Rail Transit Bridges

Overcoming challenges with cost-effective, low-maintenance, segmental concrete solutions

by William R. Cox, American Segmental Bridge Institute

The first precast concrete, segmental, post-tensioned rail transit bridges in the United States were built for the Metropolitan Atlanta Rapid Transit Authority in 1985. Photo: FIGG.

Rail transit projects have become more prevalent over the years as municipalities look to encourage rail transport to alleviate congestion. In a growing number of cases, segmental concrete bridges are creating the optimum solution for cost-effective, quickly constructed, and aesthetically pleasing structures.

Today, 35 major metropolitan areas have passenger rail systems, with many of them elevated above surface streets and highways. These systems are often challenging to construct, with limited right of ways, obstructions to span, and small radius curves. They also are highly visible to the public, requiring more attention to detail, especially on the substructures and the underside of the superstructures that are more apparent to pedestrians and drivers.

Segmental concrete bridges offer a variety of benefits that overcome these design and construction challenges. They provide an optimum span length of 100 to 150 ft but can extend to 350 ft or more when required.

Segmental construction can be used in a variety of difficult site conditions. Piers can be set in tight footprints, and superstructures can go over and around community landmarks and roads. The segments also can be set from above, alleviating ground congestion and disruptions. Segmental designs allow tight radii for curved spans. Precasting, using shortline casting methods, allows segments to be cast and erected with speed and accuracy.

Generally, no specialized transport equipment is needed to deliver segments to the site, where they can be picked and placed immediately, allowing faster on-site handling. Power supplies and other rail service requirements can be located inside the box girders leaving an uncluttered outside concrete appearance.

The designs offer aesthetic versatility by allowing concrete to be cast into sleek geometric shapes from piers to superstructure and railings. Designs also can use formliners to create textures that fit with an existing neighborhood.

Transit projects have been using segmental concrete construction since the early to mid-1980s, and they continue to grow in number and diversity, as the following examples show.

Atlanta's MARTA

Completed between 1983 and 1985, two precast concrete, segmental, post-tensioned structures for the Metropolitan Atlanta Rapid Transit Authority (MARTA) were the first of their kind for a railway bridge in the United States. They showed transportation officials nationwide that segmental techniques could economically solve bridge construction needs in heavily congested urban areas.

The project's original plan for using cast-in-place concrete box girders was value-engineered to a precast concrete segmental design erected using span-by-span construction with external post-tensioning tendons. The tendons were located within the box-girder void but external to the concrete.

The first segmental structure is 5230 ft long and 30.35 ft wide, and was designed to carry two tracks. It consists of simple spans ranging from 70 to 100 ft in length. The box-girder superstructure segments are 10 ft long, 7 ft deep, and weighed approximately 30 tons.

The second structure, which is 1900 ft long, has span lengths from 75 to 143 ft. It includes a four-span continuous unit. Continuity was accomplished by

The 8.7-mile-long concrete segmental guideway at JFK International Airport features precast concrete segmental box girders that were erected with four erection trusses working simultaneously using the span-by-span method. Photo: FIGG.

modifying the post-tensioning pattern of the pier segments where the tendons are anchored. The outside concrete dimensions are the same as those for the first structure, allowing the same side forms to be used.

For erection, identical triangular trusses on each side of the box section were used to support the box girders under their wings. To accommodate the variety of span lengths, the truss was adapted with the addition of 40-ft, 8-ft 10-in., or 5-ft-long sections. This was the first application of the triangular truss system for span-by-span construction in the United States and proved successful.

New York's JFK Airtrain

This 8.7-mile-long concrete segmental guideway links the terminals at JFK International Airport with New York City's mass transit systems. The structure spans parking lots and active roads, and runs along an expressway right-of-way. The segmental structures were built while maintaining traffic of 160,000 vehicles per day.

Two types of concrete boxes were precast to create the 5195 segments needed, all of which were barged from Virginia to Camden, N.J., and then trucked to the site for delivery.

The Type I box, with a width of 19 ft, was designed for a single track. The Type II box, with a width of 31 ft, was designed for dual track. Both types are 7 ft deep and vary in length from 8 to 9.5 ft in 6-in. increments. These variations accommodate the varying span lengths in the congested urban setting.

The segments were erected using span-by-span methods, with four erection trusses working simultaneously in different parts of the project. Twelve segments were fabricated each day using 14 casting machines. Twin triangular erection trusses were used to erect one span (with epoxy joints) in 1½ days, with an average of 800 ft of bridge erected each week. The structure has 460 spans and was completed in 2001 two months ahead of schedule.

Seattle's Sound Transit

Engineers designing the Seattle Sound Transit rail system, which was completed in 2008, used a similar design to the one they had recently completed in Vancouver, B.C., Canada. The restricted right-of-ways on both projects were a key reason for using a segmental design, which features 26-ft 6-in.-wide, 7-ft-deep precast concrete box girders.

The 4.2-mile-long elevated project used 2207 segments and 160 concrete piers to carry twin tracks with continuously welded rails on top of the superstructure. Typical span lengths are 120 ft, with spans of 220 to 350 ft used where the bridge spans I-5, the BNSF rail tracks, and the Duwamish River.

The box girders feature a unique triangular-shaped cross section. The width of the bottom slab was sized to satisfy the box-girder bending stresses. Lateral stability at the piers is provided by external diaphragms, which are integrated with the pier shapes. This creates a sleek, narrow section that significantly reduced material quantities.

Speed of construction was a key benefit, as the project represented the last section of the rail system.

Seattle's Sound Transit project in 2008 features twin, 26-ft 6-in.-wide precast concrete box girders.. Typical span lengths of 120 ft were used, with spans of 220 to 350 ft to traverse ground obstructions. Photo: Hatch Mott MacDonald.

The Miami Intermodal Center—Earlington Heights Connector features three types of concrete spans, including precast, post-tensioned segmental concrete box girders. Thirteen single-cell, constant- and variable-depth box girder units were erected using the balanced cantilever method. Photo: Rizzani de Eccher USA.

The superstructure was erected using an overhead travelling gantry. The segmental design cut the estimated schedule by more than nine months, as site work was performed while segments were cast. The winning bid also came in more than 10% below original estimates.

Miami's Intermodal

The Miami Intermodal Center—Earlington Heights Connector provides a light rail connection between the new Miami Intermodal Center Metrorail station and the existing Earlington Heights Metrorail station. The 2.4-mile-long elevated guideway carries both single and double tracks.

The concrete box-girder portions feature 13 units over 1.1 miles with constant- and variable-depth, single-cell precast concrete box girders. The single-track box girders have a constant depth of 7 ft 8 in., while the dual-track box girders have a variable depth ranging from 8 ft at midspan to 14 ft at intermediate piers.

The segments were erected using the balanced-cantilever method. Cantilever stability was achieved with frames around columns supported on permanent foundations and stability towers on one or both sides of the piers on temporary foundation pads.

Because the guideway corridor is located along some of the most heavily traveled highways in south Florida, construction was designed to keep traffic flowing. The segment-lifting system consisted of the lifting frame, overhead traveling truss, lifting beam, and a secondary spreader beam. The project opened for use in 2012.

WMATA/Dulles Corridor

The Dulles Corridor Metrorail Project is a two-phase, 23-mile extension of the existing rail system for the Washington (D.C.) Metropolitan Area Transit Authority (WMATA). Heavy congestion in the work site led to the use of segmental construction for two sections of the 3 miles of elevated concrete guideway. The guideways used more than 2700 precast concrete, match-cast segments approximately 7 ft 6 in. wide by 8 ft deep, with a top flange approximately 16 ft wide for typical guideway segments. The box sizes change to 7 ft wide by 5 ft deep with a 16-ft-wide top flange through the stations, where the spans are about 50% shorter. The webs and slabs are 9 in. thick in the guideway spans and 10 in. thick in the station spans.

Segments were trucked in individually and hoisted into place by a truss erector, where their match-cast faces were coated with epoxy, joined together, and aligned. Segments were approximately 10 ft long, depending on the radius of the alignment at that location. Span lengths generally were dictated by the availability of ground space to locate the concrete piers, which are mostly located in the medians of heavily travelled thoroughfares. Where support was required in the roadway, straddle bents were constructed.

Bridge construction was not allowed over active roadways, so much of the work was done at night. The guideways were completed in May 2012, and the first new riders will board the trains in late 2013.

Portland's Willamette River Bridge

A sleek, 1720-ft-long cable-stayed bridge across the Willamette River will serve as the centerpiece for the Portland-Milwaukie Light Rail Transit project that is currently under construction. The

The Dulles Corridor Metrorail Project used segmental construction to handle heavy congestion in the work site. More than 2700 precast concrete match-cast segments were erected using overhead trusses. Photo: Chuck Samuelson, Dulles Corridor Metrorail Project.

Now under construction, the 1720-ft-long cable-stayed bridge across the Willamette River features three spans of 390, 780, and 390 ft with constant-depth, open-edge segmental girder sections erected using the balanced cantilever method. Rendering: T.Y. Lin International.

The Honolulu High-Capacity Transit Corridor Project for the Honolulu Authority for Rapid Transportation, currently under construction, features single-cell trapezoidal box girders to carry a dual track. This rendering shows the Kamehameha Highway section of the project. Photo: FIGG.

bridge will connect a planned campus for Oregon Health & Sciences University with the Oregon Museum of Science & Industry. It will carry the rail trains as well as buses, bicycles, and pedestrians. It also is planned to accommodate the Portland Streetcar in the future.

The bridge's three spans of 390, 780, and 390 ft, use constant-depth, open-edge girder sections and are being constructed using the balanced cantilever method. Each bridge is being built from its tower outward, followed by installation of cable supports. The cable is threaded through the towers to the deck sections as each section is added. The bridge's main span will connect above the middle of the river with a center closure placement and then to the landside-span portion on both banks.

Construction has been designed to minimize impacts to river users and disturbances to habitat and wildlife, especially protected fish species. Because in-water construction can take place only during a four-month window from July 1 through October 31, two temporary work bridges and two cofferdams were placed in the river to create barriers between the river and pier construction sites.

The bridge is expected to be completed in 2014, but it will not become functional until lighting is installed and the rail service begins in 2015.

Honolulu's HART

The Honolulu High-Capacity Transit Corridor Project for the Honolulu Authority for Rapid Transportation (HART), which began construction in 2011, consists of 20.5 miles of railway connecting 21 stations and is divided into four sections. Two of the sections, the 7-mile-long Farrington section and the 4-mile-long Kamehameha section, are being completed under design-build delivery systems, while the other two are using design-bid-build delivery. The design features single-cell, trapezoidal box girders to support a dual track.

The Farrington section has 268 spans, while the Kamehameha section has 165 spans, all with typical span lengths of 125 ft. Each span comprises 12 constant-depth segments, which are 11 ft long, 30 ft wide, and 7 ft 2 in. deep. The majority support two tracks per box, although a few have a single track.

This approach is being used because of the need to construct the bridge down a narrow median of a busy major artery. Handling the existing utility infrastructure also will be easier with concrete segmental bridges. The project is expected to be completed in 2019.

Summary

These projects give an idea of the range of challenges that segmental construction can help overcome on transit projects of all types. Concrete segmental construction is a strong choice to create long-lasting, quickly erected, aesthetically pleasing, and cost-effective solutions for America's infrastructure needs.

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A list of segmental concrete projects can be found at www.aspirebridge.org and click on "Resources."