PROJECT

I-5 Willamette River Bridges

Longest concrete arch spans in Oregon

by Jim Bollman, OBEC Consulting Engineers

In late 2009, construction of new twin arch bridges commenced in Eugene, Ore. The bridges carry Interstate 5 (I-5) southbound (SB) and northbound (NB) over the Willamette River, a local highway, railroad tracks, an off-ramp, and two multi-use paths. To span the complex project area, the bridge lengths are 1759 and 1984.7 ft for SB and NB, respectively. The bridges replace the original structure built in the early 1960s, which was closed in 2004 due to structural deficiencies. Since 2004, traffic had been using a detour bridge near the alignment of the NB replacement structure.

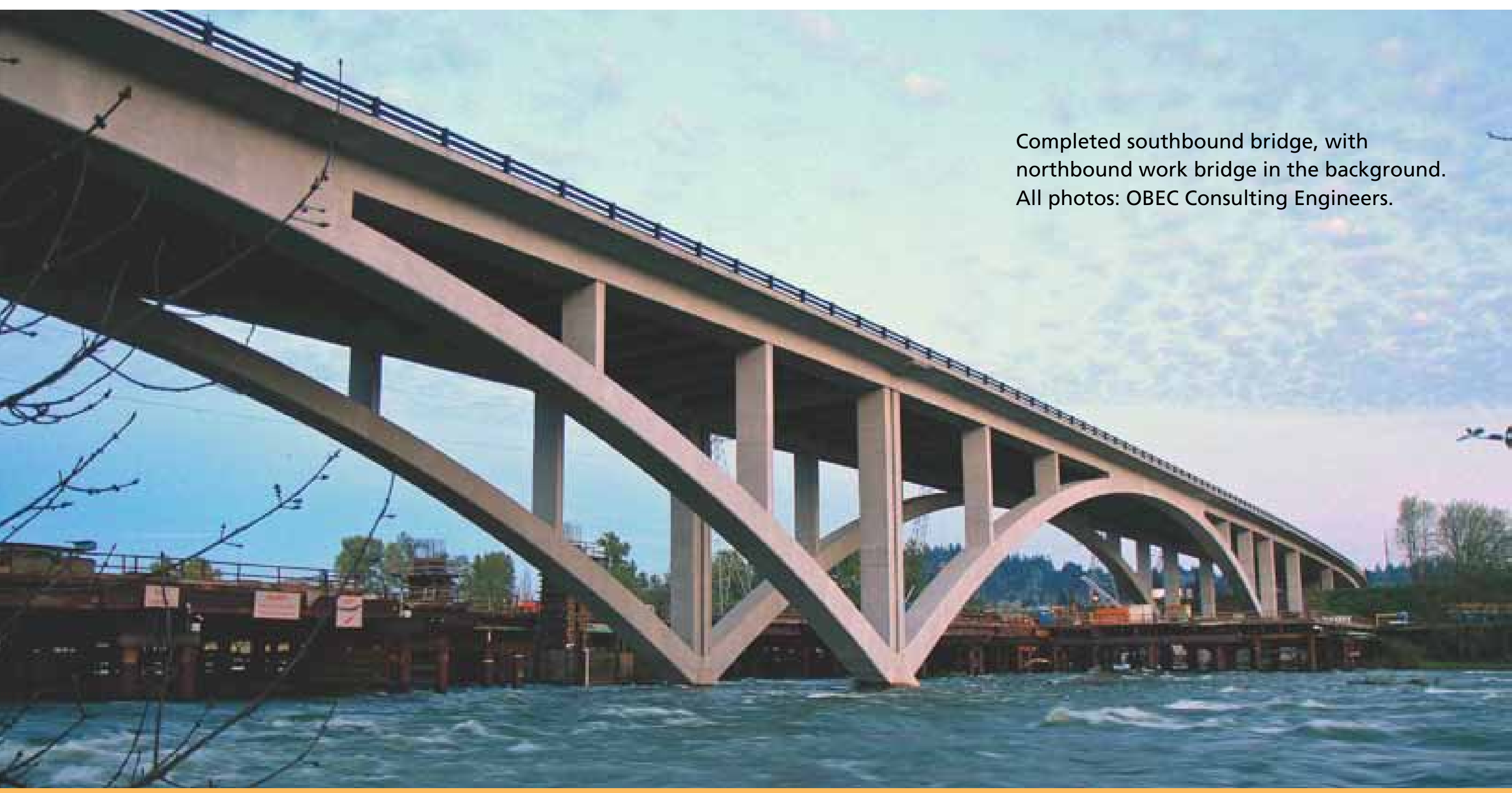
The Willamette River Bridges (WRBs) are exceptional in many respects:

- The spans over the river are the longest concrete arch spans in Oregon.
- The project is the last and largest of the $1.3 billion, multi-year Oregon Transportation Investment Act (OTIA III) program.
- It is the largest bridge replacement project ever undertaken by the Oregon Department of Transportation (ODOT).

Structural Arrangement

Oregon has an impressive inventory of historic concrete arch bridges, providing aesthetic and functional crossings of estuaries and rivers throughout the state. More than 20 of the structures completed in the 1920s and 1930s are credited to Conde McCullough, a highly influential engineer who worked for ODOT into the 1940s. The WRBs fit nicely with these older bridges that are well known for their aesthetic mix of Romanesque, Gothic, and art-deco architectural styles.

However, the WRBs also represent two of the few contemporary concrete arch bridges in Oregon. The basic form of the WRBs builds on the Maple Avenue Bridge, a 2005 award winning OBEC



Completed southbound bridge, with northbound work bridge in the background. All photos: OBEC Consulting Engineers.

profile

I-5 WILLAMETTE RIVER BRIDGES / EUGENE, OREGON

BRIDGE DESIGN ENGINEER: OBEC Consulting Engineers, Eugene, Ore.

CONSTRUCTION ENGINEER: Jiri Strasky, Consulting Engineer, Greenbrae, Calif.

PRIME CONTRACTOR: Hamilton Construction Company, Springfield, Ore.

CONCRETE SUPPLIER: Knife River, Harrisburg, Ore.

Consulting Engineers-design spanning Dry Canyon in the City of Redmond, Ore. The WRBs similarities to the 2005 design include slender un-strutted ribs, composite crowns for lateral stability, compact supports at rib intersections, double columns for bearing-free thermal joints, and sleek clean lines with an open, uncluttered appearance. The WRBs are unique in their scale, spandrel column arrangement, floor system, and span-rise ratio of 7.09.

Rendering of structural arrangement for the southbound Willamette River Bridge in Eugene, Ore.

Finished view of bent 3 shaft cap/arch rib/column joint in foreground, with floor system visible above. At far end of rib, a solid soffit of post-tensioned box girder spans adjoins arch span.

The main spans of each bridge consist of two arch spans with lengths of 390 ft (span 2) and 416 ft (span 3) cast with 6000 psi compressive strength concrete. A girder-floor-beam-slab system comprises the superstructure with one girder in the vertical plane of the two arch ribs. Ribs are composite with the longitudinal girder for 124 ft over the rib crowns.

The arches for each bridge consist of two parallel ribs without transverse bracing. The arches are supported by 8-ft-diameter drilled shafts in bedrock. Two shafts spaced at 20 ft, support each rib at bents 2 and 4 with one shaft per rib line at a midstream rock outcrop (bent 3). The north approach span uses post-tensioned girders with the same superstructure form as the arch spans. The south approach spans are cast-in-place, variable depth, multi-cell box girders, which match the width and depth of the outside faces of the arch span girders where they adjoin at bent 4 on the south riverbank.

Two spandrel columns at equal spacing are used in each open spandrel for each rib half. The short column is hinged top and bottom to limit flexure with thermal movements, while the tall spandrel columns and bent columns are fixed, thin, and of sufficient height to be flexible along the length of the bridge. Columns at bents are arranged in pairs with one on each side of the deck joint between arch spans and adjacent spans to provide for thermal movements without bearings.

The floor system consists of a tapered thickness cantilever deck outside the girders and a 10-in.-thick longitudinal deck between girders and supported on custom-designed, rectangular, precast, prestressed (PCPS) concrete transverse floor beams spanning between girders. The PCPS concrete stem section was designed to provide falsework support for deck casting. Floor-beam spacing is coordinated with the column spacings so columns frame into the girders at mid-spacing of floor-beams, avoiding conflicts between column and floor-beam reinforcement. Both the girders and floor-beams become composite T-beams with the deck for resistance to live load.

Recycling Concrete

Recycling of demolished concrete is an important factor in concrete's life-cycle environmental impact, so for the Willamette River Bridges project the architect and engineer partnered with the concrete supplier and owner to develop a mix design using recycled-concrete aggregate (RCA) in such proportions to be suitable for selected components of the new northbound bridge. Testing of both the crushed material and the class 4500 mix produced with 30% RCA demonstrated equivalent performance in many respects to the class 4500 mix with virgin aggregate. Strength, shrinkage, and permeability were included in the testing program, which concluded with use of an RCA low-heat mixture used in the mass concrete shaft caps for bents 2 and 4, where freezing and thawing, and slightly lower modulus of elasticity are not issues. Using the demolished concrete of the detour bridge in the foundations for the new bridge will help keep concrete waste out of landfills.

Special-Purpose Concrete

The bent 2 and 4 shaft caps are mass concrete incorporating the development length of the bundled No. 18 shaft bars from the two shafts, and the development length of the No. 14 rib bars midway between the shafts. Thermal cracking from differential temperature between the cap core and surface was a risk, mitigated by a low heat of hydration mix design. Specific limits are a maximum water-cementitious materials ratio (*w/cm*) of 0.45, maximum 660 lb/yd^3 of cementious materials with 60% ground-

THE OREGON DEPARTMENT OF TRANSPORTATION, OWNER

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

REINFORCEMENT FABRICATOR: Farwest Reinforcing Division, Eugene, Ore.

BRIDGE DESCRIPTION: Twin southbound (SB) and northbound (NB) structures consisting of one cast-in-place post-tensioned concrete girder span; two concrete deck arch spans over the Willamette River; three spans of cast-in-place, constant-depth, post-tensioned box girders over Franklin Boulevard; and three spans (SB) or four spans (NB) of cast-in-place, haunched, post-tensioned box girders over UPRR and I-5 exit ramp granulated, blast-furnace slag, minimum coarse aggregate solids/total volume of 0.46, and a maximum concrete placing temperature of 70°F. Acceptance of 4500 psi design compressive strength was based on 56-day test results.

At bent 3, the ribs from spans 2 and 3 intersect with the single shaft per rib line and the double column from above. Complex reinforcing details were required for these five intersecting compression members with an approximate volume of a 7-ft cube, but with a complex shape from the different member cross sections and the small streamlined shaft cap. Each of these members was fixed to all the others in the joint to meet requirements of either the final design condition (fixed ribs and columns) or construction-stage loading. A monolithic rib/shaft connection for construction stage loading is related to rib crown jacking for arch pre-compression and camber adjustment.

After casting the arches on falsework, the transfer of their self-weight to axial thrust plus each load stage thereafter, produces both elastic and inelastic shortening. The horizontal thrust component at bents 2 and 4 deflect the shaft tops away from the ends of the arches, lengthening each span slightly. If the ribs were cast monolithically on falsework, rib shortening and span lengthening would yield a flatter curvature than initially constructed; flexure and shear would arise from imposed distortion to the as-cast shape. Rib crown jacking provided a temporary hinge and a means of lengthening and pre-compressing the rib to fill the load-lengthened span, while raising it to compensate for further compression from subsequent loads. Construction complexity was reduced by jacking span 2 and then span 3 sequentially. To control the jacked rib shape, a fixed rib to shaft connection was necessary at bent 3.

Placing rib cross-ties through bent 3 joint.

Placing column bars through rib reinforcement in bent 3 joint. Shaft cap skin reinforcement remains to be placed along with remainder of steel forms.

Casting of the reinforcement-congested bent 3 shaft cap/arch rib/column joint with special high-slump 6.0 ksi concrete.

Drilled shaft to arch rib connection bars at bent 3.

The joint including the rib to shaft connection was formed into a single placement. The 6000 psi compressive strength concrete for casting the reinforcement-congested space utilized $^{3}/_{8}$-in. maximum size aggregate and had a 9-in. slump with performance similar to self-consolidating concrete. Both internal and external form vibration were used, and the results were top quality.

High-performance concrete with specified compressive strengths of 4000 psi for the arch spans and 5000 psi for the other spans was used in the deck.

Shaft and rib reinforcement extending into partially-completed bent 2 shaft cap reinforcement cage. Column bars are not yet placed.

Span 2 ribs become self-supporting after crown jacking. Weight of each rib is carried by eight, 2.5-in. diameter, 150 ksi post-tensioning rods, two of which are visible at the side of the jacking frame.

In addition to standard specification requirements to control deck cracking (fog nozzles until curing is applied, 20 minutes maximum from placement to wet curing and 14 days wet curing, and saw-cut grooving), polypropylene fibers were included in the deck mix to provide early tensile strength for shrinkage-cracking resistance.

The SB bridge was completed in September 2011 and is now carrying four lanes of I-5 traffic. The NB bridge is expected to be completed by fall 2013.

___

Jim Bollman is a bridge engineer with OBEC Consulting Engineers in Eugene, Ore.

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