THE REPLACEMENT OF THE US 98 BRIDGE AT MEXICO BEACH

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ABSTRACT

The project is located in Mexico Beach, Florida; a coastal resort community located in the Florida panhandle. The medium span precast concrete arch alternate was selected after consideration of the improved vertical and horizontal clearance for marine traffic and the superior aesthetics.

Keywords: Medium Span, Precast Arch

INTRODUCTION

The project is located in Mexico Beach, Florida; a coastal resort community located in the Florida panhandle approximately 15 miles east of Panama City Beach. Florida Department of Transportation (FDOT) is the owner of this project. Marine traffic accesses the Gulf of Mexico by passing beneath the bridge. A large amount of recreational marine traffic utilizes the Mexico Beach Canal and future developments are expected to increase marine and vehicular traffic. Additionally, US 98 is a hurricane evacuation route and access must be maintained during all phases of construction. Figure 1 shows the location of the project.

Figure 1 – Project Location Map

Three superstructure alternatives were compared to determine the optimal replacement structure: a medium span precast arch, AASHTO Type II concrete prestressed beams, and a cast-in-place flat slab. The medium span precast arch alternate was selected after consideration of the improved vertical and horizontal clearance for marine traffic, bridge hydraulics and the superior aesthetics. The total construction cost of the replacement bridge was $1,970,600.

PROJECT ISSUES

EXISTING SITE CONDITIONS

The existing bridge was a single-span structure with sheet pile wall abutments. The superstructure consisted of a simply supported 24-foot long cast-in-place concrete deck with an overall bridge width of 45-feet 8-inches. Inspections revealed multiple cracking problems in the sheet piling abutments that required constant corrective action. The inspection report also indicated that both approach slabs showed signs of settlement and required repair. Figure 2 shows the existing bridge.

Figure 2 – Existing Site Conditions

The right-of-way within the project limits is 100 feet, 50 feet left and right of the centerline of construction. Adjacent properties have deep water canal access to the Gulf of Mexico. These properties have a premium value due to the recent and proposed development in Mexico Beach. A fundamental goal of the bridge replacement project was to avoid the requirement for additional right-of-way or construction easements.

The existing horizontal and vertical navigable opening dimensions were approximately 18 feet and 12 feet 5 inches, respectively.

Various utilities were located on both sides of the road, including overhead telephone, electric and fiber optic lines. The existing bridge supported a 6-inch water main and a 12-inch force main. These utilities were relocated under the canal using directional boring.

NAVIGATION

The new structure increases the navigable opening dimensions to 34 feet 6 inches for horizontal clearance and 13 feet 6 inches for vertical clearance.

BRIDGE HYDRAULICS

Due to the limited size of the upstream drainage basin and the bridge's proximity to the Gulf of Mexico, tidal flows are approximately 3.5 times greater than freshwater flows for the 50-, 100- and 500-year storm events. Bridge hydraulics were improved by lengthening the bridge to increase the waterway opening from 18 feet to 68 feet. The wider waterway opening significantly reduces channel velocities and scour potential without impacting the base flood elevation.

ROADWAY REQUIREMENTS

The new structure has a dimension of 59 feet 1 inch out-to-out. This includes two lanes of traffic, a left turn lane, and two 10-foot shoulders.

STRUCTURAL COMPONENTS

The new structure consists of two distinct structural sections. The center portion of the bridge is supported solely by the precast arch ribs. These ribs were cast in two segments for ease of erection and transportation to the bridge site. A cast-in-place (CIP) closure pour and mechanical splices connect each rib at the crown of the arch. An 8-inch thick CIP composite deck cast on top of the precast arch ribs completes the travel way. The approach spans are CIP flat slab units that are supported by the abutments, columns and arch ribs. Figure 3 shows the proposed bridge typical sections.

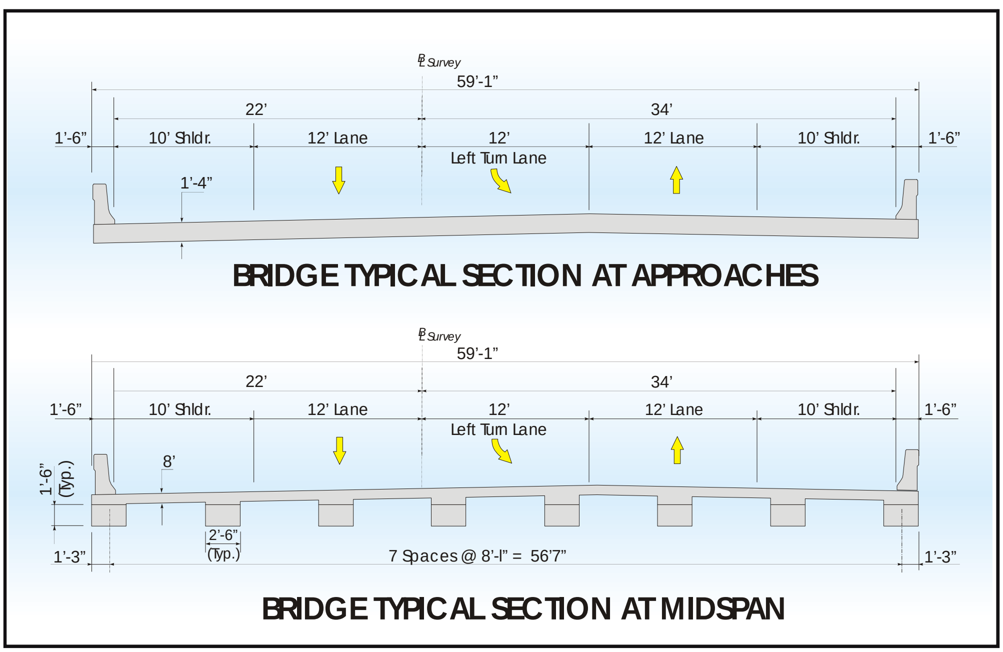

Figure 3 – Bridge Typical Sections

AESTHETICS

The structure is visible to marine traffic, the Blue Water Inn and town homes on both sides of US 98. Plans to develop property on the north side of the bridge can be expected to increase marine traffic and make the structure visible to a number of new homes.

The arch structure forms a balanced passageway under US 98, with both simple curved and vertical lines intersecting at the bridge foundation. The structural elements clearly denote the load paths from the deck to the ground. The arch ribs create an open breezy ambiance, fitting in with the surrounding beaches and coastal resort setting. Figure 4 shows a view of the completed bridge.

Figure 4 – Bridge Aesthetics

CONSTRUCTABILITY

The construction of the bridge was complicated by the need to maintain traffic, embankment removal and the limited staging area. Barge mounted cranes were not possible since the size of the barge would have blocked the navigation channel. Ground cranes at the top of embankment on either side of the canal were required for construction of the structure.

The construction of the arch required smaller crane picks than a conventional AASHTO beam bridge. The crane was also able to be located closer to the foundation, reducing the required reach of the crane. The precast arch components increased quality and speed of construction by utilizing an on-site casting yard. The precast arch ribs were able to be cast ahead of the rest of the construction, eliminating the need to wait for a cast-in-place arch to achieve the needed strength required to support the cast-in-place concrete deck. Geometric consistency between the arch ribs was also easier to achieve using a precasting yard. Also, the use of precast arches eliminated the need for complex formwork required for a cast-in-place arch rib. This allowed for easier marine traffic maintenance.

Steel sheet pile walls driven parallel and perpendicular to the road were necessary for the phased construction. After these initial retaining walls were constructed, the existing bridge was partially demolished. The soil was excavated so the concrete sheet pile walls and arch foundations could be constructed. Corbels were then cast on the foundations. The precast arch components were then set on the corbels. Temporary supports founded on pipe piles provided stability for the arch members until precast diaphragms were inserted, a concrete CIP closure pour was placed at the crown of the arch, and finally the arch pin connection was grouted at the corbels. Figure 5 shows the arch ribs supported on temporary piers.

Figure 5 – Arches on Temporary Supports –Phase I

The end bents and columns that support the flat slab sections of the bridge were then constructed. The portion of the deck composite with the arch ribs was then poured. Finally, the CIP slab, approach slabs and bridge barriers were poured, completing the first phase of bridge construction. Traffic was shifted to the newly completed bridge and the second half of the bridge was constructed in the same manner.

Utility relocation became a major issue because of the lack of right-of-way. Foundations in phase one were redesigned after a relocated sewer force main was found to conflict with multiple piles of the arch foundation.

COMMUNITY ACCEPTANCE

The arch bridge was selected at this site based on feedback from the citizens of Mexico Beach. The importance of marine access to the Gulf of Mexico was given special consideration to selection of the arch bridge at this location. The local economy is dependant on marine access to the Gulf of Mexico as three marinas and the public boat ramp are located inland of the US 98 bridge and nearly all marine traffic must pass beneath the US 98 bridge to access the Gulf of Mexico. Future developments are planned on the inland side of the US 98 bridge, resulting in increased marine traffic through the bridge.

At the request of local developers, a pedestrian/golf cart underpass was designed at the west end of the bridge to accommodate safe access across US 98 in the future. A MSE wall was designed to wrap around the west abutment to facilitate this pathway. The underpass adds to the sustainable growth and livability of Mexico Beach. Figure 6 shows the completed pedestrian underpass.

Figure 6 – Pedestrian Underpass

The appearance of the replacement structure was an additional consideration since Mexico Beach is a resort beach community and access to the Gulf of Mexico attracts people to the community.

TECHNICAL ISSUES

DESIGN DETAILS

The arch portion of the bridge was modeled using two concurrent programs. The ribs were modeled using WinSTRUDL, a finite element structural modeling program. Composite deck section properties were used in the analysis. Live loads and dead loads from the structure were applied to the model. A moment magnification analysis was used in designing the reinforcing in the arch ribs. Florida Pier, a non-linear soil structure interaction program, was used to model the arch foundations using soil parameters provided by the geotechnical engineer. This model took into account the steel sheet pile walls to be used as soil thrust plates, in the form of springs. AASHTO LRFD Bridge Design Specifications, 2nd Edition was the code used in designing the bridge. The design process followed these steps:

- Define arch geometry and loads. Create the finite element model.
- Run the arch model, find the axial loads transferred to the foundations.
- Define foundation geometry and soil properties. Create the Florida Pier model.
- Run Florida Pier model using the loads obtained from the arch analysis. Find the foundation deflection.
- Calculate the foundation stiffness (Spring Constant) from the arch analysis and foundation deflection.
- Revise the finite element model to include foundation stiffness in the form of springs at the base of the arch.
- Re-run the Florida Pier model based on the new output from the finite element model and repeat until the foundation stiffness converges.
- The piles were then checked for ultimate and service loads from the Florida Pier model.

ARCH RIB DETAILS

Eight precast arch ribs with a composite deck were designed to facilitate phased construction. Each rib was cast in two equal segments to facilitate handling and shipping. Each rib was also cast next to one another, ”match casted” with the splices at the crown of the arch in place. This ensured the segments would fit when erected and the reinforcement was spliced at the site. This also allowed a greater control of the arch geometry, creating a better end product with continuous curving lines.

The length of 82 feet from centerline of arch support to centerline of arch support required optimized arch rib dimensions of 2 feet 6 inches wide by 1 foot 6 inches deep. These dimensions allowed the use of two 2-inch diameter stainless steel pins in each arch rib for the interface at the arch foundations. Twelve number 11 bars in the top and bottom face of the arch ribs were required in high moment areas in the arch. Half of this reinforcement was needed at the crown and hinges of the arch.

In the areas where the arch ribs are composite with the deck, mechanical splices were used to connect shear reinforcement inserted into the CIP slab. These splices were cast into the arch ribs and connected to a U-bar within the rib. Figure 7 shows an elevation view of the arch ribs.

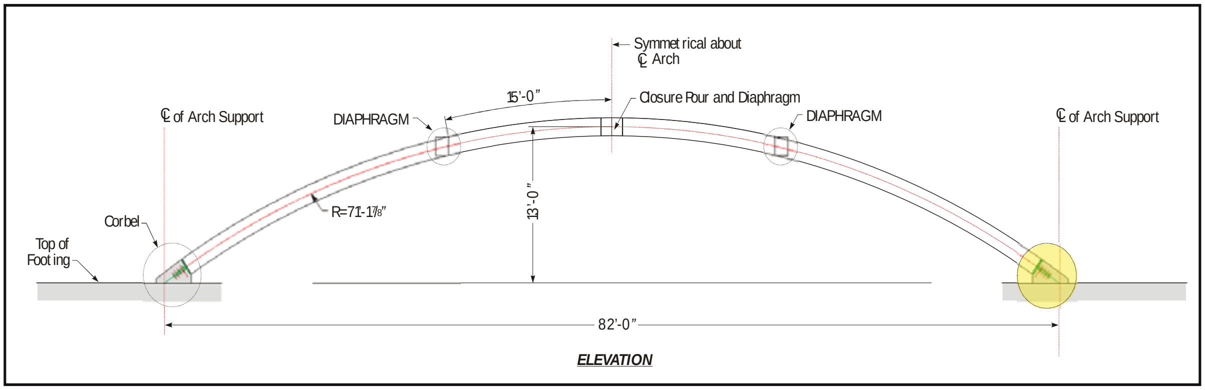

Figure 7 –Arch Geometry

CONNECTION DETAILS

The arch was designed as a pin connection. Two 2-inch diameter stainless steel rods were used as the pins to resist shear forces transferred from the arch ribs. The CIP corbel at the arch foundation included two sleeves in which to insert the pins. Sleeves were also cast into the ends of the arch ribs. These sleeves were sized to allow for construction tolerances. After the corbels were cast, the pins were inserted using wire to center the pins in the hole. The arch ribs were then set on the temporary supports so that the pins fit in the sleeves in the arch ribs. Shims on the temporary supports were used to adjust the placement of the arch ribs to ensure the pins were properly positioned in both the corbels and the ribs. Figure 8 shows a detail of the pinned connection at the corbel/arch rib interface.

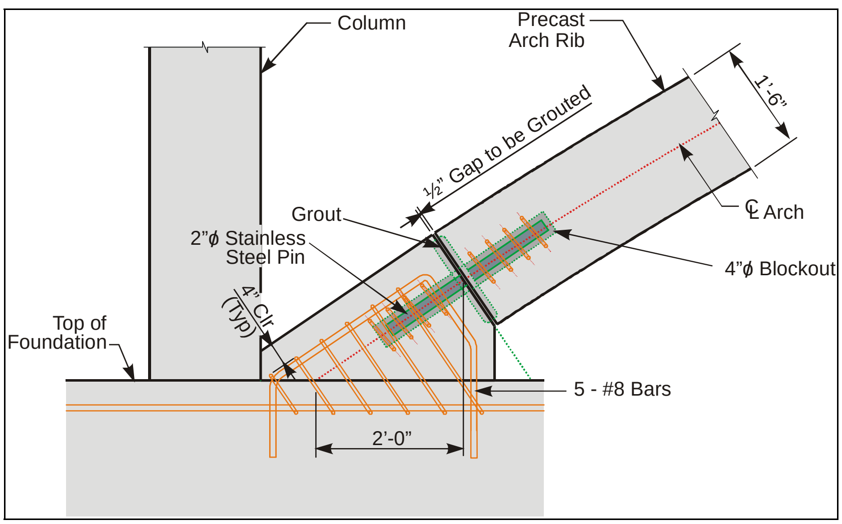

Figure 8 – Arch Pin Connection

A CIP closure pour at the crown of the arch connected the two arch segments using mechanical splices. The closure pour was dimensioned to allow a variety of mechanical splice systems to tie the main arch reinforcement together. This CIP closure pour also includes a 1-foot by 1-foot 9-inch diaphragm to stiffen the arch at the crown. Figure 9 shows the spliced arch reinforcement at the crown of the arch, awaiting the closure pour.

Figure 9 – Mechanical Splice at Arch Crown

The CIP diaphragms at the flat slab/arch interface were designed to support the flat slab and stiffen the arch during construction like the diaphragm at the arch crown. A 1-foot 2-inch by 1-foot 9½-inch diaphragm was adequate to create a support point for the flat slab unit. Roofing paper was used under the flat slab since this is an expansion joint. These diaphragms are connected to the arch by mechanical couplers and embedded reinforcement in the pre-cast arch ribs. Figure 10 is a view of the arch diaphragms looking from below the bridge.

Figure 10 – Arch Diaphragms

After the CIP closure pour and diaphragms were constructed, the blockouts containing the stainless steel pins were grouted to transfer the axial forces from the arch ribs and to seal the pins. This created a joint that is easy to inspect and maintain.

Spiral reinforcement and U-bars in the corbel handle the bursting and compressive forces transferred from the arch into the foundation. The corbels themselves are tied to the foundation by five number 10 bars and six number 4 bars that confine the previously mentioned reinforcement.

SUBSTRUCTURE

The sandy soils at this site were not ideal for the large lateral loads generated by the arch thrust. No layer of bedrock adequate to anchor the foundation to account for the loads was present. The footing was designed by using 24-inch square precast prestressed concrete piles embedded 4 feet into the cap to create a full moment connection. Each side of the bridge utilized 28 piles and a 7-foot deep by 18-foot 6-inch long by 61-foot wide concrete footing.

The piles were battered at 2 inches per foot to generate more axial force from the arch ribs. A 4-foot wide closure pour was used to tie the two phases together. Steel sheet pile walls, which were used to facilitate crane placement for the arch foundation pile driving and construction of the arch footer, were cut off and reused as thrust plates by pouring non-structural concrete between the footer and the wall. This added to the longitudinal stiffness of the arch foundations and minimized deflections that could lead to cracking of the arch ribs. Figure 11 shows a schematic of the arch foundation. Figure 12 is a picture of the completed arch foundation, before the corbels and columns had been cast.

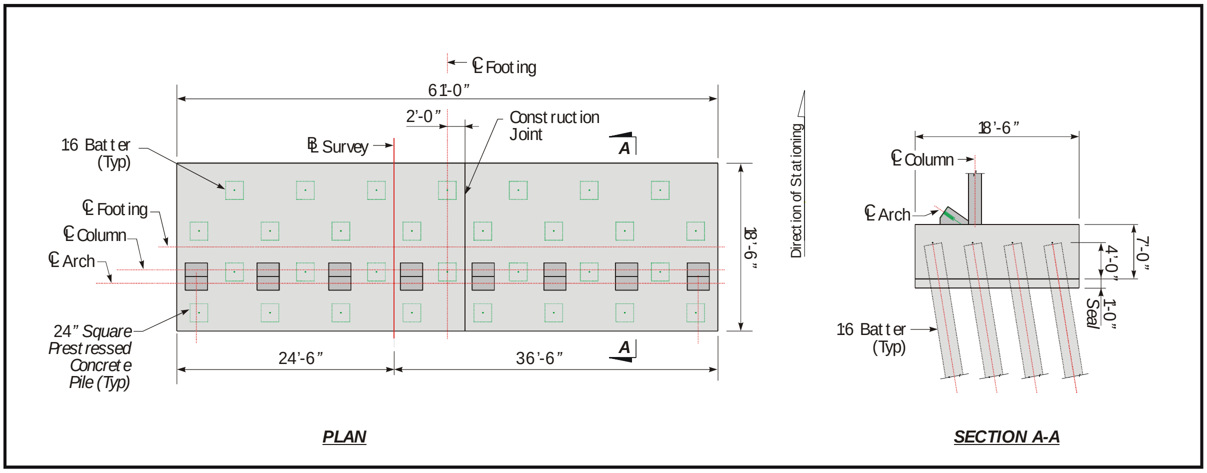

Figure 11 – Arch Foundation

Figure 12 –Foundation after Form Removal

CAST-IN-PLACE FLAT SLAB UNITS

Flat slab units connect the arch supported deck to the roadway. This was achieved using two 27-foot 6-inch spans, supported in the middle by an integral 1-foot 6-inch transverse beam. CIP columns under the integral beam are supported by the arch foundation. One 2-foot 6-inch by 1-foot 6-inch column for each arch at the corbels creates the look of a continuous structure. The flat slabs are fixed at the integral transverse beam leaving expansion joints at the end bents and the ends of the arch supported unit. Figure 13 shows the flat slab section of the bridge supported by columns.

Figure 13 – Flat Slab at Transverse Beam

CONCLUSION

The construction of the arch bridge at this particular location necessitated many innovative design solutions. These solutions culminated in an aesthetically elegant structure that not only provides functionality, but is also a landmark of the City of Mexico Beach (Figure 14).

Figure 14 – Completed Arch Elevation

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