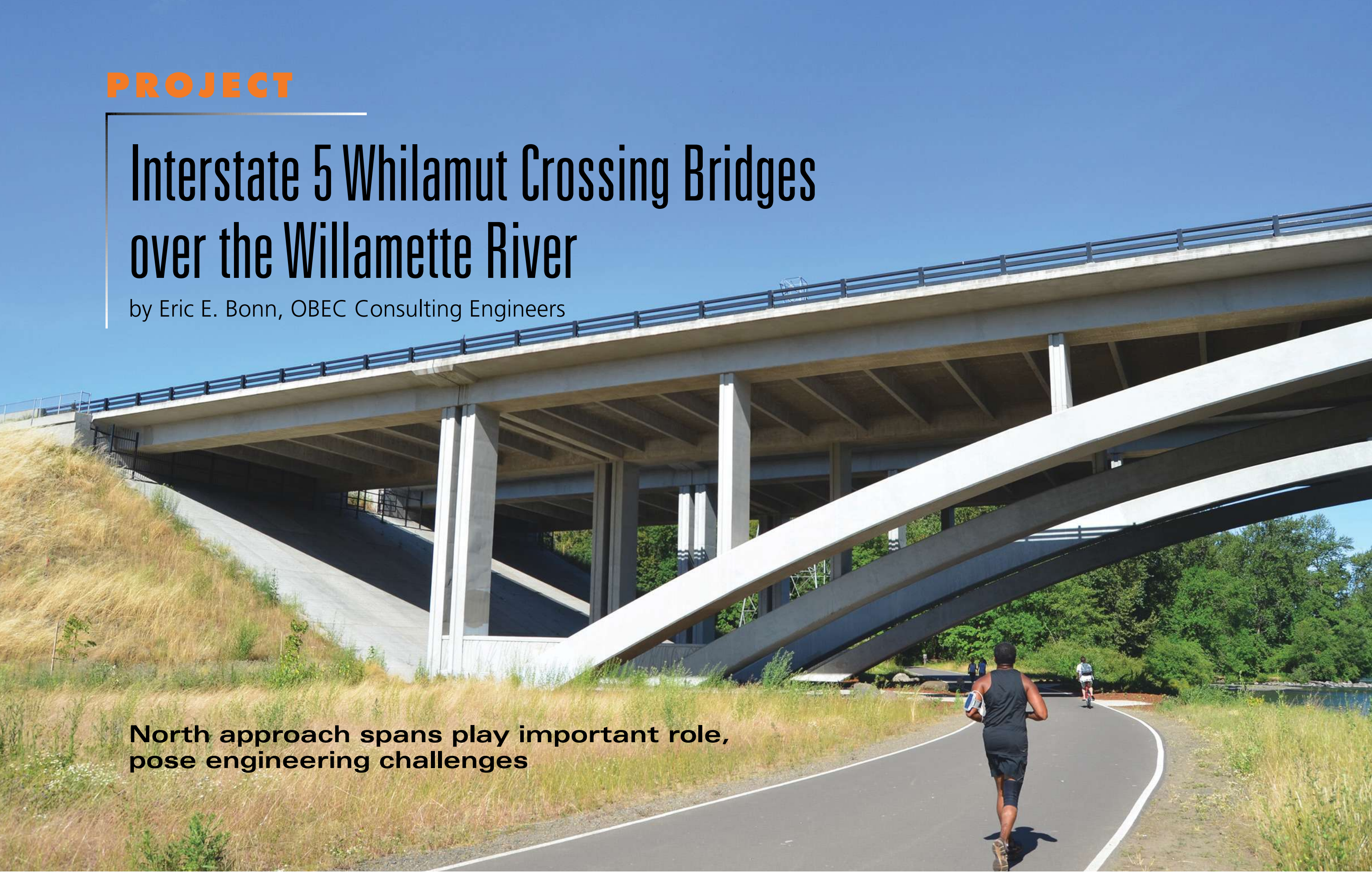
PROJECT

Interstate 5 Whilamut Crossing Bridges over the Willamette River

by Eric E. Bonn, OBEC Consulting Engineers



North approach spans play important role, pose engineering challenges

Approach span and start of arch span showing path going underneath. All Photos: OBEC Consulting Engineers.

It can be easy to overlook the 84-ft-long north approach spans in these nearly 2000-ft-long bridges, especially when the main spans are the award-winning arches of the Interstate 5 (I-5) Whilamut Crossing Bridges over the Willamette River in Eugene, Ore. However, these apparently straight-forward, utilitarian structures incorporated several unique engineering aspects. The design and construction of the main spans are detailed in an article in the Summer 2012 issue of *ASPIRE.*™

Bridge Type Selection

Span 1 of Whilamut Crossing Bridges land on the north bank of the Willamette River within the limits of the city of Eugene's Alton Baker Park. The approach roadway is on earth fill. The span's two arches are founded near the riverbank and have one of the major park trails running under them. Span 1 is the transition between the approach fill and the arch spans.

Various alternatives were considered for this transition, including retaining walls and precast concrete box or bulb-tee girders. Typical mechanically stabilized earth (MSE) walls could have eliminated the need for the span 1 structure. However, the mass of the 40-ft plus tall MSE wall that would be required was not in keeping with the light and airy appearance of the arch spans and would visually close in the recreational path corridor.

Standard Oregon Department of Transportation (ODOT) precast, prestressed concrete box girders or bulb-tee girders could support the span, but the transition between the precast concrete approach span and cast-in-place concrete main spans was determined to be visually unappealing and not in keeping with the clean, repetitive pattern desired.

To best combine span 1 with the rest of the structure, it was designed to mimic the adjacent main spans. In the arch spans, the main elements supporting the deck structure are longitudinal T-beams that are supported by spandrel columns springing from the arch ribs. The 10-in.-thick deck spans about 11.75 ft longitudinally between transverse floor beams that frame into the T-beams. The 6.75-ft-wide deck overhangs are supported directly from the T-beams. The floor beams are 40-ft-long, 10-in.-wide, and 2-ft 9-in.-deep precast, prestressed concrete rectangular sections. The same floor

profile

INTERSTATE 5 WHILAMUT CROSSING BRIDGES OVER THE WILLAMETTE RIVER /
EUGENE, OREGON

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

PRIME CONTRACTOR: Hamilton Construction, Springfield, Ore.

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

PRECASTER: Knife River Prestress, Harrisburg, Ore.—a PCI-certified producer beam design was used in span 1 as in the main arch spans. While details, such as number of spans and span lengths of the entire northbound and southbound structures vary slightly from each other, span 1 dimensions and details were the same for both the northbound and southbound bridges.

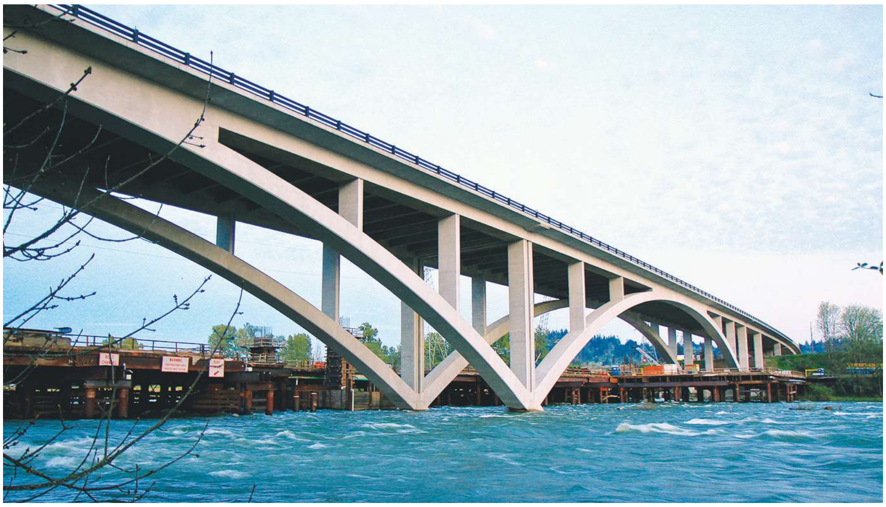
The T-beam stems are 7 ft wide, only 5 ft deep, and are spaced 47 ft apart under the 64.5-ft-wide deck. The typical column-to-column span of the T-beams in the arch spans is under 50 ft. This allowed the T-beams to act continuous over their entire length and be conventionally reinforced. The 82-ft-long, simple-span condition of span 1 exceeded the ability of mild-steel reinforcement to adequately support the structure, therefore post-tensioning was added. Each T-beam has four tendons with twenty-three, 0.6-in.-diameter strands. All tendons were tensioned from the abutment end of the span for ease of construction because friction losses were low over this short span.

Design Considerations

Typical design considerations related to the post-tensioning had to be considered including bending stresses, ultimate moments, and shears. Special consideration was given to the tensioning order, anchor set, bursting reinforcement in the deck, effective flange width, and the configuration of the bent 2 anchor zone.

The 47-ft spacing of the T-beams created a long lever arm and necessitated the tendon stressing to alternate between the left and right beams to limit superstructure bending about the vertical axis. A limit was set that no more than ⅙ of the total prestressing force could be eccentric about the bridge centerline at any time based on a stress analysis of the deck overhangs.

Setting the anchor locations at the centroid of the T-beam sections—to eliminate prestress tensile stresses at the ends of the spans, accommodate the shallow 5 ft height of the member, and provide the minimum possible offset of the strands from the beam soffit—resulted in the drape of the post-tensioning strands being limited to approximately 2.5 ft. The prestress losses due to friction were low due to the limited angular change in the strand path. While this was beneficial to the strength of the T-beams, it caused the length of the anchor set loss to extend nearly to the opposite end of the span, which would undesirably reduce the strand stress at the dead-end anchorage. Limiting the anchor set to a low value of ⅜ in., which is less than the ODOT standard procedure of ½ in., prevented the stress loss from reaching the far anchor.


Completed southbound I-5 Whilamut Crossing Bridge looking toward south approach spans, with northbound work bridge in the background.

Typical strut-and-tie methodologies were employed to distribute the jacking force first into the T-beam stem and then into the deck. The results of these analyses indicated large tensile forces would be generated in the deck just inside the anchorages as the post-tensioning forces tried to distribute inward toward the centerline of the bridge. A two-dimensional finite element model using plate or shell elements was created to verify that the strut-and-tie model layout closely approximated the actual distribution of forces in the deck. An additional 24 transverse No. 11 bars were required to resist these tensile forces.

The effective flange width of the deck due to the wide spacing of the T-beams was a concern. In the American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*, the effective flange width for an exterior beam is allowed to be the sum of the deck overhang, girder, and one half of the spacing to the adjacent girder. The minimum span-length-to-girder-spacing ratio investigated in developing this provision was 3.1. The corresponding ratio for this bridge is 1.7, so it wasn't prudent to use half the deck width (32.25 ft) as the effective flange. Instead, a conservative estimate of approximately 21.75 ft, similar to the previous limit of one-quarter of the span length, was used in the flexural stress and moment checks.

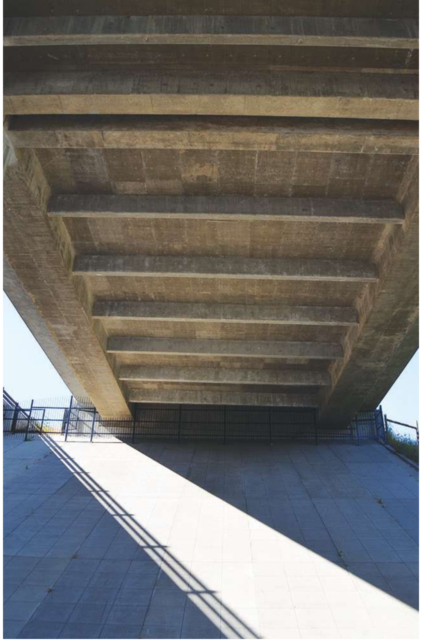
The last design issue of concern was the configuration of the dead-end anchorages at bent 2. Because the T-beams were located directly over the columns and there was no beam

OREGON DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Each north approach span consists of two simple span, cast-in-place, post-tensioned T-beams with a span of 82 ft.

STRUCTURAL COMPONENTS: Each structures consists of two 7-ft-wide, 5-ft-deep T-beams with precast concrete transverse floor beams spanning between them.

View of the north approach span.



Soffit view of approach span showing T-beams and floorbeams.

Arch and approach span falsework for the I-5 Whilamut Crossing Bridges.

Approach span falsework and formwork plus bent 2 column reinforcement.

overhang past the column, the post-tensioning anchorage trumpets were in direct conflict with the vertical reinforcing bars extending from the column. The longitudinal reinforcement in the transverse end beam also contributed to the congestion. Seismic design requirements called for the full development of these bars within the T-beam so plastic hinging would occur within the column. Bar development was achieved through careful placement of the vertical reinforcement, and limited use of hooked bars or headed reinforcement. Multiple reinforcement details were included in the project plans for just this one location to clearly indicate the design intent.

The specified concrete compressive strength for the T-beams and deck was 5.0 ksi, which is the minimum concrete strength allowed by ODOT for prestressed concrete members. ODOT's high-performance mixture proportion modifications, which requires a fraction of the portland cement to be replaced with supplementary cementitious materials, such as silica fume and fly ash, were used for the deck concrete for increased durability. Maximum aggregate size in both the T-beams and the deck was ¾ in.

Construction

Construction of the T-beam stems used conventional falsework supported off the ground. The dead and prestressed loads were balanced to the extent that only ⅛ in. of camber was required in the formwork. The stem falsework also held the precast concrete floorbeams in place so their extended strands and reinforcement could be cast into the stems. The deck falsework between the T-beams was suspended by hangers attached to the floorbeams while brackets mounted on the T-beam stems carried the deck overhang formwork.

Once the deck was cast and cured, the post-tensioning was applied and all the falsework and formwork removed. After the tendon grouting was complete, the post-tensioning anchor blockouts were filled and bridge rails and joints were installed. Span 1 construction for the southbound and northbound bridges occurred in 2011 and 2012, respectively, with no significant complications over a period of about 6 months. Because this work was only a small portion of the overall project that was paid for on a lump-sum basis under a construction manager-general contractor arrangement, the construction cost of span 1 is unavailable.

Summary

While only a fraction of the total length of the Whilamut Crossing Bridges, the span 1 structures had their own share of technical challenges and played an important role in the overall coherent appearance of the project.

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

EDITOR'S NOTE

The Summer 2012 issue of ASPIRE™ *included a project story on the southbound and northbound main-span bridges carrying Interstate 5 over the Willamette River, at that time called the I-5 Willamette River Bridges.*