FROM TOP TO BOTTOM

Top-down construction is getting the thumbs-up on segmental flyover bridges in the USA. Craig Finley reports.

While the city of Miami goes about its typical day, a bright yellow monster sits idle, high above one of South Florida's busiest roadway networks, waiting for its work to begin. As midnight nears, the 140m-long, 431t launching gantry comes alive, preparing to continue the only task it was built to perform - erecting four segmental bridges in the heart of Miami.

At the end of September, the first of 783 concrete segments was erected for the four segmental bridges that form the centrepiece of the new US$559 million Palmetto/Dolphin Expressway Interchange. This milestone marked the beginning of a 36-month construction process that will result in the reconfiguration of the roadway where SR826 - the Palmetto Expressway - meets SR836 - the Dolphin Expressway.

The design-build-finance project entails the construction of a four-level interchange at SR826 and SR 836, as well as the reconstruction and modification of two existing interchanges. Known as Section 5, it is the final and largest piece of the 12-part, 20-year, multi-billion dollar Palmetto Expressway reconstruction project.

This interchange is a critical component of the South Florida transportation network, as the Dolphin Expressway is a major route to Miami International Airport. Four complex precast segmental bridge ramps will traverse the core of the interchange. Curving at radii ranging from approximately 183m to 396m, the bridges are each 14m wide and range in length from 335m to 747m.

Total deck area of the four bridges is 33,510m², with a total length of bridge of 2.4km. The longest span is 81m and the tallest pier is 25m; the proposed maximum superstructure deck height is 29m above ground.

Located as it is in an urban area, the site conditions and owner stipulations create a number of challenges that require creative design and erection solutions. "This is a very complex project because of the volume of traffic travelling under the new interchange," says Florida Department of Transportation design project manager Ali Toghiani. "There is also limited area in which to construct the bridges and limited right of way, and the proximity to the airport makes it even more difficult."

The segmental flyover bridges are being built over multiple roads that carry an average of more than 430,000 vehicles per day. Owner FDOT demands that the project cause minimal disruption to traffic around and beneath the project site. As a result, the majority of construction takes place overnight, between 11pm and 5am.


Reinforcement cage for segmental construction being moved in the casting yard (Rizzani de Eccher)

With these and other restrictions at issue, the project team opted for top-down construction, allowing work to progress while causing as little traffic disturbance as possible. Rather than raising the precast units into place from below, the team is using the self-launching overhead gantry to build the bridges in balanced cantilevers, working out from the piers. This eliminates the need for substantial temporary falsework supports and for earthbound cranes that require redirection of traffic during critical construction periods.

When *Bd&e* went to press, work in the early stages of the project had confirmed that the process was being carried out successfully. "The gantry is operating well," says the joint venture contractor's project manager Gus Quesada. He leads the team of Community Asphalt/OHL Group, Condotte America, and The de Moya Group, which is responsible for building the new structures. Italian contractor Rizzani de Eccher designed the gantry specifically for the Section 5 project with the assistance of its equipment manufacturing subsidiary, Deal. RDE is also responsible for erecting the segmental bridges using the gantry.

The gantry was manufactured by Deal in Italy, then shipped in containers by sea to Miami where it was assembled on site and load tested before commissioning. Remote-control operated and powered by a 500V generator, the gantry's self-launching speed is approximately 24cm per minute.

For the gantry to operate at the necessary level of efficiency, bridge designer Finley Engineering Group worked closely with RDE to ensure that the design meshed with the speciality contractor's construction methods and equipment.

For example, the desired size of the gantry required that segment weight not exceed 80t, so the 2.7m to 3.7m segments range in weight from 54t to 79t.

Moreover, Finley's design enlisted the pier caps to support the balanced cantilever during construction. This innovative approach was primarily the handiwork of Jacques Combault, who is the technical director for Finley, engineer-of-record for the project's segmental bridges. "I probably spent most of the time that I worked on this project trying to find a design for the pier heads that could stabilise the deck so we could eliminate temporary supports," says Combault.

The pier cap solution included providing for loop tendons through the caps to tie down the launching gantry and the curved balanced cantilever superstructure. Combault had used a similar technique in the design of a viaduct near Paris with similar site constraints. "Using the pier caps as supports has been done before, though probably not as often as it should be," he says. In addition to their vital functional role in the construction process, the pier caps contribute to the overall aesthetics, an important factor because of the prominent location of the interchange.

The design team also proposed an alternative technical concept that incorporates polystyrene in the hollow pier columns, except at the base and caps, which are solid. This eliminates the need for interior formwork and reduces the overall mass of the structure and amount of concrete required. As this is not standard specification for FDOT, a technical special provision was required.

Finley designed footings in varying geometric shapes to accommodate the limited space available and specified 610mm-diameter prestressed concrete piles in lieu of drilled shafts for more efficient foundation design. In addition to the changing geometric shapes, the orientation of each footing is specific to that pier, and they are designed to accommodate various hurricane-level wind angles and overturning moments from the launching gantry and out-of-balance cantilever load conditions.

The top-down approach enabled by these and other innovative solutions forms the linchpin of the design that is bringing to reality a project that it seemed would never happen. Indeed FDOT had been planning to reconstruct this section of the expressway project for more than a decade, but the site constraints and other difficulties prevented initial attempts to get the project off the ground from complying with the necessary budget, schedule and logistical detail.

In 2009 it was resurrected with FDOT requesting a design-build project delivery approach with gap financing,. The Community/Condotte/de Moya joint venture of three Miami-based contractors was one of a handful of teams that responded. Working with Finley and BCC Engineering, the team submitted a redesign that eliminated two complex segmental bridges and extended the remaining four. It also eliminated two loops in the middle of the new interchange and replaced them with a turnaround slightly to the west of their original position.

Ultimately, the team gave FDOT everything it wanted within its US$559 million budget and in significantly less time than allotted. Where FDOT set the maximum programme at 3,500 days, the JV submitted a proposal with a construction period of 1,825 days, with extensions for rain days and holidays.

Another problem was the proximity to Miami International Airport. The interchange is directly in the approach path of one of the airport's runways, meaning the project had to keep within a certain height limit, including during the construction phase.

The top-down approach first eliminated the need for a long-boom crane that would have exceeded the height allowance for construction. Secondly, the height limitation drove another innovative design decision - the use of variable-depth segments. "We decided to use variable-depth segments to satisfy the clearance limitations," says Combault. "This also made the project more economical by reducing the weight of the segments and the amount of material."

By haunching the first four segments, the high shear demand of the launching gantry can be supported directly by these segments. The haunches also allow for an increase in span lengths, reduction in the amount of substructure construction required, and overall simplification of the interchange. This simplification resulted in fewer segmental bridges and elimination of intermediate expansion joints.

Additional cantilever post-tensioning was introduced in the haunched segments to significantly reduce the required external post-tensioning. The external post-tensioning, to include unique deviator-to-deviator tendons, was designed to eliminate the need for internal bottom slab post-tensioning.

Because the redesign proposed by the joint venture hinged on the ability to place the highest of the segmental bridges at a fourth level, the ability to stay below the limit set by the flight path made the design come together.

"The variable-depth superstructure ranges from 3.7m at the columns to 2.7m within about 12m of the columns," says BCC Engineering president Jose Munoz. "We could only go so high with this project, and the variable-depth deck allowed us to reduce the third and fourth-level bridges by 1.2m in height each. This extra 2.4m enabled us to keep a level-four flyover in the design."

Several other innovative technologies were used on the Section 5 project, including the first use of tendon diabolos in the state, which the DOT had banned for use in Florida almost a decade previously. These curved pipes in deviators which offer an alternative solution to detailing individual tendon pipe bends were banned because of the possible effects of localised bearing stresses and the 'potentially lesser quality of the corrosion protection system'.

However Finley has used diabolos successfully on several other segmental bridges; they eliminate the more traditional bent steel pipes that are cumbersome to fabricate, install, and connect to HDPE pipe. They also allow variable tendon geometry and continuous external tendon ducts. Diabolos were incorporated into the segmental bridge design conditionally upon receiving FDOT's approval to use them as an alternative technical concept.

The project team received a project-specific modified special provision to use the diabolos, setting a limit of a 3m radius within the diabolos and requiring testing of wear resistance and creep for approval.

Another advantage of the diabolos is that they allow for the stressing of any

Aerial view of the SR826/836 interchange with the Deal L66 gantry visible at the bottom left of the picture

single span or multiple spans in the future. "When the tensioning is inside the blocks, you don't have to stop or divert traffic," says Combault. "Everything is made inside the box."

Additionally, Finley's design provided interior supports for use of temporary balanced cantilever stabilisation jacks, and moved cantilever tendons from the bulkhead face to the interior blisters to remove tendon grouting from the critical path. By rebalancing the span arrangements and using haunched girders, Finley also reduced the number of spans and piers and eliminated the intermediate expansion joints.

For example, the original design of the longest of the four segmental bridges at 774m, demanded four expansion joints. Finley's design eliminated the two interior expansion joints, offering a 50% reduction in construction labour and materials associated with this detail change. The redesign also reduced the number of spans from 15 to 11, and consequently the number of piers from 14 to 10. This saved 29% in the number of piers and associated substructure material at these locations. Other enhancements include the elimination of longitudinal closure pours at gore areas, where two adjacent segmental bridges were originally spliced together.

Some design decisions were driven by site constraints at ground level. The area of the interchange abuts buildings on one side and the airport on another, busy roadways run under, through and around the site, and a canal intersects the project area. Additionally, the high water table in South Florida limits the depth of foundations.

Technology of all kinds is aiding in the logistical coordination of the project, including the team's use of bridge information modelling, which infuses 3D CAD models with data that allow engineers and technicians to more easily and efficiently manipulate design and construction drawings. This process instantly reflects how a single change affects all other components, saving significant time drawing and redrawing plans.

The design team used Bentley's RM Bridge V8i, MicroStation V8i and Rebar programs to generate segment and tendon geometries. When incorporated into other bridge information modelling solutions, the additional functionality allowed for easier and more efficient checking of web intersection conflicts with the internal tendons, sizing of diabolos, checking of tendon stressing jack conflicts and routing of internal tendon ducts.

This enabled the tendon geometry for four segmental bridges to be evaluated within weeks, and the segment dimensions for the project could be established early in the design stages, saving valuable time on the design-build project. The project team is also using Sharepoint software for electronic collaboration of MicroStation files, project files, schedule coordination, transmittal letters, internal design and construction requests for information.

As of mid-October, 110 of the 783 segments had been cast at the casting yard that was already producing segments for a Miami Orange Line rail project involving Community/OHL and RDE. The yard is approximately 16km away in Hialeah, and has two casting cells dedicated to the Section 5 project. This enables the fabrication of two segments a day and an average of eight per week. The concrete volume per 2.7m to 3.7m segment ranges from 22m³ to 30m³ and the rebar weight within each segment varies from 2,540kg to 8,600kg.

The journey from the casting yard to site can take from 30 minutes to as much 90 minutes, depending on the route and time of day. The route taken is dictated by the weight of the segment.

The self-launching gantry erection sequence begins with the erection of the expansion joint segment and first segment being placed on the falsework. The gantry then launches forward on the main truss, engaging its front leg on the pier cap. The pier segment is set in place on temporary jacks. After relocating the necessary supports, the gantry launches forward again on the main truss and begins erecting the balanced cantilever up to 13 segments each side of the pier, and locating the counterweight.

The next step is to erect the end span segments on falsework and the remaining balanced cantilever segments, erecting the downstream segment of a pair first. Strongback beams are then installed, the closure is poured and, once the required concrete strength is reached, continuity tendons are stressed. The main truss is then moved forward and to prepare for self-launching and the process continues.

As of mid-October, the project was exactly one day ahead of schedule, says Quesada. "We have 34% of contract time passed and 39% of the contract amount billed and constructed." The notice to proceed was given in November 2009 and it is due to finish in November of 2015, though the bridges will open on a staggered schedule.

The Section 5 project is design-build-finance because it requires a level of gap financing throughout most of the project. FDOT set out a schedule of payments that initially meshes with the design-build team's progress. At about 18 months, however, the FDOT money falls below the point of cumulative work completed. The design-build team must account for the gap in financing for the remainder of the project's life and beyond. Factored into the fixed-fee price is the cost of borrowing to finance the gap until FDOT's final US$46.5 million payment in January 2017, more than a year after construction is scheduled to be done ■

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