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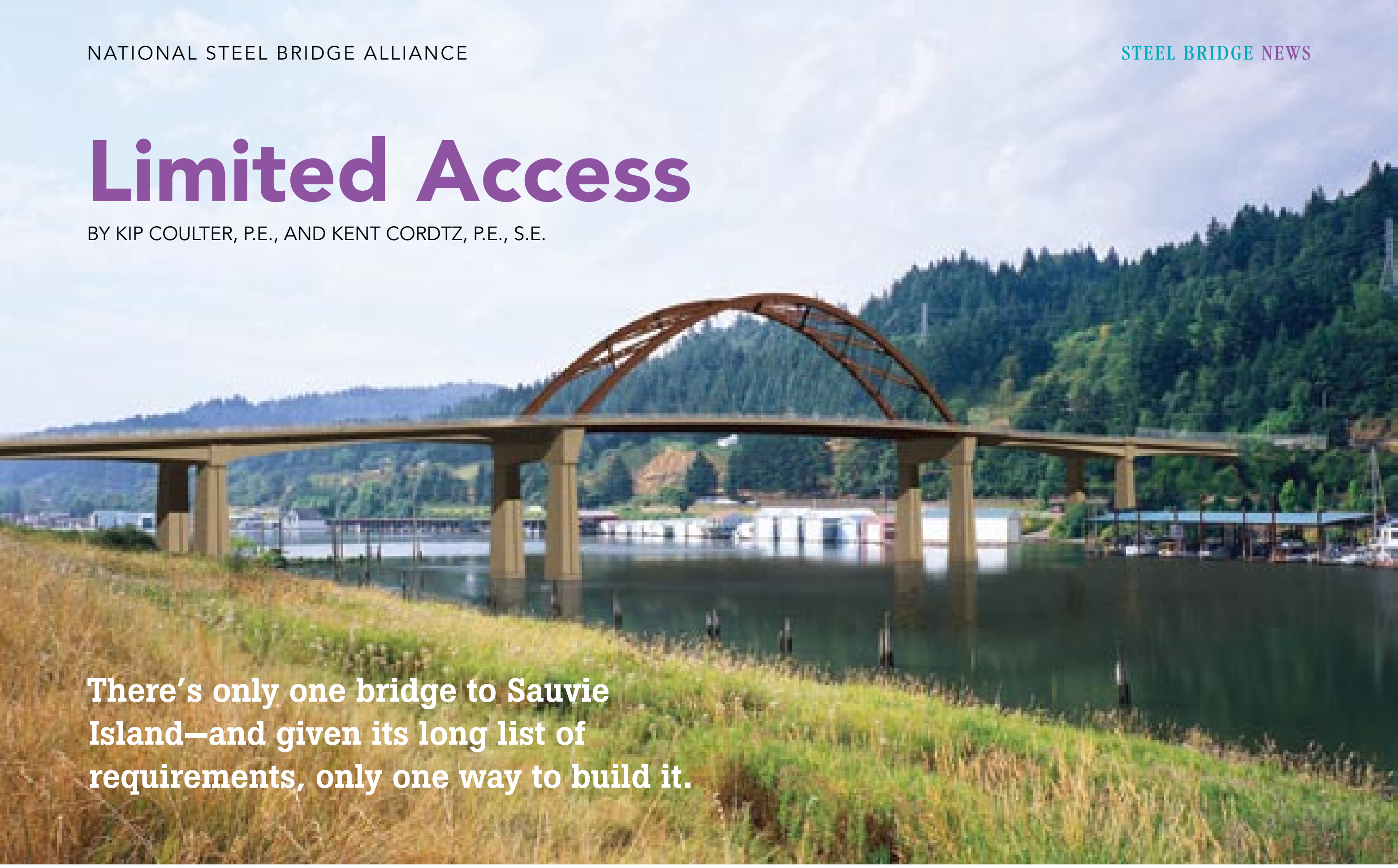

There's only one bridge to Sauvie Island—and given its long list of requirements, only one way to build it.

Photo simulation of the five-span replacement bridge. (Courtesy 2L2 Architects/Planners LLC)

THE IDEA OF "A TOUGH ACT TO FOLLOW" isn't limited to the entertainment business. In the construction world, for example, such a situation might come up in the form of having to replace a structure that's eligible for listing on the National Register of Historic Places—while also having to pay homage to it.

Such is the case with the Sauvie Island Bridge in Oregon. Located approximately 10 miles northwest of downtown Portland, the bridge provides the only vehicular access to Sauvie Island, a largely agricultural 24,000-acre island bounded by the Columbia River, the Willamette River, and Multnomah Channel.

The original 1,198-ft long bridge, constructed in 1950, featured 14 spans. It was constructed using concrete girder and steel deck truss approach spans, and featured a steel through truss over the main navigation span. Despite its historical significance, the bridge required emergency structural repairs and was eventually classified as functionally obsolete and structurally deficient—and slated for replacement.

Considering Configurations

Led by project owner Multnomah County and with the active participation of the public and various stakeholders, viable alternative configurations for the replacement bridge and its approaches were developed to meet the following key criteria:

- The State Historic Preservation Office (SHPO) required that a portion of the replacement structure be above the bridge deck (i.e., a through truss or arch) in order to memorialize the historic existing through-truss bridge.
- The main bridge span was required to clear a 175-ft-wide by 52.5-ft-high navigation envelope (above the 100-year high-water scenario).
- The maximum grade on the bridge and its approaches was limited to 6%.
- The bridge must be constructed without falsework in the channel, and with minimal disruption to navigation.
- Life cycle costs, environmental impacts, construction duration, aesthetics—and, of course, budget—were important considerations.

A total of 21 structure alternatives were initially identified, and a multi-step process was employed to screen these down to the options that best met all project criteria. The approach grade constraints, coupled with the required vertical navigational clearance, quickly led to the conclusion that a structure with a very shallow floor system was required; this would also support the SHPO requirement for a through structure. A half through-steel arch with a 425-ft center span and twin 155-ft side spans was initially preferred for the main span, but rising construction costs forced the team to consider other similar but less costly alternatives.

Steel Tied-Arch

The team ultimately selected a 5-span, 1,177-ft-long replacement bridge featuring a 365-ft Grade 50W weathering steel tied-arch main span. The tied-arch and its unique radial cable pattern satisfied the stakeholders' desire for an aesthetically pleasing bridge while meeting the stated project and site constraints. The graceful steel tied-arch span reduces the number of piers in the channel, permits an increased navigation opening, meets vertical clearance requirements, and could readily be constructed without requiring temporary falsework.

Haunched post-tensioned concrete box-girder approach spans, constructed on falsework, complement the slender tied-arch main

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Than hanger cables are 2.5-in.-diameter galvanized structural strand. The cast-steel sockets for the lower strand connections use molten zinc to fuse the strands into a conical "basket," locking in the cable tension.

span, and are reminiscent of the existing concrete approach spans.

Tied-arch bridges employ tension-tie girders in the plane of each arch to resist all arch thrust forces; no horizontal thrust forces are transmitted externally from the arch span to the supporting piers. The tie girders also support the transverse floor beams that carry the roadway deck structure, and resist local bending moments and deflections resulting from dead loads and moving live loads. Since complete fracture of either of the two tension tie girders could result in structure collapse, these important main members are considered to be fracture-critical. The fracture-critical nature of the main tie girders was addressed by detailing the tie girders as fully bolted members without any welding. The tie girders are built-up steel box sections consisting of web and flange plates connected by bolted corner angles. This provides for internal redundancy, as a fracture in one plate cannot propagate to the entire cross-section and lead to collapse. The bolted built-up tie girder was designed for the loss of a single web or flange plate using a special LRFD Extreme Event load combination.

The arch ribs consist of welded box sections with internal diaphragms at the hanger locations. The depth of the ribs were dictated by the minimum access openings through the diaphragms required by Multnomah County, to facilitate internal access for periodic inspection.

Hanger Cables

The hanger cables consist of 2.5-in.-diameter galvanized structural strand, per ASTM A586. Non-adjustable cast steel open-strand sockets are provided at the upper connection to the arch rib. Cable tensioning is performed at the open bridge sockets provided at the lower connection to the tie girder. Zinc spelter sockets are employed to attach the structural strand to the anchor sockets. This method of attaching structural strand cables to cast steel sockets has been in use for many years, and employs molten zinc to permanently join the individual wires of the structural strand to a conical "basket" in the cast steel socket. The resulting hanger cable assemblies provide a dependable and internally redundant tension member.

Bridge hanger cable assemblies, and the hanger plates to which they are attached, are designed with a minimum factor of safety of 4.0 for breaking strength versus unfactored dead load plus live load and impact. Bridge hanger cable assemblies are also designed for the loss or replacement of any one cable under traffic, with a minimum factor of safety of 3.0.

The unique radial cable pattern is not as structurally efficient or as stiff as a traditional vertical cable pattern or a crossed-cable pattern, but it was selected during the public involvement process primarily on aesthetic value. In other recent tied-arch projects, a crossed-cable pattern has been found to be most effective in stiffening the entire structural system and minimizing differential live load deflections, particularly when the live load is placed at the one-quarter point of the arch span.

An iterative process was employed to develop the most efficient arch shape, as the cable forces, arch rib and tie girder moments, and deflections are extremely sensitive to the arch-rib geometry with this unique cable pattern. The final shape of the arch differs somewhat from the classic shape of a uniformly loaded arch, and also from the common approximation of that shape by a second-order parabola.

Floor System

The floor system consists of longitudinal stringers supported by transverse floor beams. Due to vertical clearance requirements over the navigation channel and roadway approach grade restrictions, the top of the stringers and floor beams coincide. This results in the least structure depth and the lowest roadway profile. The stringers are composite wide-flange sections with moment connections at the floor beams. The floor beams are composite welded plate girders with moment connections to the tie girder that occur at each hanger cable node.

Erection Schemes

A significant challenge of the project was to develop a feasible means of erecting such a large steel structure. To attract the maximum number of bidders, the tied-arch span was designed to be erected by either of two methods. The first method was cantilever erection using temporary towers and stay cables, with material delivery and erection by barges. The towers would be located on the piers adjacent to the channel, with backstays anchored to the approach spans. The second method was to assemble the tied-arch and floor system off-site, deliver it to the site on barges, and erect it on the piers. Both methods were presented in the plans as suggested erection schemes only; the contractor was responsible for performing the final erection engineering for his chosen scheme. The contractor selected the float-in erection method, because it allowed for concurrent construction of the approaches and main span, as well as a savings in schedule.

Fabrication and Erection

The steel fabricator employed a progressive shop-assembly technique to complete final fit-up of all major steel members. The components were then dismantled and shipped to the Port of Portland dock on the Willamette River, approximately eight miles from the project site, where the final assembly was completed. The tie girder and floor system were assembled to

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The tied arches and floor system were assembled eight miles from the bridge site and delivered to the site on barges.

the correct cambered geometry on timber blocking supported on the dock, followed by arch assembly from temporary shoring towers supported on the tie girder. Temporary compression struts between the arch and tie girder were installed to stiffen the structure during load-out and erection. Following steel assembly, the hanger cables were installed and tensioned to the specified initial tension.

The 365-ft arch structure was raised on the barge at the assembly dock, and the bridge span was eventually floated the eight miles to the project site. Once at the site, the span was carefully lowered and guided onto temporary bearing pedestals at its final vertical and horizontal location.

When completed this year, the new Sauvie Island Bridge will include 1,250 tons of steel and will provide the required capacity to support the heavy vehicles operated by the island's agricultural and industrial businesses, while also providing for safe bicycle, pedestrian, and truck use. And the chosen steel tied-arch meets the project's stringent engineering and permitting requirements while also satisfying the aesthetic and historical desires of the stakeholders. MSC

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