline of the bridge. The span locks are actuated linearly with a gear box to a guide attached to the flanking span bottom flange. The lock bars are provided to center the span properly with the roadway and transfer swing span wind load to the rest piers. In the event of a hurricane steel tie rods are anchored to the rest pier can be connected to the swing span to ensure the span is secure.

Span Balance

Swing spans have an advantage over the other two major movable bridge types, bascule and vertical lift, in that they are typically symmetrical about the axis of rotation. This symmetry provides balance without the use of a large counterweight as required by bascule or vertical lift bridges. Although swing spans are inherently balanced there can be some small imbalance both longitudinally and transversely caused by machinery, electrical equipment, roadway asymmetry, and specialized structural components. Minor balancing was required to compensate for longitudinal and transverse imbalance due to the asymmetric roadway section. Specifically the sidewalk is provided only on the west side of the bridge. The concrete deck was made thicker on the east of the roadway to compensate for the sidewalk. Additional ballast was required underneath the sidewalk to compensate for the heavier deck than anticipated.

Community Relations Plans

The design and construction of the Ben Sawyer Bridge attracted great interest from the local residents of Mt. Pleasant and Sullivan's Island along with marine traffic utilizing the Intracoastal Waterway. The D-B team recognized SCDOT's need to deliver a modern swing span bridge which maintained its historic integrity. The team understood the value of experience and professionalism in public information and community outreach. For this reason, Civic Communications, Inc. a local DBE public relations firm was an integral part of the team to assist with community relations.

The Community Relations Plan committed to serving local residents, their related community organizations, and the public leaders and exemplified effective partnering between the team and the SCDOT. Public involvement and community relations services included information sharing and outreach through written materials as well as personal contacts. To ensure information was accurate and provided in a timely manner, the source of all information including background information and schedules was provided by the D-B team members.

Beyond being available to address one-on-one outreach as necessitated by specific public concerns, information was shared with interested communities and their leaders on a daily basis with the creation of a project web page on the SCDOT website. On this site community members received updates, would follow project progress, received traffic announcements, and were given the opportunity to provide feedback. In addition to the information above, the plan also included:

- A construction community forum to allow persons to ask questions regarding the construction process.
- Detour announcements for vehicular and marine traffic - sent as necessary at least 48 hours in advance.
- Leadership updates were provided as necessary, via paper and e-mail to area politicians, media, and interested community organizations.
- Flyers to address specific issues or concerns that may arise over the schedule of the project.
- Speakers and presentation materials were made available to the SCDOT, as needed for public presentations.

Environmental/Permitting/Erosion Control

The D-B team's construction method complied with the permits prepared during the preliminary design phases of the project prior to the RFP advertisement. The construction was performed as follows to ensure (USCOE and USCG) permit compliance:

- The bridge was constructed on the existing alignment with no shift in right-of-way.
- No temporary or permanent fill was used in critical areas (wet lands) during construction activities.
- Access trestle mitigated construction impacts to critical areas by allowing daily tidal inundation in the construction area.

– As required, marsh areas impacted by the access trestle were returned to original contours, re-vegetated, and monitored after construction.

– Construction of the new swing span was completed off-site, thus reducing the impacts to wetland areas.

An erosion and sediment control plan was developed based on the bridge access plan. The erosion and sediment control plan implemented best management practices as needed to minimize the impact to the environment. Based on the location of the project, the plan was submitted to the Town of Sullivan's Island, City of Isle of Palms, and the South Carolina Department of Health and Environmental Control Office of Coastal and Resource Management (OCRM) for approval. Throughout the project PCL worked with local inspectors, OCRM, and the SCDOT to ensure the sediment and erosion control procedures were maintained which limited impacts to environmentally sensitive wetlands on the north and south approaches.

Maintenance of Traffic

The bridge remained open to two lanes of vehicular traffic at all times during construction, with the exception of permitted nighttime lane closures in accordance with the constraints set forth in the RFP and the total bridge closure period.

Marine Traffic Coordination

The D-B team had a great working relationship with the US Coast Guard (USCG). USCG was considered part of the project team and coordinated construction planning with them early in the project to ensure required closures of the navigable channel did not interrupt marine traffic. This coordination included continuously submitting construction sequence plans, mooring plans, and the project CPM schedule to the USCG for review and comment. Marine traffic was maintained throughout construction except for the minimal time required to complete construction activities which required occupation of the navigable channel. PCL submitted an application for a Marine Event Permit 120 days prior to the scheduled marine traffic interruptions. Following approval of the permit, the USCG issued a Notice to Mariners to alert the public of approved channel restrictions.

Bridge Construction

Approach Spans

Use of temporary support bents with trestle access was used to expedite removal and replacement of the approach spans during the bridge closure. New approach spans were pre-fabricated directly west of the existing structure on temporary bents (Figure16). The north and south approach spans were constructed concurrently to meet the schedule constraints and closure requirements. During the bridge closure the existing approach spans were shifted east to temporary bents spaced identically to the existing concrete piers, and the new spans were shifted east onto the existing concrete piers by placing rollers underneath the existing and new superstructure and translating the spans with the use of tension jacks pulling the spans into proper position.

Access Trestle/Temporary Bents

After the designed erosion control was in place and the embankments cleared and grubbed, the east and west access trestle and temporary bents were installed simultaneously using top down construction methods. Installation commenced at the abutment and progressed toward the rest pier as each trestle section was completed. This cycle continued until the complete access trestle and all temporary approach bents were installed at each quadrant of the bridge (NW, NE, SW, and SE).

Structural Steel Erection

Prior to shipment all components were shop primed and intermediate coated in accordance with the approved paint system submittal, in accordance with SCDOT Standard Specifications. Each three span continuous unit (2 each side) was erected independently by PCL. The north and south approaches were constructed simultaneously beginning at the abutment and progressing toward the rest piers. The main girders were erected on grillages on the temporary bent header beams. This enabled the load from the new approach spans to be transferred to rollers upon completion. A temporary jacking beam was connected to the underside of the main girders to facilitate jacking and load transfer upon completion of erection. The grillages underneath the girders were used to connect the tension rods to pull the girders.

Deck and Sidewalk Construction

Each three span continuous approach deck was placed in two separate nighttime pours. As each three span continuous approach was erected (east and west), the concrete deck crew commenced construction of the stay-in-place deck forms, followed by installation of rebar, and replacement of concrete. A Bidwell was used to ensure a superior finish that meets SCDOT rideability standards. (Figure 15). The final deck surface was planed and grooved to provide an exceptionally smooth deck. The sidewalk and curb was placed with a secondary pour after construction of the bridge deck.

Figure 15: Night-time concrete deck pours.

Span Replacement

The new and existing approach spans were shifted in two operations; the four existing three span units and the four new three span units were shifted in unison with each other and rolled off and onto the respective temporary bents and substructure using 50 ton tension jacks pulling high strength rods connected to the grillage/rollers underneath the superstructures in 4 inch increments (Figure 16). A concerted and organized effort to ensure that the spans were all pulling at the same rate was monitored to ensure the spans did not become misaligned during the rolling operation. The operation of moving the existing superstructure off and the new superstructure on the existing substructure took approximately 24 hours for each approach. After the spans were in place, the girders were jacked and fitted with new isolation bearings and grouted in place.

Figure 16: North Rest Pier looking North showing temporary bents and crane trestle. New Approach spans are on the existing substructure and the old approach spans have been moved to a temporary bent ready for demolition.

Swing Span Construction

Method

The new swing span, including the structural steel, control house, mechanical, electrical and exodermic deck grating was erected off-site at a staging yard at the Port of Charleston terminal. The close proximity of this terminal to the Ben Sawyer Bridge site significantly reduced the risk associated with a long distance float-in. All swing span components were delivered to this location for erection, including: 1) structural steel, 2) control house materials, 3) mechanical/electrical system, and 4) deck grating.

Shop Erection

Upon approval of shop drawings and submittals, the span was shop fabricated and assembled by Florida Structural Steel of Tampa Florida (Figure 17). The structural steel was shop primed and intermediate coated prior to erection in accordance with the approved paint system. The span was supported by temporary bents which were designed to ensure the structure was not overstressed during shop erection. Components were temporarily bolted to minimize alignment issues during final erection of the span. PCL and H&H coordinated with the team QC Manager to make sure all parties understood the progress of the work and addressed any concerns throughout shop erection.

Figure 17: Swing span shop erection at FSS yard.

Onsite Preclosure Work

Prior to the bridge closure, crews prepared the onsite mechanical and electrical components for replacement of the swing span. This work included: 1) replacing a segment of the existing track/adding a new rack, and 2) installing the submarine cables.

Electrical Work and Control Construction

Shop drawings, logic control programming and shop witness testing is a proven approach that minimizes on-site startup problems. Integrated shop drawings and coordinated project planning facilitated the installation of the electrical work and the controls on this project. Electrical work including conduit, wiring, submarine cable installation, terminal cabinets, control house wiring and service wiring was completed in advance of the closure. Limit switch and gate simulations were performed prior to the float in, which ensured there were no start-up challenges during the closure. After installation of the new swing span, the span mounted terminal cabinet was connected to the terminal cabinet on the center pivot pier with flexible cables, and startup was initiated immediately with minimal troubleshooting due to the pre-installation testing previously completed.

Float-In Procedure

An engineered floating scheme was used to transfer the swing span and ensure that all temporary supports were properly positioned. The PCL Project Manager coordinated all aspects of the swing span construction, the floating procedures and the transfer of the existing and new swing spans.

A two-barge false work system was utilized to remove the existing and place the new swing span on the existing pivot pier. The false work located on the barges was at an elevation that allowed the system to float under the old swing span at low tide and lift the span at high tide (Figure 18).

Prior to the closure of the bridge, the new swing span was transferred to the 50x180 feet barge at the Port of Charleston where the swing span was in its near completed condition including the mechanical and electrical system. The transfer was engineered to ensure the span was not overstressed during the move. To transfer the 700 Ton swing span from the staging yard to the barge, a hydraulic pulling system and rollers was utilized similar to the system used to transfer the approach spans onto the existing piers.

After the swing span was rolled onto the barge and prior to the bridge closure, the span was floated to the bridge site adjacent to the original swing span. At this time the channel was closed to navigation with the permission from the USCG and the bridge was closed to vehicular traffic. The false work mounted on the barge came in underneath the swing span and lifted the span with the rising tide in conjunction with raising the barge mounted false work with hydraulic jacks. After the original swing span was transferred from the pivot pier to the barge, the barge pulled the span from the bridge turned 180 degrees around to position the new swing span in alignment with the new approach spans.

After the existing swing span was removed, crews began work on the rest pier and pivot pier modifications. Concrete modifications were required at the center pivot bearing as the new bearing is larger than the existing. Also, the track/rack overlapped with the existing, and therefore could not be replaced until the closure. Anchor bolt holes were drilled using templates made from the machinery components and placed on the pier. The new span lock receivers were set on the rest piers, but not permanently mounted until the new swing span was set. This ensured proper alignment of the guide and receiver were achieved.

Figure 18: Float-in barges with new and old swing spans.

Figure 19: Swing span floating into position over pivot pier. Note all machinery including the rack and pivot bearing is assembled to the swing span.

Upon completion of the required center pivot pier and rest pier modifications, the barge with the new span moved over the pivot pier and with the receding tide placed onto the pivot bearing (Figure 19). The installation process was completed in reverse of the removal process. Once the new span was set, the rack segments were shimmed and aligned with the pinions. After final alignment of the pivot bearing, rack, track, span locks and end lifters, the components were grouted in place. The span was then manually rotated using the cap stands to the open position to allow marine traffic to pass through the channel. The span electrical system was then tested. With minor tweaks to the system since the system was pre-tested, the span has been operating flawlessly. After a total of 260 hours the bridge was opened to traffic on February 19, 2010 at 1:50AM. Mayor Carl Smith of Sullivan’s Island was the first to cross the new superstructure in a 1928 Model A Ford.

Figure 20: Project site showing old bridge in service and new bridge ready for the move onto the existing substructure.