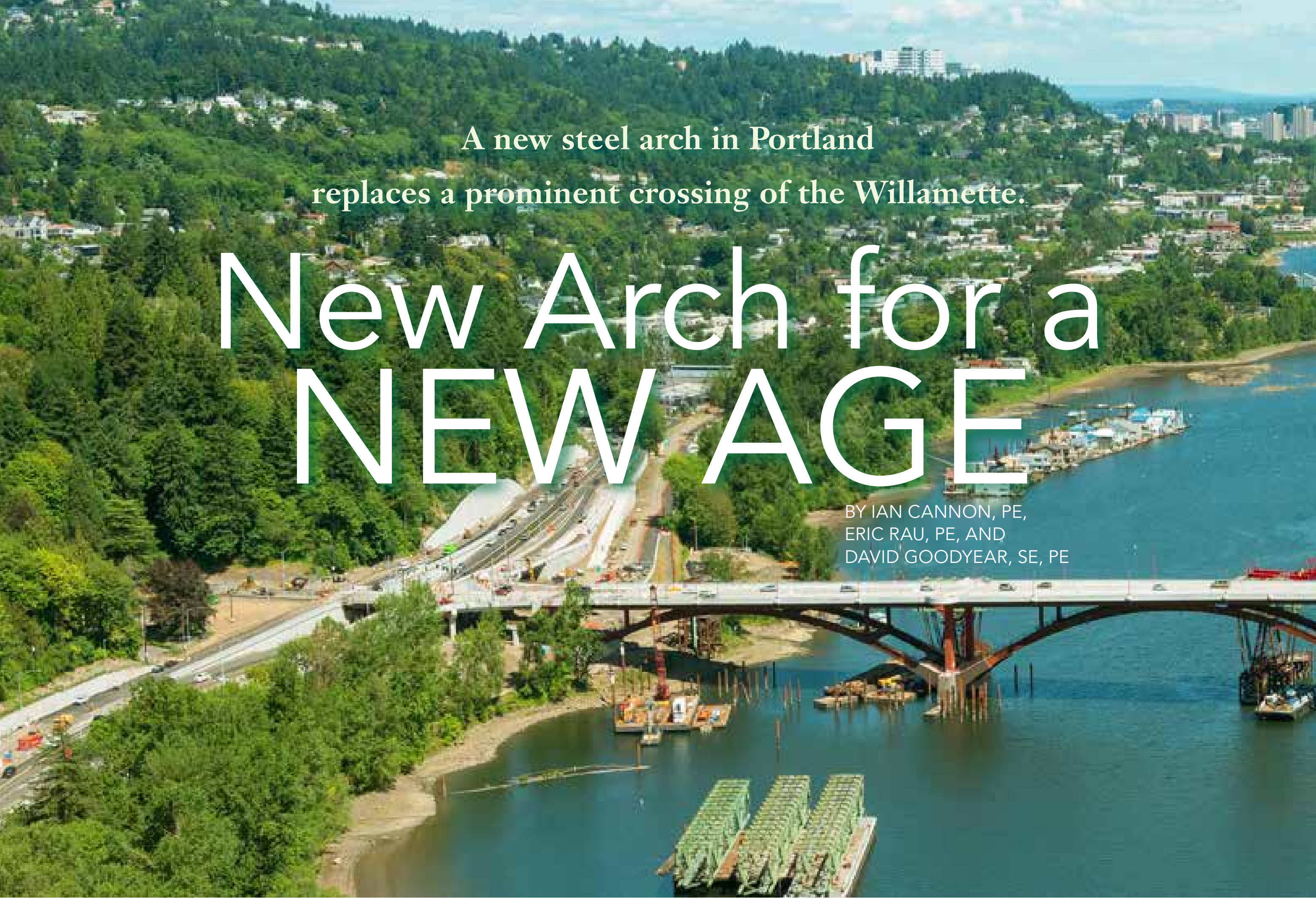

A new steel arch in Portland replaces a prominent crossing of the Willamette.

New Arch for a NEW AGE

BY IAN CANNON, PE, ERIC RAU, PE, AND DAVID GOODYEAR, SE, PE

TWO OUT OF 100. That was the National Bridge Inventory (NBI) sufficiency rating that the 90-year old Sellwood Bridge received in 2005 after the latest round of engineering studies, emergency repairs and additional load restrictions. Multnomah County, Ore., the owner of the bridge, was keenly aware that shoring up the old bridge was no longer an option.

Constructed in 1925 to replace the Spokane Street Ferry, the Sellwood Bridge spans the Willamette River just south of downtown Portland. It was designed by Gustav Lindenthal, a noted bridge engineer of the time and—along with the nearby Ross Island and Burnside bridges—was built with funds from a $4.5 million local bond measure.

Lindenthal was hired to redesign the Sellwood Bridge as a result of cost overruns on the Burnside Bridge. The result was a unique and efficient four-span continuous steel truss costing a mere $541,000. At 32 ft wide, the bridge was extremely narrow: two lanes, no shoulders or median and one 4-ft-wide sidewalk. It was Portland's first "fixed span" bridge across the Willamette and the first to not be designed for streetcars.

The NBI rating of 2 for the old bridge reflected a number of critical issues ranging from movement of an ancient landslide on the west bank of the Willamette to general deterioration of the 90-year old concrete approach structures.

The County began the NEPA (National Environmental Policy Act) process in 2006, and an engineering team of CH2M and T.Y. Lin International (TYLI) was retained to perform the engineering studies and develop alternatives for a new crossing. The evaluations included rehabilitation and replacement options for the main bridge, a dozen structure types for the main crossing and various

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The new Sellwood Bridge over the Willamette River near downtown Portland, Ore., replaces a more-than-90-year-old span that had become unusable.

alignments and project configurations. The recommendation was replacement on the same alignment, and through an active and meaningful public outreach process, the Community Advisory Committee's (CAC) preferred alternative—a steel deck arch—was approved by the County Board of Commissioners.

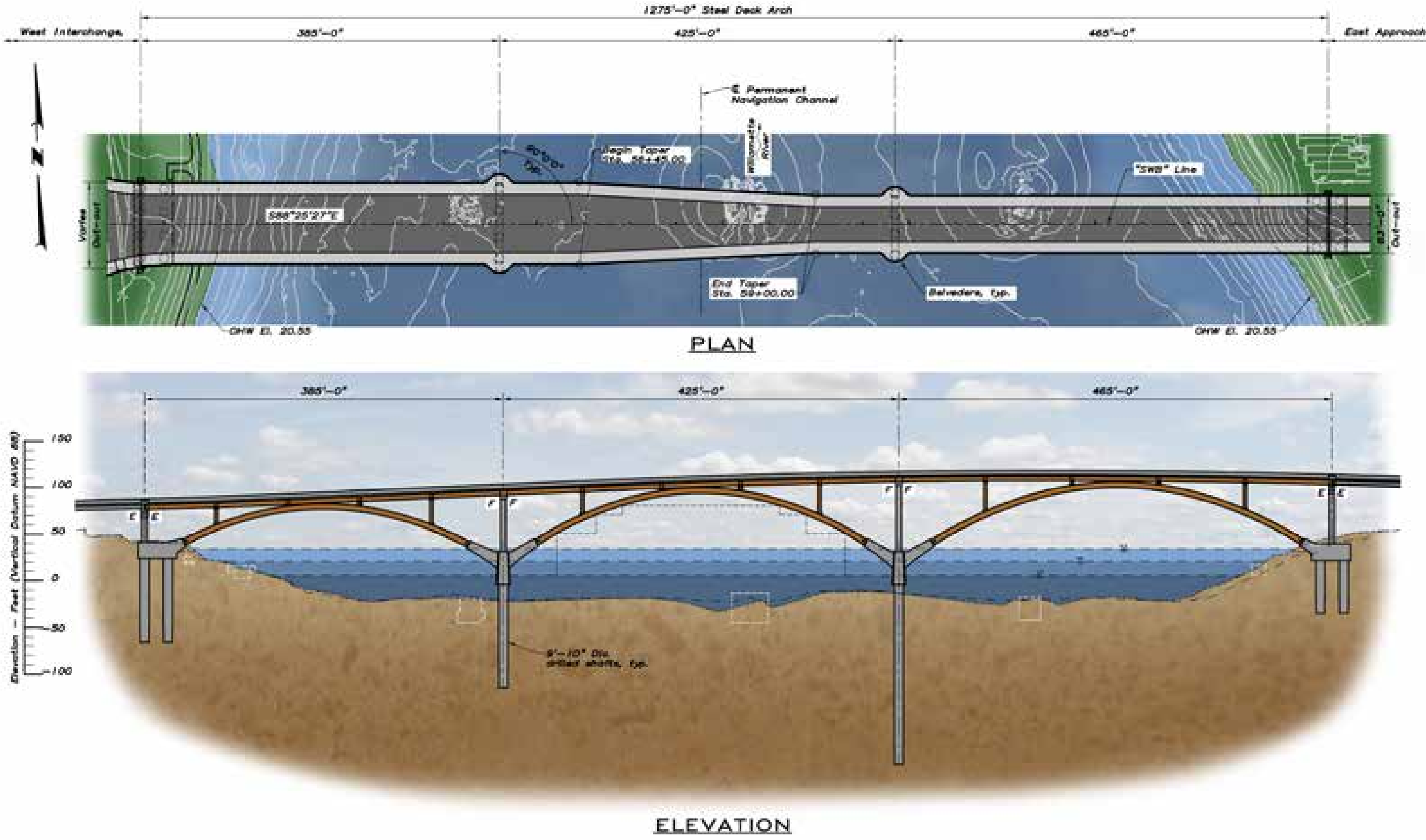
Forming a Team

Multnomah County elected to use the construction manager/general contractor (CM/GC) method of project delivery. A primary advantage of this method is that the contractor, in the role of construction manager, provides direct input to the owner and design team regarding constructability, pricing, scheduling and phasing of the work throughout the design process. In 2009, Multnomah County selected SSJV, a joint venture between Sundt Construction and Slayden Construction, as the CM/GC for the bridge based on a competitive qualification based proposal. In 2010, TYLI and CH2M were selected to develop the final design. To facilitate the CM/GC process, Multnomah County established a collocated project office with full-time staff from the owner, owner's representative David Evans and Associates, the engineering design team and the CM/GC.

The 1,275-ft main structure over the river is flanked on the east by a five-span concrete approach structure extending 500 ft from the riverbank into the adjacent Sellwood neighborhood. On the west side, the structure terminates with a significant interchange connection to Oregon Highway 43, which is composed of approximately 3,600 ft of bridge and retaining wall ramp structures.

The west side of the project site is located within an ancient landslide, which had moved about 4 ft since the original bridge opened in 1925. To prevent movement during construction and stop chronic seasonal movements in the long term, an anchored shear pile system that spanned the full 500-ft width of the landslide was employed. Consisting of 40 6-ft-diameter drilled shafts connected by a grade beam and 70 ground anchors with loads up to 850 kips per anchor, the system is designed to limit seismic deformation to under 4 in. during a moment magnitude scale (MMS) 9.0 Cascadia Subduction Zone earthquake. The landslide mitigation was bid at a construction cost of $14 million.

Both the original truss bridge and new arch bridge have only two through-traffic lanes. This was the recommended configuration from the environmental impact statement (EIS) stage, driven by the request from the Sellwood neighborhood to restrict traffic to two lanes to match the capacity of Tacoma Street to the east. While the existing bridge had an overall structure width of 32 ft, the new structure provides 6-ft, 6-in. shoulders, designated bike lanes and raised 12-ft sidewalks on each side of the bridge. The result is a pedestrian-friendly structure that has a nominal width of 63 ft. The structure width increases on the western half of the bridge to 90 ft, allowing for additional turn



Plan and elevation drawings of the new bridge.

lanes to and from Highway 43. Using 5,000 tons of structural steel, the bridge opened earlier this year.

Steel Deck Arch Structure

The 1,275-ft-long three-span steel deck arch has a span arrangement of 385 ft-425 ft-465 ft, with two arch ribs per span. The progression of span lengths generally follows the rise of the bridge in grade from west to east.

A reinforced concrete Y-arm extends from the pier and footing substructure to meet the steel arch rib at the springing connection in order to keep the steel ribs above the 100-year flood stage. These extensions are up to 36 ft in length at the river piers and follow the curved geometry of the arch.

The solid-ribbed arches are welded box sections with a constant web depth of 70 in., a flange width of 54 in. and a smooth parabolic curve profile (all steel curving was performed in-house by the project's fabricator, Thompson Metal Fab). Each of the three arch spans has four spandrel columns, which coincide with the location of the portal bracing between the two ribs. Each spandrel column supports a transverse steel cap beam, with longitudinal girders spanning between them.

Both the girders and cap beams have an overall steel depth of 60 in. and are composite with the reinforced concrete deck. The girder system is 15-span continuous over the 1,275-ft arch structure, with five to seven girder lines spaced up to 14 ft, 6 in. Based on pricing feedback from the CM/GC, plate transition splices were eliminated and flange and web plate thickness were held constant for the entire girder system. Flange plate width varied based on structural demand but was held constant within a spandrel span.

Top and bottom girder flanges are connected across the cap beams with a continuity connection plate while the girder web is connected with traditional clip angles. The cap beam has an internal diaphragm at the girder line, and the entire connection is bolted. The CM/GC requested slotted holes at specific girder locations to increase tolerances for fit-up during erection.

The transverse cap beams are built-up box-shape members composed of two welded I-girders with top and bottom cover plates. The entire assembly is bolted to eliminate the possibility of crack propagation across the entire section and is designed for the loss of either I-shape or cover plate.

The spandrel columns are welded box sections with dimensions of 42 in. × 36 in. and plate thicknesses varying between 1.25 in. and 2 in. The connection of the spandrel columns to the arch rib is a bolted end-plated moment connection.

Establishing the articulation of the spandrel columns was an important aspect of the design. Design iterations evaluated various configurations of "pinned," "fixed," and "free" boundary conditions at the 12 column locations, with the primary challenge being to balance structure stiffness and load path during seismic and thermal response.

The final articulation uses unidirectional bearings at the top of spandrel columns in the flanking spans 3 and 5 and fixed end-plate moment connections for the columns in the center span 4 (the middle arch span). These fixed columns function similarly to a closed arch crown, while the deck structure is free to move at the ends.

➤ The shallow nature of the bridge's fixed arches led to increased bending demands.

Engineering Development

Like many replacement projects, local site conditions and the associated built environment imposed a number of engineering challenges. The structural system of the new Sellwood Bridge had to meet the following constraints:

- ➤ Provide a horizontal and vertical navigational opening that meets or exceeds that of the existing bridge.
- ➤ Provide a span layout that, when combined with the existing bridge, would allow continued navigation throughout construction
- ➤ Limit the amount of structure constructed in the waterway to comply with no-net-river-level-rise criteria.
- ➤ Provide a similar roadway profile as the existing bridge in order to limit project extents and facilitate construction staging

Meeting the profile grade requirement resulted in limited rise in the west arch. The three arches have a rise-to-span ratio that varies from 1:7.7 (0.13) to 1:6.4 (0.16). The shallow nature of the fixed arches led to increased bending demands compared to the more efficient arching action that could be attained with more ideal geometry.

In order to limit the effects of flexural demands on the size of the arch section, the springing connections were left in a pinned condition during construction from initial rib placement through concrete deck placement. The two-hinged arch freely rotated during construction loading, resulting in "simple span" bending, with zero negative moment at the springing support and increased positive moment at the crown. After deck placement the springing connection was fixed, shifting the flexural response toward "fixed-fixed" beam action for subsequent loading.

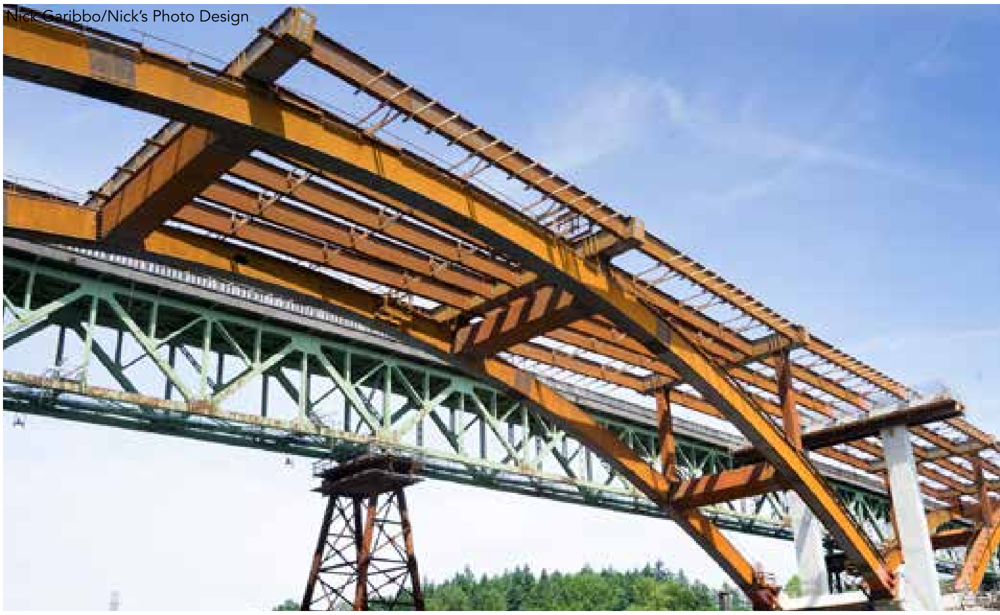
The springing connection consists of ten 4-in.-diameter ASTM A354 Gr. BC high-strength steel rods that are embedded up to 15 ft into the concrete substructure. In the temporary hinged condition, the rods are not tightened to the end of the arch ribs. A high-strength (15-ksi) UHMW pin plate was placed at the springing connection to transfer axial thrust while allowing rotation, and was coupled with an external frame support for vertical loads. Upon completion of staged construction, the fixed connection was completed by


Nick Garibbo/Nick's Photo Design


Nick Garibbo/Nick's Photo Design

▲ There are three segments per rib span, with lengths up to 148 ft.

▼ The 1,275-ft-long three-span steel deck arch has a span arrangement of 385 ft-425 ft-465 ft, with two arch ribs per span.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Steel was transported to the site on barges and placed with cranes operating from work bridges and barges.

grouting the pin plate gap and prestressing the anchor rods for service level moments.

Thompson Metal Fab proposed piece-by-piece stick erection, with arch ribs placed on shoring towers instead of a float-in system originally considered for arch erection. Each rib span contained two bolted field splices to match the optimum weights chosen by the CM/GC for fabrication and erection, resulting in three segments per span with lengths up to 148 ft and weights up to 146 tons each. Steel was transported to the site on barges and placed with cranes operating from work bridges and barges.

When the bridge opened to traffic, the crossing immediately jumped to a sufficiency rating of 100. ■

Owner
Multnomah County, Ore.

General Contractor
Slayden/Sundt Joint Venture
Slayden Construction Group, Stayton, Ore.
Sundt Construction, Tempe, Ariz.

Structural Engineer
T.Y. Lin International, Beaverton, Ore.

Architect
Safdie Rabines Architects, San Diego

Steel Team

Fabricator
Thompson Metal Fab, Vancouver, Wash. AISC CERTIFIED FABRICATOR

Detailer
Candraft Detailing, Inc., New Westminster, B.C. AISC DETAILER