Tilikum Crossing, Bridge of the People

New light-rail structure over the Willamette River to open in the fall of 2015

by Norman Smit and David Goodyear, T. Y. Lin International, and Aaron Beier, Kiewit Infrastructure West Co.

Nestled between the Marquam Bridge to the north, and the Ross Island Bridge to the south, the Tilikum Crossing is a new structure spanning the Willamette River in Portland, Ore. This is the first new crossing of the Willamette River since the Freemont Bridge was constructed in 1973. This unique cable-stayed bridge is designed to accommodate the multimodal transportation needs for the sponsoring agency, TriMet, and is a critical link across the Willamette River for the new 7.3-mile light-rail transit (LRT) connection between Portland and Milwaukie. The new extension of the LRT system is expected to serve over 25,500 weekday riders by 2030. The owner, in collaboration with the design-build team, has completed the new bridge on schedule so the LRT extension can open to riders in 2015.

Bridge Type Selection

The alignment of the new LRT extension was finalized in 2008, and a citizen's advisory committee was formed to consult with the owner as to the bridge type, geometry, and architecture of the new bridge. The design was chosen by the owner prior to executing the contract to complete the final design and construction of the bridge. The two-year advisory process resulted in a cable-stayed bridge being chosen to span the Willamette River. The preliminary design was completed in 2010.

Design-Build Delivery Method

TriMet chose the design-build delivery method for the bridge because the critical path for delivering the LRT extension to Milwaukie ran through the design and construction of the new Tilikum crossing. To open the new LRT line by 2015, it was essential that the bridge had to be completed by August 2014. The following were the critical milestones for the project:

- Type selection—February 2009
- Design-build contractor selected—October 2010
- Final bridge design begins—January 2011
- Bridge construction begins—July 2011
- Final bridge design complete—August 2012

Aesthetic lighting is programmed to change colors as the river changes. Photo: Mike Brewington, 2014.

profile

TILIKUM CROSSING, BRIDGE OF THE PEOPLE / PORTLAND, OREGON

BRIDGE DESIGN ENGINEER: T.Y. Lin International, Olympia, Wash.

OWNER'S ENGINEER: HNTB Corporation, Bellevue, Wash.

OWNER'S ARCHITECT: Donald McDonald, San Francisco, Calif.

QUALITY CONTROL: Cooper Zietz Engineers, Portland, Ore.

PRIME CONTRACTOR: Kiewit Infrastructure West Co., Vancouver, Wash.

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

CABLE-STAY SUPPLIER: Freyssinet, Rueil Malmaison, France

FORM TRAVELER DESIGN: Parkin Engineering, Vancouver, Wash.

BEARING SUPPLIER: R.J. Watson, Buffalo, N.Y.

- Bridge turned over to owner for systems installation—August 2014
- Systems installation and testing complete—October 2015

Due to the tight construction schedule, the design period overlaps with construction by approximately 12 months, which shortened the total duration for final design and construction of the structure. This compressed schedule allowed the owner to meet the overall construction schedule for the LRT project.

Program Requirements

Having been through the public process to develop the geometry and architecture of the new bridge, the owner wanted to be sure that the final, built structure was consistent with that vision. Therefore, all the key elements of the design were prescribed in the contract documents as "program requirements." Some of the elements that could not be changed by the design-builder included: width of bridge deck, transitway geometry, angle and depth of edge beam, location of bridge expansion joints, deck geometry at tower, traffic barrier and handrails, geometry of towers, shape and dimensions of columns, stay arrangement, deck cross section, and edge girder and floorbeam dimensions.

The owner prescribed these program requirements to assure that the architecture, bridge type, and geometry from the public process was achieved in the finished bridge. The disadvantage of this prescriptive approach was that the full benefits of allowing the design-builder to provide the most efficient and constructible bridge were not realized. The emphasis placed on prescriptive program requirements in the request for proposal (RFP) provided limited opportunities for the design-builder to optimize the design. The main elements that were open to the design-builder's innovation included:

- Main pylon foundation type
- Solutions for liquefiable soils on the Portland (west) side of the bridge
- Midspan edge girder and stay anchorage design
- Construction means and methods

With the visual look of the bridge prescribed, the design-build team concentrated their efforts on cost saving items in the foundations, edge girder designs to address geometry constraints at midspan, and the methods of construction. The contractor has extensive experience constructing all types of cable-stayed bridges, beginning with the first

Balanced cantilever construction with work bridges to the main pylons to deliver material to the four construction fronts at the tips of the cantilevers. Photo: Sahnow's Air Photos, Banks, Ore.

precast concrete segmental cable-stayed bridge in the United States at Pasco-Kennewick in Washington. The design engineer has similar experience designing a wide range of cable-stayed bridges, from precast to cast-in-place bridges. So the evaluation of construction methods was comprehensive.

Site logistics were a challenge, with good water access for the main span, but limited water access over much of the backspans, and a parallel contract for hazardous-material remediation under the west backspan. In addition to limited access for floating equipment on the backspans, the open-edge girder section prescribed for the superstructure was not conducive to short line precasting, a lesson learned by the design engineers on the East Huntington Bridge in West Virginia. So the contractor chose to erect the bridge using overhead form travelers, developing a scheme in conjunction with a specialty subcontractor.

The erection method had to be selected at the outset, since temporary loading

TRIMET, OWNER

EXPANSION JOINT SUPPLIER: Watson Bowman Acme, Amherst, N.Y.

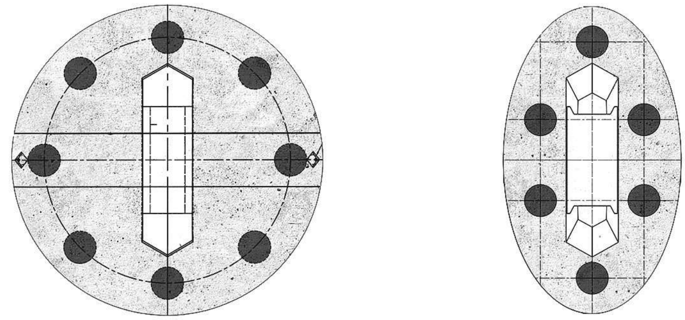
RAIL EXPANSION JOINT SUPPLIER: Atlantic Track, Wheaton, Ill.

REINFORCING BAR SUPPLIER: Harris Rebar, Tacoma, Wash.

BRIDGE DESCRIPTION: A five-span, 1720-ft-long, cable-stayed bridge across the Willamette River in Portland, Ore. The main span is 780 ft long, the backspans are 390 ft long, and the two pylons are 180 ft tall. The typical bridge width is 75.5 ft; at the towers, the width is 110.5 ft. The bridge was constructed using the balanced cantilever cast-in-place segmental construction method in 16-ft-long segments.

STRUCTURAL COMPONENTS: The concrete edge girders are 6 to12 ft deep and 6 ft wide. The transverse floor beams are spaced at 16 ft on center. Cable anchors supporting the superstructure are 32 ft on center. The cables are continuous, passing through saddles in the towers.

BRIDGE CONSTRUCTION COST: $109 million and construction means and methods for this type of structure define the final dead load condition of the completed bridge. In addition, the slender dimensions of the edge girders, the short towers, and the cable saddles made it critical that the cantilever construction did not overstress the deck or allow the cables to slip through the saddles as the segments were cast on opposite sides of the towers. Each construction operation needed to be coordinated and integrated into the design.

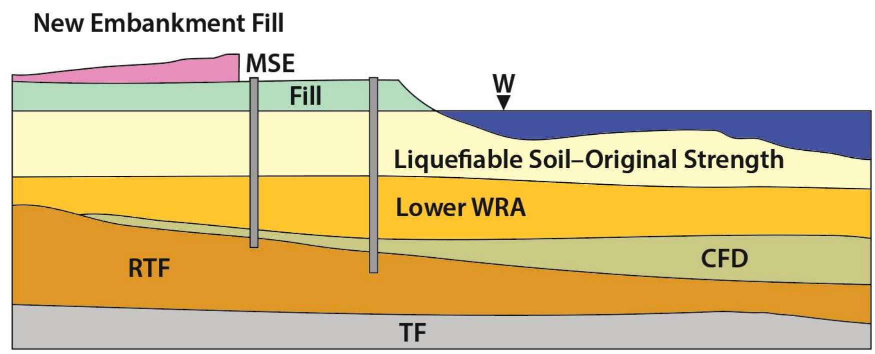


The figure shows the main foundation reference concept on the left and the final design on the right. Drawing: T.Y. Lin International.

Pylon Foundations

The reference concept provided by the owner included a large circular foundation supported on eight 10-ft-diameter shafts. Preliminary analysis showed that much of the mass supported by the shafts was in the footing itself, so that by reducing the size of the footing the number of shafts could be reduced. The figure shows the reference concept and the final design. The shape was made more oval and the number of shafts was reduced to six 10-ft-diameter shafts. This resulted in a significant reduction in concrete quantity, lowered seismic demands, reduced the size of the cofferdam required to construct the footings, and shortened the construction duration for the main foundations. The main controlling load cases evaluated for the foundation included seismic, wind, ship impact, and light rail vehicle (LRV) live loads in combination with the dead load of the structure.

The shafts are embedded in an extremely hard deposit known as the Troutdale Formation. This formation is a dense, compact granular material that provides excellent support for the bridge. O-cell shaft capacity tests were performed to verify their ability to support the structure. This testing showed that the end bearing and side friction of the shafts exceeded even the higher predictions and, therefore, the final shaft tip elevations were reduced further based on the test results. Knowledge of the strength of local subsurface conditions allowed the design to use capacities considerably higher than classical values for both end bearing and side friction.



The figure shows the soil layers that were used to model the back span piers for the soil displacement for each earthquake level. Note: WRA = Willamette River alluvium, CFD = catastrophic flood deposits, RTF = reworked Troutdale formation (still hard sand), and TF = Troutdale Foundation. Drawing: T.Y. Lin International.

Liquefiable Soils

Preliminary geotechnical investigation performed by the owner during the preliminary design phase indicated that there were potentially liquefiable soils on the west side of the project. In addition, the location of the bridge was an old dock and dumping area for a shipyard that once operated on the site, and investigations showed the fill had hazardous materials. The bidding documents indicated that ground improvement might be required to stabilize the area in the event of an earthquake.

In lieu of ground improvement strategies that would require handling a large volume hazardous material, the design-build team evaluated structural solutions, and established demands from the predicted soil liquefaction on the bridge displacements and foundation strength and ductility demands. The design criteria required evaluating a 475-year return operating and a 975-year return extreme earthquake.

For the lower-level earthquake the bridge must remain operational with repairable damage, and for the higher-level earthquake the structure must not collapse. Evaluations were performed using a three-dimensional nonlinear time history model with both liquefied and non-liquefied soils in order to bracket results. The predicted displacement demands were applied to the foundations along the length of the structure in order to design the foundation-superstructure frame for the liquefied design case. This solution was compared to a ground improvement condition, and found to be both superior in terms of performance and less expensive for construction, even without considering the environmental impacts of moving large volumes of hazardous materials.

Midspan Design

Due to the maximum bridge slope allowed for the Americans with Disabilities Act and the navigation clearance required, there was not adequate clearance below the bridge to permit the midspan cable anchors to be below the edge girder in the middle 150 ft at the midspan of the structure. This issue was left open in the RFP because the realization of height limitations came late in the project development process.

The solution developed by the bridge designer was to split the edge girder

Midspan framing showing the double edge girders with the anchors tucked between them to provide the navigation clearance in the middle of the bridge. Rendering: T.Y. Lin International.

and recess the anchorage between the split edge girders. This design produced a somewhat complicated forming system, but it allowed meeting the clearance requirements without significantly increasing the concrete volume and weight.

Means and Methods

One of the more critical elements for reducing the cost of construction is to efficiently move material through the construction site and out to the construction fronts. The construction of work bridges required for the two main towers allowed workers and materials to efficiently reach the construction fronts. There was a large preassembly yard on the Portland, Ore., side of the bridge where the reinforcing steel cages were preassembled prior to being lifted into place by the tower cranes at each pylon.

This efficient use of the site was one of the ways construction costs were reduced. Preassembly of the tower reinforcement along with aligning the cable saddles in the preassembly yard allowed for efficient assembly of the structure. The preassembled sections were then moved to the towers over the work bridges.

The overhead traveler system used to cast the segments was chosen because it was comparatively lightweight. This was necessary to avoid overstressing the deck. However, due to the shallow edge girder section, it was not possible to cast a full 32 ft between cable anchors. The segments were cast 16 ft long, and temporary cables were used to support the bridge as the permanent cables were installed.

Summary

The bridge is essentially complete, and the systems necessary to operate the LRT are being installed. The new LRT line will open to riders on schedule in 2015 due to the collaborative efforts of the owner and the design-build team. Portland, Ore., a city of many bridges, has a unique, new transit and pedestrian crossing of the Willamette River, which will serve the public for many years to come.

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AESTHETICS COMMENTARY

by Frederick Gottemoeller

Portland, like Pittsburgh, Chicago, and several other major cities, is fortunate to have a whole array of major bridges lined up along its most important waterways. They shape everyone's image of the city. The bridges are of many types and sizes, each reflecting its purpose, ownership, and period of completion. Placement of a new bridge in the midst of such an array is always a challenge. Will the new bridge hold its own in the cityscape? Will it adequately reflect the aspirations and skills of its era? And, in a city center especially, will its details stand up to the scrutiny of the thousands of people who will see it close-up every day? It appears that the new Tilikum Crossing will do all of those things.

This cable-stayed bridge, a first for Portland, inserts a clearly twenty-first century form into the mix of existing trusses and arches. The form itself is large enough and geometrically distinct enough to stand out in the cityscape. The designers have taken the form a step farther, making it visually unique among cable-stayed bridges by such refinements as the tapered pentagonal tower legs and visually simplified floor system. They had no need to seek novelty in untried structural systems. The elegance of the design will make it a strong visual anchor for the future redevelopment of the adjoining areas upstream from downtown. The generous side paths make for a natural combination of bus/light-rail transit riders, bicyclists, and pedestrians on a single structure. One hopes that we will soon see similar arrangements in other cities.

Finally, the quality of the details will make the structure an interesting bridge to be around. The oval pedestals for the tower press into service an attractive geometric shape that responds to the flow of the river. The floor system simplifies the underside appearance for boaters and riverwalk users by integrating the cable anchorages within the paired edge girders. And the aesthetic lighting will bring the bridge to life at night. Portland has a fitting new landmark to add to its array of bridges.