

Innovative U-Beams for the Wekiva Parkway #204 Systems Interchange

by Yankó Castellanos-Ibanez and David Konz, Atkins

The curved ramp K of the Wekiva Parkway is a third-level flyover that connects to State Route 453. The ramp is 2550 ft long and has both vertical and horizontal curvature. Photo: Harvey Smith.

When finished, the Wekiva Parkway will complete the State Route (SR) 429 beltway link around Orlando in central Florida, which is intended to relieve traffic and support economic development. The Wekiva Parkway #204 Systems Interchange provides fully directional access between SR 429 and SR 453 and is at the heart of the 10-mile-long corridor.

Eight concrete U-beam bridges were included in the design of the interchange. The design team delivered a unique solution by implementing a spliced, haunched, curved post-tensioned, precast concrete U-beam to improve geometrics and reduce the project footprint. The superstructure alternative came at a lower overall cost to the client than any other available option and required a revolutionary, innovative design. This innovative bridge is the first in Florida to use haunched, curved, post-tensioned, precast concrete U-beams. This approach accommodated the region's growth while protecting the environmental legacy and contributing to a picturesque parkway that emulates the aesthetic features

of nearby historic rock walls and stone cladding. (See the Fall 2020 issue of *ASPIRE*® for an article on another portion of the Wekiva Parkway project.)

Ramp Geometry

The design team worked within the constraints of the landscape by matching the vertical geometry to the naturally elevated southwestern section of the project limits to reduce the environmental impact on the region. Noting how the natural grade generally falls off toward the east, the team designed the corridor geometry to work with the landscape to reduce the parkway's footprint.

The roughly 46-ft-wide ramp K carrying SR 429 epitomizes the project's innovative bridge design. This 2550-ft-long third-level flyover curves at a 1200 ft radius. The length of the bridge was dictated by the vertical clearance required over ramp M and a limiting mechanically stabilized earth wall height of 30 ft at the approaches. The ramp K structure has seventeen 150-ft-long spans in multispans continuous units.

Haunched precast concrete U-beams were also used without post-tensioning on some of the other bridges in the interchange, which provided aesthetic consistency and value throughout the project. Modified Florida U 48 beams that vary in depth from 4 ft to 6 ft 5 in. were used on the single-span, 73-ft-long ramp J bridge; modified Florida U 63 beams that vary in depth from 5 ft 3 in. to 8 ft 5 in. were used for a two-span, 274-ft 8-in.-long bridge; and modified Florida U 72 beams that vary in depth from 6 ft to 9 ft 7 in. were used on the single-span, 131-ft 6-in.-long ramp L bridge.

Substructure

Substructure heights vary from 50 ft for an expansion pier to 17 ft for the integral hammerhead design. End bent sections measure 5 ft wide and 4 ft high. Piles supporting the end bent were staggered to improve the group effect of the deep foundation and the resistance to lateral load. The typical 12 × 6-ft pier column sections are supported by pile footings ranging from 24 to 30 piles at the expansion piers.

profile

WEKIVA PARKWAY #204 SYSTEMS INTERCHANGE / ORANGE COUNTY, FLORIDA

BRIDGE DESIGN ENGINEER: Atkins, a member of the SNC-Lavalin Group, Orlando, Fla.

PRIME CONTRACTOR: Southland Construction Inc., Apopka, Fla.

OWNER'S CONSULTANT CONSTRUCTION ENGINEERING INSPECTION: A² Group Inc., Orlando, Fla.

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

POST-TENSIONING CONTRACTOR: Structural Technologies (VSL), Pompano Beach, Fla.

OTHER SUPPLIERS: Formwork: EFCO, Orlando, Fla.; erection: V&M Erectors, Pembroke Pines, Fla.



View from the third level of the interchange. Photo: Harvey Smith.

The design of integral pier 11 required 35 piles and a 10-ft-tall, 7-ft-wide diaphragm. The cap heights on the expansion piers vary from 5 to nearly 14 ft. The design team chose to use 18-in.-square prestressed concrete piles throughout the foundations to achieve greater economy.

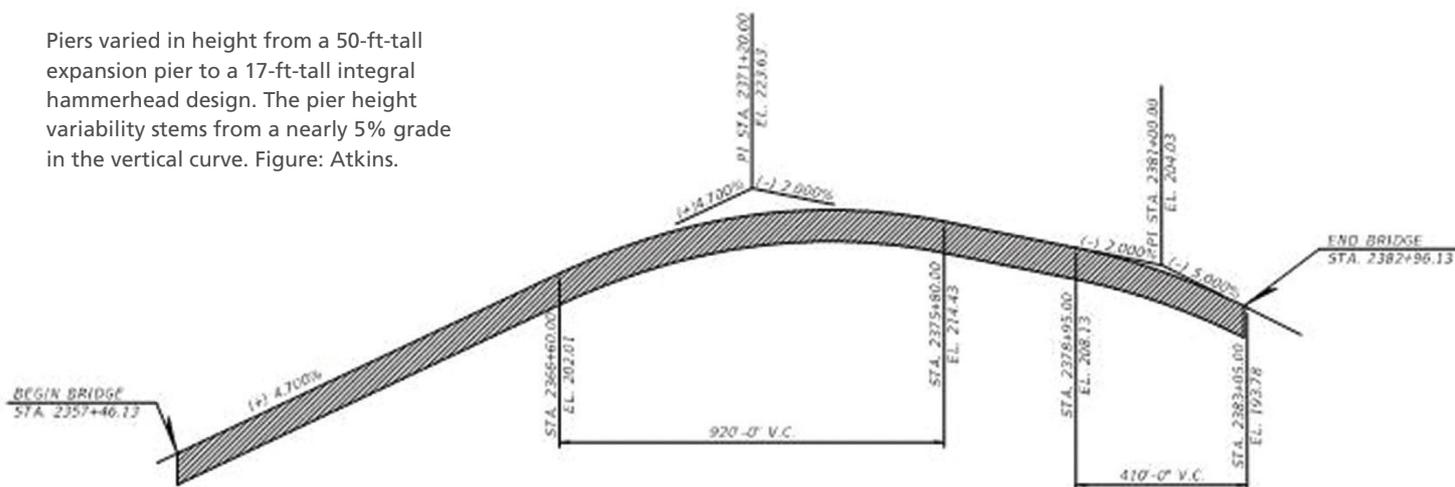
The pier height variability stems from a nearly 5% grade in the vertical curve. This relatively steep vertical curvature allowed the 8% super-elevated two-lane structure to span over Wekiva Parkway. With just over a 17-ft minimum vertical

clearance at this location, the structure depth constraints played a key role in the design efficiency. During design, a team often finds itself exploring technically challenging solutions out of sheer necessity. This project was no stranger to obstacles, and pier 11 attested to the timeless proverb “form follows function.” The use of a post-tensioned integral pier cap reduced the project footprint. The design decision lowered the overall level of the interchange (fourth to third level), reducing the project’s impact on the natural environment.

Superstructure

The superstructure of ramp K is composed of variable-depth haunched U-beams that are 6 ft deep at midspan and 9 ft 7 in. deep at the piers. The U-beams feature a constant 8 ft 6 in. center-to-center web spacing at the top of the 10-in.-thick webs. Typically, the bottom flange width varies between just over 4 ft at supports to exactly 6 ft at midspan, with 1-ft 9-in. constant-width top flanges. The haunched geometry in the spliced-girder system serves dual purposes: The more obvious is to blend aesthetically with local signature bridges

Piers varied in height from a 50-ft-tall expansion pier to a 17-ft-tall integral hammerhead design. The pier height variability stems from a nearly 5% grade in the vertical curve. Figure: Atkins.



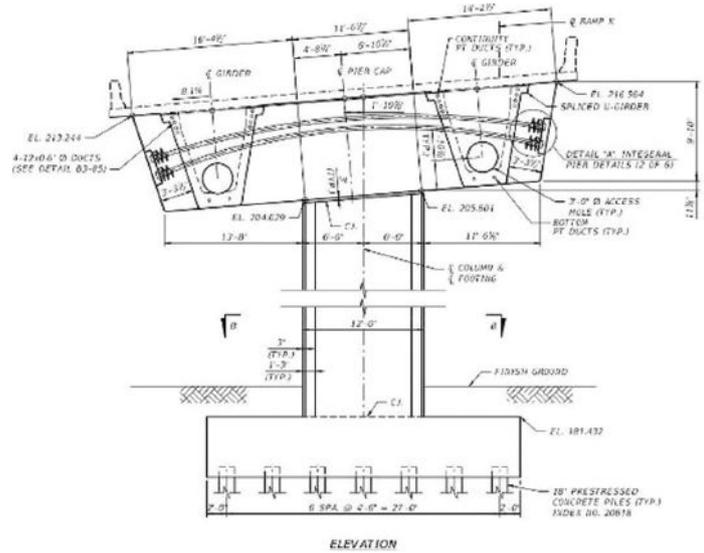
CENTRAL FLORIDA EXPRESSWAY AUTHORITY, OWNER

BRIDGE DESCRIPTION: Ramp K is 2550 ft long with seventeen 150-ft spans and is the first bridge in Florida with haunched, curved, post-tensioned concrete U-beams. Project includes eight bridges using haunched precast concrete U-beams with curvature as small as 1200 ft radius.

STRUCTURAL COMPONENTS: Curved precast concrete haunched U-beams including Florida U 48, U 63, and U 72 beams with cast-in-place columns and pier caps, one integral post-tensioned pier cap, and 18-in.-square prestressed concrete piles.

BRIDGE CONSTRUCTION COST: \$83 million for project (total precast concrete: \$16.5 million)

AWARDS: 2020 PCI Design Awards, Transportation Award: Best Main Span Bridge from 76–149 Feet, and Harry H. Edwards Industry Advancement Award Honorable Mention; 2019 ACEC-FL Engineering Excellence Grand Award; 2019 Florida Transportation Builders’ Association: Best in Construction Award



The design of ramp K's pier 11 is an example of form following function. Through the use of a post-tensioned integral cap and U-beams, the profile was lowered 12 ft and the project footprint was reduced. Figure and Photo: Atkins.

and historical arch structures. The other lies in the system's efficient use of global continuity to reduce structure depth and dead-load moment at midspan and to increase capacity at piers where negative moment demand peaks. The variable-depth post-tensioned design made it possible to span 150 ft with a relatively wide superstructure using only two 72-in.-deep concrete U-beams for the 46-ft-wide ramp.

Unique Design Solutions

To fully appreciate the structure's design, one must keep in mind that a simply supported standard 72-in. prestressed concrete Florida U-beam (without post-tensioning) typically spans 155 ft at a 12-ft center-to-center spacing. By incorporating post-tensioning and using continuity at supports, the design team was able to increase the usual 12-ft spacing

to 25 ft 6 in. and eliminate a girder line. This presented a new challenge: generating a deck design that satisfied the demand set by the 17-ft 8-in. deck span between webs of adjacent girders. Because a refined deck design with finite element analysis was performed, the resulting slab thickness could be optimized to 10 in. using conventionally reinforced concrete. The exception is the thickness of the deck overhang, which was increased to 10.5 in. when necessary to accommodate 42-in.-tall, F-shape traffic barriers in accordance with Florida Department of Transportation standard plans.

Over-the-road shipping constraints had to be carefully considered due to the 150 ft span and 1200 ft radius of the precast concrete segments. The size limits for hauling the curved precast concrete girder segments were 14-ft maximum

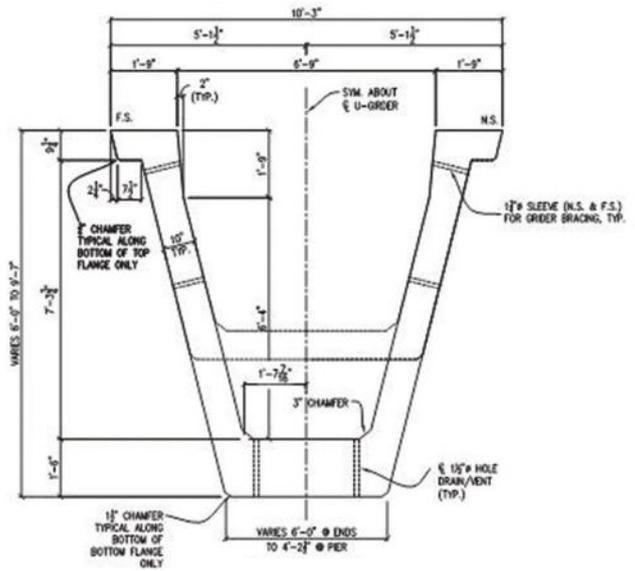
width (including curvature for the 1200 ft radius) and 135 ft maximum length. Ramp L girder segments were the longest on the project, at 131.3 ft. Segments were shipped approximately 20 miles from Leesburg, Fla., to the project site.

Materials

The moderately aggressive environment required a 2-in.-thick steel reinforcement concrete cover for the superstructure. The top surface of the precast concrete beam flanges used a 1-in.-thick cover because it would be protected by the cast-in-place deck slab. All beams used 270-ksi, low-relaxation post-tensioning strands, and Grade 60 mild reinforcement was used for the entire project. Normalweight concrete was used for all components. The bridge decks required concrete with a typical 4.5-ksi compressive strength; an 8.5-ksi design compressive

Erection of a curved precast concrete U-beam in unit 4 of ramp K. Temporary towers are used to support and stabilize girder segments prior to splicing and post-tensioning. Photo: Ken Zagers.





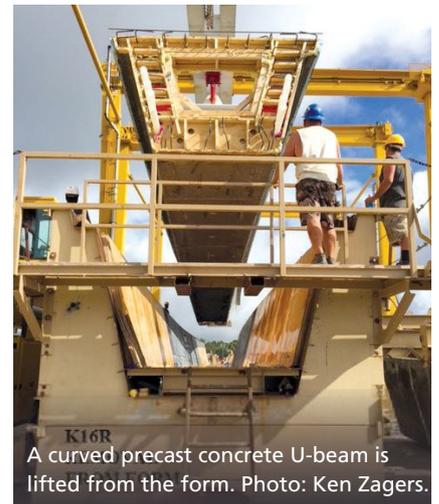
Over-the-road shipping constraints had to be carefully considered due to the 150 ft span and 1200 ft radius of the precast concrete segments. Size limits for hauling the curved precast concrete segments were 14 ft maximum width and 135 ft maximum length. Segments were shipped approximately 20 miles from Leesburg, Fla., to the project site. Cross section of haunched U-beam at the pier is shown at right. Photo: A² Group Inc. Figure: Atkins.

strength (with 6.0-ksi strength required at transfer) was used for the precast concrete U-beams.

Post-Tensioning

The tendon arrangement of the solid rectangular integral pier 11 cap consisted of six tendons centered on the hammerhead cap. A traditional downward concave tendon profile was used to balance the negative moment demand of the pier cantilevers. Each tendon was tensioned to 891 kip and was made up of nineteen 0.60-in.-diameter strands. All tendons were grouted with high-strength, non-shrink grout.

The unit 3 tendon profile is described here as an example of the project's post-tensioning design. The U 72 girders used a total of two bottom-flange tendons and four continuity tendons in each 10-in. web. Flange tendons were swept and transversely spaced at 2 ft on center over supports. At the balanced cantilevered sections over piers 10 and 11, the slab tendons were anchored at the ends of the precast concrete element. Typical to the unit, slab tendons were anchored at each splice location. The 12-strand bottom tendon profiles characteristically ran along the center of the flange and were tensioned to 522 kip each. The



A curved precast concrete U-beam is lifted from the form. Photo: Ken Zagers.



AESTHETICS COMMENTARY

by Frederick Gottemoeller

Interchanges are usually designed solely for the routing of vehicles. Their forms result from the sum of the geometries of their roadways and ramps, and their topography from the automatic application of whatever typical sections are assigned to the roadways. The outcome is generally a mechanistic landscape that looks like nothing in nature. The Wekiva Parkway's designers took a different approach: they designed the grading between the ramps as an extension of the rolling Florida topography around the interchange. The roadways and ramps look like careful additions to the preexisting natural topography. The curved

and lengthened wing walls register as attempts to preserve the existing ground surface. The user's experience is more like driving through a park than negotiating a high-speed interchange.

Ramp K is the most prominent feature of the interchange, and the innovation involved in its design has paid functional, economic, and aesthetic dividends. The curved and haunched U-beams support the interchange-in-a-park theme by minimizing girder depths at clearance points, thereby minimizing the amount of grading and the length and height of the retaining walls. In

addition, the deepening of the U-beams over the piers increases the sculptural interest of the bridge for everyone passing through the interchange. Finally, the ability of just two lines of beams to carry the ramp simplifies the appearance of ramp K from below.

It is exciting to see the use of an integral pier cap for U-beams. By reducing the height requirement at the interchange's key clearance point, the overall height of the interchange was reduced, further supporting the interchange-in-a-park theme. This pier cap may have been more expensive than the other caps, but the savings in grading and walls, as well as the interchange's smaller footprint, offset the higher cost of this one pier. The final result is an attractive driving experience for the residents and tourists in Central Florida that was also the lowest cost design available.



Ramp K pier segment erection. Photo: A² Group Inc.

exception was the midspan element between piers 10 and 11, where four-strand spot tendons were added that were tensioned to 174 kip.

The eight 12-strand (0.60-in.-diameter) continuity tendons connected the entire three-span unit. These tendons were typically centered on the web, tensioned to 522 kip each, and anchored at the 3-ft-thick end diaphragms. At the end diaphragms, the top tendon in each web is 18 in. from the top fiber, and the remaining three tendons are vertically spaced at 15 in. on center. At midspan, the tendons are equally spaced 6 in.

on center, with the lowest tendon positioned 6 in. from the top of the bottom slab. At piers 10 and 11, the highest tendon is just 4.5 in. from the extreme top fiber of the beam. The three lower tendons are typically spaced at 6 in. on center.

Conclusion

This innovative bridge is the first in Florida to use haunched, curved, post-tensioned precast concrete U-beams. The spliced, precast concrete U-beams provided a cost-effective solution that lowered profiles with haunched girders, leading to shorter columns and

minimal fill material at the approaches. The project's aesthetic goals were achieved with an efficient structure and minimal impact to the environment. Traditionally, curved bridge structures are fabricated with steel rather than concrete. Post-tensioned precast concrete increases typical U-beam girder spacing and provides improved durability, while still accommodating over-the-road shipping of the precast concrete girder segments. ▲

Yanko Castellanos-Ibanez is a structural engineer and David Konz is a technical manager with Atkins in Orlando, Fla.

Ramp K has a complex geometry with horizontal and vertical curvatures and superelevation. Pier 11 with its integral post-tensioned cap is in the median of the Wekiva Parkway at the right side of the photograph. Photo: Atkins.

