PROJECT

SR 417 and Boggy Creek Road Interchange

Florida's first curved precast concrete U-girder bridge

by Thomas W. Stelmack, Thomas E. Davidson, and Kristian Forars, Parsons

Orlando International Airport (OIA) has become the fourth busiest domestic destination in the United States due to Orlando, Florida's, many tourist attractions, job opportunities, and climate. With the steady increase in travelers, the interchange for the south entrance to the airport has become more congested. For many years, planners with the Central Florida Expressway Authority (CFX) have known the need for improving the movements from State Route (SR) 417, part of CFX's tollway around Orlando, to Boggy Creek Road and the south access road to OIA. The third and final phase of the interchange includes two direct flyover movements:

- Ramp H carries drivers from northbound SR 417 over Boggy Creek Road and SR 417 to the south access road of OIA
- Ramp I provides the opposite movement, carrying drivers over Boggy Creek Road and SR 417 from the south access road of OIA

The horizontally curved superstructures for Ramps H and I were originally designed with both steel trapezoidal box girders and precast concrete curved U-girder alternates. The design for the U-girder alternate used PCI Zone 6 concept plans adopted by the Florida Department of Transportation (FDOT) and was completed in less than 12 months. Bids for the precast concrete curved U-girders were ultimately accepted in October 2013, with the low bid of $71 million ($33.78 million for the two ramp structures) estimated to be a savings of $7 to $9 million over a steel design.

Aerial view of both Ramps H and I. Photo: SEMA Construction.

Design Details

Geometry

The project has two flyover ramps that were designed using curved precast concrete U-girders. Ramp H is approximately 55 ft above ground surface at its highest point and consists of three continuous units for a total length of 2708 ft. Each unit is comprised of several spans ranging in length from 141 to 216 ft. Ramp H has a minimum horizontal radius of 1273 ft and the width of the bridge deck is 45 ft 3½ in. with two travel lanes. Ramp I crosses over Ramp H, rising 90 ft above ground surface at its highest point and has two continuous units with a total length of 1411 ft. It has spans ranging in length from 177 to 220 ft, with a minimum horizontal radius of 955 ft, a bridge deck width of 36 ft 3½ in., and one travel lane.

profile

SR 417 AND BOGGY CREEK ROAD INTERCHANGE / ORLANDO, FLORIDA

BRIDGE DESIGN ENGINEER: Parsons, Denver, Colo. and Orlando, Fla.

PRIME CONSULTANT: Dewberry, Orlando, Fla.

INDEPENDENT CHECK ENGINEER: URS Inc., Tampa, Fla.

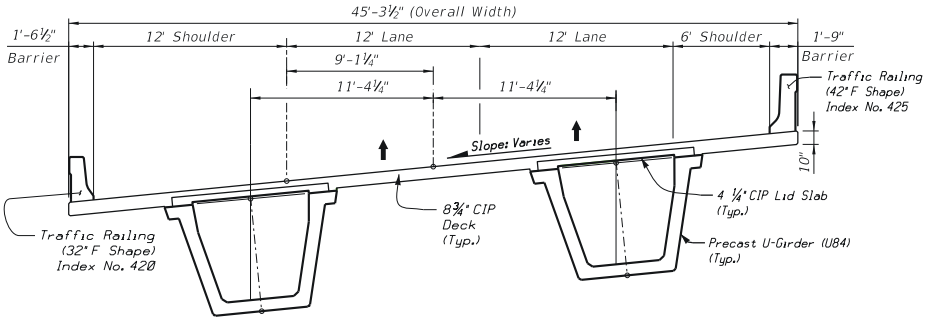
CONSTRUCTION ENGINEER: Summit Engineering Group, Littleton, Colo.

CONSTRUCTION INSPECTION: A2 Group Inc., Orlando, Fla.

POST-TENSIONING INSPECTION: FIGG, Tallahassee, Fla.

PRIME CONTRACTOR: SEMA Construction, Orlando, Fla.

View of curved forms with reinforcing steel and core form in place. Photo: Parsons.



Typical superstructure section for Ramp H. Ramp I is similar, but is 36 ft 3 ½ in. wide. Figure: Parsons.

Substructure

As the ramp structures were designed initially as steel box girders, the CFX decided not to change pier locations or foundation sizes, so the precast concrete U-girder alternative utilized the previously completed steel alternative substructure design. The prescribed span lengths were not a problem for the concrete design and the foundation designs also worked well with the concrete alternative. The foundations are driven precast, prestressed concrete piles with cast-in-place concrete footings, supporting cast-in-place, reinforced concrete piers and caps. Most piers are radial, with a few being skewed to avoid roadways or Boggy Creek.

Superstructure

The cross sections of both flyover ramps consist of two PCI 84-in.-deep U-girders with an 8¾-in.-thick concrete deck and 10-in.-thick overhangs. One of the challenges of a precast concrete U-girder structure is the heavy self-weight of the segments. To keep the segments to a manageable length and weight for lifting and transport to the site, the spliced and post-tensioned method of construction was used. The bridge was broken up into segments, with one segment over each pier and a segment in between. The length of the girder segments was limited to a maximum of 110 ft in order to enable each segment to be transported, although the maximum length was later increased to 115 ft 4 in. by the contractor. The basic sequence includes precasting the curved U-shaped segments, supporting each segment on temporary shoring towers, and splicing the sections together using post-tensioning. Gaps for the closure placements between each of the curved segment sections, which consist of cast-in-place concrete, are typically 2 ft wide. Post-tensioning tendons run through internal ducts from the beginning to the end of each unit, connecting all of the U-girder segments in the unit when stressed.

View of typical girder end details, including thickened webs, top strut, shear keys and reinforcing steel to be tied with closure placement reinforcement. Photo: Parsons.

First Ramp H girder being lifted into place, supported by abutment and shoring tower. Photo: A2 Group.

Due to the complex geometry, numerous phases of construction, and changes in support/loading conditions of the segments, a three-dimensional computer model was developed that included a detailed, time-dependent, staged construction analysis with both girder lines and deck slab. This analysis ensures that the segments meet all design requirements during each phase of construction and also allows for accurate calculation of camber.

The U-girder section has a web thickness of 10 in. to accommodate the 4-in.-diameter ducts for the 15-strand tendons. A variable thickness bottom flange is used throughout the girder line and varies from a typical value of 9 in. to 1 ft 9 in. over the piers to provide additional capacity to meet allowable stresses over the pier. The open U-girder section ultimately requires a cast-in-place lid slab to increase the torsional resistance of the

CENTRAL FLORIDA EXPRESSWAY AUTHORITY, OWNER

PRECASTER: Dura-Stress Inc., Leesburg, Fla.—a PCI-certified producer

POST-TENSIONING CONTRACTOR: Freyssinet Inc., Sterling, Va.

U-GIRDER FORM SUPPLIER: Tucker's Machine & Steel Service Inc., Leesburg, Fla.

BRIDGE DESCRIPTION: 2708-ft-long and 1411-ft-long curved, spliced, and post-tensioned precast concrete U-girder flyover ramp structures

STRUCTURAL COMPONENTS: Ninety-two 84-in.-deep U-girders with a 8¾-in. cast-in-place concrete deck; cast-in-place pier caps, columns, and footings; and 24-in.-square driven precast, prestressed concrete piles

BRIDGE CONSTRUCTION COST: $33,775,000 ($194 per ft²)

section prior to deck placement and is constructed after erection to limit the transport weight.

The post-tensioning is made up of three types of tendons. Each segment has either four-strand flat ducts or 12-strand round polyethylene ducts in the bottom flange depending on girder segment length/location and are used to enable the section to carry its self-weight. The U-girder section also has four draped continuity tendons (each consisting of 15 strands with 19-strand anchors) running through each girder web from beginning to end of the unit. The continuity tendons stitch all the girder segments together and the profiles along the girder lines are designed to keep the stresses (Service III tension and Service I compression) within allowable limits during all stages of construction and during service. The precast concrete U-girder top flange provides room for top post-tensioning tendons if needed for tensile stresses over the piers after erected.

View of erected Ramp I girders spanning above Ramp H. Photo: Parsons.

Construction Details

Being the first precast concrete curved U-girder bridge constructed in Florida, new forms were purchased by the precaster for the project. The curvature is obtained by using short straight sections with small angle breaks between the sections, for both external and internal forms. The forms are designed to handle different radii and adjustment is relatively simple. While the design plans used the same radius for each adjacent girder within spans, the contractor modified the radius of several segments slightly to further minimize the number of form radius changes.

Reinforcing bar cages, utilizing welded wire mesh, were built outside the forms and the completed assemblies lifted

First Curved Precast U-girder Bridge for Design-Bid-Build Project

The SR 417 and Boggy Creek Road interchange is a milestone project in that it is the first standard delivery project in the country to incorporate curved precast concrete U-girders as the primary design. Previous projects constructed in Colorado have all been a result of value engineering redesigns or an alternate design allowed by the contract documents and completed by the contractor. As such, the SR 417 and Boggy Creek Road interchange is the first project bid with full and complete construction documents and specifications as part of the bid package.

Spliced and post-tensioned precast concrete curved U-girders can be compared to the development of precast concrete segmental box girders in the United States. Both are phased construction methods utilizing multiple segments to make up a span requiring time-dependent phased analyses. For precast concrete segmental construction, as owners became more comfortable with the method, segmental designs became more common in standard delivery bid packages when it made sense, due in part to the Federal Highway Administration mandate for two complete alternative designs for projects costing more than a certain value. The primary difference with curved U-girders is that some states have selected standard sections to be used, which will allow precasters to purchase the forms with the assurance that they can be used for multiple projects, similar to standard precast concrete bulb-tee girders.

However, it is imperative that, similar to segmental designs, the contract documents need to provide complete details to construct the bridge and the assumptions made by the designer, while allowing the contractor the freedom to make modifications based on fabrication and construction preferences. The items that can be modified and the responsibilities of the contractor when making modifications need to be clearly stated in the contract documents. Listed below are items that should be included in contract documents and items that should be the contractor's responsibility.:

Designer's responsibility:

- Girder splice locations
- Post-tensioning layout and anchor details
- Diaphragm details
- Girder geometry, including camber and elevations
- Erection sequence

Contractor's responsibility:

- Temporary supports
- Lifting details
- Girder stability and temporary bracing

Girder at site ready to be lifted into place. Photo: Dura-Stress Inc.

The items shown in the plans that are allowed to be modified—and if the changes are made, what design and submittal requirements are subsequently required of the contractor for the changes—should be discussed with the owner and decisions made based on their preference. This will help to allow the contractor to submit its best bid and also minimize any confusion about responsibilities and requirements during construction. For this owner, producing standard project delivery packages with precast concrete curved U-girders was the best way to introduce the product to their region and to get projects built using them.

in one piece and placed in the forms. Additional longitudinal reinforcing bars were used in the webs and bottom slabs of the girders to address lifting and handling operations. To allow quicker girder removal from the forms, stresses were checked considering only the reinforcing steel, allowing the bottom flange tendons to be stressed in the yard later once the required concrete strength was achieved.

Shipping of the girders (maximum weight of 340 kips) was by multi-axle trucks to the construction site about 40 miles from the fabrication yard. Girders were shipped at night to arrive early in the morning so that placement could occur during lane closure windows.

Girder segments were supported at each end by steel shoring towers and, at the ends of the units, by an abutment or pier. Segments initially spanned over permanent piers and were adjusted to the necessary elevations. Bearings were then grouted in at the permanent piers and 2-ft, cast-in-place closure joints that accommodated construction tolerances were made between segments. Post-tensioned diaphragms were cast at the piers to tie the two-girder system together and transmit loads to the bearings.

One of the continuous post-tensioning tendons was stressed in each web prior to casting a lid slab, which closed the top of the boxes for torsional rigidity. This initial post-tensioning prevented cracking in the closure placements when the 4¾-in. lid slab was subsequently cast on permanent metal deck forms. Thereafter, the remaining three post-tensioning tendons were stressed. After post-tensioning and grouting was completed, shoring was removed and the girders were ready for placing the deck slab as with any other composite continuous girder system.

Summary

The design and construction of the SR 417 and Boggy Creek Road interchange has introduced a new girder type to the state of Florida. Where curved structures are required and aesthetics are important, the PCI U-girder provides an alternative to the steel trapezoidal box girder, increasing competition and allowing for more competitive pricing. This new system brings the advantages of standard precast concrete construction, including durability, quality and speed of construction, and minimal disruption to the area below the bridge, to curved concrete U-girders.

Mr. Donald W. Budnovich, resident engineer for CFX comments, "The Central Florida Expressway Authority is excited to provide our customers and the Central Florida Region a more efficient means to enter the Orlando International Airport through the construction of this interchange. The innovative design employing the post-tensioned curved concrete U-girders, provides a durable and cost-effective project that we expect will serve Central Florida for decades to come."

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EDITOR'S NOTE

For more information on the design consideration used for this project, see the article on p. 30.

AESTHETICS COMMENTARY

by Frederick Gottemoeller

Multi-level, high-speed interchanges between limited access roadways can be visually confusing places. Cars are moving fast along continuously curved paths, and paths merge and split as they go. The piers and abutments of the various bridges limit drivers' views of the paths ahead. Even if their views meet the minimum sight distances set by safety criteria, drivers are still left with a sense of unease about what lies ahead. If some of the intervening piers and abutments can be eliminated, drivers can better see through the interchange, alleviating their unease.

So, the first benefit of the precast concrete curved U-girders at Boggy Creek is that they allow longer spans and thus fewer piers. The piers are set well back from the edges of the under-passing roadways. The piers themselves, for the most part, use single stems that have minimal effect on the view. Drivers can see a long way ahead, with no interference from intervening piers. As an additional benefit they can better enjoy the passing landscape.

The second benefit of the precast concrete curved U-girders is that they are seen as one long, continuous curved girder. In a high speed highway environment, visually simpler is almost always visually better. The pier details enhance this result. The girders sit up above the pier caps on low concrete blocks. From many angles you can actually see sky between the bottom of the girder and the top of the pier caps (See cover photo). The bearings are so small compared to the length of the pier caps that the girders seem to be supported on pinheads. The full sweep of the girders is visible. They almost look like they are floating on air.

As a further enhancement, coating the girders with a color that contrasts with the piers and deck emphasizes the curvature and continuity of the girders. To top it all, the color chosen is an excellent complement to the lush Florida vegetation.

High-level flyover ramps are always the most prominent feature of these interchanges. It is always worthwhile to give some thought and, yes, even spend some money, to improve their appearance. The appearance of the whole interchange will benefit. And where, as here, the interchange is a gateway to a whole region, improving the appearance of the interchange will enhance visitors' impression of the entire region.