Beauty on the Banks

Aesthetically pleasing arch design requires innovation and environmental sensitivity

by Jim Markus and Gwendolyn I. Lewis, King County, and Kevin Kim, Jacobs Engineering

The York Bridge replacement project was a collaborative design and construction effort between King County and the city of Redmond, Wash. It demonstrates the ability to solve tough engineering challenges while minimizing costs and being sensitive to the environment and the community. The new bridge, with its gracefully arched, cast-in-place concrete substructure and 42-in.-deep precast, prestressed concrete girders (Washington State Department of Transportation Type W42G), required rebuilding, widening, and raising the approach roadways.

The existing bridge, which crossed the Sammamish River at NE 116th Street in Redmond, had become structurally deficient and functionally obsolete. Sizable flexural cracks had developed in the girders, requiring a low-posted load limit that restricted the bridge's usefulness. The bridge's piers also disrupted the river's flow and created dangerous, at-grade crossings for pedestrians and bicyclists along the trails on both sides of the river. The location also contains the multi-use 60 Acres Park recreational area that attracts large numbers of visitors, creating a traffic bottleneck.

Bridge Lengthened, Elevated

The bridge was designed to be 220 ft long, which is 103 ft longer than the original bridge, and 51 ft 3 in. wide overall, which is more than 25 ft wider. The bridge and approach roads were elevated 15 ft so the trails continue uninterrupted beneath the bridge, greatly improving accessibility and safety for pedestrians, bicyclists, and equestrians.

The primary goals in selecting the bridge's design and material were to minimize construction time and create an aesthetically pleasing appearance. In addition, the city of Redmond had recently completed a $14-million project downstream at NE 90th Street, and city officials were concerned that the new bridge might pale in comparison. There also were numerous agencies to work with due to the area's environmental sensitivity and the desire to maximize shoreline habitat for endangered salmon.

An extensive comparative analysis was performed early in the process. Concrete always was considered to be the best material, but finding the most efficient design solution was critical. The design process also was impacted by the desire to gain as much federal funding as possible. Federal funds would cover only the costs for the lowest-cost design alternative, with other sources needed to cover any premium. Fortunately, the created design proved to be the low-cost option, as well as the most

The new York Bridge in Redmond, Wash., is longer and wider than the original structure, allowing it to span multi-use trails on both sides of the river. The shape of the pedestrian lookout can be seen by the shadow on the girders. All photos: King County, Washington.

profile

YORK BRIDGE / REDMOND, WASHINGTON

BRIDGE DESIGN ENGINEER: King County Department of Transportation, Seattle, Wash., and Redmond Public Works Department, Redmond, Wash.

ENGINEERING CONSULTANTS: AECOM (formerly Entranco and DMJM Harris), Seattle, Wash.

PRIME CONTRACTOR: Mowat Construction Co., Woodinville, Wash.

PRECASTER: Concrete Technology Corp. Tacoma, Wash., a PCI-certified producer

CONCRETE SUPPLIER: Cadman Inc., Bellevue, Wash.

aesthetically pleasing and relatively fast to build.

Poor Soil Hampered Work

One of the biggest challenges arose from the extremely poor soil conditions, especially on the west bank. This soil consisted of significantly compressible peat, as much as 195 ft deep. Removing this with a deep excavation and subsequent backfill was prohibitively expensive and technically not feasible. The soft soil also covered a city sewer line that would have been damaged by compaction settlement.

Instead, the team installed expanded polystyrene (EPS) blocks as an environmentally friendly alternative to build up the approaches. The material is an extremely lightweight fill weighing only 1 to 2 lb/ft^3. The EPS blocks do not biodegrade, produced no net effect on the soil or groundwater and reduced muddy runoff into the river.

Full-height precast concrete panels, 4 ft wide and 6 in. thick, were used as retaining walls to cover the front faces of the EPS embankment. A total of about 18,000 ft^2 of walls were used at all four corners of the bridge. The tops of the walls were connected to the reinforced concrete load-distribution slab that capped the EPS embankment. One of the retaining walls was located directly above a large, deep sewer line. To mitigate some of the weight on the sewer line, 2 by 6 ft EPS blocks were placed under the wall to distribute the weight of the panel.

Arched Substructure

The concrete arch used for the piers and substructure also created challenges. To reconcile the desire for an arch-shape design with the functional needs of the bridge, the team created a shallow cast-in-place concrete profile spanning the river. At each end of the arch, inclined piers provided intermediate supports for the superstructure. This results in four 55-ft spans for the precast, prestressed concrete girders.

Typically, most of the structural support in an arch-designed bridge results from compression. However, the York Bridge's arched substructure is flat enough that it doesn't perform as a true arch, placing it between an arch and a beam. Providing foundational support for the piers, where the arch and the inclined columns meet, created fabrication challenges.

The foundations to support the arch and the inclined columns consisted of cast-in-place, 2-ft-diameter concrete piles with a steel casing extending 120 ft into the soil. This foundation was made extremely robust due to the pier columns and the arch contributing both gravity loads and horizontal thrusts.

Forms for the arched substructure were supported by falsework that spanned the river. The arch itself was created in one continuous placement to ensure aesthetic continuity for its full length. Admixtures were used in the concrete to make it more workable and ensure it flowed around the reinforcement.

The reinforcement was congested, especially at the location where the arched slope meets the inclined columns. Large-scale detail drawings were created for the cast-in-place arch to indicate where bars should be placed and what could be eliminated as redundant.

A cast-in-place concrete crossbeam was placed at the apex of the arch and at the tops of the inclined columns to provide support for the precast concrete girders, a common design technique in this area due to the high seismic zone. They were structurally integrated

To provide a robust foundation for the columns on both sides, 120-ft-long cast-in-pipe concrete piles were used to carry both gravity loads and thrust from the arch. At each column pier, a crossbeam was constructed on falsework to support the precast concrete girders and deck.

Support for the precast concrete girders was provided at the arched superstructure's apex with a cast-in-place concrete crossbeam.

A total of about 18,000 ft^2 of walls were used on both approach fills.

220-FT-LONG, FOUR-SPAN REPLACEMENT BRIDGE CONSISTING OF A CAST-IN-PLACE ARCHED SUBSTRUCTURE, PRECAST, PRESTRESSED CONCRETE GIRDERS, CAST-IN-PLACE CONCRETE DECK, AND PRECAST CONCRETE RETAINING WALLS / CITY OF REDMOND AND KING COUNTY, WASHINGTON, OWNERS

RAILING DESIGNER: Cliff Garten Studio, Venice, Calif.

BRIDGE DESCRIPTION: Cast-in-place reinforced concrete arch with inclined columns at each end supporting 42-in.-deep precast, prestressed concrete beams and a 7.5-in.-thick composite concrete deck

BRIDGE CONSTRUCTION COST: $12 million

AWARDS: 2009 Silver Award for Structural System from the American Council of Engineering Companies

Unique Environmental Treatment

The bridge project achieved several environmentally friendly goals. One involved embedding approximately ninety, 30- to 40-ft-long wooden logs, nearly horizontal, in the riverbank about two-thirds of their length underground. The logs were arranged to create a natural river shoreline while providing pools for the fish, ripples in the water that oxygenates it and higher ground for migratory waterfowl. The changes required 22 permits and partnerships with numerous stakeholders, including the Corps of Engineers, city, county, state agencies, and the Muckleshoot Indian tribe.

The cast-in-place deck features epoxy-coated reinforcing bar to provide corrosion protection.

The interweaving decorative railing had to adjust to the vertical and horizontal curves and asymmetrical shape of the bridge, which included sloping bulb-outs on each side to provide lookouts for pedestrians.

Expanded polystyrene lightweight fill, which is only 1/100th the weight of typical soil, was shaped and placed on the west approach to avoid adding weight above an existing sewer line and minimize settlement of the soft in-situ soils.

with the girders using prestressing strands and reinforcing bars extended from the girders. Compression seals were provided in expansion joints between the end diaphragms sitting on cantilevered abutment walls and the concrete approach slabs. The bridge has a 7.5-in.-thick cast-in-place composite concrete deck. Epoxy-coated reinforcement was used in the concrete bridge deck to provide corrosion resistance.

The project exceeded the owners' expectations on many levels even though it had to overcome a variety of difficult challenges to do so. The bridge serves as a model for creating an aesthetically pleasing structure under adverse conditions while providing a cost-effective, environmentally friendly and responsive solution to the community's needs.

The shape of the substructure arch is flat enough that it functions partially as an arch and partially as a beam. It was cast in one continuous pour to ensure a smooth surface.

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For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

Artistic Railing Added

As a final touch, a decorative artistic metal railing and screen were bolted to both sides of the bridge deck and concrete barrier. This effort resulted from a King County regulation requiring 1% of construction funding to be set aside for artistic additions on selected projects. The city of Redmond contributed an equal share to the fund, which was coordinated by the county's 4Culture cultural-services agency.

The railing accommodated the curved lookouts along both sides of the bridge. On one side, a 6-ft-wide sidewalk gradually curves out over the river, beginning just before midspan, until it is 12 ft wide; then curves in again to 6 ft wide at the bridge's end. The 10-ft-wide sidewalk on the other side curves out to 16 ft wide beginning just before midspan; then curves back to 10 ft wide at the bridge's other end. Both lookouts are 126 ft 7 in. long.