Design and Construction of the Route 895 James River Bridges, Richmond, Virginia

Joseph Showers, Taka Kimura, J. Deschamps, Parsons Brinckerhoff, Denver, CO
Victor Ryzhikov, Parsons Brinckerhoff, Tampa, FL

The Route 895, Pocahontas Parkway is a nine-mile long design-build tollway project around the southeast quadrant of Richmond, Virginia. It was constructed under Virginia's Public Private Transportation Act (PPTA) of 1995, which provided a mechanism for private development teams to participate in highway projects.

The joint-venture development team of Fluor Daniel/ Morrison Knudsen (FD/MK) was selected by the Commonwealth of Virginia to complete the design and construction of the Rt. 895 project. The crossing of the James River was recognized as a special feature of this project. A bridge type study had previously been prepared by VDOT, and recommendations had been made. Preliminary "bidding plans" were produced by the Virginia DOT in the summer of 1997 for the contractors to develop bids, based upon the structure type selected by the FD/MK design-build team. FD/MK selected a joint venture of Recchi America and McLean Construction to construct the River Crossing, approach spans, and ramps at the I-95 interchange based upon final design drawings prepared by FD/MK. After a review of the drawings and the prevailing marketing conditions, Recchi and McLane proposed a joint venture (Recchi/McLean) to combine the most appropriate elements of the alternative schemes examined in the bridge type study into one bid to be submitted to FD/MK. Negotiations were begun with FD/MK based upon preliminary drawings provided by VDOT, and continued until spring of 1998. Design was begun in the summer of 1998, directly in advance of substructure construction activities

The James River crossing is the most prominent feature of the Rte 895 project and was the result of a number of demanding geometric requirements. The 4% approach grades and 145 foot vertical clearance over the maintained channel leading to the Port of Richmond require a 4,766-foot-long bridge. After examination of alternatives, it was decided to clear span the 675-foot wide James River with the river crossing bridge. This decision eliminated the hydraulic impacts of the foundations and the need to design the foundations for ship impact. It also resulted in a main span of 672 feet, the second longest span for concrete box girder construction in the United States.

At the high level bridge crossing location, there is also an interchange with I-95. The Rte 895 mainline profile grade is approximately 125 feet above grade at the I-95 crossing at the interchange. Three ramps connect I-95 with Rte 895, resulting in long ramp structures that rise to an extraordinary height above the surrounding relatively flat topography. This visual prominence resulted in a monumental appearance and made aesthetics a major design consideration. In addition, two of the ramp gores were located at the main span piers on the west side of the river. This required a design of the main span to accommodate large variations in deck geometry, yet be constructible with the contractor's selected means and methods.

The Virginia Department of Transportation (VDOT) prepared a bridge type study for the crossing 1997. In accordance with VDOT directives, the design team was instructed to make recommendations for two competitive materials, based upon the same roadway alignment and design parameters. Alternative bridge types evaluated for the main span included:

- 410-foot-span, simple span, parallel chord steel truss
- 410-foot-span, steel tied arch
- 410-foot-span, continuous, steel plate girders
- 410-foot-span, continuous, steel box girders
- 655-foot-span, simple span, parallel chord steel truss
- 655-foot-span, steel tied arch
- 655-foot-span, cable-stayed steel deck bridge
- 410-foot-span, continuous, segmental concrete box girder
- 655-foot-span, continuous, segmental concrete box girder
- 655-foot-span, cable-stayed concrete deck bridge

The 410-foot span alternatives required piers to be located within the James River, and foundation construction to take place in the river. The 655-foot span alternatives placed the piers near the river banks, resulting in improved accessibility for foundation construction and eliminating ship impact loadings on the main piers flanking the channel. Based upon study unit prices and quantities based upon preliminary structure designs, square footage costs were computed for each alternative.

Alternative bridge types evaluated for the high-level approach spans included steel plate girders, steel box girders, and segmental concrete box girders. Alternative bridge types evaluated for the low-level approach spans included steel plate girders, AASHTO Type VI Modified Precast Concrete Girders, and Segmental concrete box girders.

The FD/MK team reviewed the VDOT study and made the final decision regarding the project bridge types in the their proposal to VDOT. The design-build team's proposal to construct the James River crossing consisted of four types of bridge construction, including three types of segmental concrete construction:

- Cast in place, variable depth, segmental concrete box girders with a maximum span of 675 feet for the Eastbound and Westbound crossings of the James River. The combined length of the Eastbound and Westbound river crossing bridges was 3,184 feet.
- Constant depth, precast segmental concrete box girders with a maximum span of 210 feet for the east and west mainline approach bridges for both the Eastbound and Westbound Bridge structures. The combined length of the . The combined length of the Eastbound and Westbound approach bridges was 6,348 feet.
- Constant depth, precast segmental concrete box girders for portions of the I-95 interchange ramps located on tangent alignments. These were located on lower level ramp portions adjacent to the abutments.
- Steel plate girders for portions of three I-95 interchange ramps located on sharply curved alignments. These ramp portions were located on higher-level areas adjacent to the concrete mainline bridges.

The FD/MK team decisions regarding bridge types were made based upon economic considerations, familiarity with construction methods, and access to specialized equipment needed for construction. From a design perspective, the complex deck geometry and multiple types of construction introduced a number of design and construction issues.

1. BRIDGE GEOMETRY

APPROACH SPAN BRIDGES

Both the eastbound and westbound bridge decks consist of two precast segmental trapezoidal concrete box girders connected by a longitudinal cast-in-place construction joint. Typical segments are 10 feet long and 10 feet tall, and vary in width.

For the West Approach Spans, the alignment is on a tangent with exception of a gore area for Ramps F and G. The gore geometry was addressed by variations in the plan geometry of the precast segments. The width of the cantilevered slab overhangs that extend from the trapezoidal box core of the girder was varied, while the distance between the tops of the webs was held constant. This arrangement standardized the core forms for the casting machines, and simplifies formwork adjustments to accommodate variations in the transverse segment geometry. The standardized core form also allowed for use of the same casting machines to fabricate both the approach spans as well as the ramp superstructures. Horizontal curves were also introduced in the girders to limit the maximum overhang dimensions. In addition, there are also variations in the segment cross slope over the length of the gore areas to accommodate the roadway cross section geometry. This complex three dimensional geometry is accommodated by the short-line, match cast, precasting equipment that was custom-fabricated for this project. The segments are transversely post-tensioned in the casting yard, and longitudinal post-tensioned in the field during erection. Unlike the West Approach Spans, there are no gore areas on the East Approach Spans, resulting in more simplified geometry. The horizontal curve on the East Approach Spans did not require extraordinary measures to be taken to accommodate the bridge deck geometry.

One unusual feature of this project is the combination of the precast segmental concrete box girder mainline superstructure with the structural steel plate girder ramp structures. Steel ramp structures are primarily used in areas adjacent to the mainline, due to tight horizontal curve geometry and tall columns on curved areas. As a result, the gore areas are detailed to accommodate both bridge types at the Ramps F and G gores. In addition, there are transition piers where the precast segmental ramp spans meet the steel girder ramp spans.

Durability of the precast segments is addressed by the use of epoxy coated deck reinforcing, the use of 45 MPa concrete with slag cement, galvanized bars for the parapets, and coated transverse prestressing hardware in the upper areas of the deck slab. In addition, the precast segments are steam cured. Further protection is provided by a minimum 2-inch latex modified concrete deck overlay.

RIVER CROSSING BRIDGES

The bridge crossing the James River supporting the Eastbound lanes is three span cast-in-place segmental box girder with a 377 ft – 672 ft – 406 ft span arrangement. There were no obstacles to a relatively typical three span arrangement for cantilever construction.

The bridge supporting the Westbound lanes has a significantly different span arrangement of spans 246 ft – 423 ft – 672 ft – 388 ft and is the result of the I-95 interchange plan geometry. At the west end of the Westbound bridge, the existing Chippenham Parkway interchange ramps limit pier placement locations, and result in the necessity to add a fourth span to the river crossing structure. This also required the completion of the 246 foot span to be done in progressive cantilevering over I-95, a major interstate highway. Cast in place cantilever construction over active traffic on this type of highway facility is unprecedented in the United States.

Both the Eastbound and Westbound river crossing bridges have ramps that merge with the mainline. Ramp E enters the Eastbound lanes in the vicinity of Pier EB-13, while Ramp H exits the Westbound lanes in the vicinity of Pier WB-12. Both ramp terminals require lane tapers and drops, resulting in variable width roadways on both bridges. In addition, there is a horizontal curve and super-elevation transition located on the east side of the river, within the limits of the river crossing structures. These roadway geometric requirements resulted in unusual, complex geometry for these long span structures.

The superstructure box girder cross section for the two bridges is also standardized to the maximum extent possible to allow for reuse of equipment and formwork. The typical "core" area of the cross section consists of two cells and three vertical webs, and a constant soffit width of 46-foot. The deck slab is cantilevered past the exterior webs, and the width of the overhang varies to accommodate the variation in roadway widths at the gore areas and also a change in the number of lanes. The deck overhang dimension varies from 8.25 feet to 15.58 feet. In many cases, the deck overhangs are not symmetric about the girder cell centerline. The torsional capacity of the large cross section accommodated torsional moments resulting from the overhang inbalance, while the foundations had sufficient capacity to resist transverse dead load moments in the piers. While this asymmetry was addressed in the design, it did not require extraordinary forming requirements for the cast-in-place construction.

From a geometric perspective, the gore areas are significantly more complex than the "typical" girder section. The gores require a large variation in ramp width over a relatively short distance. Steel plate girders were selected for the framing of a majority of the gore areas, since the extent of the widening exceeded the maximum capacity of the segmental concrete deck slab cantilevers. The ramp gore framing is supported at one end on one of the ramp piers and at the other end on a cantilevered concrete bracket projecting from the outer face of the girder diaphragm. The deck slab on top of the gore area is detailed with a longitudinal closure joint to limit the effects of the box girder stiffness on the vertical deflection of the steel plate girders during deck slab placement.

2. BRIDGE AESTHETIC ISSUES

At the early stages of project development, it was recognized that the James River crossing would extend be a prominent structure in the landscape, and that aesthetic issues needed to be addressed by the project design. The VDOT Preliminary Design was developed in coordination with the FD/MK team, and this design contained a number of features that addressed these issues.

Attention was given to the form and number of Approach Span pier columns and caps. The twin approach span box girder superstructures are supported by a single circular column with a hammerhead cap, as opposed to two girders supported by two columns.

This resulted in reducing the number of piers supporting the long structures, and reduced the “cluttered” appearance common to many interchanges. The hammerhead cap forms were standardized to provide for consistency between the portions of the interchange and to maximize the economy of the forms by providing for that maximum number of reuses. The custom forms had curved transitions between the ends and soffits to soften the visual edge at the outside faces of the pier caps.

The River Crossing pier forms also required attention. It was recognized that the 672 -foot span girders with over 40 foot of height at the piers required a relatively massive column to support them. However, it was decided to reduce the scale of the columns to the maximum extent possible to avoid overpowering the other substructure elements. This also reduced concrete quantities for the substructure and dead loads on the foundations. It was decided to use a two-piece pier consisting of a prismatic column with an 8 foot thickness and 32 foot length, along with a variable section pier cap to visually transition between the column and the 45 foot wide girder soffit. The two-piece column form also provided for visual consistency with the Approach Span columns and caps. This form was reused 13 times for the main piers and transition piers for both the Eastbound and Westbound Bridges.

An important aesthetic consideration was the visual transition between different types of superstructure construction. Ideally, it would have been desirable to have the ramps constructed with the same type of construction as the mainline bridges. However, as previously mentioned, the contractor made the decision to use steel plate girder ramps at locations where ramps tied into the segmental concrete box girder main line bridges.

This introduced a significant design problem for the main span units. The gore areas were located at the pier supporting the main span on the west side of the river. Adding an additional column to support the ramp gores was considered, but eliminated based for aesthetic and economic reasons. It was decided to construct a bracket that was post-tensioned to the pier diaphragm inside of the box girder. The eccentric dead load of the gore did not result in significant transverse eccentricity on the bridge substructure. In addition, the steel spans were of a significantly smaller scale than was the main span girder. A screen wall was constructed at the end of the bracket to reduce the visual “clutter” of the ends of the steel transition span.

During the development of the main span design, the soffit cross slope was discussed. From a detailing viewpoint, it is often advantageous to have equal web heights. However, the Rte 895 main span has a constant cross slope and a significant portion of the bridge on a horizontal curve. If constant web heights were used, the bottom surface of the bridge would not be transversely “flat”. When combined with the parabolic cross section depth, this would result in a visually complex and possibly discordant shape. This transverse geometry would also have required sloping the colujn caps and not keeping them level. Fortunately for the project aesthetics, the contractor elected to use variable web heights and a transversely flat cross slope.

3. CONSTRUCTION METHODS

Erection of the Rte 895 Crossing of the James River utilized many different erection methods. Erection of the West Approach Spans segments in cantilever was done with an overhead erection truss. This self-launching truss places segments on opposing longitudinal faces of the pier segment, minimizing longitudinal unbalanced moments on the substructure. The truss also supported stressing platforms necessary for installing longitudinal tendons in the upper portions of the segments. Overhead erection methods are preferable to use of ground mounted equipment at the west approach due to the access limitation issues resulting from the existing roadways and temporary detours directly beneath the bridge.

The truss was equipped with a chassis system that allowed for transverse launching or “sideshifting” at piers. As a result, a portion of one girder is erected, the truss sideshifted, a portion of the second girder erected, and the truss sideshifted again to finish erection of the first girder.

Erection of the East Approach Spans segments is done in cantilever from the piers. However, the erection of the east approach spans used ground based cranes, as opposed to the overhead erection truss used on the West Approach Spans, since the relatively open terrain on the east side of the river resulted in few limitations on contractor access. Longitudinal stability of the partially completed cantilevers required use of cable stays anchored into the footings to resist out-of-balance erection moments.

Erection of the River Crossing segments in “balanced” cantilever was done with traveling forms supported by the previously completed portions of the superstructure. Due to the unequal length of the side span cantilever arms relative to the main span arms, as well as the very large rotational stiffness of the twin wall piers, temporary support towers were required under the side spans at one locations to limit the erection impacts of on the substructure. Casting of segments took place over shipping traffic with no unusual restrictions other than limiting the
dimension that the girder forms could
extend below the soffit.
A unique construction feature of this
project is the use of progressive cantilevering for the 246 foot Westbound River Crossing bridge span over I-95 between Piers WB-10 and WB-11. Due to the span arrangement, it was not possible to balance the segment weight at Pier WB-11. As a result, one arm of the cantilever is made continuous with the adjacent arm well before completion of the opposite arm. A vertical jacking operation is also introduced on this arm to control service stresses and assist in limiting moments in the single column support pier. The construction of this span took place directly over active traffic on I-95 with few difficulties. While construction of cast-in-place cantilever bridges over freeways has been previously performed on projects in other countries, this is the first known application in the United States.

Erection of the segmental ramps was done using span-by-span methods and an underslung erection truss.