PROJECT

SR 520 Evergreen Point Floating Bridge—East Approach Bridge

by Greg Banks, BergerABAM, and Dellas Clark, Kiewit-General-Mason

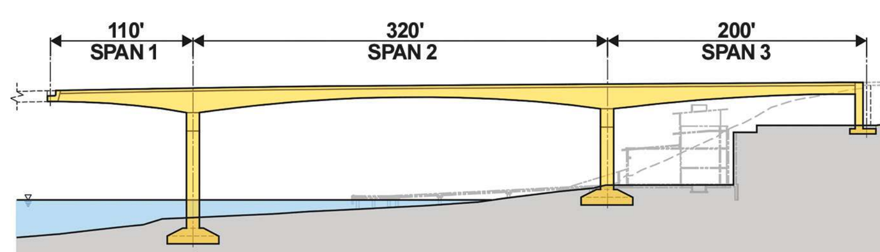
Opening ceremony of the new State Route 520 Evergreen Point Floating Bridge. The opening ceremony took place in April 2016. The East Approach Bridge starts at the near shore at the end of the asphalt pavement. The existing bridge is shown to the left of the new bridge. Photo: Washington State Department of Transportation.

Nestled between Seattle, Wash., and the nearby communities of Bellevue, Kirkland, and Redmond, is the nearly 50-mile-long, more than 1-mile-wide, majestic Lake Washington. Recent population growth in these communities has brought an increase in transportation demands on the corridors connecting them with Seattle. Washington State Route 520 (SR 520) serves as one of two corridors crossing over Lake Washington. Designed with only four traffic lanes, two in each direction, the nearly 50-year-old existing floating bridge is often clogged with heavy traffic. The aging infrastructure was also vulnerable to windstorms that required closure of the corridor due to waves crashing onto the roadway, and had seismically vulnerable approach spans that failed to satisfy current seismic design code standards.

Due to these deficiencies, the Washington State Department of Transportation decided to release a design-build contract to construct a new floating bridge across the lake. The new bridge would include an elevated roadway deck with two general-purpose lanes and one high-occupancy lane in each direction, plus full shoulders; a regional shared-use path; and means to accommodate high-capacity transit at a future date.

The new SR 520 Evergreen Point Floating Bridge is made up of a number of elevated bridge segments: the pontoon-supported low-rise and high-rise structures; single-span structures at each end of the pontoons providing transitions from the floating bridge segments to the land-based fixed segments; Pier 36 (two-column/shaft land-based fixed pier marking the west end of the contract); and the focal point of this article, the land-based, fixed, east approach bridge.

Comprising twin three-span, parabolic-arch shaped, cast-in-place concrete box-girder superstructures, one for westbound and one for eastbound traffic, the east approach bridge structures provide an elegant transition between the land-based fixed structures and the low-profile floating bridge structure. The overall length of the east approach bridge is 630 ft, with a cantilever span of approximately 110 ft, an interior span of approximately 320 ft, and an end span of approximately 200 ft. The 110-ft cantilever span supports the end of a 190-ft-long transition span structure whose other end is supported on the floating bridge. Together, the transition span and cantilever end of the east approach bridge create a nearly 300-ft span forming the lake's east navigation channel.



Schematic elevation of the State Route 520 Evergreen Point Floating Bridge East Approach Bridge. Drawing: BergerABAM.

profile

SR 520 EVERGREEN POINT FLOATING BRIDGE—EAST APPROACH BRIDGE /
SEATTLE AND MEDINA, WASHINGTON

BRIDGE DESIGN ENGINEER: BergerABAM, Federal Way, Wash.

PRIME CONSULTANTS: KPFF and BergerABAM, partners as the prime engineering team, Seattle, Wash.

PRIME CONTRACTOR: Kiewit, General Construction, Manson Construction (KGM)—a joint venture, Federal Way, Wash.

POST-TENSIONING CONTRACTOR: Schwager Davis Inc., San Jose, Calif.

Aerial view of the State Route 520 Evergreen Point Floating Bridge East Approach Bridge during construction. The eastbound structure and the first frame of the westbound structure have been completed. Construction of the westbound Pier 1 cantilever is underway. Photo: KGM.

exterior webs are sloped at a maximum of 1.75:1 (vertical:horizontal). The top slab has a minimum thickness of 10 in. and the bottom slab varies from 4 ft at the pier locations to 9 in. thick at midspan.

At nearly 90 ft and 60 ft wide, the westbound and eastbound structures, respectively, are each made up of two-cell box girders with section depths varying from 19 ft at the pier locations to 9 ft at midspan of the main span and ends of the end spans. The maximum cantilevered overhang reaches nearly 15 ft 4 in. and the maximum width of each cell of the box girder is approximately 29 ft. The eastbound structure had a truncated south overhang that was designed to allow for a 16 ft 4 in. deck widening on the south side of the bridge in the future. The webs, or vertical stems of the box girder, are 18 in. thick. The exterior webs are sloped at a maximum of 1.75:1 (vertical:horizontal). The top slab has a minimum thickness of 10 in. and the bottom slab varies from 4 ft at the pier locations to 9 in. thick at midspan.

The intermediate piers consist of single columns supported by a common spread footing. Except for height, all the columns are identical, being rectangular in section with dimensions of 24 ft long (parallel to the transverse axis of the bridge) by 10 ft wide (parallel to the longitudinal axis of the bridge). The columns are cellular, containing two cells, giving the column the appearance of a giant masonry block. Each wall of the columns is 18 in. thick. A massive 160-ft-long, 40-ft-wide, and 12-ft-thick common spread footing supports both westbound and eastbound structures at each pier. The spread footings were designed to remain elastic under the design earthquake considering the effects of out-of-phase motions of the two bridge structures.

The east approach bridge structures were constructed by balanced-cantilever methods using form travelers. Initially a pier table was constructed at the top of each column using conventional falsework to provide sufficient length to place form travelers on each end of the pier table. The form travelers supported the formwork and the weight of 16-ft segments of the bridge structure. The

Construction of the Pier 1 cellular columns. The massive spread footing is located in the coffercell below. The Pier 1 footing was constructed below the mudline and buried with aquatic habitat substrates. Photo: BergerABAM.

Form traveler used during construction of the superstructure by balanced cantilever methods. Photo: BergerABAM.

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION, OWNER

OTHER MATERIAL SUPPLIERS: Bearings: Scougal Rubber Corp., Seattle, Wash.; and expansion joints: Mageba USA, San Jose, Calif.

BRIDGE DESCRIPTION: Twin 630-ft-long, three-span, post-tensioned, cast-in-place, segmental concrete box-girder bridges with spans including a 110-ft cantilever that supports a 190-ft-long transition span, a 320-ft-long main span, and a 200-ft-long end span

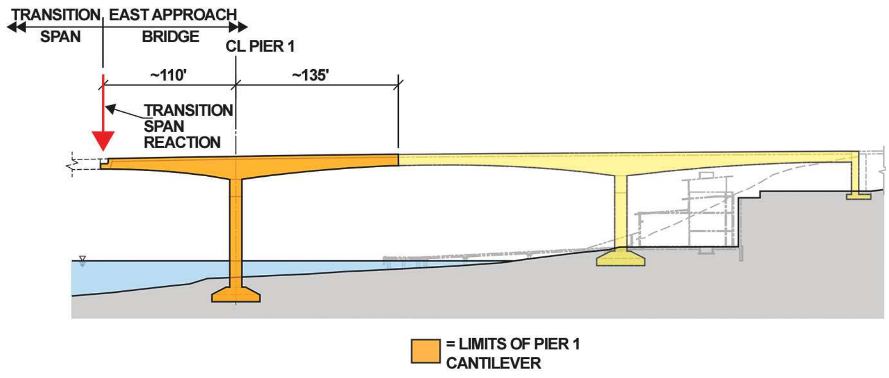
STRUCTURAL COMPONENTS: Spread footings, two-cell box columns, and thirty-two 16-ft-long cast-in-place concrete segments per bridge

bridge was then constructed in 16-ft segments at a time.

The balanced-cantilever construction method replaced the traditional cast-on-falsework methods shown in the owner-issued concept design. Using balanced-cantilever construction methods, falsework below the bridge was not needed as temporary support, and thus could be built without disturbing the shallow waters of the lake's shoreline, which provide a prime salmon spawning habitat. Notable environmental advantages included the following:

- Position of Pier 2: Pier 2 is the easternmost intermediate pier. The request for proposal (RFP) stated that Pier 2 was located partially within the wetted perimeter of Lake Washington. It was shifted upland, outside the wetted perimeter of Lake Washington. The modification preserved more than 800 ft^2 of shallow water habitat.
- Spread footings: The RFP utilized a series of drilled shafts tying into large pier caps that extended from the lake bed to the water surface. The use of spread footings reduced concrete volume by 12,500 yd^3, required smaller cofferdams, and protected a vital aquifer providing water to Lake Washington through upwelling. In addition, 95% of the permanent lake bed disturbance was eliminated by moving Pier 2 upland, and burying the Pier 1 spread footing with aquatic habitat substrates.
- No temporary falsework: Use of balanced cantilever methods eliminated the need for temporary falsework to construct the east approach bridge structures. It is estimated that the use of balanced cantilever methods reduced the amount of temporary shoring by 27,000 ft^2, eliminated 125 piles, and reduced the amount of prime salmon spawning habitat substrate disturbance by 525 ft^2.

The term *balanced cantilever* implies that bending moments and deflections of supporting piers are balanced, or nearly balanced, at any point during construction. However, depending on the specific configuration of the bridge, the sequence of erection, and the function of the bridge, the pier may not ever be exactly balanced during construction. Bridges built by balanced cantilever methods can be significantly unbalanced either during construction or after the bridge is put into service. If potential unbalanced moments in the pier exceed pier allowable bending moment capacities or cause excessive pier deflections, measures must be taken to maintain the balance to the extent necessary. Such was the case with the east approach bridge structures, which needed to accommodate large reaction forces from the transition span applied to the tip of the cantilever span in a service condition.



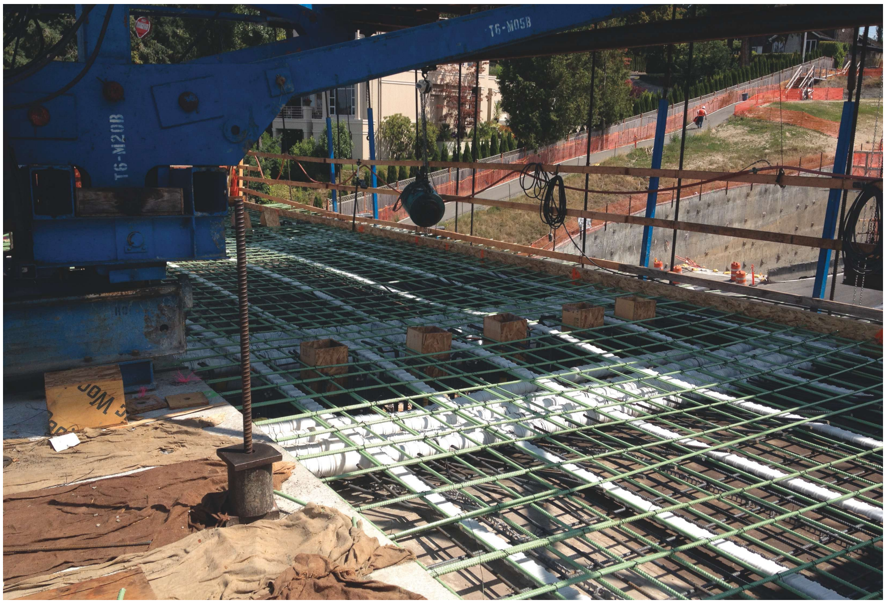
Schematic of Pier 1 cantilever. The east heading was approximately 25 ft longer than the west heading to offset the permanent out of balance demands from the transition span reaction. Drawing: BergerABAM.

The transition span reactions generate large bending moments within the superstructure, and also large bending moments within the pier columns. To help offset this issue within the substructure elements, the Pier 1 balanced cantilever construction underwent an unbalanced condition opposite of the permanent transition span reaction. The interior span side of the cantilever was constructed about 25 ft longer than that on the opposite side (that is, the cantilever side) of the pier. This temporary unbalanced situation generated construction challenges requiring counterweights—in this case, tanks filled with lake water—to keep stresses in the structure to within allowable limits, and also aid in the alignment of the closure between pier cantilevers at the middle of the interior span. The Pier 1 cantilever construction required careful geometric control during construction. As part of the construction engineering, the pier displacements were field monitored at each construction stage and compared with the estimated values. Model inputs were continually adjusted to predict the required counterweight and necessary form adjustments.

A new superstructure segment was cast every 3 days. The form traveler could not be advanced until the cast segment was post-tensioned. Further, the segment could not be post-tensioned until the concrete had gained sufficient compressive strength. A high-early-strength, 5 ksi concrete was used so that approximately 16 hours after casting the segment could be post-tensioned and anchored to the far end of the cantilever on the opposing heading.

Post-Tensioning

Post-tensioning was provided transversely, longitudinally, and vertically in the east approach bridge structures. Tendons in the longitudinal direction typically consisted of either nineteen or twenty-two 0.6-in.-diameter strands per tendon, with the largest tendons containing twenty-seven 0.6-in.-diameter strands per tendon, passing through either the top or bottom slab. Cantilever tendons in the top slab run from end to end of the cantilever, and were used during construction to stress the newly constructed segment back onto the completed bridge segments. Bottom-slab tendons (or continuity tendons) in the middle span regions were stressed after the structure was closed or partially closed. Longitudinal post-tensioning was designed to avoid tension in sections under service loads throughout the design life of the structures.



Typical top slab reinforcement and duct layout within a segment. Photo: BergerABAM.

Post-tensioning in the transverse direction consisted of four 0.6-in.-diameter strands per tendon passing through the top slab and anchored at the ends of the bridge deck overhangs. Due to the thin top slab, flat ducts were used for these tendons. Typical longitudinal spacing of transverse tendons was approximately 3 ft. To maximize the tendon efficiency, the tendons were placed near the top surface over webs and draped to near the bottom surface in the mid-cell location of the top slab.

Vertical post-tensioning was provided via 1⅜-in.-diameter, high-strength rods in each web of the box girder where needed to keep the principal tensile stresses within acceptable limits. The east approach bridge utilized epoxy-coated reinforcing steel for the top mat of reinforcing steel in the top slab of the box girder.

Now Open

Construction of the SR 520 Evergreen Point Floating Bridge project was successfully completed and traffic was shifted onto the bridge in April 2016.

Greg Banks is a bridge project manager and construction liaison engineer in the Federal Way, Wash., office of BergerABAM. Dallas Clark is a construction superintendent with Kiewit-General-Mason in Bellevue, Wash.

EDITOR'S NOTE

The low-rise superstructure of the SR 520 Evergreen Point Floating was featured in the Spring 2016 issue of ASPIRE.™