I-5 Skagit River Bridge Collapse and *Rapid Replacement*

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On May 23, 2013, the evening commute was just ending along a four-lane stretch of the Interstate 5 (I-5) corridor between the Canadian border and Seattle. At roughly 7 p.m., a semitruck heading south and carrying a permitted oversized-load struck the first portal and several subsequent sway members along the steel truss section of the I-5 Skagit River Bridge. The northern truss span of the bridge collapsed into the Skagit River. While the semi-truck made it across, several vehicles didn't and the occupants had to be rescued. Fortunately, no one was killed in the collapse.

The Washington State Patrol, the Washington State Department of Transportation (WSDOT), and local agencies responded immediately, setting up and manning detour routes both east and west of the bridge.

WSDOT immediately responded with bridge engineers to assess the damage and begin plans for both emergency and permanent repairs, while communication staff responded to the media, and sent out updates and freight alerts region-wide. Traffic engineers worked through the night to refine the detour routes for the roughly 71,000 vehicles that were detoured through the city streets of Burlington and Mount Vernon.

Within 24 hours, a contractor was hired under an emergency contract to remove the collapsed span, and began working with WSDOT engineers to install a temporary span to get the interstate back open. As the work was being done to temporarily restore I-5 traffic, WSDOT engineers began assembling contract documents for a permanent span repair.

Bridge Type Selection

Hours after the collapse, discussions were underway at WSDOT about how best to replace the collapsed span, and how to restore traffic as quickly as possible. Time requirements, vertical clearance requirements, and superstructure dead load limitations quickly became the primary guiding factors in designing the span replacement.

Minimizing traffic disruptions dictated the installation of temporary, side-by-side, dual-lane, modular truss bridge spans, which were subsequently replaced with the permanent span. For navigational purposes, vertical clearance to the river below had to be equal to or greater than that provided by the original truss span. And, importantly, to minimize any additional seismic inertial loads to the existing bridge substructure, the dead load of the replacement span could not exceed the dead load of the original truss span by more than 5%.

The design-build method (D-B) was chosen for the permanent span replacement with the goal of rapid construction. Three options were investigated: a steel through-truss (a near duplicate of the original span), a steel plate girder span with a concrete deck, and a prestressed concrete girder span with a concrete deck. The steel through-truss, though light in weight and aesthetically consistent with the original bridge, was thought to be too time-consuming to fabricate and erect. The project was advertised for proposal with the assumption that the most-likely structure types for proposal were going to be the steel or concrete girder options.

Four D-B teams submitted proposals for the permanent span replacement. Two proposals included the steel girder option and two proposals included the prestressed concrete girder option. WSDOT selected the best-value proposal, which utilized a prestressed lightweight concrete girder deck bulb-tee replacement span.

Lightweight concrete deck bulb-tee beams with a lightweight overlay erected on steel piling and bents. Photo: Washington State Department of Transportation.

Lightweight concrete was specified for the girders, diaphragms, and barriers to stay within the stipulated span dead load limitations. The chosen concrete girder proposal offered competitive initial costs, low overall life-cycle costs, the shortest girder procurement time, and the minimum closure time required to replace the temporary span with the permanent span.

Replacement Span Design

The WSDOT plan to reconstruct the I-5 Skagit River Bridge consisted of constructing the permanent replacement span using accelerated bridge construction techniques. The 160-ft-long permanent replacement span, composed of 65-in.-deep deck bulb-tee girders made of lightweight concrete with a silica fume concrete overlay, was built adjacent to the bridge and its temporary spans.

The new permanent bridge was analyzed and designed using the current *AASHTO LRFD Bridge Design Specifications* and the WSDOT *Bridge Design Manual.* The WSDOT Bridge and Structures Office provided over-the-shoulder reviews of the bridge engineer's design, shop drawings, and construction submittals.

In order to limit the weight of the superstructure, the girder spacing of 7 ft 3 in. was considered to keep the replacement structure as light as possible. Using 7 ft 3 in. girder spacing eliminated one line of girders to reduce the total superstructure weight. The total weight of the new superstructure including the lightweight concrete traffic barriers and concrete overlay was 915 tons, within the limit required by the contract.

Differential camber and reflective cracking are the two performance challenges involved with use of deck bulb-tees for long spans. In order to minimize the reflective cracking the superstructure design required the use of a 1½ in.-thick concrete overlay instead of hot-mix asphalt and the use of high-strength concrete and overlapping bars instead of welded connections.

The differential camber was adjusted using leveling beams prior to casting concrete at the closures. The predicted camber for lightweight deck bulb-tee girders was 6.5 in., and the measured girder cambers at erection were slightly above the predicted camber. The span–to-depth ratio of 29.5 for the new superstructure met the *AASHTO LRFD Bridge Design Specifications* criteria for live-load deflection.

The design compressive strength of lightweight concrete used for the deck bulb-tees was 9.0 ksi, with a compressive strength

Lightweight deck bulb-tee girders in the casting yard. Photo: Washington State Department of Transportation.

Erection of girders with a 500-ton crane on the river dike and a 200-ton crane on the barge. Photo: Washington State Department of Transportation.

Location of replacement span during construction. Rendering: Parsons Brinckerhoff.

of concrete at transfer of prestress of 7.0 ksi. The fresh unit weight of lightweight concrete was 0.122 kip/ft^3, with the unit weight of the girder of 0.133 kip/ft^3 for design and dead load calculations. A total of forty-eight 0.6-in.-diameter strands were used for design of girders.

Intermediate diaphragms were located at two temporary supports that were 20 ft from the end of girders; the support locations were moved to accommodate the bridge move. Temporary strands in the top flange of the girders were provided to compensate stresses due to negative moment at the temporary supports.

Replacement Span Construction

The contractor received notice to proceed on June 19, 27 days after the collapse and the design phase started immediately. The design was completed on July 9, which was 47 days after the collapse. The project's scope of work included construction of the new span over the river, and adjacent to the bridge's two temporary spans, then removal of the temporary spans and placement of the single, permanent span.

The permanent superstructure was constructed on steel piling and bents, just downstream of the temporary spans. The girders were set using a 500-ton crane on the river's dike and a 200-ton crane on a barge system. The crane picks were quite detailed. Each pick required 19 specific moves, including passing the end of the girder from the dike crane to the barge crane, tucking the girder under the boom of the barge crane—while re-ballasting the barge system—and finally re-ballasting the barge as the girder was placed on the temporary bents.

Deck closure reinforcement. Photo: Washington State Department of Transportation.

Separate rows of piling and bents were built to support a rail system that would be used to slide the temporary spans out, and slide the new span into place.

To complete the bridge, the girders were tied together with end diaphragms and closure concrete placements between the girders. This was followed by casting the traffic barrier and a 1.5-in.-thick silica fume deck overlay. Separate, intermediate diaphragms acting as jacking beams were also installed using reinforced cast-in-place concrete.

A vertical and horizontal jacking system was concurrently installed using a rail system supported by temporary piling and bents. To complete the installation of the new span, first the temporary spans were lifted off the existing substructure and slid off onto the temporary bents upstream of the bridge. The new span was moved upstream in a similar fashion, with the exception that it needed to be shifted ½ in. longitudinally to fit into place.

The overall construction started on July 12 and the new span was opened to traffic on September 15. It took just under 19 hours to swap the spans and open the freeway to traffic. To finish up the work, the temporary spans were disassembled onto the barge system and all of the piling was removed from the river.

Future Activities

What's next for this bridge? Successful as the replacement of the collapsed bridge was (the number of closed days totaled only 28), there is little rest for the designers and contractors. With the permanent replacement span in place, attention turns to the remaining sway-frame truss sections and their vertical clearances. While truckers are responsible for their over-height loads, states are prudent to examine over-height hits and apply mitigation if possible. In this case, that means removing and replacing the lowest height elements of the trusses, increasing the vertical clearance across the two outside lanes, and helping to extend the already long-life of the I-5 Skagit River Bridge. A

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Team members for the I-5 Skagit River Bridge included Parsons Brinckerhoff, bridge design engineer, Tampa, Fla.; Max J. Kuney Company, prime contractor, Spokane, Wash.; and Concrete Technology, precaster, Tacoma, Wash.

EDITOR'S NOTE

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