The Replacement of the I-10 Bridges over Escambia Bay

Accelerated Bridge Design and Construction Delivered Using the Design Build Method

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ABSTRACT

Hurricane Ivan struck Florida's coast near Pensacola on September 16, 2004. The Category 4 storm packed winds of over 120 MPH and produced 20 foot waves which devastated the existing 2.6 mile long bridges carrying I-10 over Escambia Bay.

The Tidewater-Skanska-Flatiron Constructors/Parsons Brinckerhoff Team developed an approach to the project which produced over 5 miles of bridge structure in approximately two years; an average of 2,000 square feet of bridge constructed per day. The D\B Team developed innovative design and construction methods to make the construction schedule achievable:

Deep Foundations:
- Specially designed 36" pile, a first in Florida.

Type I Piers:
- Precast Cap constructed on driven piles
- Beams can be set and deck constructed within days of pile driving

Type II Piers:
- Precast footings for high level piers. Innovative design limited footing weight to 80Tons.
- CIP full moment connection constructed below MHW elevation to secure footing to piles.
- Low level and mid level struts added as needed to increase ship impact strength

Typical 136' Bulb-T Superstructure Spans:
- CIP deck constructed using innovative modular forming system
- Gantry system utilized to place, strip and cycle deck forms.

Other Superstructure Spans:
- Spliced girder unit to provide 250' main span
- Deck continuity between main span unit and approach spans to increase ship impact performance
- Specialized precast girders to provide vertical clearance over RR (depth:span ratio is 1:30)

Keywords: Escambia Bay, Design-Build, Precast, Precast Connection, Spliced-Girder, Post-Tensioning, Accelerated Construction, Reusable Deck Form System.

PROJECT HISTORY

Hurricane Ivan struck Florida's coast in September of 2004, near Pensacola, with devastating effects. The category four storm packed winds over 120 MPH and produced storm surges in excess of 20' as it made its way over Interstate 10 at Escambia Bay. More than 50 spans of the existing three mile bridges were washed into the bay and another 60 were permanently dislocated. In order to reopen Interstate 10 to the public as quickly as possible, missing spans on the westbound bridge were replaced with entire spans from the more heavily damaged eastbound bridge. With the westbound bridge reopened, work shifted to the eastbound bridge. By replacing the missing 50 spans of superstructure with a temporary metal Acrow structure, the eastbound bridge was brought back into service, but with only one lane of traffic.

Figure 1 – Emergency Repair After Hurricane Ivan

With the eastbound bridge capable of carrying only one lane of traffic, immediate replacement of the Interstate 10 bridges was necessary. The FDOT quickly released a Request for Proposals (RFP) for the design-build replacement of the Interstate 10 bridges. The request mandated that all traffic be moved onto new structure by the end of 2006, and that the bridges be brought to their final condition consisting of three, 12' lanes of traffic with two, 10' shoulders no later than the end of 2007. The width of this typical section allowed for one bridge to temporarily carry four, 12' lanes and a center barrier until the second structure was finished. Considering the nearly three mile length of the new bridges, the timely completion of these works would be no small undertaking.

DESIGN/BUILD

DESIGN SUBMITTALS - With notice-to-proceed given on April 25, 2005, the design-build team of Parsons Brinckerhoff (PB) and Tidewater Skanska Flatiron Constructors (TSF), had less than 21 months to design and build a new bridge. Both bridges would need to be completed in just 33 months. These milestones forced the design schedule to be very aggressive and to be split into several submittals. By breaking the design into several submittals, both the precaster and TSF were able to begin operations before a traditional process would have allowed. The first submittal was made in just a few short weeks on May 20, 2005 and included the foundation layout and pile details. The second submittal was made on July 22, 2005 and included complete details for all the pile caps and footings. The entire plan set was completed in September, just five months after notice-to-proceed.

ALIGNMENT - The first aspect examined in the design phase was the alignment. A recommended alignment was supplied with the RFP. This alignment consisted of a new eastbound bridge immediately to the north of the existing eastbound bridge and a new westbound bridge immediately to the south of the existing westbound bridge. This alignment posed several concerns. First, the new alignment placed the new piles dangerously close to the existing piles. The vibration from the pile driving could further damage the already heavily damaged bridges. Second, due to limited barge access, the proposed alignment would have required the demolition of the existing bridges prior to the construction of the new westbound bridge.

Therefore, a new alignment was developed with both bridges located to the south of the existing bridges. The new alignment required the removal of the slope underneath Scenic Highway by the west approach. The slope removal necessitated the construction of a retaining wall immediately in front of the existing abutment. Removing the slope allowed a new eastbound bridge and approach to be constructed to carry four lanes of traffic without interrupting the existing traffic. The majority of the new bridge was designed to have 130’ of clearance to the existing eastbound bridge. This allowed for barge access and reduced the possibility of damage to the repaired sections of structure.

Figure 2 – New Alignment of Eastbound Bridge by West Approach

Figure 3 – Retaining Wall Under Scenic Highway

DESIGN GOALS - During the design of the bridge, three main goals were focused on: quality, efficiency, and ease of construction. Whenever practical, material quantities were kept to a minimum. At the same time, the elements were kept as uniform as possible. This kept both the precaster and the contractor from having to modify their formwork and production methods unnecessarily. Uniformity of the elements also helped simplify the reinforcement detailing. Close communication between the design team and the construction team helped shape the detailing to allow the contractor to pre-tie the reinforcement cages in the yard whenever possible. This not only made the fabrication of the cages easier, but helped keep the barges free for other tasks. This became a somewhat iterative process as the contractor further refined means and methods through both the design and construction phases. During the planning and design phases, the contractor also encouraged the use of precast elements whenever practical. The goal was to save time in the very tight schedule by both reducing time consuming construction on the water and distributing the workload with local precasters.

STORM SURGE - Lateral force and buoyant uplift from the storm surge associated with Hurricane Ivan led to the failure of the old bridge, which had a minimum vertical clearance of just 12’. For this reason, the RFP mandated the new bridges to have a minimum vertical clearance of 25’. To help resist lateral forces, concrete shear keys were also incorporated on all new substructures. These shear keys were cast next to the beam seats on the pier caps to block the girders from moving laterally. Coupled with providing a continuous deck, these steps will help prevent a repeat of Ivan.

SUPERSTRUCTURE

The type of superstructure selected was heavily influenced by the RFP's requirement that the typical span of the bridge had to be a minimum of 130' long and the channel span had to be a minimum of 250' long. This span arrangement, and the aggressive environment created by the saltwater in Escambia Bay, made precast prestressed concrete girders with a cast-in-place (CIP) deck the obvious choice for the superstructure. For the typical span, five 78" Florida Bulb Tees with a 12' – 6" spacing and a length of 136' was found to be the most economical. A three span post-tensioned spliced girder based on the 78" Florida Bulb Tee was chosen for the channel span.

The spliced girder is comprised of five sections; two haunched sections over the center piers, two end sections, and drop-in girder between the haunched sections. The haunched sections over the center piers increase to a maximum depth of 112". The system contains four draped post-tension ducts to house twelve 0.6" diameter grade 270 low relaxation strands. To handle the bursting stresses associated with these strands, the end beams contain an approximately two and a half foot wide by ten foot long anchor block over the full depth of the beam.

Before erection of the segments could occur, two temporary shoring towers were constructed to support the system between the end girders and the haunch girders. After the haunch and end girders were erected, the drop-in section was set into place between the haunch girders. The drop-in segment rests on two strong backs, which distribute the dead load to the haunched sections and over to the permanent and temporary supports. Once all the segments were in place, the strands in the first two post-tension ducts were stressed. At this point, the deck was placed. After the deck achieved sufficient strength, the strands in the last two ducts were tensioned. This erection sequence afforded minimum disturbance to the barge traffic in the channel.

Figure 4 – Spliced Girder Erection

NAVIGATIONAL CHANNEL - The existing navigational channel is slightly skewed to the bridge alignment. This required the stationing of the center piers to differ by approximately 35' from one bridge to another. If the spans on the eastbound and westbound bridge had remained identical and the stations continued to differ by 35', barge access during construction would have been much more difficult. To bring the surrounding piers back into station, the spans surrounding the channel differed by approximately 35' and were mirror images from one bridge to the other. This not only solved the stationing problem, but helped keep the precast elements as uniform as possible.

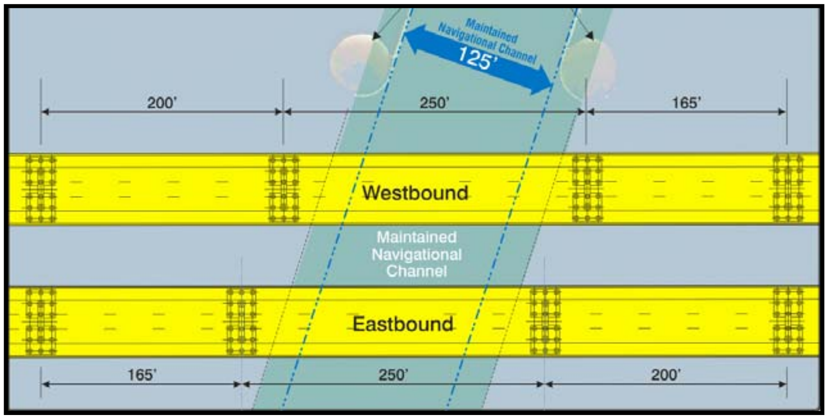

Figure 5 - Plan View of Channel Spans

CONTINUOUS DECK - The thickness of the CIP deck slab resting on top of these girders is 8.5", with the top 0.5" being sacrificial. The majority of the superstructure consists of four continuous deck spans approximately 136' in length. This equates to a length of about 544' between expansion joints. The expansion and contraction associated with this distance made the use of a 1-1/4" wide strip seal expansion joint acceptable. The 888' length of the continuous span unit over the channel mandated the use of a finger joint capable of handling the calculated movement of 4.5".

FOUNDATION

PRECAST 36" PILES - Several options were considered for the foundation, but 36" square precast concrete piles were determined to be the most efficient and economical. Cylinder piles were eliminated because of the increased vibration that would be experienced by the foundation of the existing bridges and because the contractor would have required special equipment not necessary for the other construction operations on the project. The use of 36" square piles not only reduced the problems associated with cylinder piles, but allowed the contractor to employ two local precasters resulting in a readily available product. The 36" piles were preferable to smaller piles because they greatly reduced the number of piles required for the calculated loading conditions, thereby reducing the time required to both fabricate and drive the piles. Another favorable result was that the typical span could incorporate five piles located directly under five girders, allowing for a more efficient pile cap.

PILE CONNECTION - The 36" piles have a 22.5" diameter void throughout the length of the pile, except for a four foot solid section at the tip. This was done primarily for reduction in material and weight, but it also presented the opportunity to utilize a precast pile cap. With a majority of the 207 foundations consisting of five piles cut off at approximately 22' above water level and connected with a pile cap, it was very important to achieve an efficient design. Had the piles been embedded into a CIP cap, the minimum depth of the cap required to develop the moment in the 36" piles would have been six feet. By going with a cast-in-place connection, the depth of the cap was able to be held to just four feet. This not only reduced the amount of material required for the cap, but also allowed the weight of the cap to be held to a point where the contractor could handle the cap with equipment already planned for the project, and for the precaster to manufacture and load the cap for shipping.

Figure 6 – CIP Pile Cap Connection

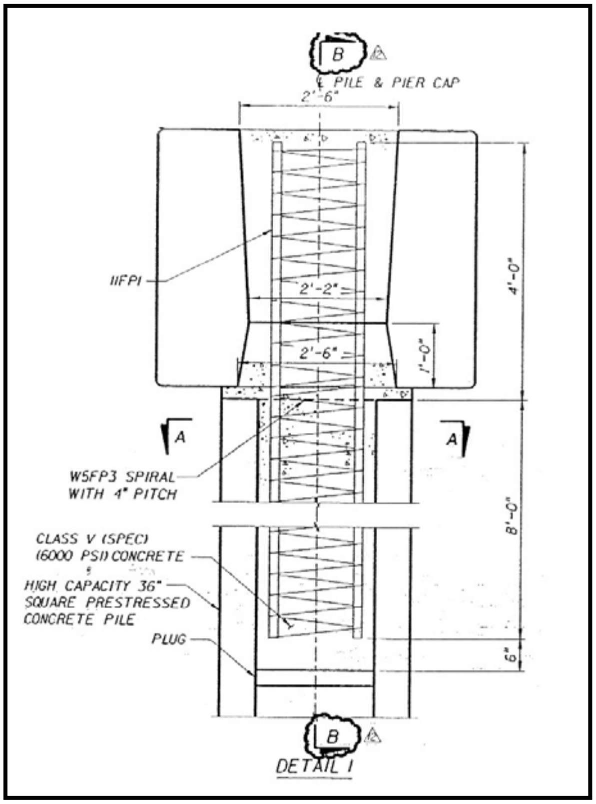

Figure 7 – CIP Pile Cap Connection Detail

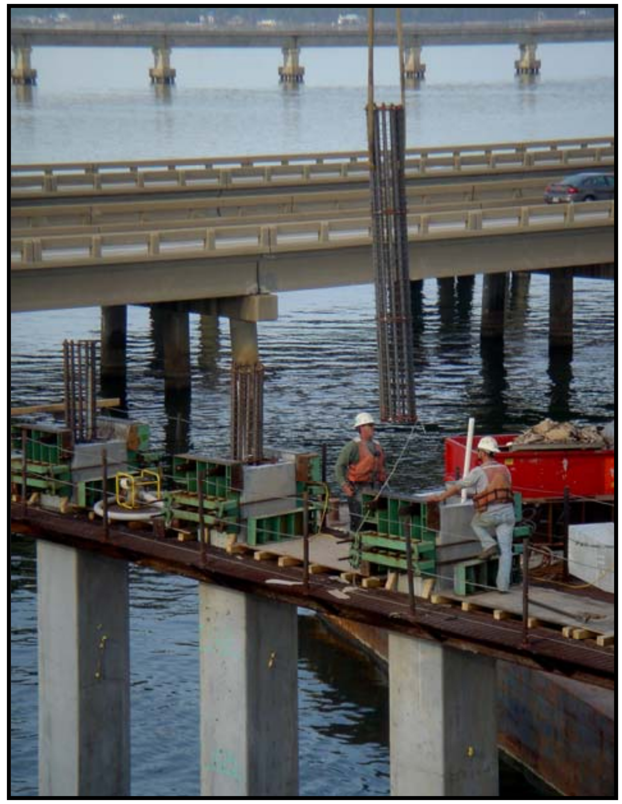

Figure 8 – Rebar Cage Set in Pile for CIP Connection

The connection between the cap and pile was made by inserting a rebar cage into the top ten feet of the pile that extends into the pile cap. With a plug that extends six inches below the cage, the void was then filled with concrete. The length of this connection was controlled by the stress transfer between the precast concrete of the pile and the CIP concrete of the plug.

Figure 9 – Low Level Pile Bents

PIER DESIGN - The RFP set the minimum vertical channel clearance at 65'. This necessitated a gradual increase in height from the typical pile bents to the piers surrounding the channel. The RFP also contained a table of ship impact loads to be applied to all substructure, which increased with proximity to the channel. Three pier types were developed to meet these requirements, all of which contained two waterline footings, two columns, and a pier cap.

The first pier type made use of two precast footings resting on triangular shaped three pile groups. The three pile group not only required the fewest amount of piles for the design loads, but also kept the weight of the footing within the limitations of the precaster and the contractor. The connection of the precast footing was done in the same manner as the bent cap. After the connection was made, two, five foot diameter circular columns, spaced 30' center-to-center, were cast-in-place atop the footings. A five foot deep trapezoidal cap was then cast on the columns. As the height of the piers increased, two 4.5' deep struts were added. One between the base of the columns and one approximately midway up the columns. These struts were added to reduce the unbraced length of the columns and distribute the ship impact load across the two footings.

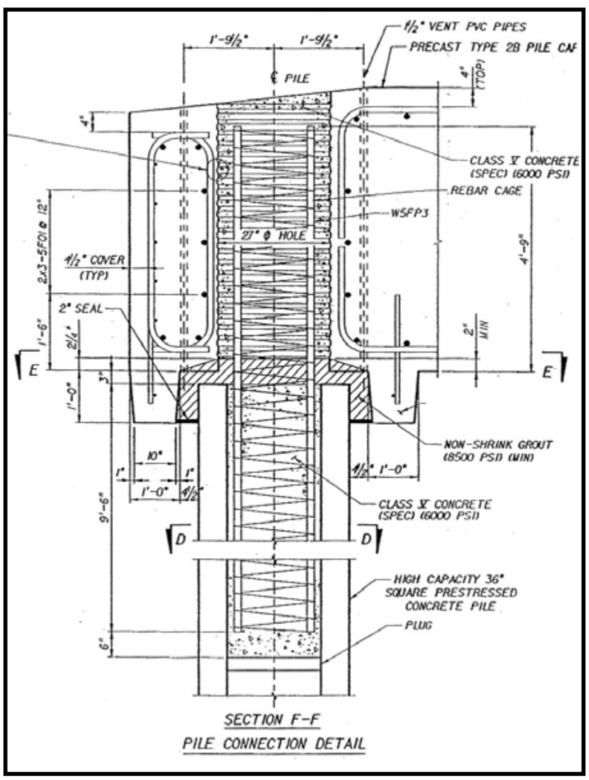

Figure 10 – CIP Pile Footing Connection Detail

Figure 11 – Typical Pier Geometry

Figure 12 – Precast Pile Footing

Approaching the channel, the ship impact load increased to 2000 Kips. Two footings with six piles per footing were found to withstand the increased loading, making a precast footing impractical. A rectangular cast-in-place footing was designed with the piles spaced nine feet apart, or 3D, and imbedded five feet into the footing. The remainder of the pier geometry is similar to the first pier type, except that the diameter of the columns is increased to six feet and the depth of the struts are increased.

The ship impact load further increased to 2400 Kips and then to 2700 Kips in the piers immediately surrounding the channel. To help distribute the increased loading between adjacent piers, additional steel was placed in the deck and the system was analyzed with the deck acting as a diaphragm between piers. This kept the pier size efficient and consistant. With exception to the number of piles, it was determined to use the same pier geometry for both loadings. The piers loaded to 2400 Kips were designed with two, eight pile footings and the piers loaded with 2700 Kips were designed with two, nine pile footings. Struts and caps on the channel piers were similar to those used on the approach piers, the only difference being an increased requirement in the depth.

Design/**Build**

The majority of the construction work was performed on barges, but the shallow water by the banks of the bay made temporary work trestles necessary. The work trestles were used for access to build the new bridges and to deliver materials utilized by the barge construction. The best method of delivering concrete for CIP construction on the first bridge, was found to be from the existing eastbound bridge. The concrete was delivered by truck from a local batch plant to the site. Since only one lane of traffic was maintained on the eastbound bridge, this created only minor traffic problems. The delivery was not allowed in the areas of the bridge containing the temporary Acrow spans, and guidelines were setup for the spacing of trucks to limit the load on the bridge. The trucks discharged into a hopper on the side of the bridge. At this point, the hopper fed the concrete to a pump located on a barge beneath the bridge. This barge was connected to a series of barges, which fed the concrete through a pipe to a pump truck located next to the new construction. The pump truck was then able to place the concrete in the new structure. When necessary, the reach of the pump truck was further improved by rotating the series of barges about its pivot point by the hopper. The reach of the system enabled the contractor to easily place two deck spans concurrently. This method was found to be acceptable to the owner, and most beneficial to the contractor.

PILE DRIVING - The first operation in construction of the new bridge was pile driving. As previously mentioned, the first design submittals included details of the piles and foundation layouts, so work could begin as quickly as possible. To meet the aggressive schedule, and keep pile driving off of the critical path, pile driving was performed on multiple fronts. The most time consuming superstructure operation scheduled was the erection of the spliced girder over the channel piers. For this reason, pile driving was started at these piers. Shortly after work began on channel piers, additional pile driving rigs began working on the pile bents by the approaches. The objective was to create four main work fronts, with two teams focusing on the spans on either side of the channel and two additional teams working at both ends of the bridge with the goal of meeting in the middle. The main focus of the pile driving crews was to stay out in front of these four teams.

At the peak of pile driving operations, TSF had five pile driving hammers in two different configurations. Two barges were equipped with hammers in fixed leads and a series of anchors. The anchors were attached to the barges through a series of winches, which could maneuver the barge both laterally and longitudinally. These outfits were used primarily on the piers surrounding the channel because of the tight spacing of numerous piles and the generally shorter length of these piles, due to their lower required driving resistance. Work started on the eastbound bridge footings and moved south to the westbound bridge footings. The piles for an entire pier could be driven with very few anchor adjustments. Moving further away from the channel, fewer piles were required per pier. This meant the barges with fixed leads required more anchor adjustments per pile driven, making them less efficient. At this point, a template system was used in conjunction with a hammer on swinging leads. Unlike with the fixed lead barges, there was very little efficiency to be gained with the template operation by driving both the eastbound bridge and westbound bridge piles concurrently. Therefore, work was concentrated on the eastbound bridge with these outfits to achieve the first goal of opening the eastbound bridge by the end of 2006.

Figure 13 – Pile Driving

CIP FOOTING – The size of the channel pier footings required cast-in-place construction, which can be very time consuming when performed from barges. To reduce the time required, most of the work was performed in the contractor's yard, or on a barge prior to arrival at the pier. To accomplish this, first a concrete seal slab cast in the yard to create the bottom form. Next, a prefabricated rebar cage was placed on the seal slab. Steel side forms were then connected to the seal slab. The tops of the side forms were then connected to each other with a series of steel girders. These girders were then connected to the seal slab with four steel tie rods. These rods were placed inside PVC pipe to accommodate removal after casting. This entire system was then lifted into place and set on top of the piles. The steel girders rested on top of steel pipes, which were placed on the piles. This process eliminated the need for friction collars on the piles and transferred the entire load down to the pile through compression. After the concrete was cast and given time to set, the steel pipes and tie rods were removed and the remaining holes were filled.

Figure 14 – CIP Footing Preperations

Figure 15 – CIP Footing, Formwork, and Rebar Cage Set in Place

Figure 16 – High Level Piers

To further accelerate construction, the majority of the reinforcement in the columns, caps, and struts were also pre-tied in the yard, or on a barge. As the formwork was erected, these pre-tied cages were set into place, making the elements ready for concrete very quickly. This method was also employed on the diaphragms which were constructed at the ends of all precast girders.

DECK CONSTRUCTION – In order to meet the aggressive schedule, two methods were employed for the construction of the deck. The majority of the spans were cast with a removable steel form system which was installed with a track driven form placer. The tracks for the placer were temporarily placed on the girders. The placer used a system of winches to lift forms, drive them into position, and hold them in place as workers tightened a series of turnbuckles to allow the forms to rest on the bottom flange of the girders. After casting the deck, these forms would be removed by a form stripper. The stripper drove over the deck on rubber tires and employed an underslung arm to access the forms from below the deck. The stripper used a system of hydraulic jacks, winches, and a sliding platform to remove forms and transport them to the top of the deck for future use.

Figure 17 – Deck Form Placer

Figure 18 – Deck Form Stripper

The second deck system incorporated stay-in-place (SIP) forms. Due to the aggressive environment associated with Escambia Bay, obtaining a technical special provision (TSP) was necessary for the use of SIP forms. This was obtained in part by using a product called Rhino-Dek, which consists of a galvanized steel form with a polymer laminate coating. Utilizing two methods for deck construction allowed the contractor to attack the project from multiple fronts. At the height of construction, the contractor was able to average over 10,000 square feet of deck placement per day!

Working on multiple fronts was not unique to deck construction. The extremely aggressive schedule associated with the project required the contractor to incorporate this philosophy on all aspects of construction. Meeting the schedule also required a great deal of manpower. Leading up to first deadline, TSF had over twenty cranes on site and a work force of over 350 people working day and night to complete the first bridge. This deadline was met on December 19, 2006 when all traffic was shifted to the new bridge.

After opening the eastbound bridge, the contractor had just 12 short months to finish the second bridge. To complete the second bridge, a large portion of the existing bridges needed to be demolished and shipped out to the bay, were the material was used to create a fishing reef. The westbound bridge was also finished ahead of the milestone date when it was opened to traffic on December 12, 2007. Even with all of the resources dedicated to the construction of the I-10 replacement, achieving the goals mandated by FDOT was a monumental task. From the day notice to proceed was given, meeting the project deadlines required an average of over 2,000 square feet of bridge be constructed per contract day!

Figure 19 – Demolition of Existing Bridges

CONCLUSION

The main advantage to utilizing a design-build approach for the replacement of Interstate 10 over Escambia Bay was its ability to tackle the extremely fast-paced schedule associated with the project. Having just 21 months to design and build the first bridge and another 12 months to finish the second, a traditional bid-build project simply could not have kept pace.

Constant communication between team members was instrumental to accomplishing these goals. By involving TSF in the design process, a set of plans could be delivered that best fit their means and methods. The sharing of ideas assured that the owners concerns could be met while providing a quality product to the state of Florida both efficiently and in record time.

Interstate 10 provides the traveling public a vital link between Florida and the southeastern United States. Interstate 10 functions as a major corridor for the delivery of goods and services, and also as an essential evacuation route. The importance of re-establishing this link could not be said more simplistically and truthfully than as stated by the former governor of Florida, Jeb Bush, at the ribbon cutting ceremony for the eastbound bridge, “This was a big damn deal!” These bridges will stand as a testament to what can be accomplished when a crisis challenges the tenacity and perseverance of the bridge building community.

Figure 20 – New Interstate 10 Bridges Open to Traffic