Innovative Use of Precast Aids the Design and Construction of the SB I-95 to EB SR-202 Flyover Bridge in Jacksonville, FL

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ABSTRACT:

The SB I-95 to EB SR-202 Interchange Flyover Bridge is part of a design-build project in Jacksonville, FL to redesign the traffic interchange at I-95 and SR-202. The interchange handles heavy traffic volume and was in need of a significant upgrade. The flyover bridge uses precast elements in several innovative ways to provide a signature structure while aiding constructability on a tight jobsite.

The new flyover bridge is a curved, seven span structure on an 1,100 foot radius. It is composed of two units with expansion joints at each abutment and at interior Pier 5. Two lines of curved precast U-girders, post-tensioned for continuity, support the superstructure. The substructure consists of six single column piers with two CIP and four precast pier caps. The precast caps are designed to support the girders during construction at jobsite locations with no room for falsework. Each unit has significant sections that are constructed over traffic which utilize straddle frames and strong back supported from cantilevered girders during erection. The design of the superstructure was significantly impacted by the construction methods and tight clearance requirements necessary to accommodate maintenance of traffic.

Keywords: Creative/Innovative solutions and structures, Curved girders, Spliced girders, Post-tensioning, Design-build, Precast substructure

INTRODUCTION

The intersection of Interstate Highway 95 (I-95) and State Route 202 (SR-202) is a major traffic interchange south of downtown Jacksonville, FL. I-95 carries the flow of north/south traffic through the heart of Jacksonville, while SR-202, also known as JT Butler Boulevard, carries east/west traffic to beaches on the Atlantic Coast. Both roads carry significant commuter traffic through the greater Jacksonville area.

In 2014 the Florida Department of Transportation awarded a design-build contract to redesign and construct the I-95 and SR-202 Interchange. The team of SEMA Construction and Horizon Engineering Group was awarded the project. Summit Engineering Group was contracted as a subconsultant to Horizon to design the SB I-95 to EB SR-202 Flyover Bridge. In addition, Summit contracted with SEMA to serve as the contractor's construction engineer for the entire project. This unique position allowed Summit to tailor the design and staging of the flyover bridge in such a way as to accommodate the unique construction challenges identified by the design-build team.

Fig 1: Flyover Bridge During Construction

The project consists of four total bridge structures, new ramp configurations, new highway alignments, and roadway widening of both I-95 and SR-202. The total project value is $66.7 million. The project was completed and fully opened to traffic in September 2017.

As mentioned previously, Summit Engineering Group is the EOR for the SB I-95 to EB SR-202 Flyover Bridge, also referred to as the Flyover 1 Bridge. This is a new ramp bridge designed to alleviate the traffic jams and traffic safety issues caused by the previous configuration. Prior to completion of the Flyover 1 Bridge, traffic from SB I-95 going to EB SR-202 exited the highway to a traffic light intersection. During peak travel times traffic would back up onto I-95 for up to a mile, creating long commute times and safety issues for the travelling public.

The new Flyover 1 Bridge is a seven span, 1342 ft long structure. There are two superstructure units, with expansion joints at each end bent and Pier 5 on the interior. Unit 1 has four spans with a total length of 767 ft. Unit two has three spans with a total length of 575 ft. It has a 47'-6" overall width that accommodates two 12 ft wide travel lanes plus 8 ft and 12 ft shoulders. The structure is curved on an 1100 ft radius and span lengths vary from 140 ft to 232 ft. The superstructure is composed of curved spliced precast concrete U-girders that are post-tensioned for continuity. There are two girder lines with 84" constant depth precast sections that support a 9" thick deck, which includes a 1/2" sacrificial depth for grinding and wear. The substructure consists of single column piers supported on prestressed pile foundations. Of the six interior piers, four utilize precast concrete pier caps that allows construction to take place with minimal falsework as required by the site conditions.

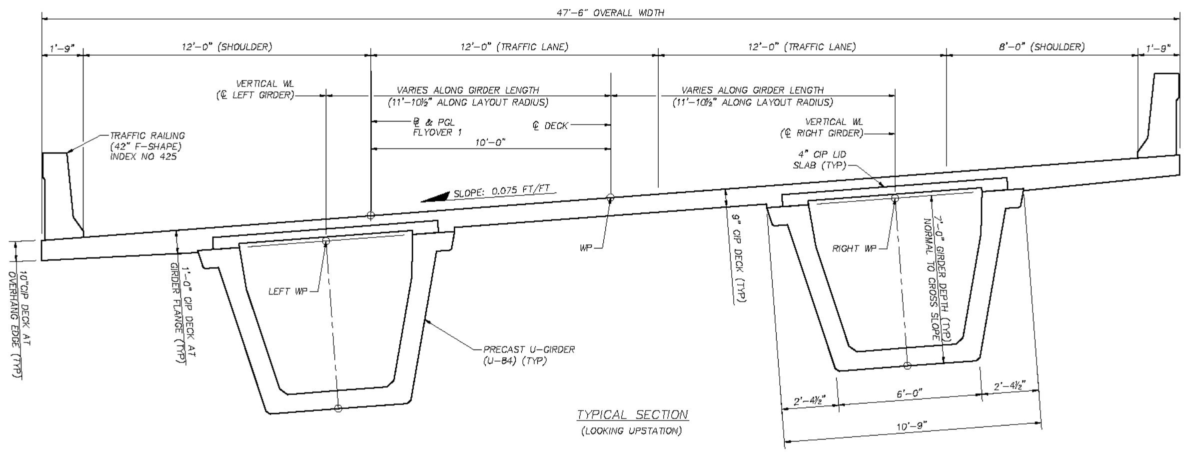

Fig 2: Typical Superstructure Section

SITE CONDITIONS AND CONSTRUCTION CHALLENGES

The SB I-95 to EB SR-202 Flyover Bridge is constructed over three major traffic crossings: SB I-95, NB I-95, and WB SR-202. During construction FDOT required that all lanes remain open to traffic. Only overnight lane closures were allowed, providing 6 to 8 hour windows for all of the construction and erection procedures that needed to occur in traffic areas. In order to facilitate construction, the Maintenance of Traffic (MOT) plan was integral to the success of the project. Therefore, several traffic shifts were executed to open up different areas of the project site for construction while maintaining all of the travel lanes as required by FDOT.

In order to accommodate the constant flow of traffic through the jobsite, Summit incorporated several innovative features into the bridge design. The design incorporated precast pier caps at the interior piers. These locations were adjacent to traffic during construction, so using temporary shoring to support formwork was not an option. The precast pier caps were cast by the contractor on site with a central blockout to form a CIP connection with the column.

Fig. 3: Precast Pier Cap Erected onto Temporary Falsework

The precast pier caps also served to support the pier girders during construction, eliminating falsework towers within the traffic zone. The pier girders were erected onto temporary falsework towers at one end and supported on the precast pier cap with large cantilevers. At Pier 2, 96’-6” ft long pier girders were erected with a 45 ft long cantilever. Precast barrier sections were temporarily placed in the pier girder back span as a ballast load to provide a sufficient factor of safety against overturning during construction.

Fig. 4: Precast Pier Cap Supports Pier Girder During Construction

Summit Engineering designed a modular temporary falsework system to support the girders during erection. The towers were designed in 12ft, 16ft, and 20ft modular heights that can be bolted together in many different combinations to achieve the required tower heights.

Due to the geometry of the site and the active traffic lanes, minimizing the amount of falsework towers was a key component in the design of the Flyover 1 Bridge. The cantilevered pier girders supported drop-in girders on strongbacks, thus eliminating the need for falsework towers at these locations. The strongbacks connected to the girders through a partial depth diaphragm, supporting them from the top. This strongback configuration helped to provide the minimum vertical clearance over traffic because there was no hardware from the strongbacks projecting below the bottom surface of the girders.

Fig. 5: Drop-in Girder Supported on Strongbacks Over I-95

Span 6 of the Flyover 1 Bridge is one of the longest spans in the structure, at 228’-11” along the structure baseline. Girder shipping weights limited the maximum piece length to 100 ft for pier girders and 115 ft for drop-in girders. Due to the pier locations and site geometry, a single drop-in girder could not span between pier girders in Span 6. Summit designed a temporary straddle bent to support two drop-in girders at the central splice location in this span. The straddle bent spanned approximately 70ft to provide clearance for three traffic lanes.

Fig. 6: Erecting Temporary Straddle Bent Over SR-202

Some of the temporary works, while out of the traffic lanes, were still within the clear zone envelope and required crash protection. Therefore, Summit Engineering designed a crash protection system. This system was installed prior to erecting girders for any falsework support leg within 10ft of a traffic lane. It combined precast concrete traffic barriers with a steel "rub rail" to prevent a truck from overturning over a barrier and crashing into the falsework. The crash protection was required at two locations: a falsework tower adjacent to I-95 and the north tower support of the straddle bent adjacent to SR-202

Fig. 7: Crash Rail Protection Adjacent to I-95 Traffic

SUBSTRUCTURE DESIGN AND CONSTRUCTION

The Flyover 1 Bridge foundations are composed of 24" square prestressed concrete piles driven to an average depth of 100ft below grade. The piles are cast with 6000 psi concrete and pretensioned with 16-0.6 in. strands or alternate strand pattern per FDOT design standards. Test piles were driven and monitored at each bent location to ensure that the required load carrying capacities were achieved. The end bents are designed with a single row of piles that extend into a CIP bent cap. The typical interior piers are designed with a 3 x 5 pile group extending into a 6 ft thick CIP pile cap footing. Pier 3 is located in the median between NB I-95 and SB I-95. To minimize the amount of concrete pavement removal, and to provide sufficient clearance for construction access adjacent to traffic, the pile group was designed as a 4 x 4 layout.

A single CIP column supports each interior pier. The column geometry was controlled by the amount of space in the median between NB I-95 and SB I-95 at Pier 3, leading to a 4 ft by 7 ft rectangular cross section with 1⅝ in deep vertical reveals.

The interior piers use a combination of CIP and precast pier caps. The CIP pier caps are located at interior piers 4 and 5. These piers are designed with slide bearings to accommodate girder movement due to post-tensioning, creep, shrinkage, and temperature. Pier 5 is the expansion pier between units 1 and 2, so slide bearings are required at this location to allow for the expansion movements. Pier 4 is the only interior bearing with slide bearings. All other piers are designed with integral diaphragms. During the design phase Summit determined that bearings were required at Pier 4 to reduce the amount of longitudinal moment in the columns. Locating the slide bearing at Pier 4 adjacent to the Pier 5 expansion joint provided the greatest moment reduction, maximizing the efficiency of the column design.

The CIP Pier caps are constructed with six transverse post-tensioning tendons and designed with 5500 psi concrete. The tendons are comprised of 15-0.6 in 270ksi strands stressed to 659kips each. The post-tensioning is designed to be staged, so as not to overstress the CIP pier cap. After casting the cap and removing the formwork, the first three tendons are stressed and grouted once the concrete reaches a minimum compressive strength of 4500 psi. Next, the girders are erected and the final three tendons are stressed and grouted. After the final tendons are stressed and grouted, the pier diaphragms and deck are cast.

Fig 8: CIP Column and CIP Pier Cap Supporting Precast U-Girders

In addition to the CIP pier caps discussed above, four of the interior piers were designed and constructed using precast concrete pier caps. The precast caps are located at Piers 2, 3, 6, and 7. Tight site conditions adjacent to live traffic drove this design decision. CIP formwork and shoring would have violated both the traffic envelope and the minimum vertical clearance requirements on the project.

The precast caps were cast on site and erected over the CIP columns cast at each pier. They were designed as mildly reinforced for handling and erection, with staged transverse post-tensioning to carry construction and final design loads. There are four 12-0.6in 270ksi strand tendons in each precast pier cap and the 28-day concrete strength is 5500 psi.

Fig. 9: Precast Pier Cap – Blockout with Shear Keys

The column-to-cap connection was designed to transmit out-of-balance loads during girder erection and work in concert with the CIP diaphragms to transfer all composite loads to the column. The precast cap is built with a full depth vertical blockout one inch wider than column cross section dimension in each direction. On the face of the blockout, four rows of C6 channels are installed to create four continuous shear keys around the perimeter. The cap is erected by threading it over the column reinforcement and bearing on temporary support brackets. Once it is in place, 10" long shear studs are welded to the shear key channels and the blockout is cast to complete the connection.

Fig. 10: Column-To-Cap Connection.

Summit designed staged post-tensioning of the caps to facilitate the remaining superstructure construction. After the connection concrete is cast and cured, the first two tendons are stressed. Next the precast girders are erected and then the final two tendons are stressed. In the next stage the integral diaphragm is cast. The diaphragm is designed with three 12-0.6 in. 270 ksi strand tendons, which are stressed prior to casting the deck. The diaphragms at the precast pier caps are designed as integral with the precast caps.

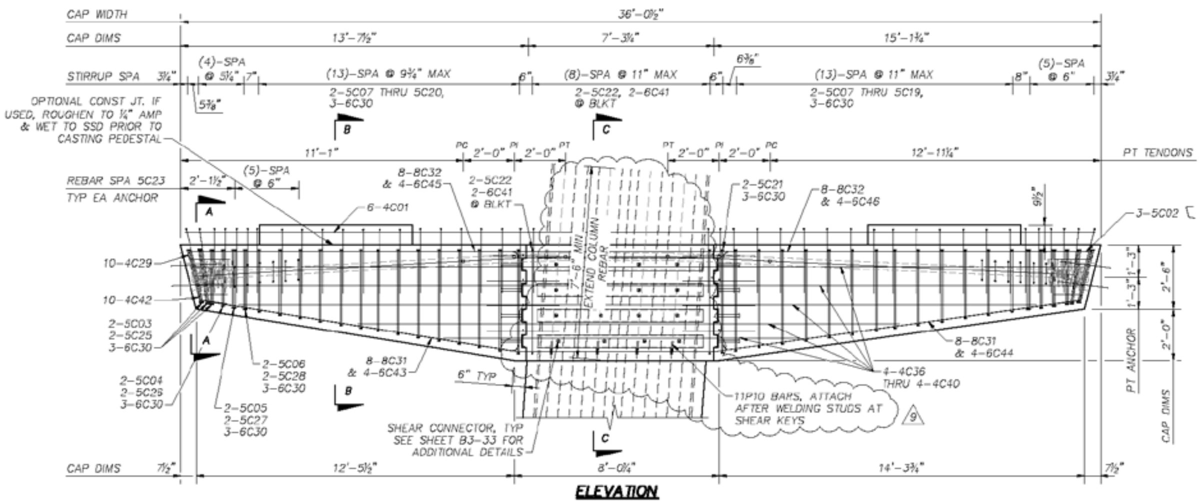

Fig. 11: Precast Pier Cap Elevation.

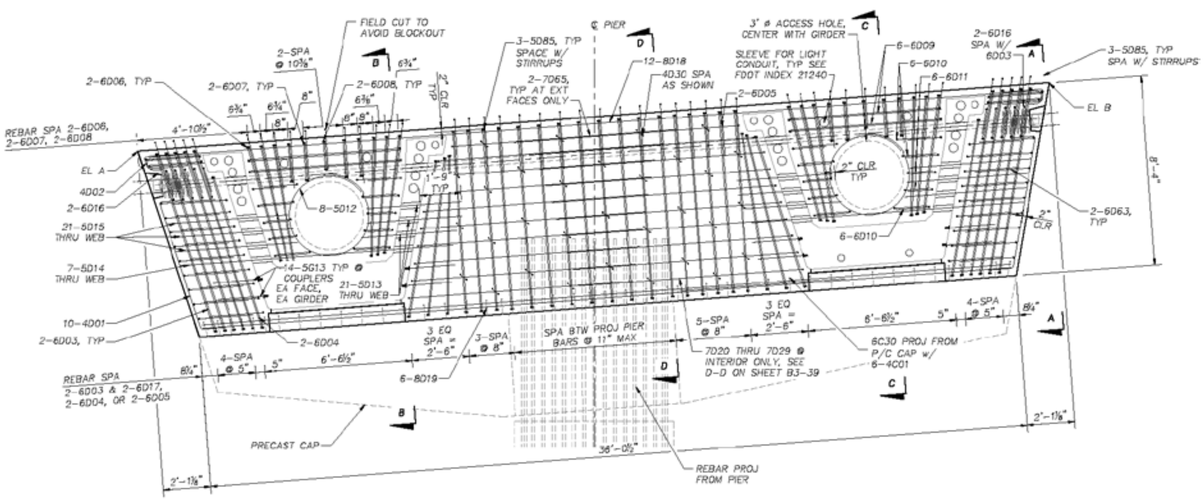

Fig. 12: Integral Pier Diaphragm Elevation

SUPERSTRUCTURE DESIGN AND CONSTRUCTION

The SB I-95 to EB SR-202 Flyover Bridge is composed of precast spliced post-tensioned U-girders. This is the second structure type using this technology designed in the State of Florida, and it is the first project using this technology for the Florida Department of Transportation (FDOT). Summit Engineering designed the structure using time-dependent load-history analysis. Each stage of construction is included in the analysis, and the structure is aged to 30 years to account for long-term creep and shrinkage effects.

The superstructure has two girder lines of 84 in deep precast U-girders spaced at 23’-9” center to center. The structure is curved at a radius of 1100 ft along the baseline. To minimize form changes, both the left and right girders are designed to be cast at an 1110 ft radius, which is the average radius of the two girder lines. For a 100 ft girder segment, this translates to a 3/16 in horizontal girder sweep from the theoretical value. This is less than half of the allowable sweep tolerance per PCI guidelines. It does not significantly affect the design, but allows for vastly increased efficiency in girder production.

Summit Engineering designed the girders for the entire life cycle from casting in the precast yard to final service and ultimate conditions in the superstructure. The girders are designed with a 28-day concrete strength of 8500 psi and a stripping strength of 6000 psi. When initially stripped from the formwork and stored at the precast yard, the girders are mildly reinforced. Handling devices are located at approximately 0.2*L to balance the positive and negative moments when handling the precast section.

Fig. 13: Precast Girders in Storage

The precast girders are comprised of three different girder types: end girder, pier girder, and drop-in girder. All girders are designed with 8 in thick end diaphragms to provide torsional rigidity for handling and for even load distribution into the CIP splices. Both the end girder and drop-in girder maintain the typical cross section through their length. The end girders are constructed with a 4 ft long tongue section that bears the girder weight during construction. The tongue also allows for the posttensioning anchorage hardware to be cast in a CIP diaphragm at the end bents. The pier girders have a variable thickness bottom slab to provide sufficient area for the negative moment compression block over the piers. Designing the thickened slab to be internal to the girders allowed the designer to maintain a constant girder depth in order to simplify precast forming and to minimize shipping weights for the pier girders.

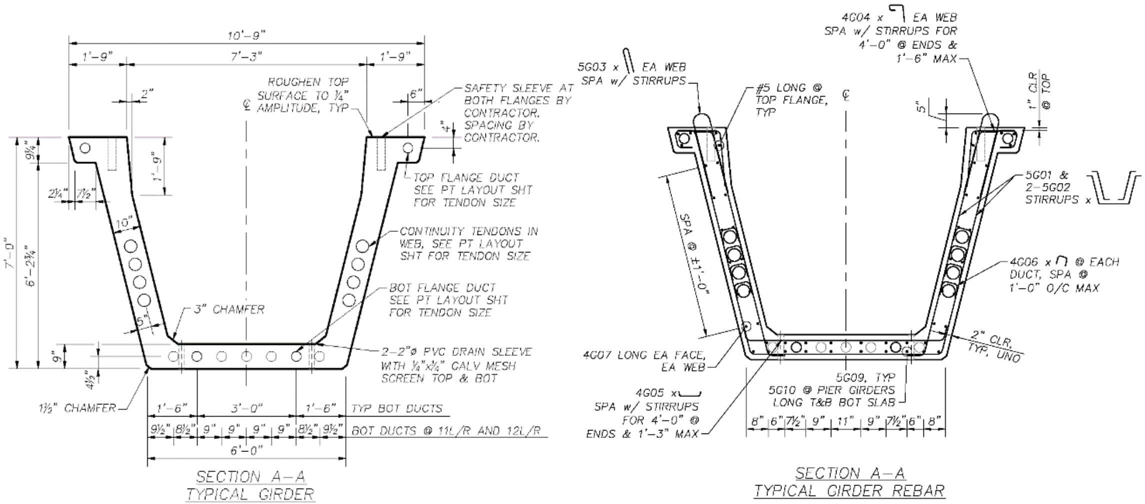

Fig. 14: Precast Girder Details – Typical Section and Reinforcement

After stripping the girders, post-tensioning tendons are installed in the precast yard to control concrete stresses during shipping and erection. The end and drop-in girders have two tendons in the bottom slab to control positive moment stresses and to allow handling from the lifter at the girder ends during erection. Allowing for different handling locations in the plant and at the jobsite allows for greater flexibility in crane placement. The pier girders are designed with two tendons in the bottom slab and two tendons in the top flanges. The bottom slab tendons control positive moment stresses and to allow handling from lifter at the girder ends during erection, while the top slab tendons provide reinforcement and stress control for the large cantilevers of the pier girders during erection.


Fig. 15: Tongue Section at End Girder

Due to the tight geometric constraints of the jobsite and the requirement to keep all traffic lanes open, construction staging was a very important part of the superstructure design. Because Summit was in the unique position of being the EOR for the Flyover 1 Bridge and the specialty construction engineer for the contractor, we were able to coordinate the means and methods of the contractor with the superstructure design. Special blockouts and embedments required for girder erection were considered in the design and incorporated into the precast girder shop drawings. This coordination proved very valuable in maintaining a fast construction schedule.

MOT requirements made it necessary to design strongbacks and a temporary straddle bent to support girders over traffic. Summit was able to coordinate with the contractor to use existing materials for these elements, saving time and material cost.

In order to erect the drop-in girders, all other girders in the superstructure unit must be erected with splices cast, lid slabs poured, and partial-length continuity tendons stressed. This required a detailed erection sequence and coordination among the contractor, precaster, and post-tensioning subcontractor to minimize schedule impacts.

Fig. 16: Precast Girders Supported on Straddle Bent Over SR-202

CIP lid slabs are cast on the girders after erection and prior to applying post-tensioning. Casting the lid slab on site minimizes the girder weights for shipping, allowing for longer girders and less falsework. Prior to casting the lid slab, the U-girder is an open cross section that is susceptible to torsional cracking. Summit analyzed the girder sections to ensure that torsional cracking would not occur due to placement of the lid slab concrete.

Fig. 17: CIP Lid Slabs Cast in the Field

Once the lid slab cures, the torsional stiffness of the cross section is increased significantly, up to a factor of 100 times the open section. The stiffer section is able to resist all continuity post-tensioning loads and torsion loading caused by the wet weight of the CIP deck.

The cantilever sections of the pier girders range from 28 ft to 45 ft from end of girder to center of pier. The drop-in girders were up to 115 ft long, weighing over 300 kips each. Prior to erecting the drop-in girders, partial-length continuity tendons were stressed and grouted to supplement the top flange tendons which were stressed in the precast yard. This provides sufficient reinforcement for the cantilever to support the drop-in girders. In order to accommodate the stressing hardware and reinforcement in the precast, Summit designed blockouts in the top flange. Each blockout is cast back with a secondary pour that contains the post-tensioning anchorages and reinforcement. Similarly, the drop-in girders were cast with blockouts and secondary pours to accommodate the strongback diaphragm. The strongback diaphragm is partial depth and is designed to attach the steel strongbacks with no hardware protruding beneath the girders. This design helps maintain the required vertical clearance for traffic at the jobsite when the girders are erected.

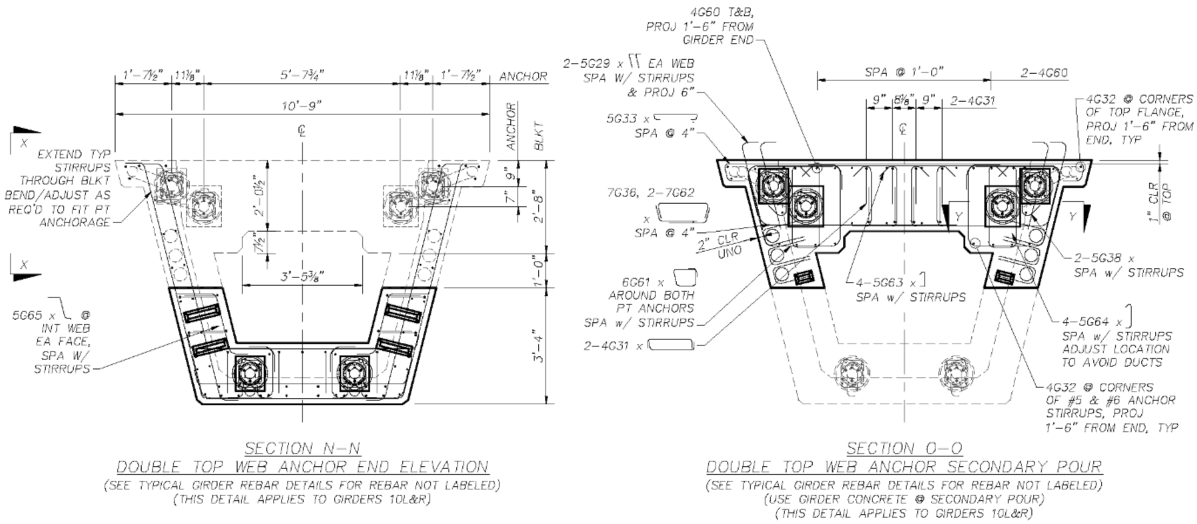

Fig 18: Blockout and Secondary Pour for PT Anchor Zone

After erecting the drop-in girders, the final closures are cast and the continuity post-tensioning is stressed in each superstructure unit. Secondary diaphragms are cast at the End Bents 1, 8 and Pier 5 to provide protection and concrete cover for the post-tensioning anchorages. The deck is reinforced longitudinally with #6 bars spaced at 3 in. over the piers for negative moment and #4 bars spaced at 6 in. at the positive moment regions. The deck casting is sequenced to cast positive moment regions first and negative moment regions last in order to minimize the potential for deck cracking.


Fig 19: Precast Girders Supported on Strongbacks

CONCLUSION

The design and construction of the SB I-95 to EB SR-202 Flyover Bridge is an excellent example of the versatility of precast concrete construction. Precast concrete designs can provide innovative and unique solutions to many bridge design challenges. The project was a collaboration among all stakeholders to deliver a high quality structure while improving local traffic needs for years to come. The curved, precast post-tensioned U-girders are a perfect solution for this flyover bridge structure, providing a beautiful aesthetic with comprehensive engineered solutions.