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Rehabilitation of Historic Components at the Bridge of Lions

Steven Shaup, PE
TranSystems
Fort Lauderdale, Florida

CARIBE ROYALE RESORT
ORLANDO, FLORIDA

Introduction

An $80 million bridge rehabilitation was recently completed for the National Register-listed Bridge of Lions in St. Augustine, Florida, a rolling lift bascule bridge, that included restoring the bridge to its original glory, including replication of original features that had been replaced during the bridge's more than 80 years of service. What makes the bridge historic was identified in order to assess the critical components of the bridge that dictated what elements of the bridge could be replaced and which needed to be rehabilitated in order for the bridge to retain its National Register status. How the work was affected by the elements that made the bridge historic and how design challenges were addressed and resolved to meet the historic characteristics are discussed. Design details and as-built works are compared to evaluate changes that occurred during construction to address the challenges of using modern materials to restore or replicate the original components.

General Bridge Information

The Bridge of Lions is located in the heart of the historic district of St. Augustine, Florida, which lays claim to the title "Oldest City in America." The Bridge of Lions was built in 1927 to replace an older swing span crossing of the Matanzas River (Atlantic Intracoastal Waterway). See Figure 1. The 1,545-feet long, 24-span bridge is composed of a double-leaf rolling lift bascule span with a clear span of 83-feet between piers and 23 built-up, steel, girder-floorbeam approach spans (14 west of the bascule span (St. Augustine side) and 9 east of the bascule span (Anastasia Island side). The overall width of the bridge is 36-feet and has a 22-feet wide roadway that accommodates two lanes with 1-foot shoulders at each side. There are 5-feet wide sidewalks supported by brackets cantilevered from the haunched approach girders. The bridge is detailed to be visually pleasing and compatible with the character of St. Augustine's historic area. In 1982, the bridge was listed in the National Park Service's National Register of Historic Places, the country's official list of those places judged worthy of preservation.

Figure 0 - Partial Elevation (ca. 2000)

What Makes the Bridge Historic

The bridge was listed on the National Register of Historic Places in 1982. National Register Criteria for Evaluation are defined as "the quality of significance in American history, architecture, archeology, engineering and culture is present in districts, sites, buildings, structures and objects that possess integrity of location, design, setting, materials, workmanship, feeling and association and four criteria:

A. That are associated with events that have made a significant contribution to the broad patterns of our history; or
B. That are associated with the lives of persons significant in our past; or

C. That embody the distinctive characteristics of a type, period or method of construction that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or
D. That have or may be likely to yield information important to prehistory or history.

The Bridge of Lions is eligible under criteria A and C. The bridge was listed for its significance in the development of the barrier island, as well as its appearance and how it is an extension of the architecture present in the City of St. Augustine. The bridge is a civic amenity as much as a utilitarian facility spanning between the City of St. Augustine and Anastasia Island. The bridge is named for the two marble lion statues that were donated by a prominent businessman in the 1920s. See Figure 2.

Figure 0 - Marble lion statue at west end of bridge.

The bridge is well-proportioned, with Spanish Colonial-inspired octagonal towers. The bridge, from the substructure to the shape of the superstructure and approach work, is consistently detailed in the classical taste to be visually pleasing and compatible with the character of the city's historic area. See Figure 3. The approach span substructures consist of two reinforced concrete columns with a wall between them. The tops of the walls are flat, but the bottoms repeat the arched shape of the superstructure. The columns at each pier are detailed with a stylized base, shaft and capital to resemble a classical column. The bases are at a constant elevation across the bridge, just above mean water elevation, but the shafts increase in height as the approach spans extend towards the bascule piers.

Figure 0 - Bridge architecture compatible with that of historic St. Augustine.

The architectonic reinforced concrete bascule piers are the dominant feature of the bridge. The octagonal-ended bascule piers are well proportioned with the rest of the bridge and are classically detailed. Each octagonal-ended face is set with a bracketed overhang and a slender octagonal-shaped tower. Elephantine square pilasters define the girder bearing areas on both faces of the piers.

The two story towers are finished with Spanish terra cotta tile roofs and elongated, circular-headed openings on the second level. The main level is finished with channels and trabeated fenestration, which in all but the operator's tower at the northwest quadrant originally were open to the elements. The sidewalk continues around each tower to facilitate observation.

Some changes have been made to the towers since construction. The northwest tower was converted to house electrical equipment. The operator stayed in the northeast tower between openings, moving to the northwest tower during span operation. Several openings at the other towers were boarded up.

The historic architectural elements of the bridge included the concrete approach piers, the haunched steel girders, the bridge railing, the movable span traffic gates, the roadway lighting, the bascule piers and their towers.

The design of the bridge is not technologically significant. The rolling lift bridge type had been used successfully many times prior to completion of this bridge.

Need for Action

Figure 0 - Crutch bents to relieve loads at approach piers.

In 1971, the ornate railings and luminaires were removed and replaced with modern tubular railings and lighting units. In the early 1980s, the FDOT found problems with subaqueous components at several piers and performed some underwater repairs. The bridge was NR-listed in 1982. By the mid-1990s, the bridge had been load posted to 15 tons. In 1997, the National Trust for Historic Preservation named the Bridge of Lions one of the "11 Most Endangered Historic Places." In 1999, crutch bents were installed to relieve loads at several deteriorated piers. See Figure 4.

The 83 year old bridge suffered from widespread deterioration to its components. The structural steel for the approach span girders and the bascule span had widespread areas of section loss. Where members consisted of built-up plates and angles, pack rust was found between the plies, causing deformation due to expansion of the rust byproducts. As would be expected, the worst conditions were found in the vicinity of deck joints. Cracks and spalls were widespread on all concrete components. See Figures 5 and 6. In addition, the concrete in the substructure units was found to have chloride levels above the threshold for chloride ions facilitating corrosion in concrete. Figure 7 includes a sampling of chloride content at selected depths taken at the bascule piers.

Figure 0 - Typical deterioration inside bascule pier towers.

A scour analysis was performed for the existing bridge. Analysis results indicated the 100-year scour depth was such that the bridge foundations would be completely scoured and cause the bridge to collapse.

The analysis of the entire bridge revealed that the most seriously deteriorated and prone-to-fail components of the bridge were the approach span piers, the non-redundant girder floorbeam systems of the approach spans, and the non-redundant superstructure and operating machinery of the movable span. The bascule piers and towers could be conserved and reused. Although the girders for the approach spans were no longer adequate to carry modern traffic loads, they could be conserved and reused in a limited capacity for the new structure.

Figure 0 - Large spalls at bascule piers.

Design Requirements

The project goals of improving the load-carrying capacity and the functionality of the bridge while respecting the structure's historic and cultural value were challenging. The rehabilitation of the bridge was required to meet current AASHTO and Florida DOT guidelines for structures design and the Secretary of the Interior's Standards for Rehabilitation. The Florida DOT design guidelines required that bridges have barriers with approved crash level TL-4 designs, 42-inch high pedestrian railings, as well as solid roadway surfaces throughout.

The Secretary of the Interior's Standards for Rehabilitation provide a set of rules that should be followed when performing work on a historic property. Adherence to these standards results in conformance from the State Historic Preservation Officer (SHPO). Work performed needs to follow these rules in order to meet the litmus test that will determine whether the work has an adverse effect on the property. These rules can be characterized as follows (underlines added by author for emphasis):

Chloride-Ion Analysis Results				
Sample Designation		Chloride Ion Content		Threshold for Chloride Ions Facilitating Corrosion
Sample	Depth (inch)	% by weight of Concrete	Lbs. per yd^3 of Concrete	
1 (West B. Pier)	2	0.0923	3.61	1.02
	4	0.0607	2.37	1.02
2 (East B. Pier)	2	0.1234	4.83	1.02
	4	0.1437	5.63	1.02
3 (West B. Pier)	2	0.1014	3.97	1.02
	4	0.0813	3.18	1.02
	6	0.0418	1.64	1.02
4 (East B. Pier)	2	0.2523	9.88	1.02
	4	0.2049	8.02	1.02

Figure 0 - Chloride-ion analysis results at bascule piers.

1. A property will be used as it was historically or be given new use that requires <u>minimal</u> change to its distinctive materials, features, spaces and spatial relationships
2. The historic <u>character</u> of a property will be <u>retained and preserved</u>. The removal of distinctive materials or alteration of features, spaces and spatial relationships that characterize a property will be avoided.

3. Each property will be recognized as a physical record of its time, place, and use. Changes that create a false sense of historical development, sucha s adding conjectural features or elements from other historic properties, will not be undertaken.
4. Changes to a property that have acquired historic significance in their own right will be retained and preserved.
5. Distinctive materials, features, finishes and construction techniques or examples of craftsmanship that characterize a property will be preserved.
6. Deteriorated historic features will be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature will match the old in design, color, texture and, where possible, materials. Replacement of missing features will be substantiated by documentary and physical evidence.
7. ...Treatments that cause damage to historic materials will not be used.
8. Archeological resources will be protected and preserved in place...
9. New additions, exterior alterations, or related new construction will not destroy historic materials, features and spatial relationships that characterize the property. The new work shall be differentiated from the old and will be compatible with the historic materials, features, size, scale and proportion, and massing to protect the integrity of the property and its environment.
10. New additions and adjacent or related new construction will be undertaken in such a manner that, if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

The goal of a historic rehabilitation is to preserve as much as possible and replicate components only when preservation is not possible.

Restore Bridge to Original 1927 Appearance

In the years since the bridge was constructed, several of the features on the bridge had been replaced. The ornate pedestrian railing had been replaced with a much more contemporary aluminum two rail with vertical pickets-style railing. The paired fixtures mounted to concrete poles that constituted the roadway lighting were replaced with aluminum supports for single light fixtures of a much more contemporary style. The rotating gates of similar styling to the original railing had long since been replaced with modern traffic signals and traffic gate machinery that meets today's requirements.

In order to meet the requirements of modern design and retain enough of the bridge to result in a finding of No Adverse Effect by the SHPO, which would keep the structure on the National Register, the decision was made to increase the width of the bridge on the approach spans to accommodate geometric design requirements as much as possible. The bridge was widened to accommodate 5-foot sidewalks and the addition of a low profile traffic barrier between the sidewalks and roadway. This would allow the ornate pedestrian railings to be restored without the TL-4 load requirements.

See Figures 8 and 9 for images of the appearance of the original bridge and the bridge prior to rehabilitation.

Figure 0 - Section at bascule pier looking west (ca. 1927).

Figure 0 - Section looking east (ca. 2000).

Approach Spans

The existing haunched girders that comprised the approach spans needed to be reused in order to retain the No Adverse Effect determination. See Figure 10. The plan for the superstructure on the approach spans was to reuse the existing girders in a capacity that required them to maintain some structural function. For any historic rehabilitation, it is important for historic components to continue to serve, at least partially, a structural function. These girders were placed in line with the decorative ends to the piers as they had been on the original substructure to maintain the bridge's appearance. During construction, the girders were removed from the bridge and sent to a shop for wholesale repairs to areas of section loss. Where areas of section loss were found, the areas were cut out and replaced with new material welded into place. The repaired girders were metalized and painted to extend their life as long as possible. The primary load carrying members of the approach spans consist of a brand new system of girders and floorbeams that are completely hidden within the profiles of the reused steel girders. The floorbeams frame into the reused steel girders at the piers, where additional steel plate and angles have been installed to allow for proper load transfer.

Figure 0 - Original haunched girder-floorbeam approach spans.

Because the girders were to be removed as part of the reconstruction of the approach spans, it was decided to increase the roadway width from 22-feet to 25-feet and install a plain, low profile traffic barrier between the roadway and the sidewalks. A TL-4 approved corral-type rail was used. The approach span sidewalks were kept at 5-feet wide, with the exception of the bascule span, which was reduced to 3-feet in order to accommodate the additional roadway width. Installation of the traffic barrier improved motorist and pedestrian safety and allowed the original ornate pedestrian railings to be replicated. The pedestrian railings were replicated from the original design plans, but with the railings designed with structural steel instead of cast iron and the height modified to meet current railing height requirements. See Figure 11.

Figure 0 - New bridge cross section. Note corral railing at curbline that separates roadway from sidewalks.

The original steel girders consisted primarily of continuous steel girders with half spans at each end, which in the original configuration placed the joints at every other midspan. With the new support structure consisting of multiple girders and floorbeams at each pier location, the haunched girders were modified in order to locate the joints at more conventional locations above piers. The rehabilitated approach spans now provide two and three span continuous units. See Figure 12.

Because of the deterioration to the approach span piers, extent of chloride intrusion in the concrete and the inability of the piers to withstand a 100 year scour event, it was determined that they be completely replaced. The new approach piers were detailed to mimic the appearance of the existing piers, but with a slightly increased width to accommodate the widened roadway. The existing pairs of caissons at each pier were replaced with two 90-inch diameter drilled shafts. In order to maintain the appearance of the existing bridge, the new shafts were located outside the existing shafts so that the views of the bridge from each shoreline would be essentially the same as before.

In order to accommodate the reconstruction that was required, a temporary bridge was installed to the north of the existing bridge for the duration of the project. See Figure 13.

Figure 0 - New approach span framing. Note existing haunched girders re-used, modified to provide bearing support for the floorbeams over each pier.

Figure 0 - Temporary bridge carrying traffic during rehabilitation.

Bascule Span

In order to maintain the finding of No Adverse Effect and keep enough of the bridge to maintain its National Register listing, the bascule piers needed to be retained. The bascule span was not technologically significant and could be replaced, which was good given the FDOT design requirements of a solid riding surface, which could not have been done cost effectively on the existing bascule leaves given the strengthening that would have been required for the span to carry modern design loads and accommodate all the added dead load that would be added for the modern design.

Figure 0 - New bascule span during construction. Note built up construction to left side of splice and built up welded construction to right and welded built up plate girder floorbeams.

Because of the significance of the appearance of the bridge, the new bascule span used built up bolted construction using dome head direct tension indicator (DTI) bolts that would mimic rivet heads, oriented so that the round heads were on the exterior faces of the bascule girders and on the undersides of the flanges as much as possible. The built up section was only required for the portion of the span visible when the bridge was down, so the heel portions of the bascule girders were of welded plate girder construction. See Figure 14.

Figure 0 - New bascule span traffic barrier.

The bascule span haunched shape was replicated from the original 1927 design plans. Sidewalk brackets were designed as built up sections using the dome head DTI bolts to connect the parts. Because the parts of the bridge interior of the bascule girders did not require any specific appearance, the floorbeams were designed as welded plate girders, which supported an exodermic deck spanning longitudinally between the floorbeams. The floorbeams and brackets were spaced to match the dimensions from the original design plans in order to minimize the change in appearance.

The traffic railing was maintained across the bascule span using steel and mimicking the design of the Illinois side-mounted rail, which had the same height as the corral rail. See Figure 15. The pedestrian railing was of the same design as the approaches.

Bascule Piers and Towers

The bascule piers needed repairs to retain strength and integrity. Analysis showed that the bridge would not meet current vessel impact standards or withstand the 100-year channel scour event. The bascule piers were strengthened by the addition of a new reinforced concrete footing at the waterline that is supported by five new reinforced concrete drilled shafts that extend deep enough to support the piers in case of an extreme scour event. The new footing is located just below the existing bascule pier footing and undergirds the existing footing, so that should the existing caissons fail due to deterioration or lose supporting soil, the new footing will continue to support the piers. See Figure 16.

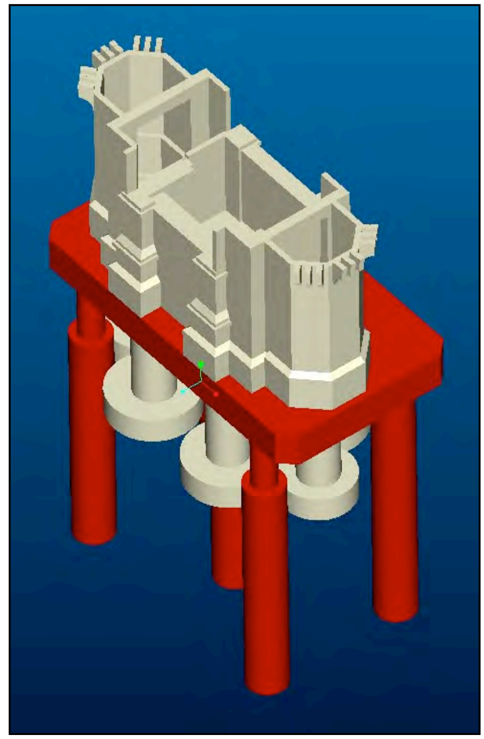

Figure 0 - Schematic of supplemental footing below existing bascule pier. New elements shown in red.

The reinforcing steel in each bascule pier wall was located only 1 ½-inch below the surface. The chloride intrusion was enough to begin the corrosion process. To address this, the existing concrete at surfaces exposed to water was removed to a depth of 6-inches, which removed the chloride infused concrete. On the exterior faces of the piers, new concrete was added to provide 3-inches of cover over the existing reinforcing steel and an impressed current cathodic protection system was installed over it to provide additional protection. This type of cathodic protection uses a titanium mesh cast inside a 1 ½-inch thick layer of latex modified epoxy mortar that is wired into the electrical system. The system prevents charged ions in the chlorides from reaching the reinforcing steel and starting the corrosion process. See Figure 17.

Figure 0 - Completed overlay containing impressed current cathodic protection system. Because of the size of the bascule piers, the addition of the overlay and build out of concrete cover did not affect overall appearance of pier.

Cracks and spalls were repaired using epoxy injection and latex-modified mortar repair materials. Original detailing was documented prior to demolition for replication.

The towers had numerous cracks and spalls. These deficiencies were repaired using methods similar to the bascule piers. The goal for repairs was to conserve and retain as much of the sound original material as possible.

After repairs were completed, all concrete above the waterline for the bascule piers and towers were coated to achieve a uniform appearance. The coating was required to match the coloring of a test area on one of the bascule piers, which the contractor sampled and the engineer had to approve. See Figure 18.

The original roofs at the towers were deteriorated and required replacement according to the original plans, including the use of the original? terra cotta Spanish tiles. New doors and windows to match those from the operator's house were installed in existing openings.

Figure 0 - Completed bascule pier tower. A coating that was color matched to the original bascule pier concrete was applied to all concrete surfaces above waterline for uniform appearance.

Mechanical and Electrical Systems

The mechanical and electrical systems at the bridge were not technologically significant and could be replaced with modern components. One of the challenges at this location was replacing the bascule span with similar girder depths yet provide enough space for the machinery. As a result, the machinery could not be located on the moving leaves. The solution was to construct a machinery platform at the back side of both bascule piers where all of the machinery would be located and struts used to pull the span open. The platforms were located high up on the back walls of the piers, where visibility of the platforms and machinery would be minimal and provide little impact to the bridge's appearance. See Figures 19, 20 and 21.

Figure 0 - Installation of operating machinery during construction.

Figure 0 - Construction of new machinery platform at rear of bascule pier.

Restoration of Historic Details

Every Historic Project has Very Involved Stakeholders

The process of getting to rehabilitation of the bridge was a very long one indeed, having begun in the mid-1970s. Growing concerns about the bridge's condition started new studies in the 1990s, and after a decade-long environmental review process, the Final Environmental Impact Statement (EIS) was issued in 2003. The public was given many opportunities for input, and there were strong sentiments from varies parties to rehabilitate the bridge, as well as replace it. The final EIS identified rehabilitation/preservation as the preferred alternate.

Figure 0 - View of strut attachment to rolling leaf.

The City of St. Augustine has a well organized historical society that proved invaluable in the preparation of contract documents and design details.

Railings

Railings that were sufficient for pedestrians and bicyclists were required by the FDOT. As such, the original 44-inch high rails were replicated but at 54-inches high to meet this requirement. The original design plans were used to detail the railing, with some modifications required where original shapes were no longer available or modern steel shapes could be used with no impact to the railing's appearance. For example, the original horizontal rails used tubes and bars bent into a C-shape. The sizes that were shown in the original plans were not used anymore, but current sizes of pipe and a small standard channel shape were available that had no impact on the appearance of the railing. To accommodate the taller railing that was required, it was possible to stretch the railing, but the modification did not significantly alter the railing's appearance from the original. See Figure 22.

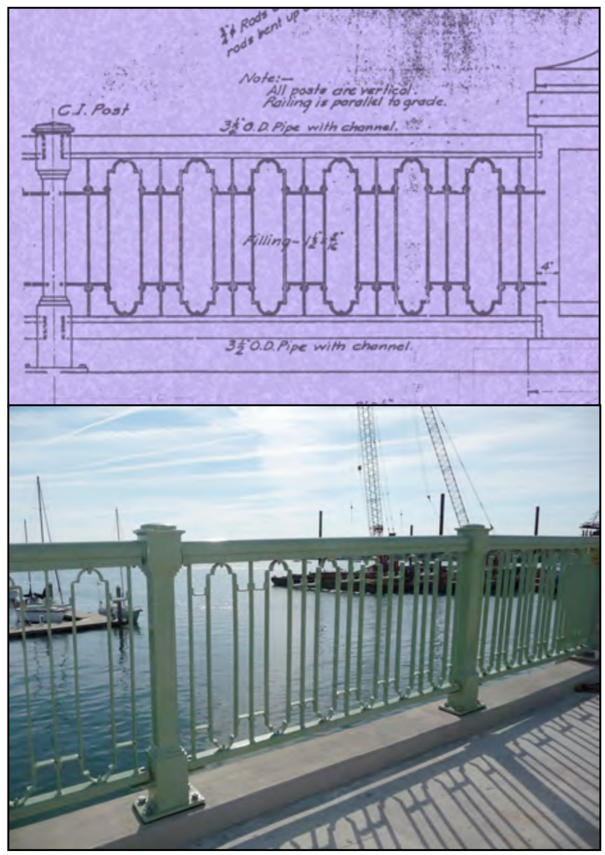

Figure 0 - Railing design from original plans at top; new railing with adjusted height at bottom. Note that height change has little impact on railing appearance.

Roadway Lighting

The roadway lighting had long been removed from the bridge. Fortunately, the original specifications for the luminaires had been preserved and kept at the Historical Society and it was possible to replicate the luminaires. The concrete pole used to support the pairs of luminaires in the original design was replicated by making use of precast concrete poles that were positioned vertically on the concrete pedestals using precast leveling nuts. See Figure 23.

Figure 0 - Original design drawings detail for roadway lighting at left; replicated lighting at right.

Traffic Gates

The bridge traffic control devices were far less than what is required today. The traffic was controlled by a pair of wrought iron gates that swung from mounts at the curbline. Modern traffic control devices were installed on the bridge for safety reasons, but as part of the restoration of the bridge, these ornate gates were replicated using original design drawings supplemented by original design photos. As was done with the pedestrian railings, the round tube and C-shape horizontals were replicated using stock sized steel pipe and standard steel channels. The original traffic gates were located at the curb level, but the placement of the traffic barrier at the curbline required the gate to be located at the top of the traffic barrier. This change was found to be acceptable because safety considerations outweighed the benefits of having the railing any lower. See Figure 24.

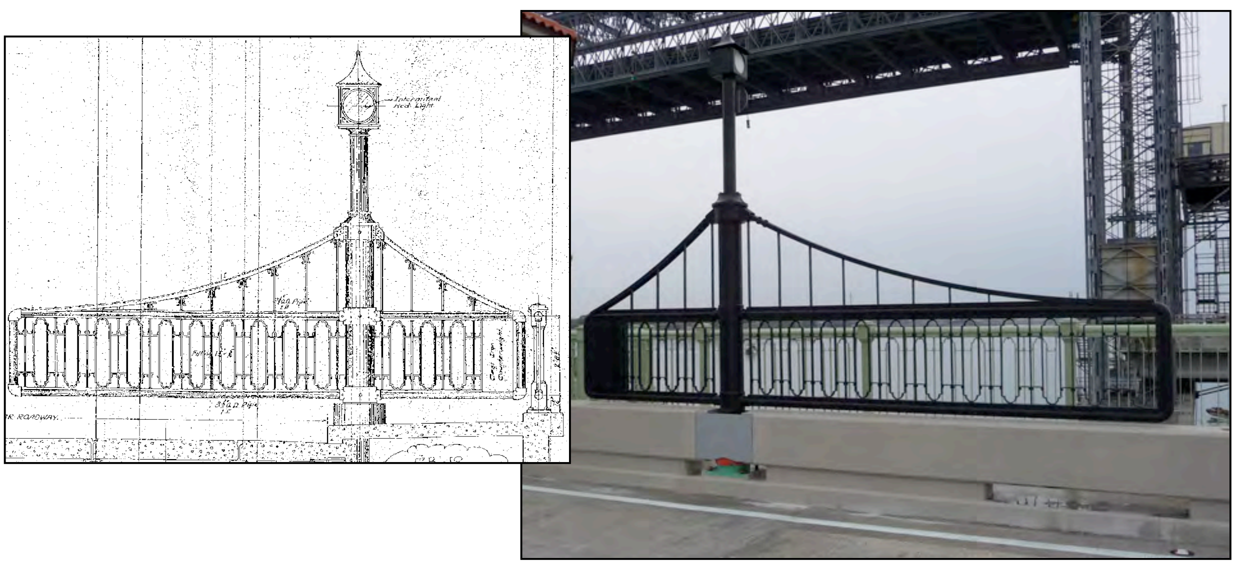

Figure 0 - Original gate details at left; replicated gate at right.

The light fixtures atop each post were found to differ between the original design drawings and the photos. The 1927 design drawings were originally used to replicate the fixture, but the design was modified once the photos were examined and the differences made known. The size of the post and the fixture were determined by scaling various dimensions from available photographs. See Figure 25.

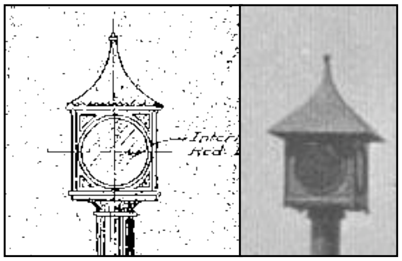

Figure 0 - Original design traffic gate head lamp detail at left; constructed lamp at right.

Bascule Towers

In order to restore the towers as much as possible and provide enclosed spaces that would be more maintenance-friendly, all openings had windows installed. Where the openings previously had windows installed, the windows were detailed to match the multi-pane appearance using single pane windows with adhesive strips to replicate the multipane appearance and meet current requirements for windows meeting Florida's windstorm criteria.

Where the openings were previously open to the elements, single clear windows were installed to differentiate historically open locations from those that had multi-pane windows. This is an appropriate practice for historic structures where it is undesirable to create a "fake" history by showing things that were not part of the original structure. See Figure 26.

The original bridge used the northwest tower to house the operator's control console. Because of the power feed from the east side of the bridge and the skew of the channel, the new design changed the control tower to the southeast tower. Because of the lack of space for electrical equipment, components were located in the northeast and northwest towers.

Figure 0 - Restored bascule pier towers. Clockwise from top left: NE tower, SE tower (tender house), SW tower, NW tower.

In order to provide access to the upper levels of the towers for maintenance, concrete floors and vertical ladders were installed. Modifications inside the towers did not impact the appearance of the towers.

Paint Color

There was some question as to the color of the original paint on the bridge. Over the years, the bridge had been painted numerous times, and at the time of design the steel had been painted a light tan color. Review of records at the historical society and careful removal of the layers of paint on existing steel indicated that the original bridge was painted a light grayish green color. This was confirmed by a local resident who was present at the grand opening of the original bridge and had part of the old railing in their possession. The resident confirmed that the color was accurate. See Figure 27.

Figure 0 - Views of the completed bridge with the steel painted original green.

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