HEAVY MOVABLE STRUCTURES, INC.

NINTH BIENNIAL SYMPOSIUM

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OCTOBER 22 - 25, 2002

ROYAL PARK BRIDGE REPLACEMENT
- EMERGENCY SIGNATURE BASCULE BRIDGE -

By James M. Phillips III, P.E.
Vice President, E.C. Driver and Associates, Inc.

OWNERSHIP/PUBLIC USE and MANAGEMENT

Introduction

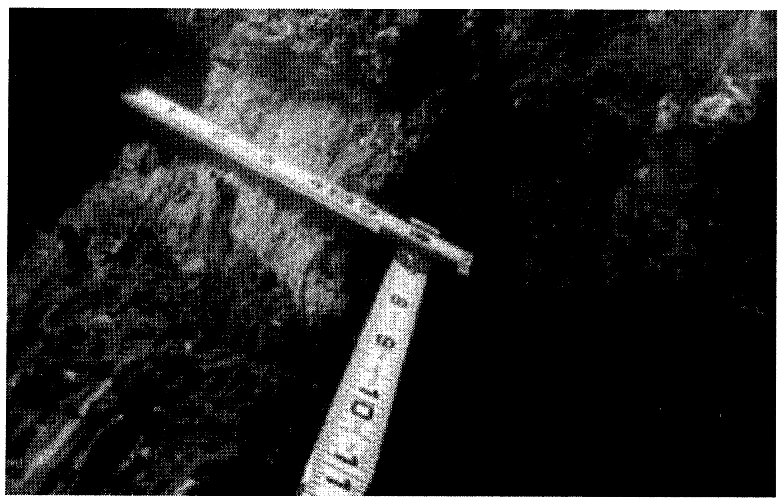
The old Royal Park Bridge was constructed in 1929 to provide access from the mainland of Florida to the barrier Islands in Palm Beach County. The bridge was widened from two to four lanes in 1959 and since that time has served as a major urban arterial link carrying State Road 704 over the Atlantic Intracoastal Waterway (locally known as the Lake Worth Lagoon) between the City of West Palm Beach and the Town of Palm Beach. As a designated emergency vehicle and hurricane evacuation route, the facility is a vital element of the Palm Beach County transportation system. The Florida Department of Transportation (FDOT) owns and operates the bridge.

The 1929 structure featured a swing span for the main span and cast-in-place concrete, earth-filled arch approach spans. Both the bascule pier and approach pier foundations feature massive concrete footings constructed on timber piles. Cofferdams and tremmie seals were used to construct the foundations. In 1959 the parallel widening was accomplished by duplicating the replacing the swing span and pivot pier with a four-leaf Scherzer type rolling bascule span and widening the approach spans. Rather than construct a true arch for the widening, cast-in-place concrete Tee Beams with a concrete deck were used. The widened portion was supported on prestressed concrete piles and waterline bent caps. To mimic the look of the older bridge, the exterior girder of the widening was deepened to match the shape of the arch spandrelwall. Based upon the age and type of construction of the existing bridge, and in particular, the arches of the older approaches, the bridge was potentially eligible for listing on the National Register of Historic Places.

In the mid-1980's FDOT bridge inspections reported pour concrete conditions and discovered significant scour at many of the piers. Concrete repairs and scour countermeasures, including riprap and tremmie concrete, were employed as corrective measures. However, scour continued to develop and the bridges overall condition also continued to deteriorate. As a result FDOT initiated a Project Development and Environment (PD&E) Study to determine a course of action to assure the functionality of the facility.

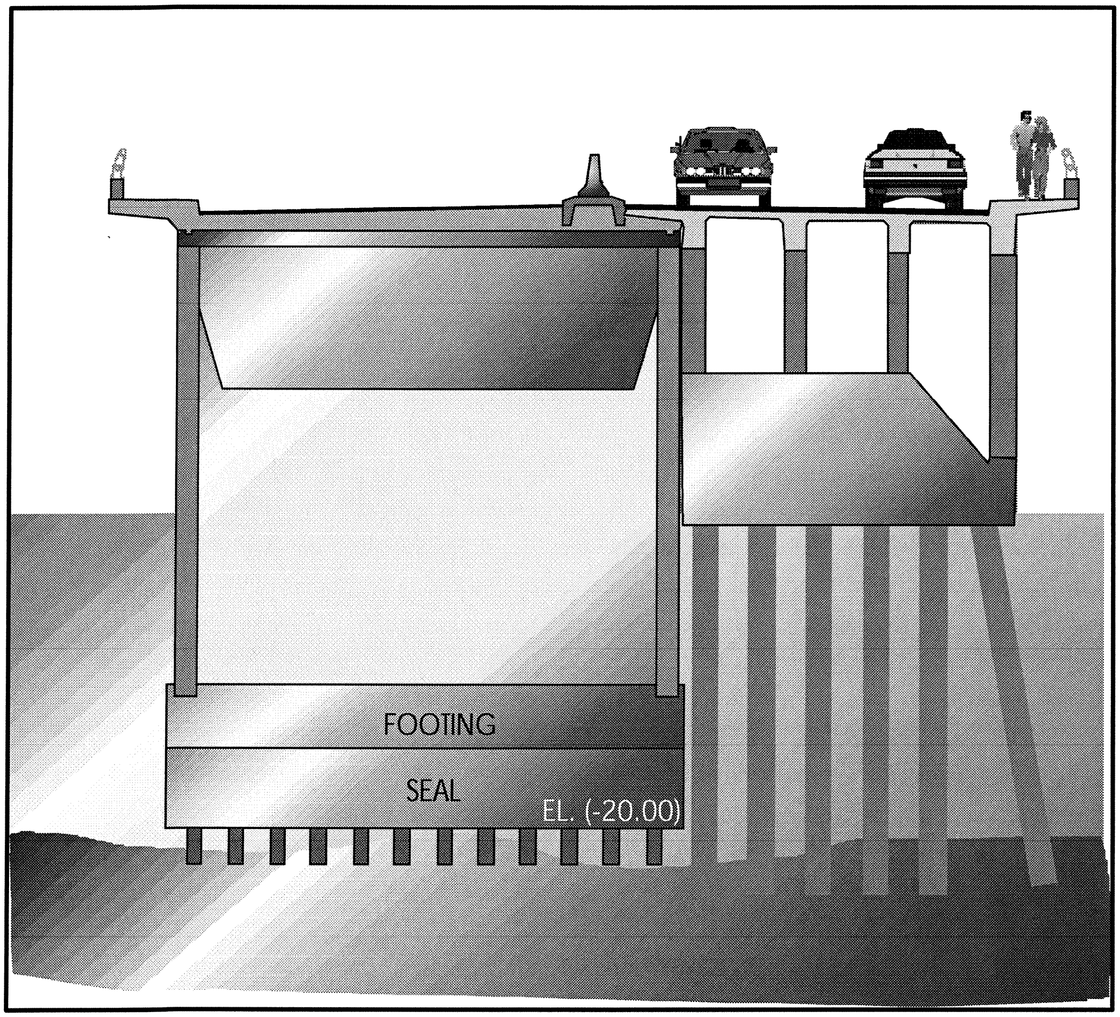
E.C. Driver and Associates, Inc., was selected as the lead consultant for the project. The consultant team was comprised with several specialty subconsultants, including Kimely-Horn and Associates, Inc., for environmental studies, roadway and landscape design, H2L2 Architects for architectural design, and PSI, Inc., for geotechnical engineering. Notice to proceed was issued in June of 1998 for the PD&E Study with the following planned project schedule:

Phase	Duration	Start Date	Completion Date
PD&E	29 months	May 1998	Aug. 2000
Final Design	24 months	Aug. 2000	Sept. 2002
Ad Bid & Award	10 months	Sept. 2002	July 2003
Construction	42 months	July 2003	Dec. 2006



Just as the PD&E study was getting under way underwater inspections revealed that scour under the piers of the old bridge had progressed to a critical point. The inspection found exposed timber piles with severe marine borer section loss. Many of the piles were measured to have up to 70 percent section loss. Still other piles that were shown in the existing plans were not found at all. In response, FDOT implemented a load test of the bridge in August of 1998. The load test results and concurrent structural analysis indicated that the old bridge did not have adequate capacity to carry traffic.

Further analysis of both bridges revealed two key facts. First, concurrent with the economic studies conducted within the PD&E bridge analysis, it was determined that repair or rehabilitation of the existing bridge was not feasible. Second, review of the design of the 1959 bridge revealed that the substructure of the widening was dependent upon the massive foundations of the 1929 structure for lateral support. Not only did the widened structure need the old foundations for lateral support, the piles of the 1959 substructure would be overloaded if the massive foundations of the 1929 structure were to shift laterally. As a result of these analyses and subsequent confirmation from the FDOT's Structures Design Office, the old bridge was closed to traffic on September 15, 1998.



With an emergency declared, the PD&E team was asked to evaluate the entire program and make recommendations to expedite restoring four lanes of traffic on a reliable structure. This effort involved examining several alternative concepts and combinations of concepts. It also involved shifting the focus of the consultant team from PD&E alone to PD&E and Final Design. The following are some of the key issues that were studied in detail.

Fast Tracking PD&E & Final Design: During the peak season that occurs in the winter month's, traffic on SR 704 is heavy and four lanes are needed. This is especially true when considering emergency vehicle needs. FDOT and local municipalities considered it critical to restore four-lane capacity as quickly as possible. Therefore fast tracking of the final design with the PD&E phase was requested. This presented several challenges, most notably the need to obtain Location Design Acceptance from Federal Highway and approval from the State Historic Preservation Officer (SHPO) all while advancing the design.

Design/Build Temporary Bridge: It was believed that the quickest way to implement construction would be by way of an emergency design/build project. However, the scope of that contract needed to be carefully thought out and evaluated. Would a two lane temporary bridge be adequate or would a four-lane structure be best? How could the temporary bridge be constructed within existing Right-of-Way without conflicting with construction of a permanent bridge that was yet to be designed?

Removal of Earth Fill: Removal of the earth fill from the arches of the 1929 structure to reduce the dead load on the deteriorated timber piles was given a top priority. Until this was accomplished there remained a risk that the piles could fail causing the old foundations to settle or worse yet, to shift laterally. Monitoring of the existing bridge for signs of movement was evaluated.

Phased Demolition: Concepts for demolishing all or only part (fill removal) of the existing bridge were evaluated. In addition, a separate demolition contract was evaluated as a means of fast-tracking construction.

Phased Construction / Traffic Control: A key element of the planning phase, this study involved evaluation of phased construction. Without phased construction the new bridge would be constructed in one stage thereby requiring either a detour or a four lane temporary bridge. Phased construction would involve replacement of one half of the bridge at a time. Phased construction would involve either a two lane temporary bridge or a detour for some period of the construction.

For each of the combinations of the above concepts, a project schedule and cost estimate was prepared. Each of these alternatives was evaluated and presented to FDOT for review and comment. Following reviews the following plan was implemented:

1. Implement an emergency design/build contract for construction of a four lane temporary detour bridge with a bascule main span. Establish a minimum offset from the existing bridge that provides adequate room for future construction of a permanent replacement bridge on the same alignment as the existing bridge. Allow for use of the existing bascule leaves and machinery as part of the temporary bridge.
2. Include in the emergency design/build temporary bridge contract the work of removing the concrete deck and earthen fill from the 1929 arch approach spans. The purpose of this activity is to reduce the risk of failure of the existing piling by reducing the dead load of the structure.

3. Implement a separate demolition contract concurrent with preparation of final design of the replacement bridge. This action is to save time in construction by allowing the demolition to take place prior to award of the permanent bridge, thereby allowing permanent bridge construction to proceed without delay following award.
4. Include drilled shaft core borings and a drilled shaft load test program in the demolition contract. Drilled shaft core borings are normally done early in construction and used to establish final shaft tip elevations. This action is to allow final drilled shaft tip elevations to be established in advance of award of the construction contract for the permanent bridge.
5. By constructing a four lane temporary bridge, construct the permanent bridge in one stage. This eliminates the dual phases of construction and associated costs due to additional mobilization and longer construction duration. The studies demonstrated that the additional cost of the four lane temporary bridge over the two lane temporary bridge were offset by savings resulting from a single phase of construction.
6. Fast track the PD&E and Final Design activities. Preliminary design activities were advanced to occur concurrently with PD&E so that permit applications could be submitted directly upon receipt of Location Design Acceptance. Final design was scheduled to run concurrently with the permitting process so that the permanent bridge contract could be advertised directly upon receipt of permits. Adequate time was scheduled to allow for coordination with SHPO, the United States Coast Guard, and the Federal Highway Administration.

Significant benefit was achieved with the emergency declaration and new fast-track schedule. Scheduled completion of the project was moved from 2006 to 2003 and opening of four lanes of traffic was moved to February 2002. The following summarizes the fast-tracked project schedule:

Phase	Duration	Start Date	Completion Date
Design/Build Ad	1 month	Sept. 1998	Nov. 1998
Design/Build Temp.	12	Jan. 1999	Feb. 2000
PD&E	18 months	May 1998	Nov. 1999
Demo Design	9 months	Jan. 1999	Oct. 1999
Demo Bid/Award	6 months	Oct. 1999	April 2000
Demo Construct.	12 months	April 2000	May 2001
Final Design	12 months	Aug. 1999	Sept. 2000
Ad Bid & Award	8 months	Sept. 2000	May 2001
Construction	24 months	June 2001	July 2003

Design Criteria

Design criteria for the replacement bridge was established in the course of the PD&E Study and preliminary design. General criteria included providing for a new four-lane bridge on the existing alignment and featuring a bascule span over the Intracoastal Waterway. The following specific criteria were established and used for design:

- Bridge Aesthetics: Provide a bridge that is appropriate for a "Gateway to the Palm Beaches". Provide a "Signature Bridge" that is unique to itself and yet is reminiscent of the original 1929 vintage arch bridge.

- General Design Specification: American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges, 1996 and FDOT Structures Design Guidelines.

- Movable Span Design: AASHTO Standard Specifications for Movable Highway Bridges, 1988.

- Design Units: SI (Metric) Units

- Design Speed: 60 kph

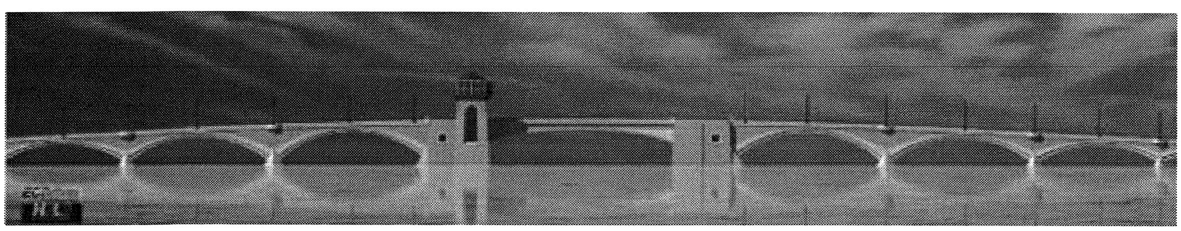
- ADT = 33,000 (2023), T = 2.9%

- Movable Span Cycle Time = 68 seconds

- Movable Span Deck System: Concrete riding surface

General Elements of the Design

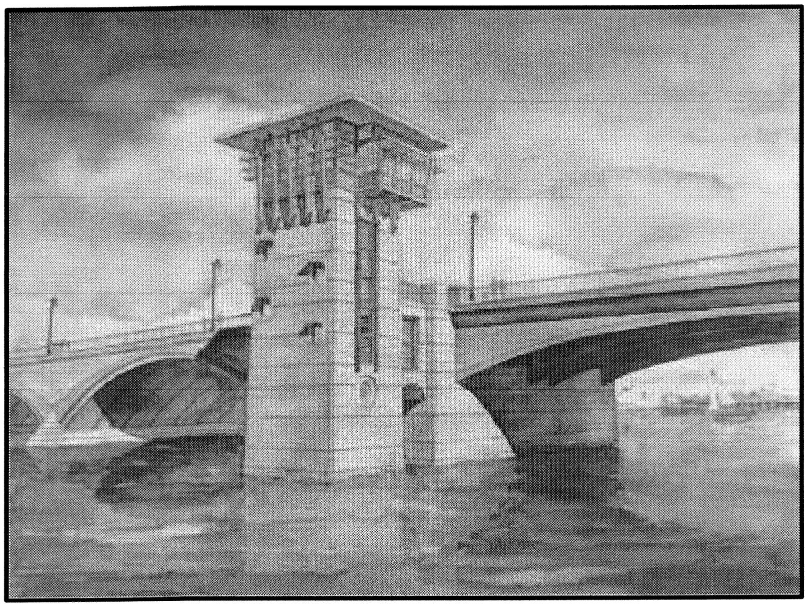
The replacement bridge provides for twin bridges each providing a typical section of two 3.6m wide travel lanes, a 2.4m outside shoulder, a 400mm inside shoulder, and a 2.45m wide sidewalk. The sidewalk is separated from the roadway by a traffic barrier and the median varies from a raised concrete median, to an opening flanked by traffic barriers, to a turn lane and raised median.



The resulting overall width of the bridge deck is 33.05m.
To span the waterway the overall length of the bridge between abutments is 332.64m. The bascule span is 56.0m between centerline of trunnions and 76.0m overall including the bascule piers. The approach spans consist of segmental concrete box girders, also with an exaggerated variable depth to emulating an arch. Three approach spans are provided on the west side of the bascule and five on the east. Approach span lengths vary from 18.74m to 39.00m.

Bascule Span Features

Many design elements of the permanent bridge were dictated or influenced by agreements reached with the State Historic Preservation Officer (SHPO). As replacement of the existing bridge constitutes an adverse impact on the resource, several requirements were imposed within the Memorandum of Agreement between FDOT and SHPO. Most significant were the requirements that the bridge look similar to the existing 1929 vintage arches and that the aesthetic details were reviewed and approved by the Town of Palm Beach Landmarks Preservation Commission.



For the bascule span the conditions established by the Landmarks Preservation Commission had two principal impacts. First, the requirement to feature the arch form was carried through the bascule span. This was incorporated into the design through the use of an exaggerated variable depth of the bascule main girders. Furthermore, the bascule span was configured with a small deck overhang, in other words, the main girders are spread out near the coping of the deck, to enhance the visibility of the arch shape formed by the variable depth main girders. Secondly, the bascule piers were detailed with precast architectural concrete walls similar to traditional stone faced piers. In addition, the bascule span features several noteworthy design elements including the following that are discussed below:

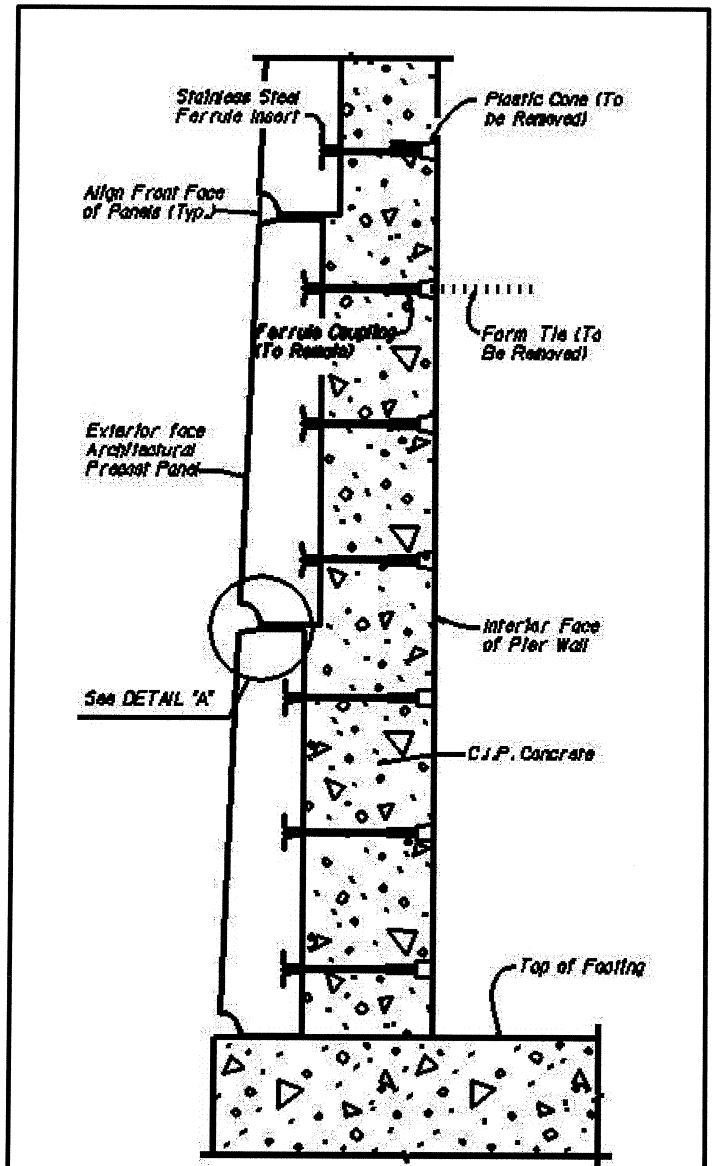
- Concrete Deck on Bascule Span
- Pipe Lateral Bracing Members
- Adjustable Rack/Girder Connection
- Enhanced Pier Maintenance Access

Variable Depth Main Girders

To emulate the arch shapes of the approach spans, the bascule main girders feature variable depth webs that follow an elliptical profile. At the center of the channel the web depth starts at 1.40m. The webs increase in thickness to just channel side of the live load shoes at which point the depth is 4.37m. From this point to the tail of the girder the bottom of the web is horizontal to facilitate connection of the rack frame assembly. When paired as they are with the bascule leaves in the closed position, the girders form an arch similar to that of the approach spans while still satisfying the vertical clearance requirements.

Precast Architectural Concrete Bascule Pier Walls

The architectural review committee expressed a strong desire for a stone finish look on the piers. A principle challenge to this was providing a finish that would be durable in the extremely aggressive salt water environment of South Florida. Concern was raised that the hardware used to attach precast elements to the pier concrete would be subject to corrosive deterioration that would lead to failure or unsightly staining. The solution to this was found in using the architectural panels as a form for the pier wall construction.

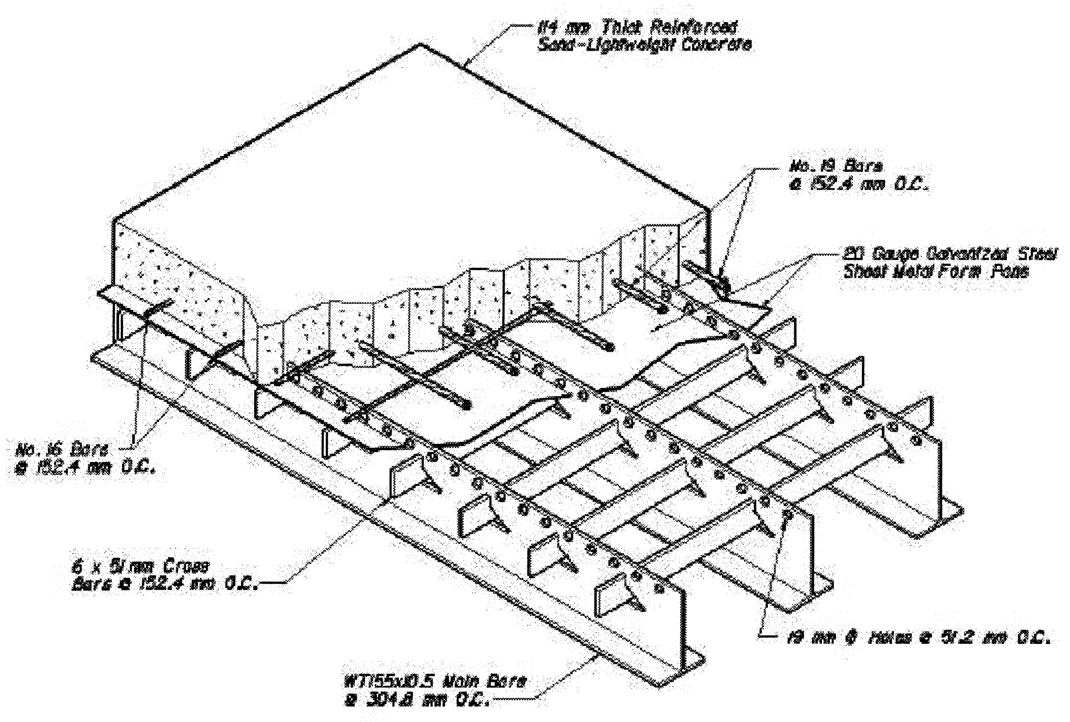


TYPICAL BASCULE PIER WALL SECTION

The design calls for the architectural concrete panels to be precast with a form liner to achieve the desired quality and tolerances. Panels were designed with 75mm of concrete cover, concrete containing calcium nitrate corrosion inhibitor, and stainless steel inserts for attachment to the pier wall. The panels are then to be set in place as the exterior form of the pier walls. The interior forms are made in the conventional manner and tied to the panels with stainless steel form ties. Pier concrete is then poured into the forms. In this manner fresh concrete is poured directly against the precast architectural panels, thereby eliminating the typical cold joint between applied panels and hardened concrete.

Concrete Deck on Bascule Span

The bascule leaves have a closed concrete deck system provided by use of the latest exodermic deck system, Exodermic 2. This system is similar to the original exodermic deck as was used on the S.E. 17th Street Causeway Bridge in Ft. Lauderdale, FL. The differences however are important. In the next generation design, the fatigue sensitive shear connector detail is eliminated in favor of a perforated Tee section main bar. Holes of 19mm diameter are punched at 51.2mm on



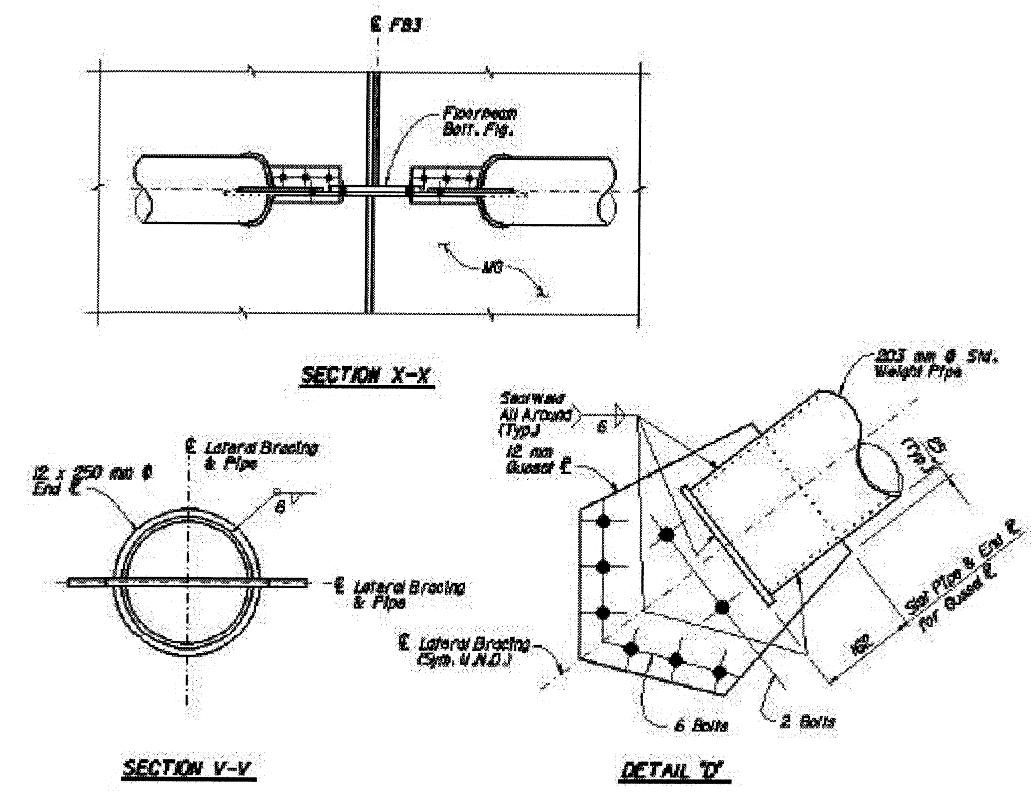
EXODERMIC DECK ISOMETRIC

center in the upward facing web of a WT 155x10.5 to provide a shear transfer mechanism between the concrete and steel.

Particular attention was paid to detailing the deck's grid system to simplify fabrication and erection. Larger Tee sections were selected rather than smaller, more closely spaced "I" sections as in previous designs. The main members are spaced at 304.8mm on center whereas in previous designs a 200mm spacing was used. By increasing the spacing of the main members, increased clearance is provided for installation of shear studs and placement of concrete. Like prior Exodermic decks on bascule bridges, a lightweight (1842 kg/m^3) is utilized to limit the weight of the system. The design unit weight of the system is 0.82 kN/m^2.

Lateral Bracing

Lateral bracing on movable spans is typically an area subject to more than its share of maintenance. Angles and Tees that are typically used as lateral bracing tend to collect dirt, debris, pigeon guano and other deleterious materials that if left to accumulate can accelerate corrosion of the member and associated connections. Angles and Tees that are turned upward can also act as troughs funneling debris and water toward gusset plates and connections on the main girders. To avoid these conditions and to utilize the lightest structural members practical for the bracing, pipe sections were used. Pipe sections do not have a weak bending axis making them ideal for bracing



TYPICAL LATERAL BRACING END CONNECTION DETAILS

structures that rotate like bascule leaves.

An example of the economy of the pipe sections can be seen by examining the bottom lateral bracing member between Floorbeams 1 and 2. The length of this bracing element is 9.5m between working points. The controlling design criteria for this member is the minimum stiffness of the member per AASHTO 10.7.1. If a typical steel W, HP, or Tee section were used the minimum member meeting the criteria would have a mass of about 79 kg/m. The pipe section used, a 203mm schedule 40 pipe, meets the criteria with a mass of only 43 kg/m.

Rack/Girder Connection

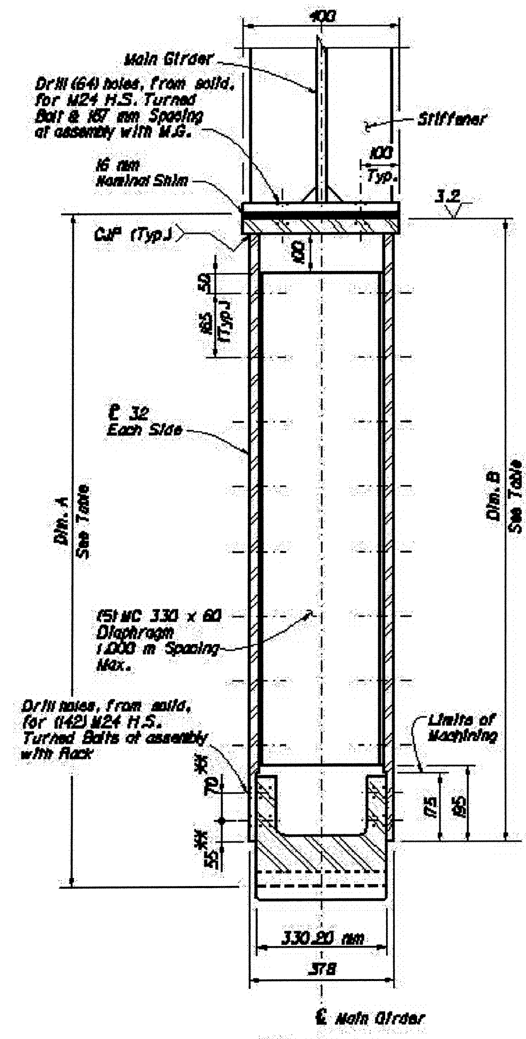
Connection of a rack to a bascule leaf main girder must provide adjustability to accommodate fabrication and erection tolerances. For the Royal Park Bridge a detail was employed that provides for multiple means of adjustment. This is particularly important for large radius racks such as that used on the Royal Park Bridge, which features a 4064mm radius.

Rack Data:
Equivalent Metric Tooth Module = 33.87
Tooth Form = 20° full depth involute
No. Teeth = 51 (of 240 full circle)

Face Width = 330.20mm
Material = ASTM A148, Grade 895-795 cast steel
Hardness = 270 BHN

Pinion Data:
No. Teeth = 21
Material = ASTM A291, Class 5, forged steel
Hardness = 300 BHN

The rack is constructed in three segments that may be aligned together for machining of the tooth profiles. The three segments are fastened between the two side plates of a rack frame that is in turn bolted to the bottom flange of the main girder.



SECTION A-A

At initial fabrication in the shop, the main girder bottom flange is machined to a plane parallel to the trunnion axis and normal to the faced web of the girder at the trunnion. The rack is installed in the rack frame with temporary undersized bolts, and the top plate of the rack frame is machined on a matching plane offset to allow nominal shims between the top plate and main girder bottom flange. The rack frame internal diaphragms are bolted to the side plates to reduce weld induced warping and allow for some adjustment in making the side plates parallel to each other and normal to the top plate.

During shop assembly, the rack/rack frame sub-assembly is aligned with the trunnion, secured with temporary dowel pins, and attached to the main girder with a limited number of temporary undersized bolts. At this point, there are two primary means of adjustment. First, the shim pack thickness can be adjusted and/or tapered shims can be installed thus providing vertical and skew adjustment. Secondly, the temporary bolt holes through the main girder flange are not drilled until the rack/rack frame sub-assembly is positioned normal to the trunnion axis and the rack pitch line is concentric with the trunnion. The rack can be shipped assembled to the girder or match-marked and disassembled prior to shipment.

In the field, there may be some variations in the structural steel alignment from that achieved in the shop. Additionally, there will be some deformation of the main girder as the dead load of the structure is applied. Therefore, the specifications prohibit the drilling of the final rack bolts prior to achieving alignment of the deflected girder. In the event that the rack alignment requires field adjustment, the temporary undersized bolts connecting the rack to the rack frame or those connecting the rack frame to the main girder may be removed and the holes reamed or re-drilled to allow repositioning. If necessary, shims may be added or removed from between the rack frame and main girder or special tapered shims may even be installed.

Pier access

Many bascule piers are difficult to navigate and provide limited maintenance access to some systems. In general it is not practical to provide access throughout the pier if the bridge is relatively small. However, a large pier like that used on the new Royal Park Bridge provides an opportunity for easy access throughout. Taking advantage of this the design team provided several features to enhance access.

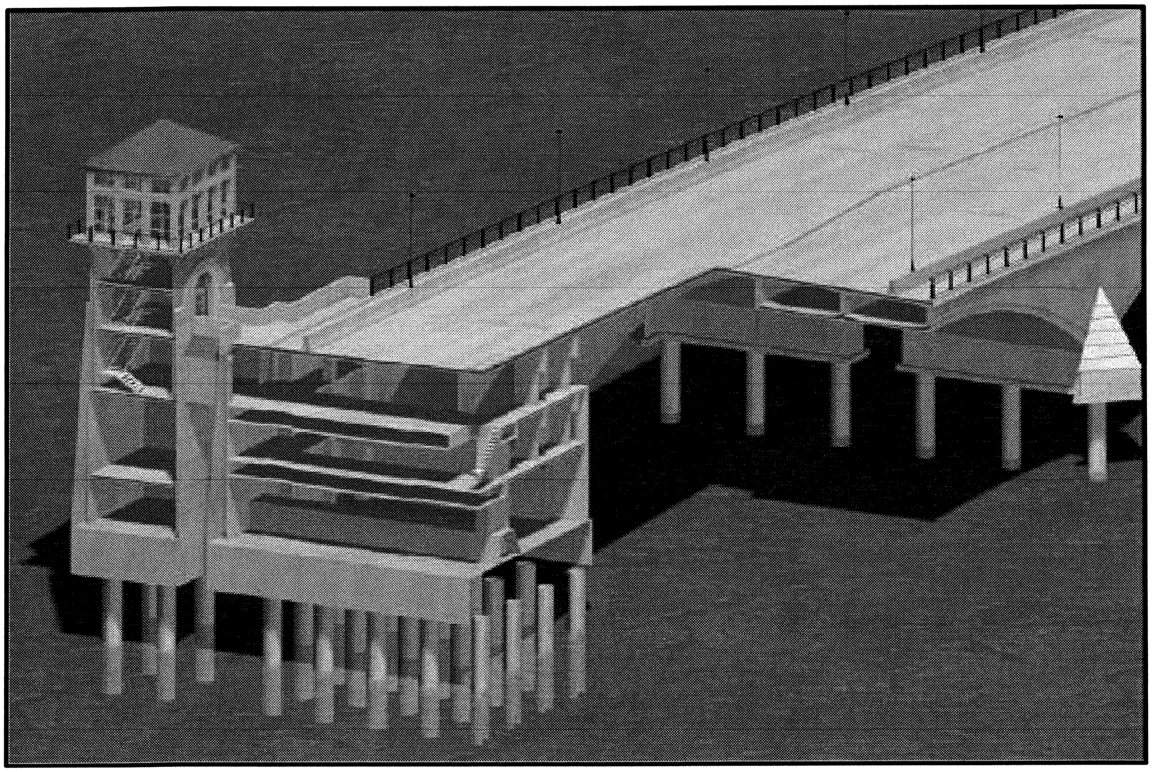
Although counterweights do not require regular maintenance, access to the balance block pockets for adjustments and to steel surfaces for painting can be invaluable during rehabilitation. With this in mind maintenance access walkways were designed around two sides of the counterweights by way of trunnion level platforms. In addition, the adjacent box girder section on the approach span features a ladder accessible platform with access to the counterweight balance block pockets.

The new bridge features simple trunnions. Therefore, there are inboard trunnion bearings that typically require access ladders and platforms. In this case however, a concrete floor was provided that spans the full width between the main girders at the trunnion bearing level. This floor provides ideal maintenance access to the inboard trunnion bearings as well as the inside surfaces of the main girders. Furthermore, this trunnion level floor provides a waterproof cover over the entire machinery platform with the exception of the slots at the main girders. Removable panels are provided in the floor of sufficient size that the largest machinery components (the secondary reducers) could be lifted out if necessary. Access from the deck or control house to the trunnion level floor is provided by way of a reinforced hole through the main girders. The hole features hand grab holes and steps to facilitate passage.

Except for limited areas where they are not practical, all areas are accessible by standard stairs rather than ladders or ships ladders. This feature simplifies access for maintenance personnel particularly when they are carrying tools and equipment.

Summary

The new Royal Park Bridge was programmed to replace the existing bridge under an emergency fast-tracked schedule. This program accelerated design and permitting so that approximately three years were shaved off the schedule. Despite acceleration the Royal Park Bridge features many unique and aesthetic features that make it worthy of "Signature Bridge" status.



Bascule Span Quantity Summary

Bascule Pier Concrete: 2640 cubic meters
Bascule Leaf Dead Load: 8940 kN per leaf
Bascule Leaf Structural Steel: 141,000 kg per leaf
Bascule Leaf Drives: 2 – 40 HP Variable Speed Drives per leaf