FRP retrofit helps Seattle I-90 bridge stay afloat to support innovative light-rail lake transit

PROJECT INFORMATION

Project
I-90 Homer Hadley Floating Bridge in Seattle, Washington

Project Category
Seismic Retrofit

Project Owner
WSDOT; Sound Transit

Application
FRP reinforcement of concrete columns and beams, and lining cable openings in concrete pontoon walls

Simpson Strong-Tie Products
CSS-CUCF22 and CSS-CUCF44 code-listed unidirectional carbon fabric; CSS-ES epoxy primer and saturant

CHALLENGE

Design a way to support light-rail mass transit on floating concrete bridges shared with automobile traffic.

SOLUTION

Strengthen concrete columns and beams with layers of fiber-reinforced polymer (FRP); layer FRP inside cable openings in floating concrete pontoons.

RESULTS

FRP retrofits to concrete completed ahead of schedule, enabling bridge and pontoons to support light-rail traffic at much less expense than a new bridge would entail.

BACKGROUND Transit planners sought viable and economical structural support for a light-rail connection between Seattle and Bellevue

In 2008, Sound Transit, the local public transportation system, endorsed a tax measure for a mass-transit corridor linking Seattle with the communities of Mercer Island, Bellevue and Overlake across Lake Washington. This would fulfill a government pact dating as far back as 1976 to add high-capacity transit — either rail or bus — to the west-bound I-90 Homer M. Hadley Memorial Bridge. The bridge was originally completed in 1989 and named for Homer More Hadley, architect of the Lacey V. Murrow Bridge, the east-bound I-90 span running directly beside it.

THE CHALLENGE Using the current floating bridges, engineer a structurally sound alternative to building a new bridge or tunnel

Sound Transit considered several options, none of which entailed going around the lake, because the extra distance involved probably wouldn't appeal to commuters looking to decrease their travel time. The route needed to cross the lake directly in order to serve commuter demand. At the same time, Lake Washington is more than 200 feet deep in the middle, making an underground (or underwater) tunnel impracticable, and likewise discouraging installation of the

View from on top of the floating pontoon structure and below the bridge deck showing the east-bound I-90 span running adjacent.

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THE CHALLENGE Using the current floating bridges, engineer a structurally sound alternative to building a new bridge or tunnel (cont.)

columns needed to support a new bridge. So the route would have to traverse one of the existing bridges, whether I-90 or SR 520 farther north.

The great challenge, from an engineer's point of view, was that neither of the existing bridges is entirely "fixed" in place; instead, both of them were designed to "float" for substantial stretches. I-90 rests for more than a mile of its span on floating pontoons subject in some degree to the lake's currents: Lake levels naturally rise and fall as much as two feet with the seasons; waves, wind and traffic cause slight undulations and rotation of the bridges' surface; and a fully occupied train would be heavy enough to lower the pontoons several inches deeper into the water. So the platform for the tracks would need to be able to absorb all these vertical and lateral pressures without derailing trains moving at commuter speeds.

Beneath the platforms, the bridge itself would also need to be reinforced to support the extra weight and forces of the rail traffic. And the concrete pontoons on which the bridge stood would need to be retrofitted using steel framing and tensioning cables to stabilize movement caused by water and wind, while also providing the extra resistance needed to support trains laden with commuters. This involved coring horizontal tunnels in the concrete to pull the cables through — openings that would require protection and reinforcement from the inside.

THE SOLUTION Retrofit supporting beams and columns, as well as the pontoons on which they stand, with fiber-reinforced polymer (FRP) from Simpson Strong-Tie

View of scaffolding around support bent in preparation for strengthening installations.

The engineering challenge, as we've seen, was twofold: (1) to design a platform for the railway that would allow but minimize bending and twisting of the tracks and eliminate the possibility of a train's derailment; and (2) to retrofit the bridge and its underlying support to bear the increased loads. The first challenge is considerably more unique and formidable. The solution that was arrived at involves engineering technology borrowed from seismic designs for tall buildings — namely, the use of high-strength bearings to allow a fixed structure to "roll" or sway from side to side without breaking. The implementation of this highly ingenious solution is outside the scope of this case study and still underway.

The retrofit challenge may have been less unprecedented but was equally fundamental to ensuring the safety of the new transit way. The Engineer of Record, KPFF, determined that the most economical solution for the concrete retrofit would involve fiber-reinforced polymer (FRP) because it's strong but very lightweight and thus wouldn't significantly increase the dead loads. The contractor, FD Thomas, had worked with Simpson Strong-Tie previously and brought the opportunity to Simpson. Simpson Strong-Tie FRP products were chosen because they came with the best pricing and the most extensive field support for complex projects of this type, as well as fully meeting all the Engineer of Record's specialized design parameters. Before the work began, Simpson's technical sales team trained the installation crew at the Simpson facility in Kent, Washington, to ensure that everybody involved with the FRP application was up to speed.

The FRP retrofit involved four stages: (1) The columns were wrapped with five layers of CUCF44 code-listed unidirectional carbon fabric, the heaviest carbon fabric; (2) four layers of CUCF22 code-listed unidirectional carbon fabric were applied in a U-wrap configuration at the bent support girders for shear reinforcement; (3) the same girders received four layers of CUCF22 along their lengths to reinforce for flexural loads; and (4) CUCF22 was used to reinforce the interior of the new pontoon openings bored to receive the steel tensioning cables. To meet application and curing specs, the FRP had to be installed in appropriate temperatures, spread out over a number of months; installers were able to apply FRP to the pontoon holes in November by heating their interiors. A Simpson Strong-Tie Repair, Protect and Strengthen (RPS) specialist was available all through the complicated installation to provide onsite technical assistance.

View of FRP column reinforcement during installation.

View of FRP girder reinforcement during installation.

THE RESULTS FRP concrete retrofits were completed in January 2020, delivering great savings in time and money compared with building a new bridge

View of completed FRP reinforcement at the interior of pontoons prior to coring for future tensioning cables.

View of completed and coated FRP reinforcement at support columns.

The FRP installation on the pontoon openings, the bridge columns and the support girders was completed in January 2020, ahead of schedule and within budget.

Currently, the entire 14-mile corridor from Seattle to Bellevue, including stations, trains and signal systems, is budgeted at $3.7 billion. Despite the expense of redesigning and reinforcing the bridge and approaches, the I-90 crossing is slated to cost far less than building another bridge — especially one traversing so deep a lake — according to extensive analyses performed by the Washington State DOT in coordination with Sound Transit.

FD Thomas spoke to the particular advantages of partnering with Simpson Strong-Tie for the FRP concrete retrofit:

> “This was a large project encompassing various sites within the WSDOT I-90 corridor. [. . .] FRP systems were assembled using CFRP [carbon] anchoring. For the execution of this complex project, FD Thomas Structural Specialties teamed up with Simpson Strong-Tie (SST).
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> Working with Simpson Strong-Tie proved to have multiple benefits. [They] include the fact that SST’s materials [. . .] allowed us to use fewer FRP layers in many instances, which translated to savings for the client. Also, SST having a large facility in the Seattle area provided immediate support and material availability to our team performing the work.
>
> FD Thomas Structural Specialties has maintained a close alliance with SST and is performing projects nationwide.”

When complete, the reversible lanes will form the East Link light-rail line for Sound Transit — the world’s first light-rail system constructed on a floating bridge!

MORE INFO

For complete information regarding specific products suitable to your unique situation or condition, please visit **strongtie.com/css** or call your local Simpson Strong-Tie RPS Specialist at **(800) 999-5099**.