The Skagit River Bridge Collapse and Recovery Plan

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Abstract

The Skagit River Bridge in Interstate 5 in Burlington Washington was struck by an oversize-load vehicle and the northern truss span of the bridge collapsed into the into the river. Emergency responders at Washington State Department of Transportation (WSDOT) and partnering agencies mobilized immediately and, thankfully, no lives were lost.

The WSDOT recovery plan to reconstruct the Skagit River Bridge comprises of three contracts: 1) installing a temporary bridge to reconnect the Interstate 5; 2) Replace the permanent span using the accelerated bridge construction technics, and; 3) Rehabilitate the remaining trusses to the current functionality standards.

Introduction

On May 23, 2013 the evening commute was just ending along a four-lane stretch of the Interstate 5 corridor, which lies between the Canadian Border and Seattle. At roughly 7 p.m., a semitruck heading southbound and carrying a permitted oversized-load struck the first portal and several subsequent sway members along the steel truss section of the bridge. The northern truss span of the bridge collapsed into the Skagit River. While the semi-truck made it across hitting several more sway frames along the way, several vehicles didn’t and the occupants had to be rescued. No one was killed in the collapse.

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

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Bridge Type Selection for Replacement Span

Within hours of 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 side-by-side single lane temporary modular truss bridges (supplied by ACROW, and 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%.

Three options were investigated for permanent span replacement; a steel through-truss (a near duplicate of the original span), a steel plate girder span with concrete deck, and a prestressed concrete girder span with 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 Design-Build Teams submitted Proposals for the Permanent Span Replacement. Two of the Proposals included steel girder replacement spans, and the remaining two Proposals included prestressed concrete girder span options. WSDOT selected the best value proposal, which utilized a prestressed concrete girder deck bulb tee replacement span. Lightweight concrete was specified for the girders, diaphragms and barriers, to stay within the stipulated span dead load limitations. The concrete girder Proposal chosen 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 recovery plan to reconstruct the Skagit River Bridge consisted of constructing the permanent replacement span using the accelerated bridge construction technics. The permanent replacement span, composed of deck bulb tee girders made of lightweight aggregate with concrete overlay, was built adjacent to the bridge and its temporary span as shown in Figures 1 and 2. The roadway was closed to traffic for a period of 19 hours while the temporary span was moved out and permanent replacement span was moved into position.

Figure 1. Conceptual Truss Span Replacement with Prestressed Concrete Girders

Figure 2. Conceptual Temporary Bridge and Setup for Span Replacement

The new permanent bridge was analyzed and designed using the current LRFD Bridge Design Specifications and the WSDOT BDM. The WSDOT Bridge and Structures Office provided over the shoulder reviews of the design, shop drawings, and construction submittals.

In order to limit the weight of superstructure, the girder spacing of 2.316 m was considered to keep the replacement structure as light as possible. Using 2.316 m girder spacing eliminated one line of girders to reduce the total superstructure weight. The total weight of new superstructure including the lightweight concrete traffic barriers and concrete overlay was 915 tons, within the limit required by the contract. Figure 3 shows the headed bars of deck bulb tee girders at the fabrication plant.

Figure 3: Headed bars at closures

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 1) use of 38 mm of concrete overlay instead of HMA for this project, 2) use of high strength concrete closure and overlapping bars instead of welded ties.

The differential camber was adjusted using the leveling beams prior to casting concrete at the closures. The predicted camber for lightweight deck bulb tee girders was 6.5”, and the measured girder cambers were slightly above the predicted camber. The Span to depth ratio of 29.5 for the new superstructure met the LRFD Bridge Design criteria for deflection. Figure 4 shows the variation between measured and predicted cambers.

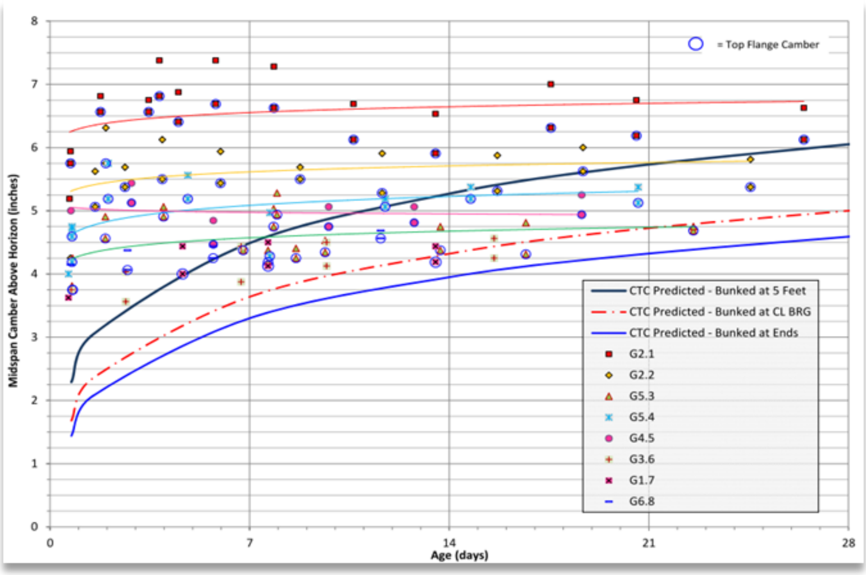

Figure 4: Measured and predicted cambers.

The design compressive strength of lightweight concrete used for the deck bulb tees was 62mPa, with a compressive strength of concrete at transfer of prestress of 48 mPa. The unit weight of lightweight concrete mix was 1952 kg/m^3, with unit weight of girder of 2128 kg/m^3 for design and dead load calculations. A total of 48-15mm diameter strands was used for design of girders.

Two temporary supports at 6 m from the end of girders were provided at intermediate diaphragms locations to accommodate bridge move. Temporary strands in top flange of girders were provided to compensate stresses due to negative moment at the temporary supports.

<u>Replacement Span Construction</u>

The Design-Build method was used with the goal of rapid construction. The project's scope of work included construction of the new span 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 a steel piling and bents, just downstream of the temporary spans as shown in Figure 5.

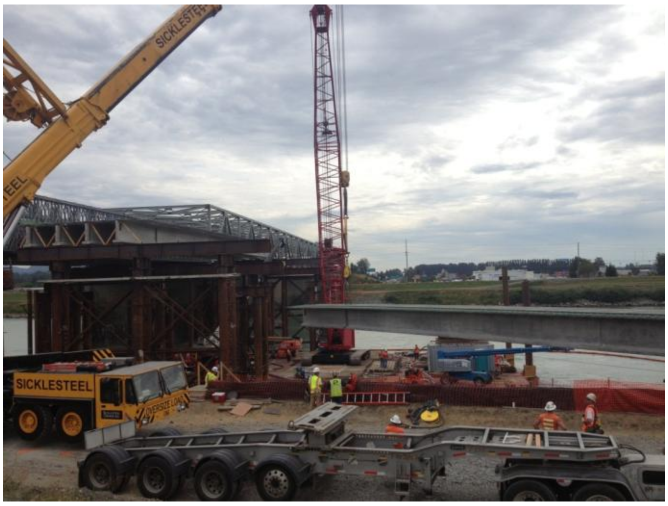

Figure 5: Permanent superstructure constructed on a steel piling and bents downstream of the temporary spans

The girders were set using a 500 ton crane on the river's dike and a 200 ton crane on a Flexifloat barge system. The crane picks were quite detailed. Each pick required 19 specific moves, including passing the end of the girder from the dike 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 bent.

A time lapse series of the entire girder setting operation can be found at this link (www.youtube.com/watch?v=-IdUap4_IvY)

A separate row 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 as shown in Figure 6.

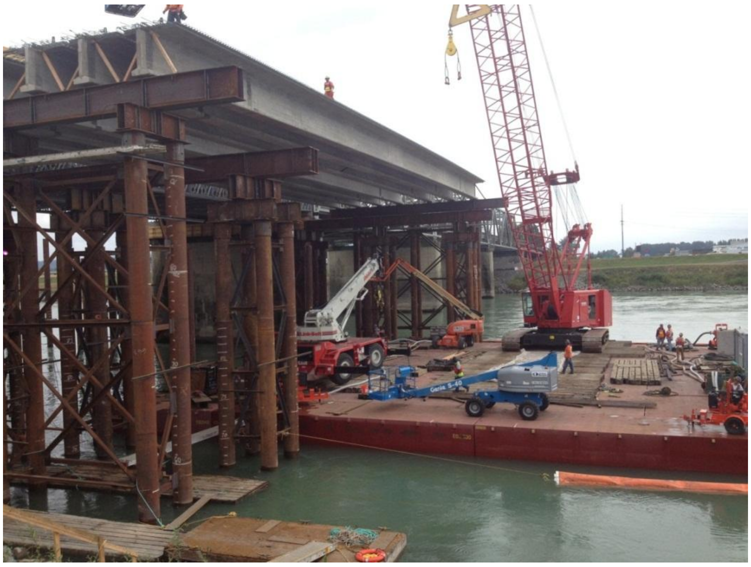

Figure 6: Supports for slide of the new span into place

To complete the bridge, the girders were tied together with closure pours between the girders and end diaphragms. This was followed by pouring the traffic barrier and a 38 mm micro silica deck overlay. A separate intermediate set of diaphragms or jacking beams were also installed using reinforced cast-in-place concrete. Figure 7 shows the placement of deck bulb tee girders.

Figure 7:   Placement of deck bulb tee girders

A vertical and horizontal jacking system was concurrently installed using a rail system supported by temporary piling and bents as shown in Figure 8.

Figure 8:   Jacking system for Bridge Slide

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 in a similar fashion, with the exception that it needed to be shifted a half inch to fit into place. Figure 9 shows the slide of the temporary Bridge.

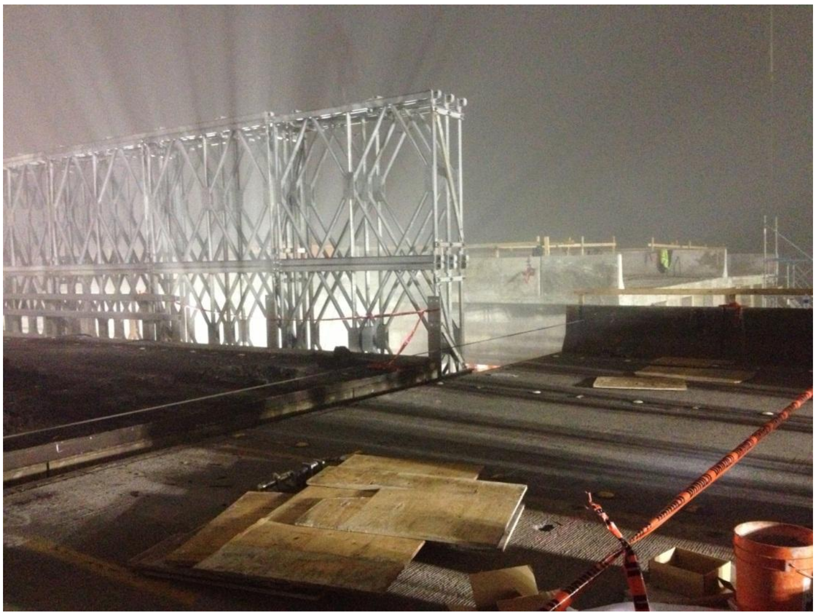

Figure 9: Temporary Bridge Being Slide Out

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 as shown in Figure 10.

Figure 10: Completion of Span Replacement

To finish up the work, the temporary spans were disassembled onto the Flexifloat barge system and all of the piling was removed from the river as shown in Figure 11.

Figure 11: Dismantling of Temporary Bridge on Flexifloat Barge and Removal of piling

Conclusion

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, helping to extend the already long-life of the I-5 Skagit River Bridge.