DESIGN AND CONSTRUCTION OF I-4/S.R. 408 INTERCHANGE

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ABSTRACT

The SR 408/I-4 Interchange in Downtown Orlando is one of the most heavily utilized corridors in Florida. The convergence of these two major transportation corridors yields an annual average daily traffic volume of over 300,000 vehicles resulting in a Level of Service F. As a result, a massive reconstruction effort is being undertaken jointly by the Florida Department of Transportation (FDOT) and Orlando-Orange County Expressway Authority (OOCEA) to improve the traffic flow at this location. This is being accomplished through the development of a new ultimate four-level interchange comprised of multiple flyovers. The interchange improvements will be completed in two phases, an interim contract currently under construction and an ultimate build-out of the multilevel interchange. The Orlando Interchange Joint Venture (OIJV), a joint venture of HNTB Corporation and URS Corporation, was first selected in 2001 to develop a concept design for both interim and ultimate phases. Following completion of that design, the JV was next tasked to complete the final design for the interim contract. The design of the interim phase for the interchange was completed in 2005 and a $119M construction contract was awarded that same year to PCL Construction. This thirty month construction contract is scheduled for completion this year and the subject of our proposed paper.

Keywords: Florida U-beam, Concrete box beam, AASHTO beam, Bridge aesthetics, Bridge architecture, Hammerhead pier, Straddle bent, MSE walls

PROJECT OVERVIEW

The SR 408/I-4 Interchange in Downtown Orlando is one of the most heavily utilized corridors in Florida. The convergence of these two major transportation corridors yields an annual average daily traffic volume of over 300,000 vehicles resulting in a Level of Service F. As a result, a massive reconstruction effort is being undertaken jointly by the Florida Department of Transportation (FDOT) and Orlando-Orange County Expressway Authority (OOCEA) to improve the traffic flow at this location. This is being accomplished through the development of a new ultimate four-level interchange comprised of multiple flyovers. The interchange improvements will be completed in two phases, an interim contract currently under construction and an ultimate build-out of the multilevel interchange is planned to start around 2013. The Orlando Interchange Joint Venture (OIJV), a joint venture of HNTB Corporation and URS Corporation, was first selected in 2001 to develop a concept design for both interim and ultimate phases. Following completion of that design, the OIJV was next tasked to complete the final design for the interim contract. The design of the interim phase for the interchange was completed in 2005 and a $119M construction contract was awarded that same year to PCL Civil Constructors Incorporated. This thirty month construction contract is scheduled for completion this year and the subject of our proposed paper.

Fig. 1 Interim Interchange

This interim interchange project (see Fig. 1) includes over 6,100 linear feet of new bridge in combination with the widening of 2,200 feet of existing structures while maintaining current levels of traffic throughout the corridor. Precast/prestressed concrete beams were used extensively throughout the project for cost effectiveness, durability and aesthetic reasons at the new bridges and existing bridge widenings. Five major ramps/structures located at the first, second and third levels of the four level ultimate interchange are being constructed in the interim phase. These new bridges are:

- Ramps D/D1and C/C1, two major direct connection ramps between SR 408 and I-4
- Anderson Street over I-4 and adjoining Ramp F1 carrying traffic exiting from Anderson Street to I-4 eastbound
- Ramp F2 carrying traffic exiting from I-4 westbound to Anderson Street

Also, the following two new bridges are constructed only for the interim project and will be replaced in the ultimate phase of the project:

- Ramp E carrying traffic exiting from I-4 eastbound to Downtown Orlando
- Ramp B5 carrying traffic from local roads to I-4 westbound

The following four existing bridges carrying I-4 over local streets in Downtown Orlando required widening to accommodate the connections from the new ramps:

- I-4 eastbound bridge over South Street
- I-4 eastbound and westbound bridges (Church Street Viaduct) over Church Street Pine Street, Central Avenue and Washington Street
- I-4 eastbound and westbound bridges over Robinson Street

AESTHETICS

Aesthetics were extremely important due to the high visibility of the interchange. Approximately five percent of the project construction cost (approximately $5.5M) was allocated to achieve a high level aesthetics at the bridges and retaining walls as well as improving landscaping/hardscaping along the corridor. Bridge aesthetics included arched hammerhead piers, colored coatings, extensive use of form liners on the bridge substructure and bridge parapets, textured finish and colored coatings on retaining wall surfaces, decorative bridge lighting and logo panels mounted on the retaining walls and bridges. Hammerhead piers were selected over the commonly used multi-column piers. They offered more open and pleasing appearance in the transverse and diagonal views and displayed a slender support element in the elevation view of the bridge and at the same time accentuated the ribbon effect. Several features were introduced to enhance the functional form of the basic hammerhead pier consisting of a column and a cap. A modified octagonal shape was selected as a column cross-section with the purpose of creating an interesting and appealing

Fig. 2 Hammerhead Pier

Fig. 3 Hammerhead Pier Decorative Pedestal

look with differentiating surfaces and shadow planes. An arch element was introduced between the pier cap and pier column to emphasize the continuity and a flowing form from the column to the cap (see Fig. 2). The ends of the pier caps were slanted to match the 1:4 slope of the box girder webs. All pier columns featured an eight-foot tall decorative pedestal with embossed panels and raised horizontal banding (see Fig. 3). In combination with decorative pedestals, a vertical band of rustication was applied above the pedestals. To achieve economy in the pier formwork and uniformity of appearance at all piers, the same arched geometry was used. The structural demands of increasing pier heights, span lengths and bridge deck widths were met by adjusting the length of the flat surfaces along the transverse and longitudinal axes of the column. At the corners of the end bents (abutments), a gateway pylon element (see Fig. 4) was introduced with architectural features similar to the decorative pedestals used at the piers. The gateway pylon consisted of an L-shaped column supported on five steel HP piles. For the superstructures of the highly visible flyover ramps, concrete box beams and steel box girders were used to further enhance the bridge aesthetics by creating a ribbon-like appearance.

Fig. 4 Gateway Pylon

FIRE SUPPRESSION SYSTEM

A unique feature of the project is the incorporation of a fire suppression system at the request of the Orlando Fire Department to fight vehicle fires on the high level interchange ramps. Based on an earlier vehicle fire incident that damaged the superstructure of a ramp bridge from SR 528 to I-4 westbound roadway, the fire department decided to implement a dry pipeline system similar to the fire suppression system used in the Boston Artery project. The system at the interchange consists of twenty-five 6-inch diameter dry pipelines. Each pipeline starts from an inlet location at the ground level, travels underground to a nearby pier location, runs inside the pier column, exits through the pier cap and terminates with a T-fitting behind the bridge railing barrier (see Fig. 5). The pipe ends at the inlet and outlet locations are fitted with Storz type connections for quick connection to the fire department equipment. The outlet locations are

Fig. 5 Fire Suppression System Stand Pipe

spaced at a maximum of 700 feet to enable the fire department to fight the vehicle fires effectively on any location on the bridges and along the retaining walls.

PROJECT CONSTRAINTS

The project improvements were required to be carried out with a minimum disruption to the heavy daily traffic on I-4, SR 408 and CSX Railroad as well as the downtown traffic on the local roads. The bridge span layouts were selected to avoid impacts on the existing transportation system and also required to accommodate a future light rail system planned to serve Downtown Orlando. Additionally, the bridges were located over or adjacent to the existing buildings and parking lots in the southern part of Downtown Orlando. This necessitated strict vibration control measures during the pile driving operations for the foundations to avoid damage to the existing buildings. To complicate the matters further, numerous utilities were present along or under the local roads including crucial power, telecommunications and cooled water lines feeding the downtown businesses. Presence of numerous existing facilities severely limited suitable locations for the substructure placement and complicated the foundation selection process.

One important mandate was to minimize the cost of the throw-away construction when the interim phase facilities are integrated to the ultimate phase interchange. This was achieved by completing the geometric design of the entire ultimate interchange prior to the final design of the interim interchange.

DESIGN CRITERIA

All new bridges were designed according to the AASHTO Standard Specifications for Bridge Design and Construction, 17th Edition and FDOT Structures Design Guidelines (SDG) for Load Factor Design, 2000. The following additional design criteria were adopted as per SDG:

- Wind loads on the structures located more than 30 feet above ground were increased to 56 lbs/sf in consideration of hurricane force winds.
- As for the seismic loads, only connections between superstructure and substructure were designed for the seismic loads calculated based on the AASHTO Seismic Performance Category B.
- Thermal affects were based on 50º F temperature range for concrete bridges and 70º F temperature range for concrete deck slabs on steel superstructures.
- Additionally, as a compensation for the use of the LFD method in lieu of the LRFD method, HS-25 (HS-20 plus 25%) truck was selected as the design live load for all new bridges. The bridge widenings were, in turn, designed using HS-20 truck.

RAMP D/D1

Fig. 6 Ramp D/D1, Spans 1 thru 5

This bridge carries the Interim Ramp D1 connecting SR 408 westbound to I-4 eastbound and the Ultimate Ramp D that will eventually connect SR 408 westbound to I-4 westbound. This complex arrangement required three distinct bridge segments to accommodate the horizontal alignments of two diverging ramps. First 652 feet of the bridge (Spans 1 thru 5) is on a tangent horizontal alignment with two ramps gradually diverging (see Fig. 6). This bridge segment starts with one lane and gradually transitions to two separate lanes. The second segment of the bridge (Spans 6 thru 10A) is 1,035 feet long and follows a series of horizontal circular and spiral curves with two ramps rapidly diverging. This bridge segment carries two lanes separated by a variable width gore area. Ramp D terminates at the end of this second segment awaiting the ultimate phase for completion and Ramp D1 continues to the third segment of the bridge. The last segment of the bridge (Spans 10 thru 16) carries one lane with left and right shoulders for a length of 1,446 feet. It follows a horizontal alignment with radii as small as 710 feet. The last several spans of the bridge are configured to accommodate both the interim and ultimate ramp alignments.

Superstructure

The selection of the superstructure type was driven by accommodating the requirements of the horizontal ramp geometry, avoiding/minimizing the impacts on the existing facilities and providing highest level of aesthetics. In Spans 1 thru 5 where the horizontal alignment is on a tangent and impacts on the existing facilities were minimal, precast/prestressed concrete 72-inch deep Florida U-beams (FUBs) with span lengths varying

Fig. 7 Ramp D/D1, Elevation View of Spans 1 thru 5

from 123 feet to 135 feet were used (see Fig. 7). Construction of 653 feet of the bridge within these five spans required 2,100 feet of FUBs. The superstructure width varied along these spans to accommodate the transition from one lane to two lanes in the following manner:

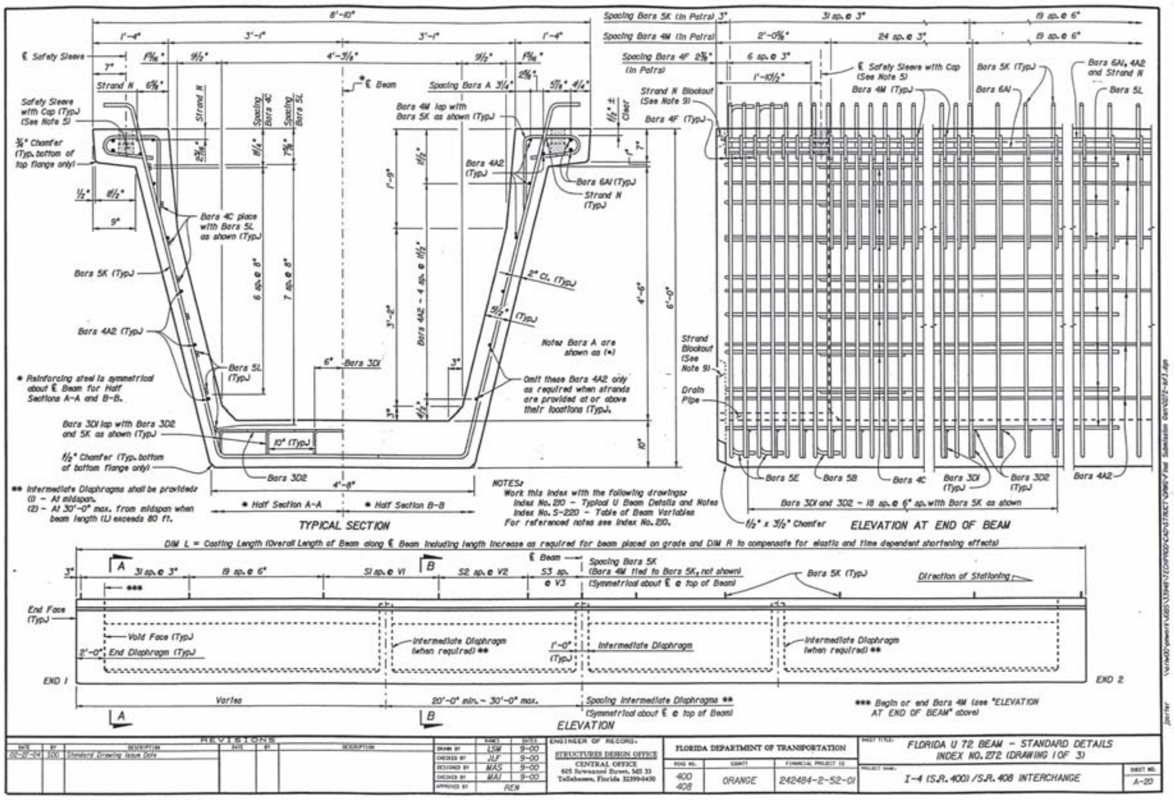
Span No.	Span Length	FUB Size	No. of FUB's	FUB Spacing	Deck Slab Width
1	123-0"	72"	2	From 14'-11 1/4" to 20'-11 3/8"	From 27'-0 1/8" to 32'-11 1/2"
2	130'-0"	72"	3	From 10'-5 11/16" to 14'-4"	From 32'-11 1/2" to 40'-8 1/4"
3	130'-0"	72"	3	From 14'-4" to 15'-9"	From 40'-8 1/4" to 43'-6"
4	135'-0"	72"	4	10'-6"	43'-6"
5	135'-0"	72"	4	10'-6"	43'-6"

In comparison with the remainder of the bridge where long span curved steel box girders were required, the use of FUBs provided economy and durability while providing a high level of bridge aesthetics. Florida U-beams were erected span-by-span starting from Span 1 towards Span 5. Two cranes were used to hoist each beam during the erection. Trapezoidal shaped FUBs featured full depth intermediate and end diaphragms (see Fig. 7A). The beams were made composite with an 8 ½ inch cast-in-place deck slab and the ends of the deck slabs were thickened between the beams. 8,500 psi concrete and ½" diameter Grade 270 low relaxation strands were used for all beams. The cast-in-place deck slab utilized 4,500 psi concrete and Grade 60 reinforcement. Each FUB was supported on one elastomeric pad at one end and two smaller pads at the other end to provide higher stability. Pourable silicone sealants were used at all FUB span deck joints.

In the remainder of the bridge, Spans 6 thru 16, where the alignment is on circular and spiral horizontal curves, longer span lengths, varying from 200 feet to 230 feet, were required to avoid impacts on the existing facilities. A superstructure consisting of a reinforced concrete deck slab made composite with ASTM A709, Grade 50 steel box girders was used.

Substructure

Initially, single 10-feet diameter drilled shafts were considered for the support of piers to minimize the impacts on the existing utilities and vibrations at the nearby buildings. However, the concerns about the constructability and inspection of 100-foot to 120-foot long drilled shafts ultimately changed the foundation design approach to the use of driven piles. It was decided that steel HP piles be used at all foundations located within 200 feet of any existing building/facility to limit the ground vibrations to 0.5 in/sec during pile driving and avoid damage. At other foundation locations, precast/prestressed concrete piles were considered to be the most economical foundation solution.



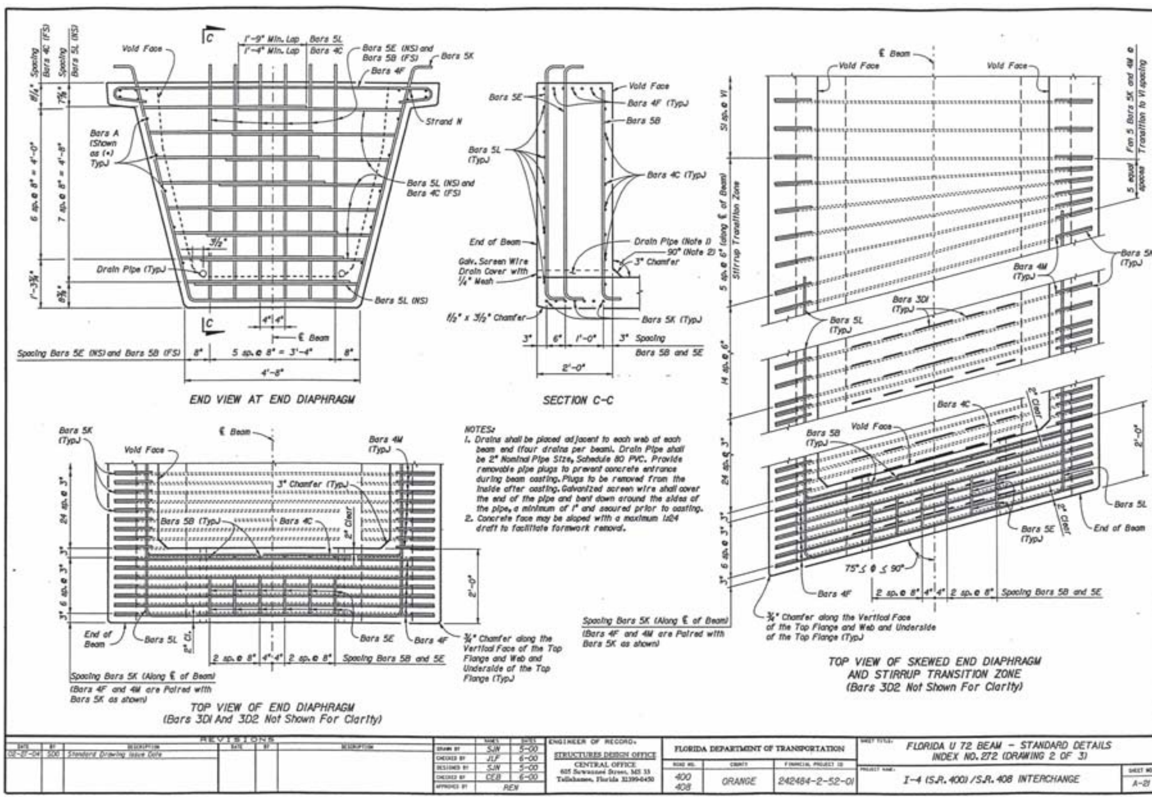


Fig. 7A 72-inch Florida U-Beam Details

Fig. 8 Straddle Pier 9

Bridge end bents consisted of a reinforced concrete pile cap and backwall with a wrap-around mechanically stabilized (MSE) wall. Out of sixteen pier locations, hammerhead piers were used at Piers 1 thru 8 and Piers 11 thru 16. Hammerhead pier heights varied from 27 feet to 45 feet. At Piers 9 and 10, straddle type piers were used to accommodate the existing and future local roads. The straddle Pier 9 had two columns spaced at a clear span of 43 feet and required post-tensioning in the cap (see Fig. 8 and Fig. 8A). The other straddle pier, Pier 10, featured three columns spaced at 34 foot-clear spans and the pier cap was conventionally reinforced. Piers also featured embedded piping to carry the deck drainage system for connection to the underground drainage system as well as a dry pipeline for the fire suppression system.

RAMP C/C1

Most features at the Ramp C/C1 bridge are similar to the Ramp D/D1 bridge as it carries an interim ramp and an ultimate ramp. However, this bridge has several unique features, such as a bifurcated steel box girder, a modular strip seal expansion joint and inverted-T pier caps, that are not present at the Ramp D/D1 bridge. This 1,647 feet long bridge carries the Interim Ramp C connecting SR 408 eastbound to I-4 eastbound in combination with Ramp C1 that will connect SR 408 eastbound to I-4 westbound in the ultimate phase. Similar to the Ramp D/D1 ramp bridge, three distinct bridge segments were used to accommodate the horizontal alignments of two ramps. The first 678 feet of the bridge (Spans 1 thru 6) is on a tangent horizontal alignment with two ramps gradually converging (see Fig. 9). Within this bridge segment, two ramp lanes are separated by a tapering gore area. The second segment of the bridge (Span 7) is 154 feet long and features bifurcated

Fig. 9 Ramp C/C1, Spans 1 thru 6

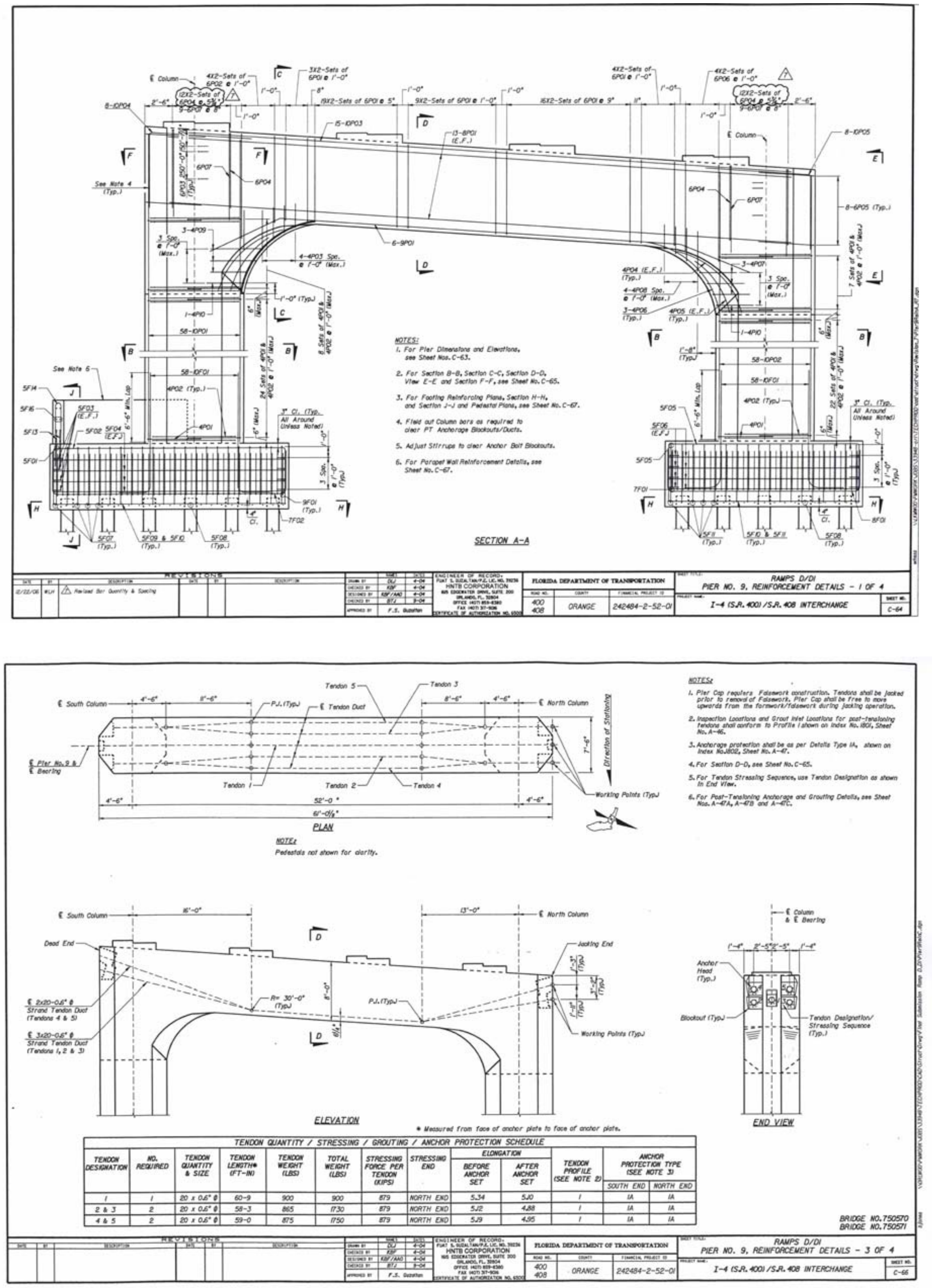


Fig. 8A Straddle Pier 9 Details

superstructure geometry to accommodate rapid divergence of two ramp lanes with a variable width gore area. Ramp C1 terminates at the end of this segment and will be completed in the ultimate phase of the project whereas Ramp C continues on to the third segment of the bridge. The last segment of the bridge (Spans 8 thru 11) is 815 feet long. It carries one lane of traffic with left and right shoulders on a curved horizontal alignment with radii as small as 559 feet.

Superstructure

The selection of the superstructure type for the Ramp C/C1 bridge was determined by the ramp horizontal alignment, the need to avoid/minimize the impacts on the existing facilities and provide highest level of aesthetics. Between Spans 1 and 6 where the bridge is on a tangent horizontal alignment, 2,680 feet of 54" and 63" Florida U-Beams (FUBs) were used

Fig. 10 Ramp C/C1, Elevation View of Spans 2 thru 5

to achieve high levels of aesthetics and economy and avoid impacts on the existing local roads (see Fig. 10). In Span 1, the superstructure and end bent were constructed wide enough to support only the interim Ramp C width due to the restrictions imposed by the adjacent drainage pond. In the ultimate phase, the connector ramp beneath this span will be eliminated and the drainage pond will be relocated allowing the widening of the interim superstructure and end bent to adequately support the ultimate Ramp C1. In Spans 1 thru 6, the varying roadway width was accommodated as follows:

Span No.	Span Length	FUB Size	No. of FUB's	FUB Spacing	Deck Slab Width
1	106-0"	54"	3	From 12'-1 3/8" to 15'-1 3/8"	From 40'-10 1/4" to 34'-6 1/4"
2	115'-0"	63"	5	From 10'-6 3/4" to 11'-11 3/4"	From 60'-8 3/4" to 54'-11 1/2"
3	116'-9"	63"	4	From 12'-6 5/8" to 14'-0 5/8"	From 54'-11 1/2" to 50'-3 3/8"
4	118'-6"	63"	4	From 11'-4 3/8" to 12'-3 5/8"	From 50'-3 3/8" to 46'-9"
5	112'-0"	63"	4	From 10'-7 1/4" to 11'-3 3/4"	From 46'-9" to 44'-6 5/8"
6	110'-3"	63"	4	From 10'-2 7/8" to 10'-7 1/4"	From 44'-6 5/8 to 44'-11 1/4"

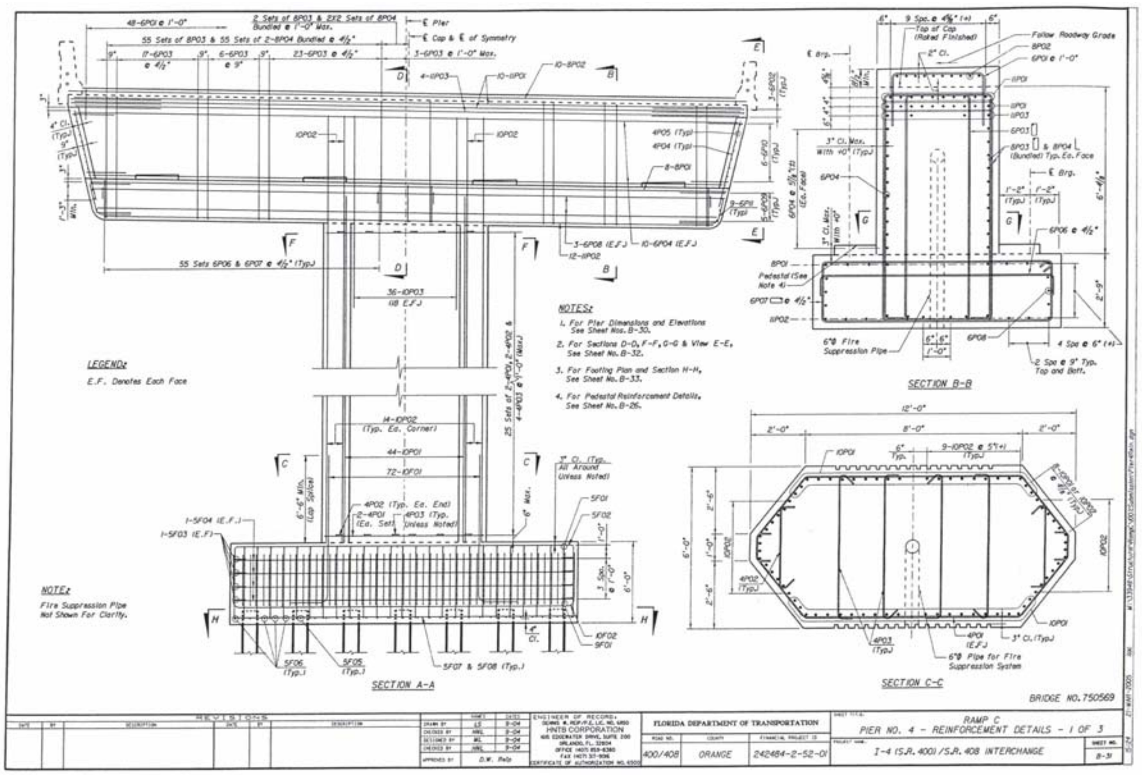
Between Spans 7 and 11, the deck slabs were supported on ASTM A709, Grade 50 steel box girders with span lengths varying from 125 feet to 232 feet. In this span range, a steel superstructure was required to avoid impacts on the existing facilities. A superstructure consisting of a reinforced concrete deck slab made composite with ASTM A709, Grade 50 steel box girders was used.

Substructure

The foundation selection process for the Ramp C/C1 bridge followed the same process undertaken for the Ramp D/D1 bridge and ultimately steel HP piles were selected for use at all foundation locations to minimize the ground vibrations at the nearby existing buildings and avoid any damage.

Fig. 11 Pier 5 with Inverted-T Cap

The superstructure was supported on two end bents and ten piers. Both end bents consisted of a reinforced concrete pile cap and a backwall with a wrap-around MSE wall. Piers 2 thru 7 and Piers 9 thru 11 were hammerhead type piers. Piers 4 and 5 were located on both sides of an existing on-ramp to SR 408 eastbound and featured inverted-T pier caps



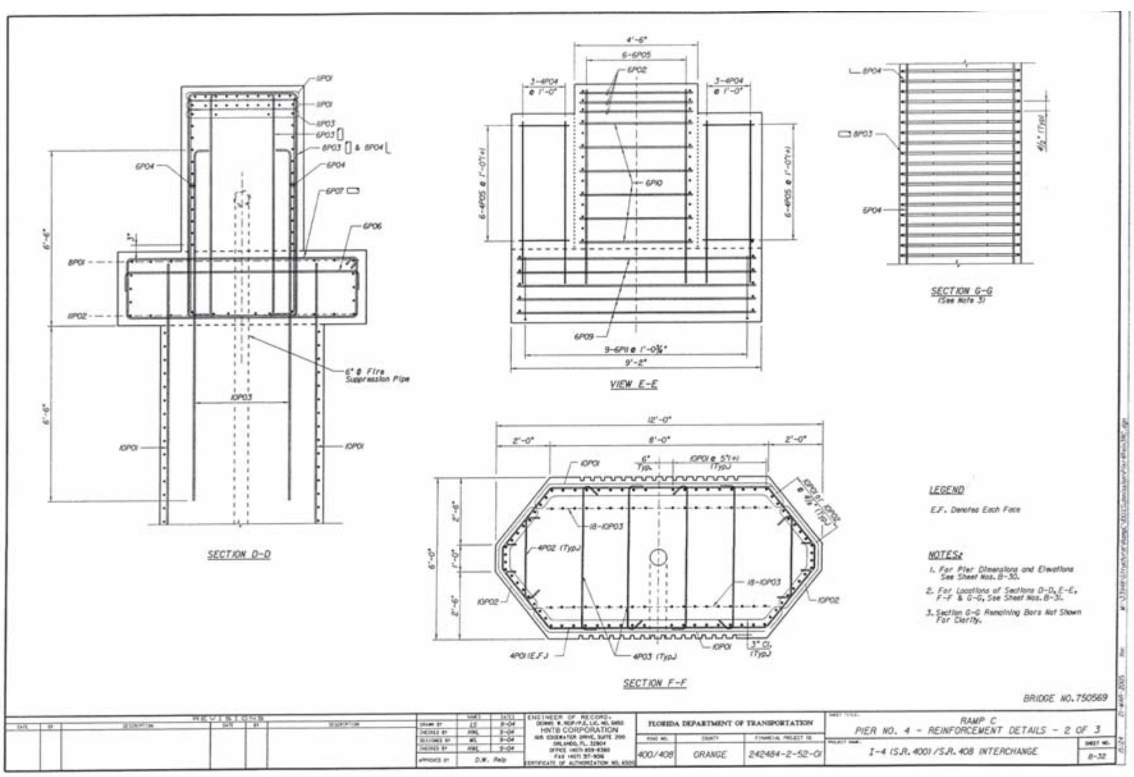


Fig. 11A Pier 5 Details

Fig. 12 Pier 8 Straddle Bent

(see Fig. 11 and Fig. 11A). This arrangement, while providing a 16'-6" vertical clearance over the existing ramp, avoided the need to raise Ramp C/C1 vertical profile. A straddle type pier was required at Pier 8 location to support the bifurcated Span 7 superstructure over a local road (see Fig. 12). The straddle pier cap was 59 feet long and required post-tensioning. Piers also featured embedded piping to carry the deck drainage system for connection to the underground drainage system as well as a dry pipeline for the fire suppression system.

I-4 EB AND WB OVER CHURCH STREET (CHURCH STREET VIADUCT)

Approximately 1,500-foot long existing viaduct carries I-4 eastbound and westbound roadways over Church Street, Pine Street, Central Avenue and Washington Street in Downtown Orlando. The twenty-six span structure was originally designed by HNTB Corp. in 1954 and widened in 1983 to increase the thru lanes from three to four. The current widening was designed by URS Corp. to accommodate an exit ramp from I-4 westbound to Anderson Street Overpass via Ramp F2 and on-ramps carrying traffic from Ramp D1 and Ramp F1 to I-4 eastbound see Fig. 13).

Superstructure

The superstructure for the widening consisted of an 8-inch thick cast-in-place deck slab supported on Type III and Type III Modified AASHTO beams. The span lengths varied from 43'-3" to 78'-0" and approximately

Fig. 13 Church Street Viaduct

5,900 feet of precast/prestressed concrete beams were used to accomplish the widening on the viaduct. Between Spans 1 and 8, the widened superstructure was supported on six beams on the westbound side and two beams on the eastbound side. Between Spans 9 and 26, the superstructure widening was supported on two beams on both westbound and eastbound sides of the bridge. 6,500 psi and 8,500 psi concrete and ½" diameter Grade 270 low relaxation strands were used for all precast/prestressed beams. The cast-in-place deck slab utilized 4,500 psi concrete and Grade 60 reinforcement.

Fig. 14 Church Street Viaduct, Pier Bents

Substructure

Between Spans 1 and 8, the widened westbound superstructure was supported on two-column pier bents (see Fig. 14). The superstructure widening in all other spans were supported on hammerhead type piers. In order to limit vibrations at the nearby buildings and adjacent viaduct during pile driving operations, steel HP piles were used for the foundation support.

I-4 EB AND WB OVER ROBINSON STREET

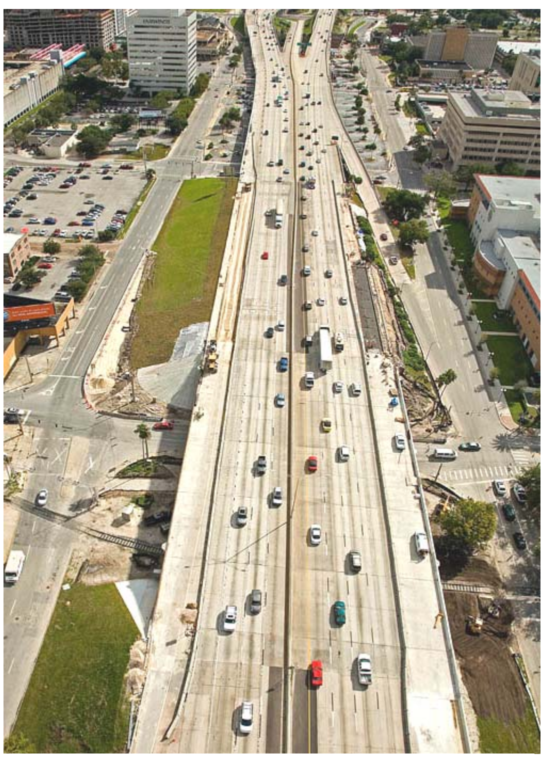


Fig. 15 I-4 over Robinson Street

The bridge carrying I-4 eastbound and westbound roadway over Robinson Street and Florida Central Rail Road tracks is located approximately 500 feet north of the Church Street Viaduct.

Superstructure

This 278-foot long and five-span bridge has a history similar to the Church Street Viaduct. It was designed by HNTB Corp. in 1954 and widened in 1983. The current outside widening, to accommodate the ramps merging to the I-4 westbound and eastbound roadways, was designed by URS Corp. (see Fig. 15). The span lengths varied from 50'-0" to 56'-6".

The widened bridge superstructure consisted of an 8-inch thick cast-in-place deck slab supported on Type III Modified AASHTO beams. The total length of the precast/prestressed concrete beams used for the widening was approximately 1,400 feet. The bridge widening on the westbound side of the bridge was supported on three beams and on the eastbound side the widening was supported on two beams. 6,500 psi concrete and ½" diameter Grade 270 low relaxation strands were used for all precast/prestressed beams. The cast-in-place deck slab utilized 4,500 psi concrete and Grade 60 reinforcement.

Substructure

The widened westbound superstructure was supported on pier bents featuring two circular columns. The superstructure widening on the eastbound side was supported on hammerhead type piers. In order to limit vibrations during pile driving operations, steel HP piles were used for the foundation support.

The widening work also included construction of a crash wall along the northernmost pier where the center line of the existing rail road tracks were located less than 25 feet to the face of the pier columns.

RAMP B5 OVER LIVINGSTON STREET

The Ramp B5 bridge is a new interim phase bridge carrying the traffic from local streets to I-4 westbound roadway. This bridge is located north of the Church Street Viaduct and I-4 eastbound and westbound bridges over Robinson Street.

Superstructure

Fig. 16 Elevation View of Ramp B5

The bridge is 154-foot long and has three spans (42'-75'-37') (see Fig. 16). The bridge superstructure consisted of an 8-inch thick cast-in-place deck slab supported on four Type III AASHTO beams. The 8 inch cast-in-place deck slab utilized 4,500 psi concrete and Grade 60 reinforcement. The total length of the precast/prestressed beams used on this bridge was 613 feet. 6,500 psi concrete and ½" diameter Grade 270 low relaxation strands were used for all precast/prestressed beams. AASHTO beams were supported on elastomeric bearing pads at both ends.

Substructure

The superstructure was supported on end bents and pier bents consisting of a pier cap and two circular columns. There were no facilities in the vicinity of this bridge. Therefore, the substructure elements were supported on 18-inch square precast/prestressed concrete piles.

RETAINING WALLS

The interim project required thirteen retaining walls. Two of the walls were cast-in-place concrete cantilever walls. Two of the walls were tie-back walls with a cast-in-place concrete facing wall. At the nine remaining wall locations, approximately 12,000 feet of MSE walls consisting of precast concrete face panels and steel reinforcement straps were used.

BRIDGE STATISTICS

Five construction firms participated in the bidding of the interim interchange project and the project was awarded to PCL Civil Constructors, Inc. in July of 2005 at a total price of $119M. The total cost of bridge structures was $68M. The following project statistics was compiled to demonstrate the magnitude of the bridge work:

- 4,780 feet of Florida U-beams approximately at $740/LF
- 6,155 feet of Type III and 1,775 feet of Modified Type III AASHTO I-beams, respectively, at $80/LF and $110/LF
- 21,320 feet of concrete piles approximately at $64/ LF
- 141,780 feet of HP steel piles approximately at $44/ LF
- 12,455 CY of superstructure concrete at $600/CY
- 12,232 CY of substructure concrete at $1,000/CY
- 6.1M pounds of reinforcement steel at $0.75/lbs
- 14.4M pounds of structural steel approximately at $1.74/lbs
- 172,800 SF of MSE walls at $28/SF

Based on the contractor's prices the following approximate square-foot bridge costs for different bridge types were calculated:

Bridge Locations	**Superstructure Type**	**SF Bridge Cost**		
		Superstructure	**Substructure**	**Total**
Ramps D and C/C1	Florida U-beams	$81	$63	$144
Ramps D/D1 and C/C1	Steel box beams	$105	$68	$173

CONSTRUCTION CHANGES

During the course of the construction, several changes were initiated with the intent of streamlining the construction operations such as:

- The construction plans were detailed with 4-inch diameter preformed holes for the installation of the bearing anchor bolts. The contractor was preforming the holes by inserting conduits while the pier cap concrete was wet. The hole locations were quite frequently misplaced and required time consuming remedial work. The tight reinforcement spacing at top of the pier cap did not allow the use of a larger diameter hole. However, the contractor tightened the quality control measures for locating and placing holes and started to use rectangular tubing with a 5-inch dimension parallel to the pier cap reinforcement and the remedial rework reduced approximately by half.

- At Ramp C/C1, the Florida U-beams were expected to fit between two inverted-T pier caps at Piers 4 and 5 with a one-inch open deck joint at each end of the span. However, the combination of slightly out-of-alignment inverted-T pier caps and longer FUBs made it impossible to erect two of the beams in Span 4. The contractor opted to shorten the beams by two inches at each end by sawcutting and chipping (see Fig. 17). The beam ends were repaired using non-shrink grout and dowelled reinforcement. As part of the repair procedure, the interior end diaphragms were thickened and cast-in-place external diaphragms were added between the repaired beams. This solution allowed the contractor to maintain his schedule.

Fig. 17 Sawcutting of Beam End

- A tie-back wall with two 90º corners was detailed around an existing bridge end bent to create open space for landscaping by removing the existing embankment. The retaining wall had multiple layers of tie-backs and located over existing power and communications lines. The contractor preferred a cast-in-place retaining wall option to avoid installing tie-backs in intersecting planes at the wall corners. The cast-in-place retaining wall was designed and detailed to straddle the existing utilities.

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