DESIGN OF THE PRECAST SEGMENTAL I-95/I-295 NORTH INTERCHANGE, JACKSONVILLE, FL

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ABSTRACT

The I-95/I-295 North Interchange Project is located north of the City of Jacksonville, Florida. Construction of a new third level ramp bridge which will carry traffic from southbound I-95 to eastbound I-295 is currently underway.

The typical section consists of two 12'-0" wide lanes of traffic. The overall width between the bridge copings is 49'-1".
The bridge is a ten-span continuous unit. The length of the new bridge is 2256'-4" as measured along the centerline of the precast box girder. The corresponding span lengths are: 170' - 229' - 274 - (4 x 249'-10") - 261' - 206' - 117'. The horizontal alignment is on a left horizontal curve of 1250' baseline radius.

The precast segmental box girder has a single cell variable depth box. Box depth varies from 9'-6" at midspan to 12"-0" over the piers. The 10-span bridge is made continuous by longitudinal post-tensioning tendons, with field-cast closure pours near the center of each span. The construction method is the balanced cantilever method.

The paper will discuss an economical design solution for bridges with limited amount of precast segments.

Keywords: Precast, Segmental, Post-tensioning, Balanced cantilever, Box girder

INTRODUCTION

The Florida Department of Transportation is undertaking an extensive reconstruction of the north interchange of I-95 and I-295. The City of Jacksonville has three major interstates providing access in and around the city. I-95 is the north-south interstate running through downtown Jacksonville and I-10 is the east-west interstate beginning near downtown heading west. I-295 begins south of the city at I-95 and loops to the west to bypass downtown and intersects again with I-95 north of Jacksonville. The I-295 designation ends east of the northern interchange with I-95 and is designated as State Road 9A east of I-95. I-95 connects the eastern shore of Florida, linking Jacksonville in the north with Miami in the south. A map of the project location is shown in Figure 1.

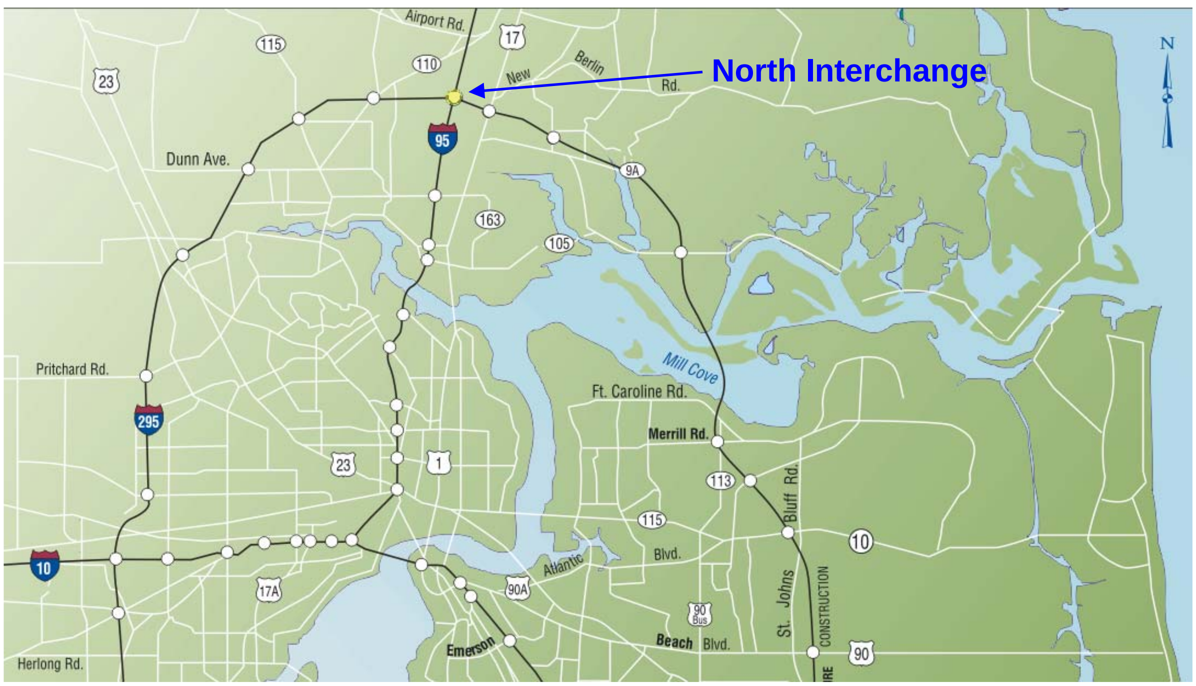

Fig. 1 Project Location

The project is located approximately one and a half miles south of the Jacksonville International Airport and is the first major interchange southbound travelers will encounter heading into or around Jacksonville. The existing partial cloverleaf interchange is being upgraded to an all-directional four-leg interchange which will allow higher capacity with higher design speeds as shown in Figures 2 and 3.

The I-95/I-295 North Interchange reconstruction project will be undertaken in three main phases. Phase 1 will construct a new third level bridge carrying Ramp SE traffic from southbound I-95 to eastbound I-295 and widening the existing bridge on SR 9A (I-295) in the SB (EB) direction over US 17 and the CSX Railroad.

Fig. 2 Existing Interchange

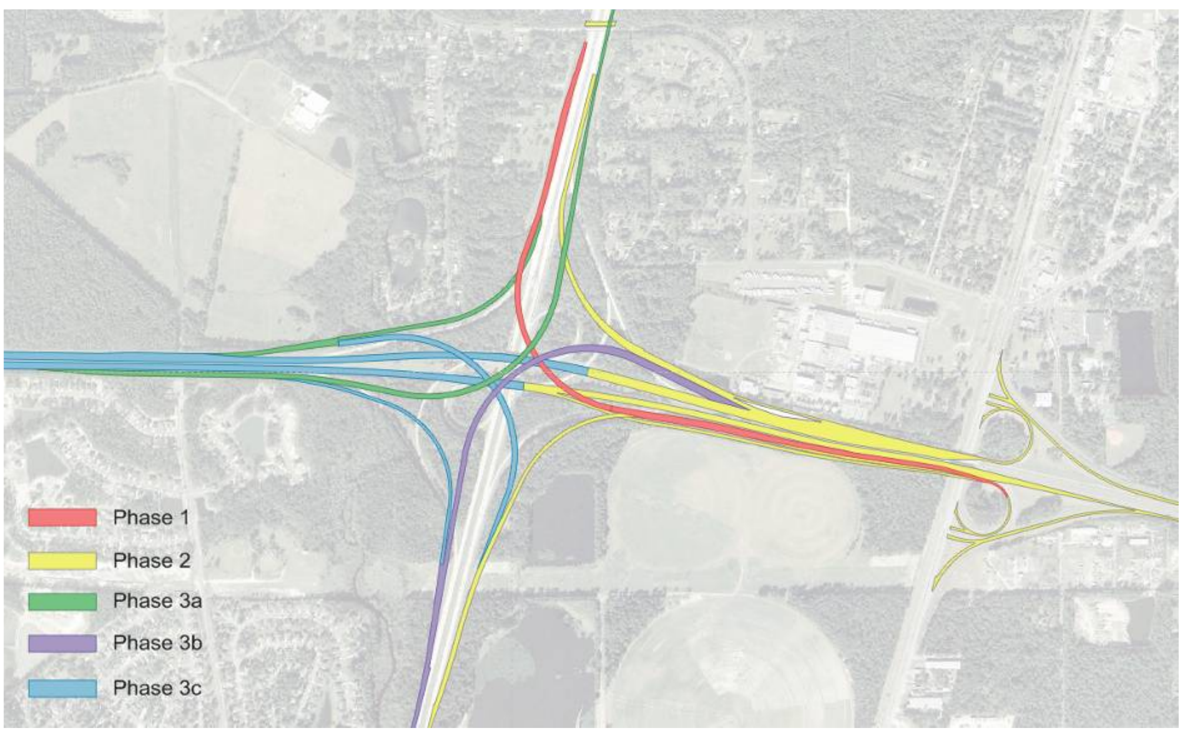

Fig. 3 North Interchange Reconstruction

BRIDGE SELECTION PROCESS

During the initial bridge type study, three types of superstructures were considered, including the concrete box girder, steel box girders and steel plate girders. Ultimately, only two of the types met the District's aesthetic requirements for this project. The two structures identified for further analysis included the steel box girder alternate and segmental concrete box girder alternate.

GEOMETRIC REQUIREMENTS

The span arrangement was similar for both superstructure alternatives and was primarily dictated by the existing features of the interchange. The bridge has a maximum span length of 274'-0 and the vertical profile was set to satisfy the required minimum vertical clearance of 16'-6". The new Ramp SE bridge rises above I-95, existing ramps and I-295 to become the third level structure in the interchange as shown in Figure 4. The structure is a ten span bridge over 2250 feet in length. The bridge has a horizontal curvature of over 90^{o} with a radius of 1250 ft.

The typical roadway section consists of two 12'-0" wide lanes of traffic, with 12'-0" wide outside and 10'-0" wide inside shoulders, flanked by 32" F Shape traffic railing barriers. The overall width of the bridge is 49'-1".

Fig. 4 Third Level Structure (Ultimate Configuration)

BRIDGE EVALUATION

The principal issues that contribute to a well-designed Ramp SE structure at the I-95/I-295 Interchange are cost, constructability and aesthetics. Based on these criteria, an evaluation matrix was used to examine the proposed superstructure alternatives. Assessing the relative importance of the principal issues and the ranking of the alternatives requires subjective judgment based on values, experiences and coordination with the FDOT. The preferred structure choice had the most favorable combination of the above criteria.

Preliminary quantities were calculated for each superstructure alternative and the proposed substructure systems. These quantities were then multiplied by the unit prices to estimate the cost for the bridge. Unit prices used were chosen using the FDOT Pay Item Average Unit Cost Reports, estimated costs from the Department's Structures Design Guideline manual as well as discussions with FDOT personnel in the Central Office.

It is generally assumed that concrete superstructures are the most economical choice for the state of Florida. However, in this case, the cost of the concrete alternative was higher than usual for a concrete superstructure due to the precast segmental nature of the system. The cost of casting the segments is inherently linked to the number of segments cast for any given project. Two different sizes of square precast prestressed concrete piles and two different sizes of drilled shafts were evaluated as foundation systems.

Each superstructure alternative presents different constructability issues. The steel alternative is generally thought to be more constructible since the steel superstructure is lighter than the precast concrete alternative and may be delivered in smaller sections which can be field spliced. As a result, the cranes required to lift the girders into place may be much smaller than the ones required for the precast concrete elements. The precast segmental alternative is more complicated than the steel alternative due to the fact that the segments are heavier and the balanced cantilever construction requires a strong-back system and post-tensioning for erection.

The substructure system for the concrete segmental alternative offers a few advantages over the system for the steel alternative. The substructure system for the concrete segmental alternative is comprised of single column piers which make it similar to the most common substructure systems throughout the state, and therefore presents no major complications to an experienced contractor. On the other hand, the substructure system for the steel alternative includes hammerhead piers, one integral pier and one integral cap pier (beams are integral to cap but cap is not integral to column). Even though the hammerhead piers are simple to construct, the two integral components included in the system present a higher degree of difficulty since post-tensioning is required in the caps.

A greater emphasis was given to aesthetic elements for this project. The evaluation of aesthetics is perhaps the most subjective element in the design process. The alternatives presented in this report offer improved aesthetics while minimizing increases in total construction cost.

Both alternatives met the aesthetic requirements for the project and posed relatively few constructability problems. The total estimated construction cost for the precast segmental alternative was approximately 5% percent lower than the steel alternative; therefore, the segmental concrete box girder bridge was the chosen alternative for Ramp SE. Due to their lower cost, the 30" square piles were the chosen as the foundation system. A summary of the evaluation matrix is shown below in Table 1.

Table 1 Evaluation Matrix

Item	Concrete Segmental Box Girder	Steel Box Girders
Estimated Cost	√	
Constructability		√
Aesthetics	√	√

CONSTRUCTION BIDS

The project was let in April 2007. Superior Construction came in as the low bidder and was awarded the contract. Construction began in October of 2007 and is scheduled to be competed by mid 2010. The bids for the bridge portion of the contract from the different contractors are shown below in Table 2.

Table 2 Construction Bids

Item	Bids
Engineer's Estimate	$43,165,480
Superior Construction	$45,082,580
Contractor 2	$46,637,655
Contractor 3	$47,336,650

DESIGN CONSIDERATIONS

Design considerations included aesthetics, superstructure design, post-tensioning protection, and substructure design.

AESTHETICS

Since the structure will be a third level flyover structure, an aesthetically pleasing structure was required by the Department. The underside of the structure will be visible as drivers travel underneath the structure on interstates I-95 and I-295. With the closed box shape, clean lines and smooth bottom soffit, the precast segmental concrete box girder was the most aesthetically pleasing choice. As an added benefit, the south I-95/I-295 Interchange also used a concrete box girder bridge, thus helping to tie the two interchanges together, creating a uniform design concept.

To further enhance the aesthetics of the bridge, octagonal columns were used and the capitals were flared at the top, matching the slope of the webs of the box girder. The tapered shape of the capital provides an elegant transition between the box girder and the supporting column as shown in Figure 5.

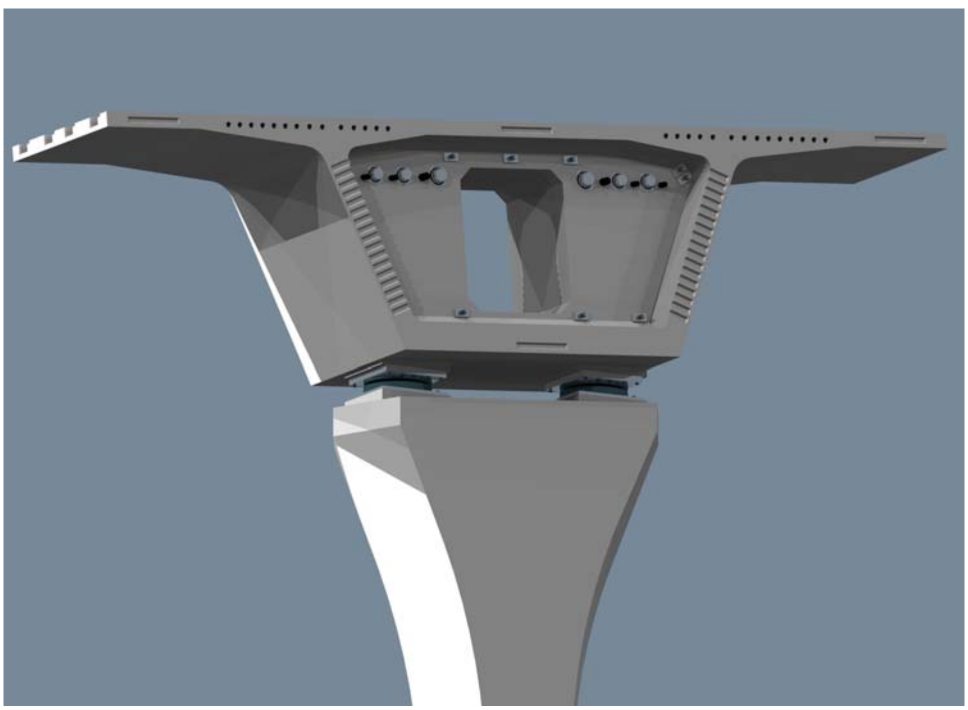

Fig. 5 Box Girder with Tapered Pier Capital

SUPERSTRUCTURE DESIGN

The bridge is a ten span continuous structure totaling 2256 feet in length. The span arrangement is shown in Figure 6 with spans ranging between 117’-0” and 274’-0”. The bridge is comprised of 234 precast segments and is being constructed on a horizontal curve with a radius of 1250 ft measured to the baseline. The bridge uses the balanced cantilever method of construction and will be erected using ground based cranes as shown in Figure 7. The bridge was designed according to the 2004 AASHTO LRFD Bridge Design Specifications (3rd Ed.)[1] and the July 2005 FDOT Structures Manual[2]. CEB-FIP Model Code 1990 was used for the time-dependent behavior analysis.

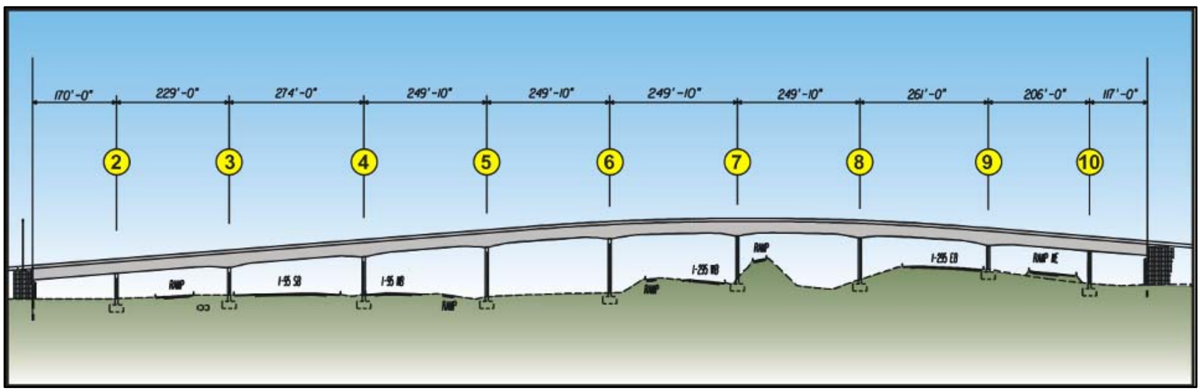

Fig. 6 Span Arrangement

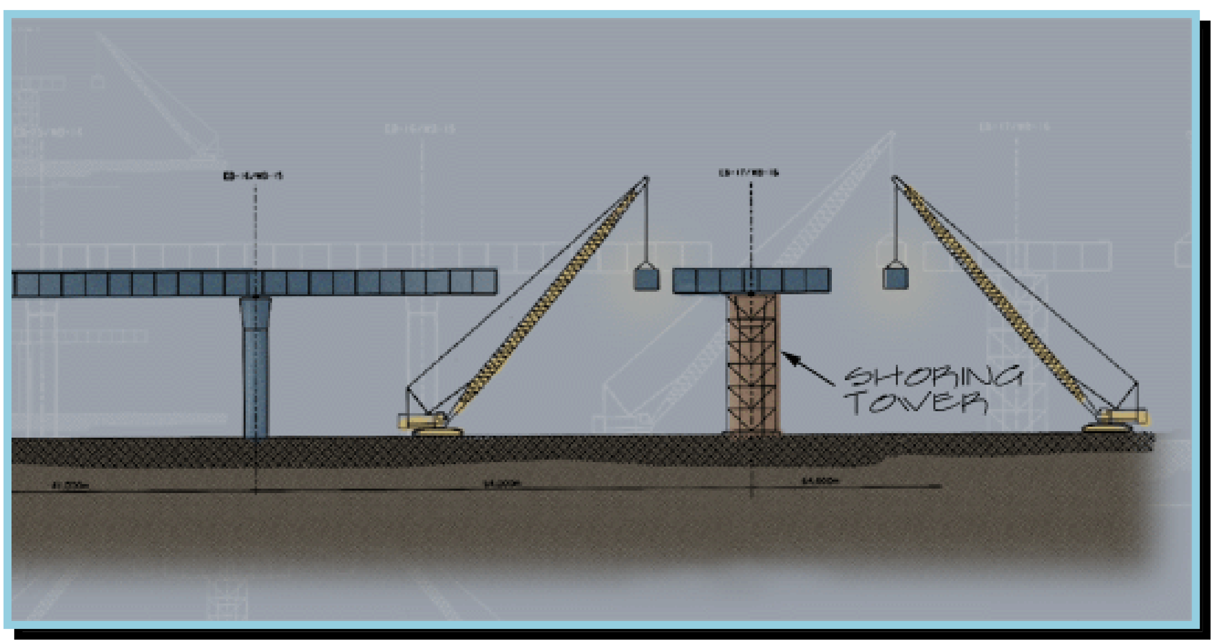

Fig. 7 Balanced Cantilever Construction

The typical box girder segment, shown in Figure 8, has a depth of 9’-6” and a width of 49’-3”. Variable depth segments are used at the piers with the depth increasing to 12’-0” to accommodate the longer spans; however the piers adjacent to the end spans did not require the additional depth and were not increased. The depth of the typical segment was controlled by the 170’-0” end span while the 274’-0” span controlled the depth of the 12’-0” pier segments. The variable depth transition occurs over 6 segments to each side of the pier table as shown in Figure 9. Bottom soffit thicknesses were increased near the pier segments for increased negative moment capacity. The box section is also transversely post-tensioned in the top slab to ensure a superior, crack free-deck and riding surface and adds a ½” thickness to the top slab for profilographic grinding to improve the riding surface.

To reduce the required lifting capacity of the erection cranes, split pier segments were used. Pier segments are initially held together by temporary PT bars before post-tensioning strands are installed.

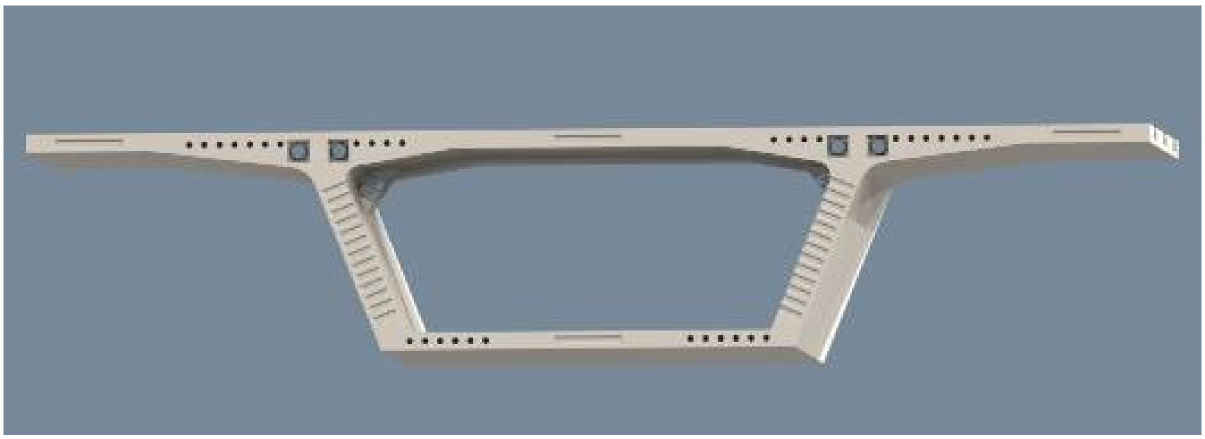

Fig. 8 Typical Segment

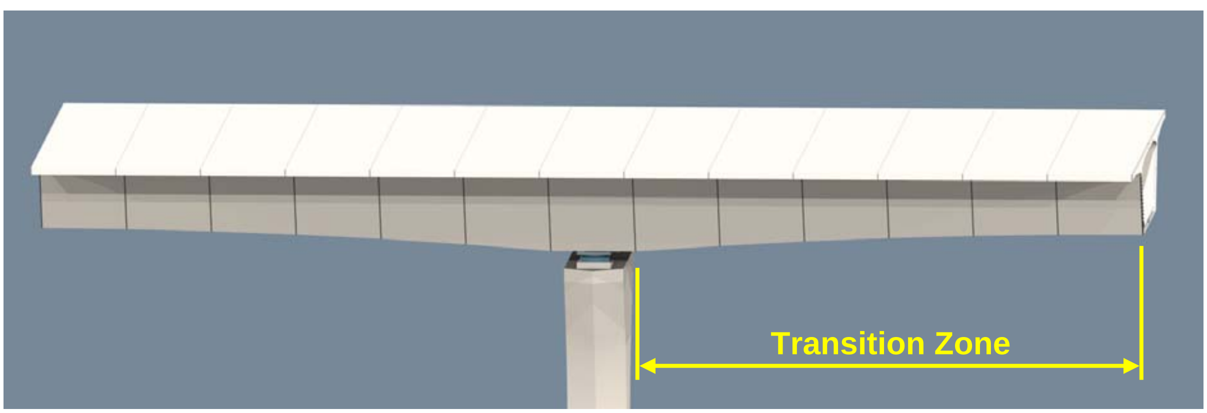

Fig. 9 Variable Depth Segments

During erection, segments are held in place using post-tensioning bars located at the top and bottom of the segment. The PT bars are tensioned enough to evenly compress the epoxy at the joints of the precast segments. Top PT bars are anchored in external blisters so that the bars can be removed and reused as shown in Figure 10. The bottom soffit PT bars are internal except in the variable depth segments where external blisters are used as shown in Figure 11. The bottom PT bars were made external in this region to eliminate potential spalling that can occur due to the radial force that develops due to the angle changes in the bottom soffit. Once the box depth becomes constant, PT bars are made internal where they contribute to the positive moment capacity of the section.

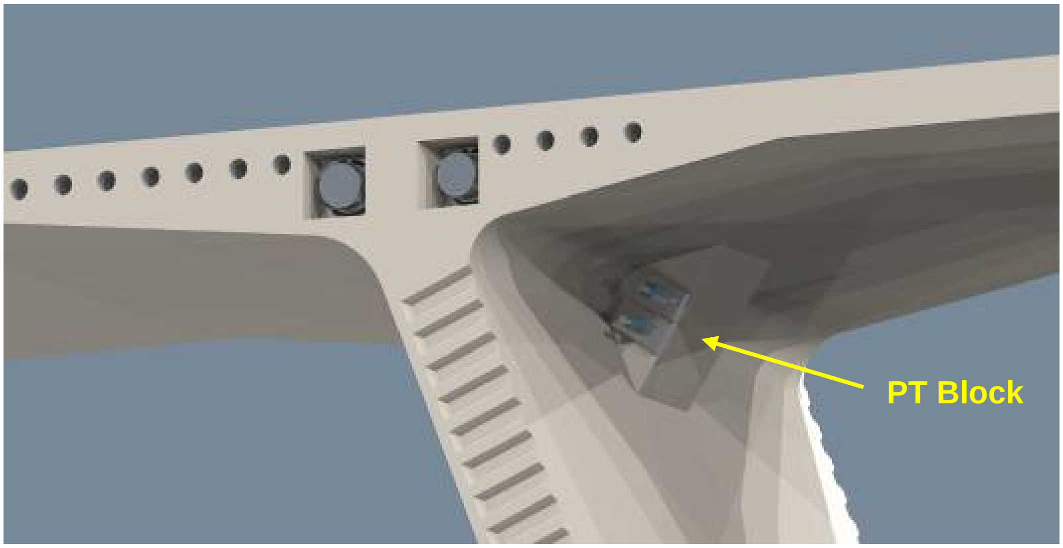

Fig. 10 Top Slab Erection PT Blocks

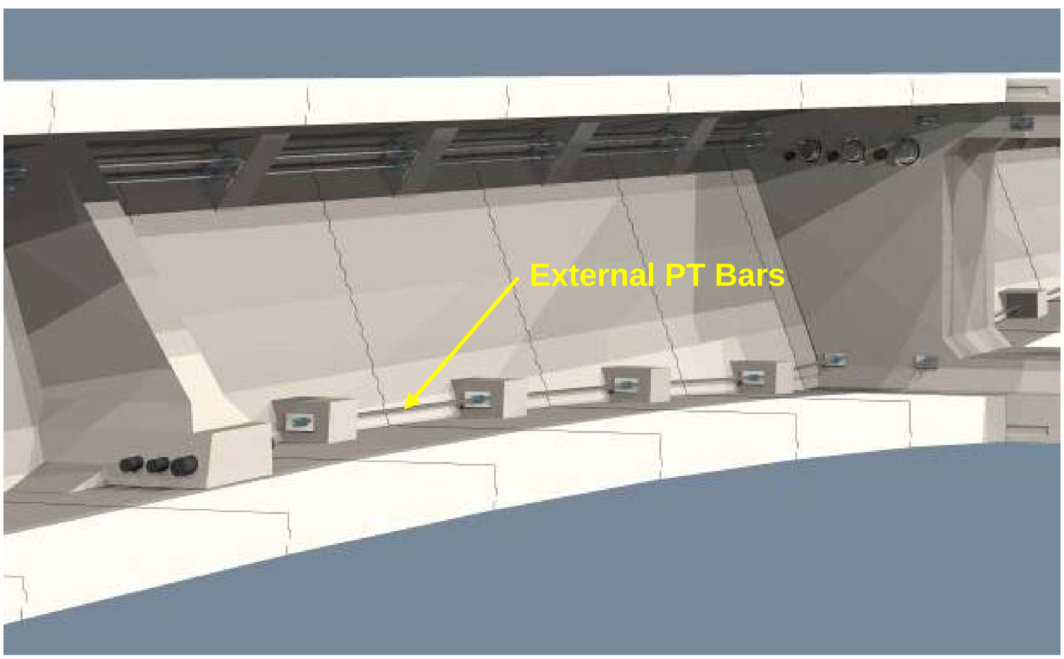

Fig. 11 External Erection PT Blocks in Bottom Soffit of Variable Depth Segments

Post-tensioned bridges designed according to FDOT design guidelines must meet minimum tendon requirements. Applicable requirements for this project are shown in Table 3.

Table 3 FDOT Minimum Tendon Requirements

Bridge Element	Requirement
Midspan Closure	Bottom Soffit – two tendons per web Top Slab – one tendon per web
End Span Units	3 tendons per web
External Draped Tendons	2 tendons per web

Deviator blocks were used to direct the externally draped tendons and were sized to accommodate a future post-tensioning tendon. All post-tensioning tendons are comprised of 12-0.6” diameter strands. Provisions for the future post-tensioning will accommodate a tendon up to 19 strands. FDOT requires the use of full height deviators to transfer load to the box section. Where necessary, bottom soffit blisters and PT bar erection blisters were incorporated into the deviators as shown in Figure 12.

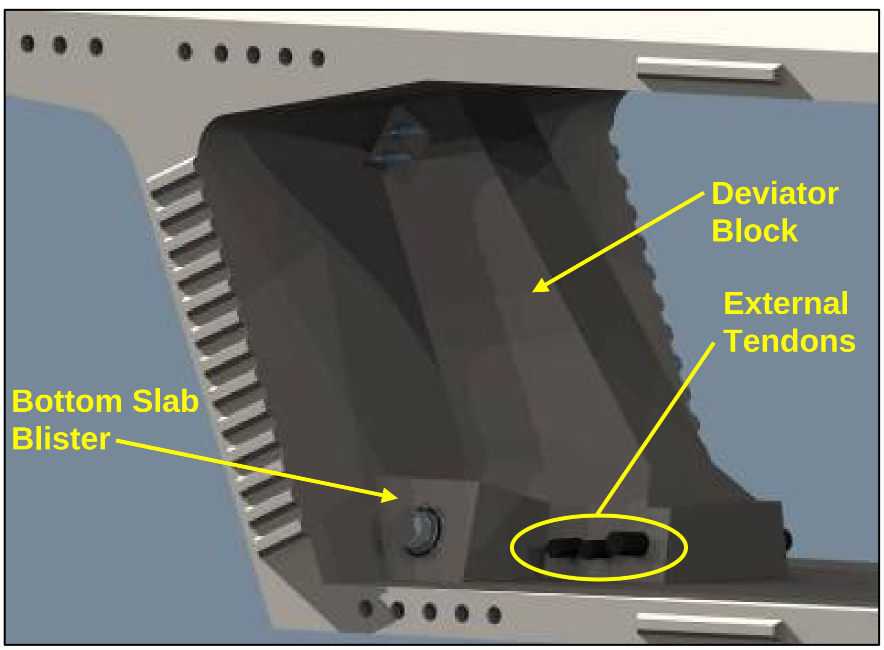

Fig. 12 Tendon Deviator

POST-TENSIONING PROTECTION

The post-tensioning system is designed to meet FDOT's stringent tendon protection requirements. The requirements utilize the multiple protection concept. The requirements adopted by the State of Florida are in response to several cases where severely corroded tendons were found in bridges around the state.

In addition to stringent specifications for grout and tendon ducts, the Department requires designers to provide four layers of protection at all tendon anchorages. For internal anchorages not exposed to the outside elements, such as interior diaphragms, the four layers are provided by the box section itself, grout, a permanent grout cap and an elastomeric coating as shown in Figure 13. At anchorages exposed to the elements; grout, a permanent grout cap, grout pour-back and an elastomeric or methyl methacrylate coating provide the four layers of protection.

Strands not at anchorages require three layers of protection. Internal tendons are protected by the concrete cover, plastic duct and grout while external tendons are protect by the hollow box itself, plastic duct and grout.

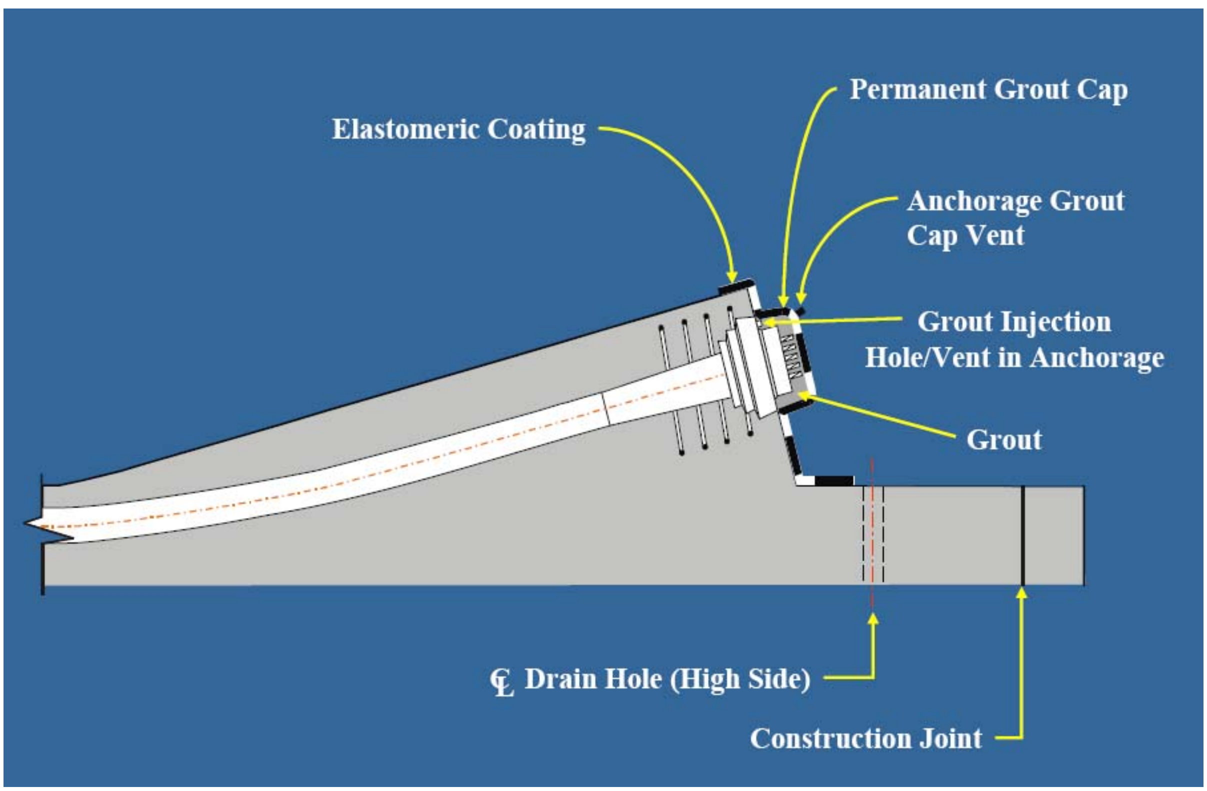

Fig. 13 Multilayer Protection of Internal Tendon Anchorage

SUBSTRUCTURE DESIGN

The superstructure rests on pot bearings, of which four of the nine interior piers are fixed against longitudinal movement. Hexagonal shaped columns were used to support the bridge. Not only does the hexagonal shape provide a visually appealing form, the shape was also chosen to maximize the strength of the pier. As the bridge curves over portions of I-95, limited horizontal clearance prohibited the use of larger column sizes. To get the most cross-sectional area from the available space, the hexagonal shape offered an ideal shape as the bridge crossed this critical location at a skew. Figure 14 shows a rendering of the typical substructure system used.

Two different sizes of square precast prestressed concrete piles (24” and 30” square) and two different sizes of drilled shafts (36” and 42” diameter) were evaluated as foundation systems. The 30” square piles were selected and conversations with local contractors supported this recommendation. Given the conditions for this project (i.e. number and length of piles), the relative ease of availability of 30,000 lb. hammers (5ft stroke) makes the use of 30” square piles more appealing. Square prestressed concrete piles are commonly used for bridge construction in Florida. These piles offer proven performance and are economically made by several prestressed concrete producers in Florida. A resistance factor of 0.65 was applied to the factored design loads before estimating the pile tip elevations.

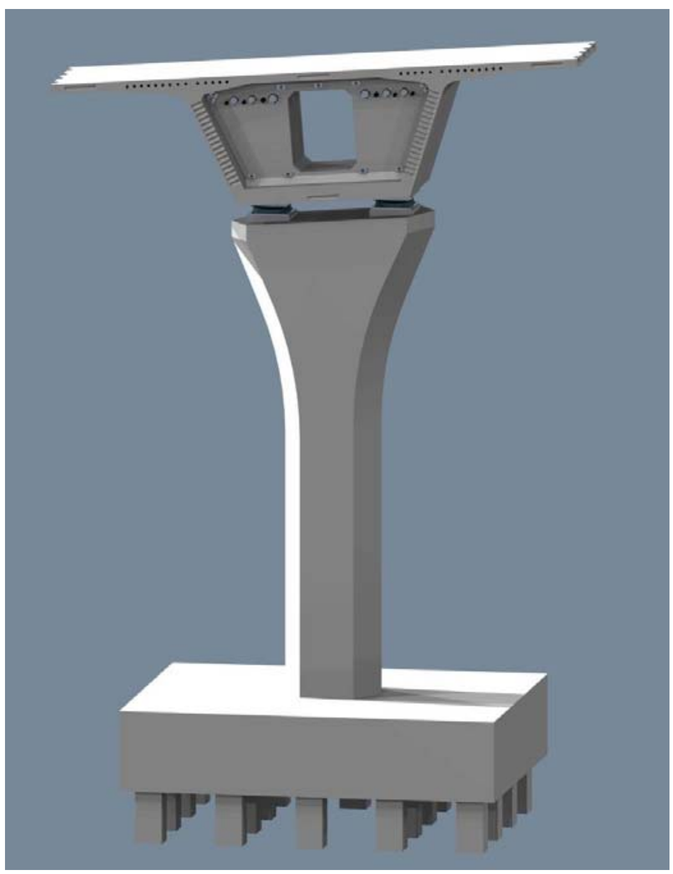

Fig. 14 Substructure

CONCLUSIONS

Designing a competitive precast segmental bridge project with only 234 segments can be a difficult undertaking. However, by using a variable depth box to minimize concrete, splitting the pier segments to reduce the maximum lift weight and using clean yet simple shapes for the bridge elements, an aesthetically pleasing bridge can be achieved.

REFERENCES

1. American Association of State Highway and Transportation Officials (AASHTO), "*LRFD Bridge Design Specification,*" 3rd Edition, 2004.
2. Florida Department of Transportation (FDOT), "*Structures Manual,*" July 2005.