TRAVIS SPUR RAIL BRIDGE REPLACEMENT
ABC TECHNIQUES IN A DESIGN BUILD PROJECT

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ABSTRACT

One of the many challenges to be overcome during Goethals Bridge Replacement Project was the replacement of the existing Travis Spur Rail Bridge (TSRB), located near the east end of the project limits, and crossing over I-278 near the Goethals Bridge toll plaza. The original TSRB, consisting of a 7-span, single track crossing, was replaced to allow for widening of the I-278 corridor below. Due to operational needs of the owner, NYC Economic Development Corp, TSRB could only be removed from service for a single 60-hour weekend. Roll-in accelerated bridge construction techniques where thus required to replace the crossing. The crossing was replaced without closing I-278 to through traffic, except for a short 10-hour window for demolition of TSRB. The new TSRB consists of a ballasted, through girder design, supported on two-column bents, founded on drilled shafts. In order to make the weekend closure schedule, the two spans were erected within the project right-of-way, adjacent to the TSRB alignment while foundation work proceeded at the site. Drilled shafts and column were located to avoid existing substructure and utilities. Precast cap beams were installed during the weekend closure using a two-crane pick. The installation of the south pier cap beam was further complicated in that it had to be installed under the existing Gulf Avenue span to remain, while being installed over the rebar of the new pier columns. With the piers complete, the new spans were rolled into place, with ballast and track already in place, atop self-propelled mobile transporters (SPMTs).

INTRODUCTION

The Travis Spur Rail Line is a single-track short line that runs north-south along western side of Staten Island, New York. The Travis Spur is part of the Staten Island Railroad (SIRR) and connects the Staten Island Waste Transfer Station at the south end of the line to the Northern Branch of the SIRR at Arlington Yard. The Northern Branch of the SIRR crosses the Arthur Kill Vertical Lift Bridge, adjacent to and just north of the Goethals Bridge, to connect to the national rail system in Elizabeth, New Jersey. Two trains per day traverse the Travis Spur hauling containers on flatbed cars from the transfer station to a landfill in South Carolina.

The Travis Spur Rail Bridge (TSRB), subject of this paper, carries the rail line across Interstate Highway I-278, which crosses Staten Island to connect the Goethals Bridge to the Verrazano Bridge and is a major link between Staten Island, NYC and central New Jersey. More precisely, the TSRB is located at the western edge of the toll plaza for the Goethals Bridge. Replacement of the Travis Spur Rail Bridge was prompted by the replacement of the Goethals Bridge and the reconfiguration of the approach roads. The original bridge carried a total of four-10' lanes with no shoulders. Each of the two parallel replacement bridges accommodate three-12' lanes with a 12' left shoulder and a 5’ right shoulder. The area between these two structures is allotted as a corridor for future mass transit.

Because of various construction window constraints imposed by SIRR as well as by the Interstate highway below, five of the seven spans of the Travis Spur Rail Bridge were removed and replaced in a single, 60-hour weekend outage. This included removal of the existing substructure (abutments, piers and surrounding fill), and installation of the new, in addition to removal and replacement of the superstructure using a variety of ABC techniques. The successful completion of this work during this outage, performed without significant incident, was due in a very large part to careful planning and collaboration between the designers and contractors of the design-build team during the design phase.

Replacement of both the Goethals Bridge and the Travis Spur Rail Bridge were performed under a single Public-Private-Partnership contract. The Goethals Bridge, owned and operated by the Port Authority of New York and New Jersey (the Authority), spans the Arthur Kill, linking Elizabeth, New Jersey, with the Howland Hook area of Staten Island, New York. The original bridge was built and opened to traffic on June 29, 1928. Given present-day traffic volumes, commercial growth and new standards, the original bridge became functionally obsolete. On April 24, 2013, the Authority authorized the $1.5 billion replacement of the Goethals Bridge. A Public-Private Partnership (P3) contract was awarded to NYNJ Link Developer, LLC to design, build, finance and maintain the new bridge, which consists of two cable stayed bridges with approaches carrying parallel roadways totaling 7,300 feet from abutment-to-abutment. This replacement increased the number of travel lanes from two 10-foot lanes in each direction, to three 12-foot lanes with shoulders. Design also allows for the addition of a future Mass Transit Corridor (MTC) to be located between the two roadways. The ABC replacement of the Travis Spur Rail Bridge (TSRB) was an integral part of the scope of this ambitious program, to remove what would otherwise be a choke point for traffic on the underlying highway and for the future transit corridor. *See Figure 1 for an Overview of the Project Corridor.*

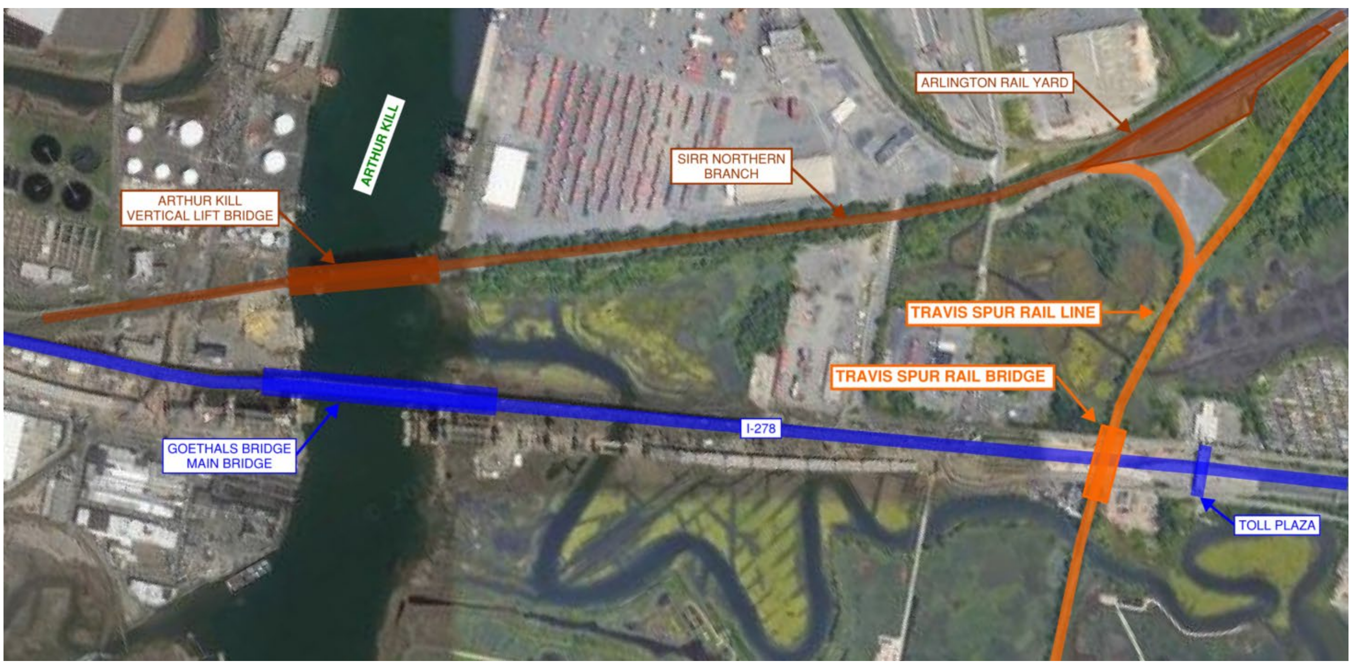


Figure 1. Overview of Project Corridor

The extensive number of stakeholders involved in this complex project contributed to the enormous coordination effort needed to complete this bridge replacement. The TSRL is part of the Staten Island Railroad (SIRR), which is owned by the City of New York and managed by the New York City Economic Development Corporation (NYCEDC). In turn, Conrail was designated by NYCEDC as the operator of the SIRR. Given the many stakeholders involved, a Memorandum of Agreement (MOA) was reached to support the project’s ambitious construction schedule. The NYNJ Link contracted with KWM, a tri-venture of Kiewit Construction, Weeks Marine and Massman as the general contractor which retained Parsons as the prime design consultant for the overall project. SJH

Engineering, P.C. (SJH) was hired by Parsons to perform the design and construction support services for TSRB replacement.

PLANNING AND SELECTION OF A CONSTRUCTION METHOD

The type of structure, its location, the operational requirements, and the complexity of the overall project lent itself to the use of ABC method, rather than conventional construction. Considerations that led to the selection of ABC method are summarized below. Owing to the unique nature of a design-build contract, these construction methods were jointly developed by the design team and the contractor, greatly streamlining the process.

Site Description

The TSRB supports a single ballasted track running north and south, located just 600-feet west of the Goethals Bridge toll plaza, near the project's eastern limit, crossing over Goethals Road North, I-278, and Gulf Avenue. The original crossing consisted of three individual bridges separated by embankment fill. The section of TSRB over I-278, replaced in 2017 during this project, was built in 1930 and consisted of a five span thru-girder bridge. The steel superstructure was set on reinforced concrete piers and abutments on spread footings. See Figure 2.

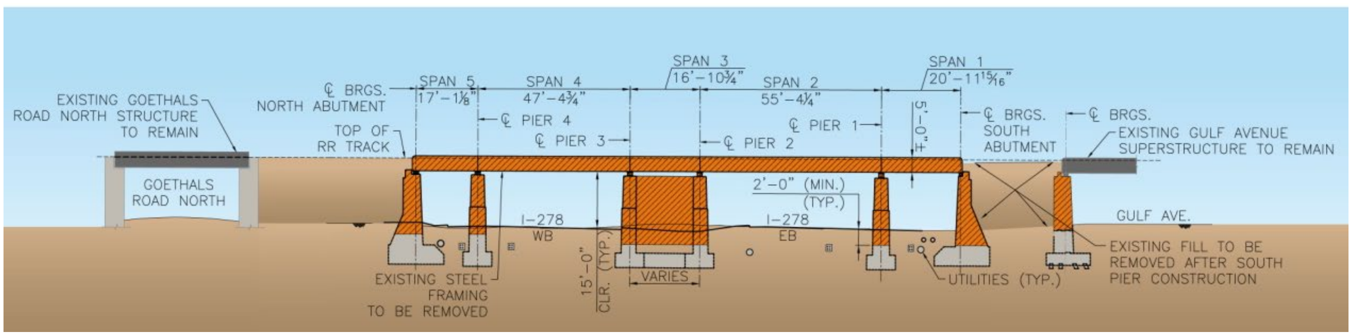


Figure 2. Elevation of the Original TSRB

Interstate route I-278 in the vicinity of the TSRB was widened and re-configured to suit the new approach roadway alignment and profiles, as well as to provide space for the future Mass Transit Corridor (MTC). As a result, the old TSRB over eastbound and westbound I-278 and the northern abutment supporting the railroad over Gulf Avenue were removed and replaced with a two-span through girder bridge that spans over eastbound and westbound roadways of I-278. The southern end of the new TSRB and the existing span over Gulf Avenue are supported on a new pier. A single, central pier now replaces the multiple piers that were located between the I-278 eastbound and westbound roadways. Consistent with the Authority's mandate to serve the public, the team collaborated closely to develop a design and construction approach that would allow for removal of the original bridge, erection of the new bridge, and a return to service of both highway and rail traffic over a single weekend shutdown. See Figure 3.

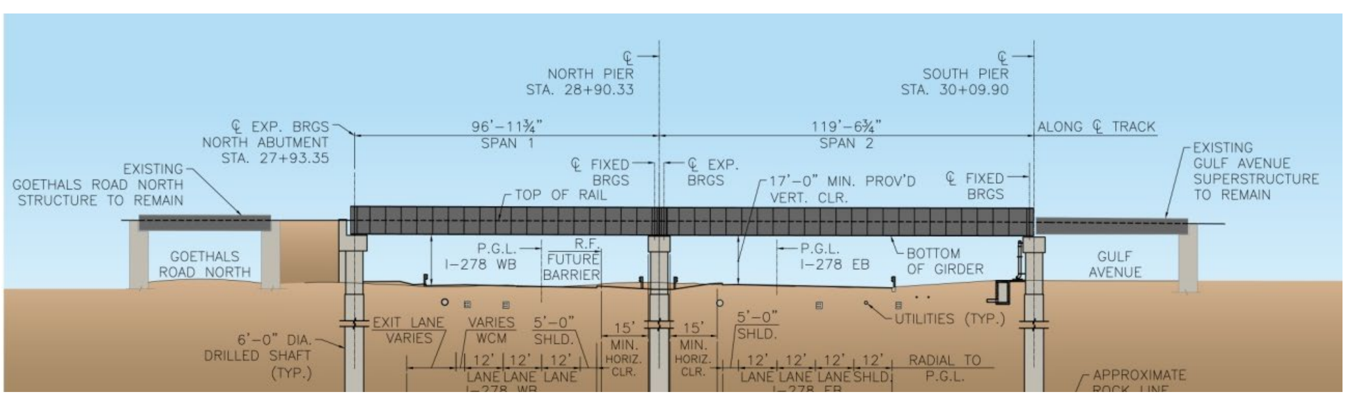


Figure 3. Elevation of the Replacement TSRB

Railroad Operation Requirements

The current regular operational activity along the rail spur and the TSRB includes two crossings per day (5 days per week, Monday through Friday) between the New York City Department of Sanitation (NYCDOS) waste station and Arlington Yard. The MOA stipulated that, "*the current regular operational activity over the Travis Spur Rail Bridge could change and/or increase at any time. The replacement of the Travis Spur Rail Bridge shall not be permitted to impact railroad operations, which must be maintained for the duration of the Travis Spur Rail Bridge Project.*" Accordingly, the operational requirements dictate that only weekend shutdowns would be permitted for replacement of the TSRB.

Interstate Highway Requirements

Traffic impacts and work zone safety were also primary concerns during the planning phase. I-278 carries over 90,000 vehicles daily, with the majority of traffic consisting of truck traffic due to the bridge's proximity to Port Newark and Port Elizabeth. Thus, replacement of the TSRB spans over the busy I-278 had to be accomplished with minimal impacts to interstate traffic. Lane closure restrictions imposed by the Authority limited the available space for the construction. Full closure of either the I-278 eastbound or westbound roadways would only be allowed during limited weekend windows. Bridge replacement over I-278 required a full closure of the interstate corridor.

Project Delivery Time

Even though the TSRB Replacement is a small piece of the jigsaw puzzle relative to the grand scheme of the overall project, its impact on the overall construction schedule can't be overlooked. The overall P3 contract was given a very aggressive construction schedule since the developer's Return on -Investment is closely tied to the new bridge's opening date. The use of ABC methods helped to achieve the overall goal of expedited delivery.

SUPERSTRUCTURE DESIGN

The new bridge is comprised of two simply-supported spans of 97 feet and 120 feet, Spans 1 and 2 respectively. The skew angles at the North Abutment and North Pier are 12 degrees and 8 degrees at the South Pier. The superstructure of the new bridge is based on Conrail's current standard thru-girder bridge design. SJH's design of the new steel superstructure follows AREMA Chapter 15 Allowable Stress Design method. The design of the reinforced concrete substructure follows the AREMA Chapter 8 Load Factor Design method [2]. In addition, Conrail's specific requirements, as stipulated in CE-12 - "Specifications For Design And Construction Of Undergrade Railroad Bridges For Grade Separation Projects," were followed [3]. For seismic design purposes, references were made to AASHTO LRFD Bridge Design Specifications [4]. The design includes a dead load allowance for 18" of future ballast. Cooper E80 train load or the alternate live load on four (4) axles, whichever results in greater stresses, were used as live load. Seismic design was in accordance with AREMA Chapter 9 and AASHTO LRFD Bridge Design Specifications. Other loads considered include wind forces on the loaded bridge and unloaded bridge, longitudinal forces due to braking or traction, and lateral forces from equipment.

The thru-girders are welded steel plate girders with a 102" web and 30" wide flanges. Floorbeams are W21 wide flange rolled shapes spaced at 2'-6" nominal center-to-center. Knee braces are spaced at 10'-0" nominal center-to-center. Seven-inch timber ties and 8 inch minimum ballast were placed on top of the steel, waterproofed deck plate. The new superstructure provides 9'-0" minimum horizontal clearance between the centerline of track to the top of the curb plates on each side, as per current standards, with wider 23'-0" spacing between through girders. See Figure 4. Conrail's standard details call for terminating the stiffener plate slightly above the floorbeam. SJH extended the stiffener plates at each floorbeam and knee brace locations to achieve full depth between girder flanges with fillet weld connections to achieve better rigidity and fatigue performance.

Since the overall width exceeds 24 ft, transportation of the fully assembled superstructure via interstate expressway was not feasible. Erection over the I-278 one girder at a time was also prohibited due to the limitations on closures of the line and of the underlying highway. Instead, the superstructure was assembled in an adjacent laydown area 150 feet away from the bridge location, between I-278 and Gulf Avenue. Each through girder was shipped in full length without field bolted splices. The deck plate/curb plate segments are shop welded to four floorbeams to make a shipping unit to simplify and expedite the on-site assembly effort. All in all, twenty two (22) units were shipped to the field and field-bolted into place. On the day of erection, Self-Propelled Modular Transporters (SPMT) were used to carry the pre-assembled spans from the laydown area to the bridge site.

SUBSTRUCTURE DESIGN

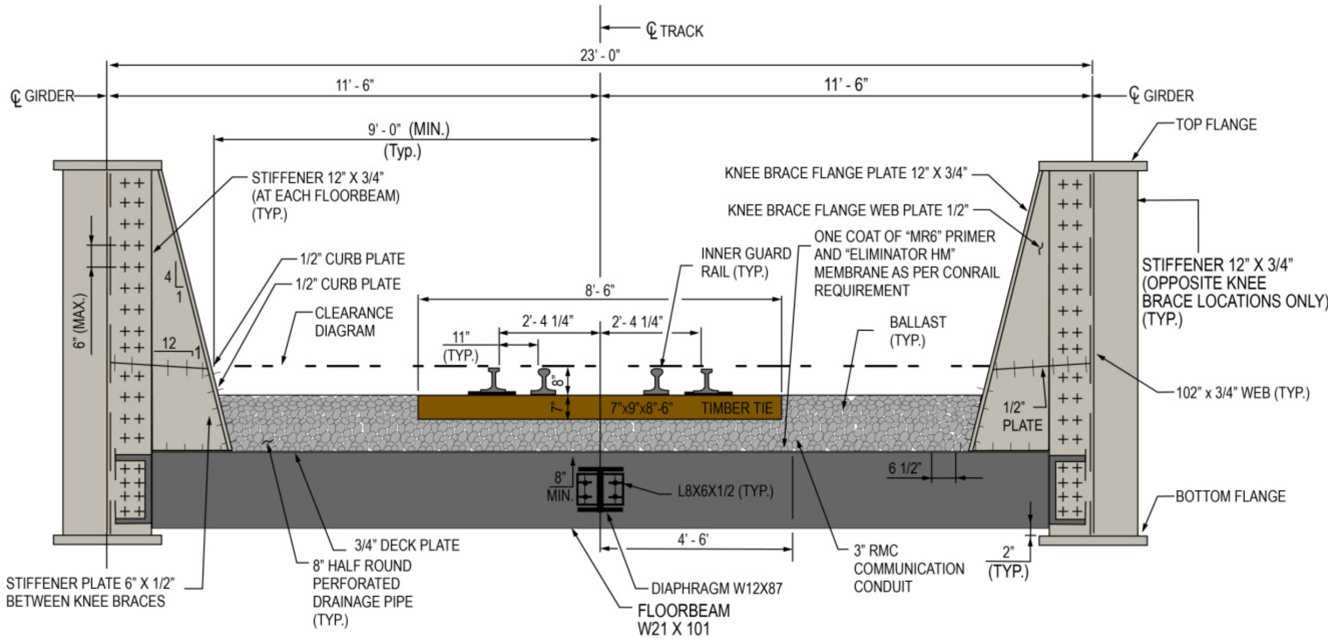


Figure 4. Typical Section of the New Through Girder Superstructure

The substructure consists of precast concrete abutments or pier caps supported on two cast-in-place 5'-6" diameter columns. Each column is supported on a 6-foot diameter drilled shaft. The contractor chose to use a larger-than-required drilled shaft size for economic reasons, since that size shaft was also being used on many of the foundations at the new Goethals Bridge's New York approach spans. The larger drilled shafts also reduced horizontal deflection of the structures due to braking and traction forces.

The drilled shafts vary from 31-feet to 41-feet in length, with 5'-6" diameter rock sockets of 10'-6" and 11'-6" in length. All drilled shafts and columns have #14 epoxy-coated rebars as the main reinforcement element and #7 welded hoops as confinement. The substructures are designed to the 2,500-year return period seismic event. A general finite element program was developed using CSiBridge to model the entire superstructure and substructure down to the points of fixity which, in turn, were developed by modeling soil-structure interactions using LPILE. Site-specific seismic design spectrums were developed for the 2,500-year, 500-year and 100-year events.

The most interesting and challenging portion of the substructure design was the connection between the precast cap beams and the cast-in-place columns. Various options were considered during design in an integrated task force environment between the design and construction teams and guided by the FHWA's, "Connection Details for Prefabricated Bridge Element Systems" [5]. Given the stringent seismic design requirements, a full moment connection is required at this connection which allows the development of plastic hinges. A proprietary grouted splice sleeve system was selected due to its space-saving design and its ability to develop 125% of the rebar strength, which is similar to the requirements on mechanical couplers. The system uses cylindrically shaped ductile iron sleeve filled with a rapid setting, non-metallic, non-shrink, cement-based grout. Reinforcing bars were spliced and inserted into the sleeve to meet approximately at the center of the sleeve, and then the interior of the sleeve was filled with the proprietary grout. The total tolerance in the grouted splice sleeves is only about 0.9 inches in the sleeve for #14 rebars.

Similar systems have been used in a number of projects within the United States in other states. Notably, however, all previous applications have rectangular rebar patterns. In this project, circular shaped columns use rebars that are set in a radial pattern, which increases the difficulty of aligning all of the eighteen #14 rebars in both columns simultaneously. To allow for construction tolerance, a 1" gap was intentionally provided between the top of the columns and bottom of precast cap beam. The gap was formed and filled with rapid setting non-shrink grout which can achieve 5,000 psi compressive strength in about 3 hours when applied at 70 degrees Fahrenheit. In order to reduce the development length of column rebars into the cap beam, LENTON Terminator (a.k.a. T-heads) were used in a staggered pattern. See Figure 5.

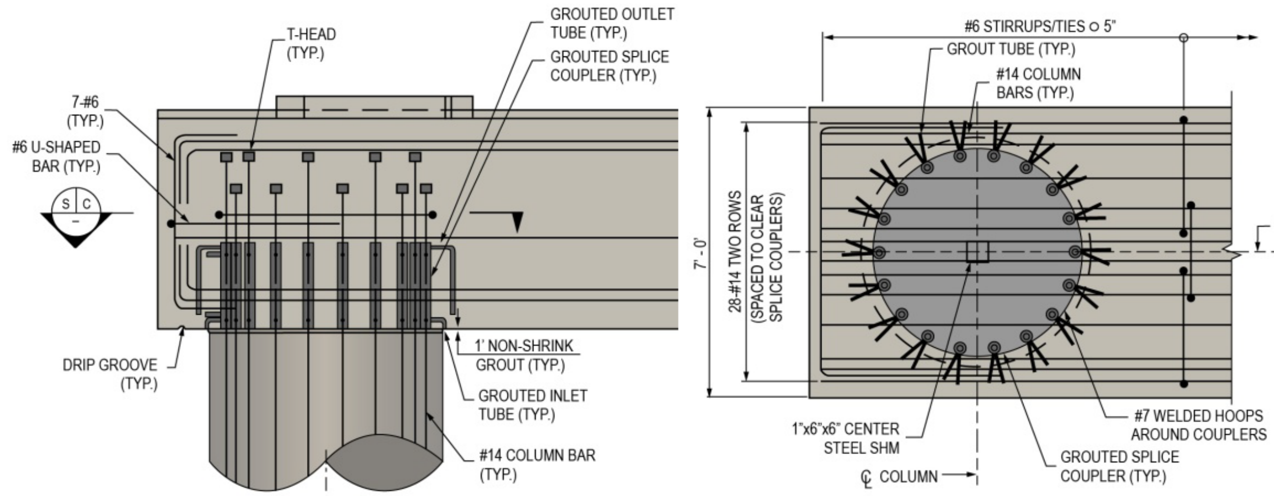


Figure 5. Typical Cap Beam to Column Connection

To the author's knowledge, the use of the grouted splice sleeves connection is a first for the Authority and for the State of New York. The application in this project was extremely challenging since it required matching each of the thirty-two (32) grouted splice sleeves in each cap with the eighteen (18) #14 rebars projecting in a radial pattern from the columns to be connected at the ends of each capbeam. The columns were constructed on either side of the original track structure prior to the weekend shutdown.

To accomplish the goal, the contractor used the patented "Cage-Rite" cage bracing system, allowing the team to accurately control the location of each column rebar to match the approved shop drawings. Upon curing of the columns, the as-built rebars were surveyed in detail in order to create an accurate template for use in setting the grouted splice sleeves in the cap beam formwork, which accounted for both columns. Each column rebar was surveyed around its perimeter several times to locate its geometric center. The survey results were brought into CADD and the template for each location was brought to the field to verify that it matched with the as-built rebar locations. Nonetheless, due to the uncertainty of cap beam installation and the need to maintain critical train operations beyond the shutdown window, Conrail requested a contingency plan ahead of the construction. SJH checked the cap beam to column connection reinforcement design and developed a plan in the event that the grouted splice sleeves didn't match the column rebars, so that a minimum amount of column rebars could be ground smaller or partially cut to ensure proper fit. All these efforts were proven to be extremely valuable as was demonstrated during the cap beam erection that the templates were almost perfect, and the contractor was able to install the cap beam on top of the columns without difficulty. SJH and Parsons were on-site during the cap beam erection to provide immediate assistance if field conditions or special needs arose.

Another challenging aspect of this project was incorporating the existing Gulf Avenue span and supporting it on the new South Pier, while replacing the original Gulf Avenue north abutment. In order to install the precast cap beam, the elevation of cap beam was intentionally lowered. Tall pedestals were provided at the new Span 2 side only, and fabricated steel bolsters were provided which were set under the original Gulf Avenue bearings and provided with a 1 ½" non-shrink grout pad on the precast pier cap. This design allowed the accelerated erection of the cap beam by sliding it underneath the existing superstructure to avoid interference with the existing superstructure and bearings. See Photograph 1.

ACCELERATED BRIDGE CONSTRUCTION

ABC techniques were used in order to complete the replacement of the original 5-spans over I-278 with a new, 2-span bridge over a single weekend. Construction was carried out in three phases, with the major items outlined below:

Phase 1: Pre-Shutdown

1. Relocate existing overhead power line, relocate or abandon existing utilities as indicated on the contract drawings and remove existing sign structures.
2. Install temporary steel sheetings as needed to maintain stability in the vicinity of proposed drilled shaft construction and support existing trackbed.
3. Install temporary shoring under existing girders in front of the North abutment of Gulf Avenue span.
4. Construct drilled shafts and pier columns on both sides of the existing bridge.
5. Pre-assemble Spans 1 and 2 of new bridge superstructure at the nearby laydown areas.

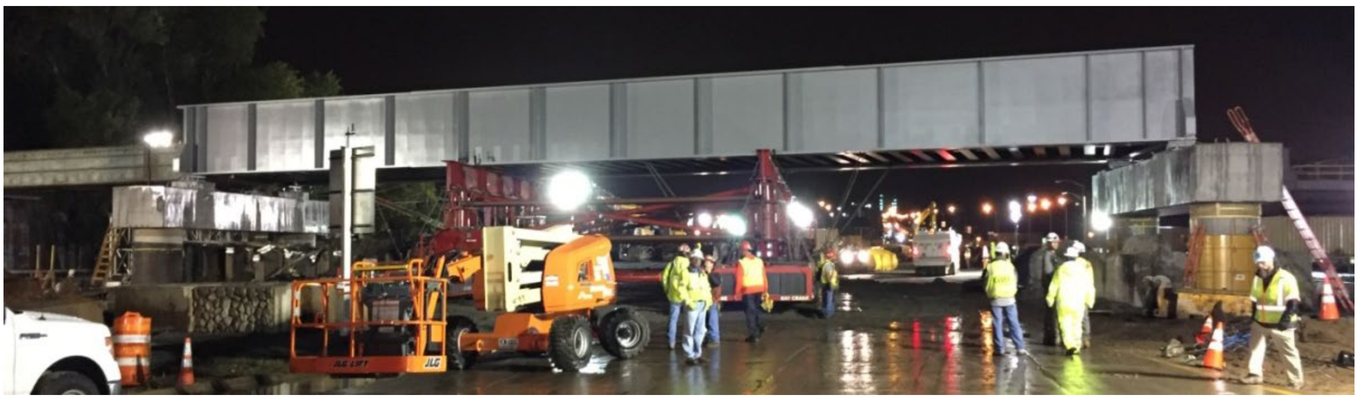
Phase 2: 60-Hour Shutdown

1. Implement eastbound I-278 detour onto Gulf Avenue.
2. Demolish existing superstructure using a 10-hour full shutdown of I-278.
3. Demolish existing piers as needed and install precast cap beams and grout connections.
4. Roll in new Span 2 superstructure using Self Propelled Modular Transporter (SPMT) to final position.
5. Implement westbound I-278 detour onto I-278 Eastbound roadway.
6. Roll in new Span 1 superstructure using SPMT to final position.
7. Tamp ballast / ties / tracks to final grade.
8. Open new bridge to railroad traffic and resume normal traffic pattern on I-278.

Photograph 1. South Pier Cap Erection

Phase 3: Post Shutdown

1. During weekday work, cut and remove temporary sheeting and existing substructure minimum 2 feet below finished grade and construct remaining C.I.P. wall under the abutment cap and wingwalls, and re-grade area under bridge to proposed widening as shown on construction plans.
2. One of the innovative methods that the contractor used was in the demolition of the existing Gulf Avenue north abutment. Upon shoring the existing superstructure, the contractor used a wire saw to cut the original 6 ft thick abutment stem into three pieces, each weighing 50,000 pounds. The sawcut was done in a way that allowed the stem segments to be pulled out using a backhoe sitting on top of the existing Travis Spur span 1. The horizontal and vertical cuts were intentionally inclined to prevent the heavy segment from rolling towards the temporary shoring side under its own weight.
3. KWM developed an alternate method to demolish the existing 5-span structure in a short time frame. A complete Goethals Bridge shutdown was implemented from 10 pm on October 7 through 8 am on October 8. Most of the ballast was removed prior to this operation. Using steel plates as protection for the I-278 roadways, KWM used six backhoes with heavy duty shear attachments to slice through the superstructure girders and floorbeams and drop the existing bridge to ground level. Backhoes with heavy duty hammers were then used to demolish the substructure. This method proved to be highly productive.



Photograph 2. Superstructure Erection with SPMT

One of the most challenging construction activities was the erection of the pre-cast cap beams. This was clearly demonstrated during the erection of the South pier cap, which is the most difficult out of the three locations, as the cap beam had to be slid under the original Gulf Avenue superstructure. The precast cap beam pick was 215 kips at the South pier and North pier including spreader beam and slings. A Liebherr 1300 crawler crane was used with a spreader beam long enough to place the slings outside the limits of the existing superstructure, allowing the cap beam to be slid into place. Traffic on Gulf Avenue was temporarily halted during the lift.

Due to the heavy pick, it took many workers manning tag lines to make even a minor adjustment in the cap beam’s position. See Photograph 1. The precast cap beam pick is much heavier (279 kips) at the North abutment. Even though a single crane has the capacity to handle the heavy pick, two cranes were used (Liebherr 1300 and Liebherr 895 crawler cranes) due to the railroad’s requirements for the picking crane(s) to accommodate 150% of the intended pick weight. Coordination between the two cranes became another challenge in which the contractor did a near perfect job in keeping the cap beam level during the lift, and erection was completed without a hitch.

Erection of the two new spans was completed by using a SPMT. The SPMT consisted of two 10-line Goldhofer PSTE/SL hydraulic platform trailers with electronic steering capable of 360 degrees of travel. The weight of the heavier Span 2 is about 500,000 pounds with ballast pre-installed to save time during the highway outage. Even though the SPMT can theoretically rotate 360 degrees, due to the skew angle of substructure and existence of the original Gulf Avenue superstructure, it turned out that the SPMT had to be rotated to almost perfect alignment before it was moved straight ahead into final position. During the weekend shutdown, each span was erected using the same SPMT about 24 hours apart allowing proper MOT/detour implementation and ground surface preparation with steel plates along the path. See Photograph 2.

SERVICE LIFE

One final unique feature of this Public-Private Partnership (P3) contract was the stringent, detailed, and specific requirements on service life of the bridge placed by the Authority. The design team developed and the Authority approved an extensive Corrosion Protection Plan (CPP) that provides detailed performance-based service life requirements for various components of the bridge and identifies future measures necessary to maintain the structure. Following the CPP, a memorandum titled, "*Travis Spur Rail Bridge Service Life Design Basis*," was prepared to address the rail bridge's specific requirements.

Performance requirements call for service life of 100 years overall, 75 years for superstructure elements and the deck, 50 years for bearings, 25 years for expansion joints and 150 years for piers and foundations. Since the foundations are anticipated to lie in aggressive soils, a minimum casing thickness above elevation -7.0 was obtained by dividing the 150-year service life by a 90% confidence level of effective loss per year. Casings above elevation -7.0 are used for serviceability/crack control only in the design, with sufficient spiral or hoop provided to resist seismic loads. Casing in regions below elevation -7.0 are used for confinement/shear design after deducting ¼" as a sacrificial layer.

All reinforcement is ASTM A615 Grade 60, epoxy-coated per ASTM A775. Concrete mix design includes a minimum of 2.5 gal/cy of calcium nitrite inhibitor (CNI) to enhance the corrosion threshold. Top surfaces of cap beams are covered with a coating-type epoxy-urethane protective sealer. Exposed vertical faces of the cap beams and backwall/wingwalls were coated with breathable penetrating silane sealer. Per Conrail's specifications, the deck plate surfaces that receive the ballast were coated with Stirling Lloyd's "Eliminator," a cold-applied elastomeric waterproofing material made by the well-known manufacturer of high-performance coatings for the protection of infrastructure and buildings. The structural steel is shop painted with one coat of Carbozinc 11HS self-curing, inorganic zinc primer and one finish coat of Carbothane 133LV by Carboline Company.

CONCLUSIONS

This project illustrates the effective use of ABC techniques for the installation of bridge structures. Using precast concrete with grouted splice sleeves, the erection of the pier and abutment cap beams was completed rapidly and seamlessly. The use of SPMTs allowed rapid superstructure erection with ballast pre-installed. Significant cost savings were achieved since it avoided the costly mobilization/demobilization and MOT costs if the construction was to be completed in two consecutive weekends. Most importantly, the selected method of construction satisfied the extremely aggressive schedule and tight weekend shutdown window and minimized the impact to the public on the heavily traveled I-278. When projects are located in very congested areas like New York City, or over critical interstate expressways where ABC techniques are appropriate, the use of ABC should be encouraged to be utilized more often with the best ABC technique being good planning, and an integrated design and construction team.

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LIST OF FIGURES