BRISSACK BRIDGE WIDENING

EXTERNAL POST-TENSIONING TO INCREASE CAPACITY OF EXISTING GIRDERS

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ABSTRACT

Located on Cedar Falls Road SE in Tanner, Washington, Brissack Bridge is a three-span bridge totaling 266 feet in length with a 30-foot roadway width. The superstructure for each span consists of five simply supported prestressed concrete girders with a cast-in-place composite deck. The north and south approach spans are approximately 78 feet long, and the main span is 110 feet across the South Fork of the Snoqualmie River.

The Brissack Bridge previously had three-foot-wide shoulders that included a 2-foot curb with a side-mounted steel guardrail along each side. Although these narrow shoulders served as pedestrian sidewalks, there was concern about user safety and the lack of adequate separation of pedestrians from traffic. This location is a popular access point to the river by canoeists and kayakers. The solution for addressing the safety concerns was to add a 5-foot-wide raised sidewalk on the west side of the bridge.

In addition to the typical live load conditions for a bridge sidewalk, King County wanted the design to include the capacity for an HS20 truck to drive on the sidewalk. The County felt that with the frequent heavy snow conditions, drivers would not know where the roadway ended and the sidewalk began. The solution for these challenges was to externally post-tension the existing prestressed precast concrete girders to gain the additional strength required for the new loading conditions. This tact avoided the replacement of existing girders, which would have increased disruption of traffic. It also eliminated a considerable amount of construction above the environmentally sensitive river and provided a cost-effective solution.

Attaching the anchor block to the bridge girder and transferring the post-tensioning force into the girder posed the following challenges:

- An anchor block adequate to transfer the post-tensioning force had to be created within the dimensional limitations and strength capacity of the existing girders.

- A mechanism had to be developed to transfer the post-tensioning force in the allotted space available between the existing girders' harped strands and the girders' end blocks.
- In order to keep from damaging existing prestressing strands, the location of existing prestressed strands in the girders had to be determined for a girder type no longer in use.

These challenges were successfully met. The Brissack Bridge now has a sidewalk that provides safe passage for pedestrians and adequate space for trucks to pass if necessary.

Keywords: epair, Rehabilitation, Strengthening and Replacement

INTRODUCTION

Located on Cedar Falls Road SE in Tanner, Washington, the Brissack Bridge is a three-span bridge totaling 266 feet in length with a 30-foot roadway width. The superstructure consists of five simply supported prestressed concrete girder lines with a cast-in-place composite deck in a three-span arrangement. The north and south approach spans are approximately 78 feet long, and the main span of 110 feet crosses the South Fork of the Snoqualmie River.

Brissack Bridge
Figure 1

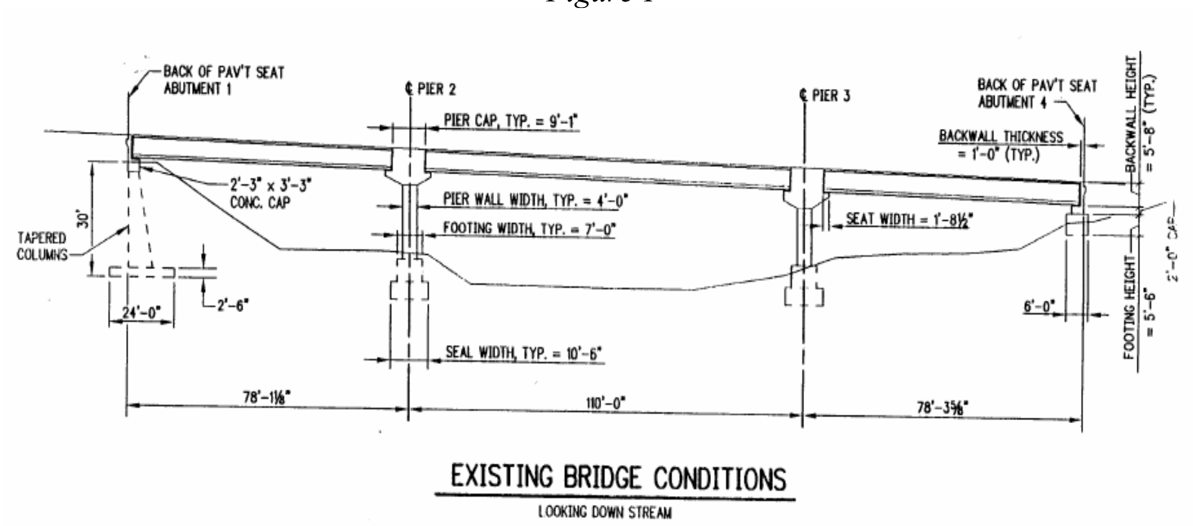
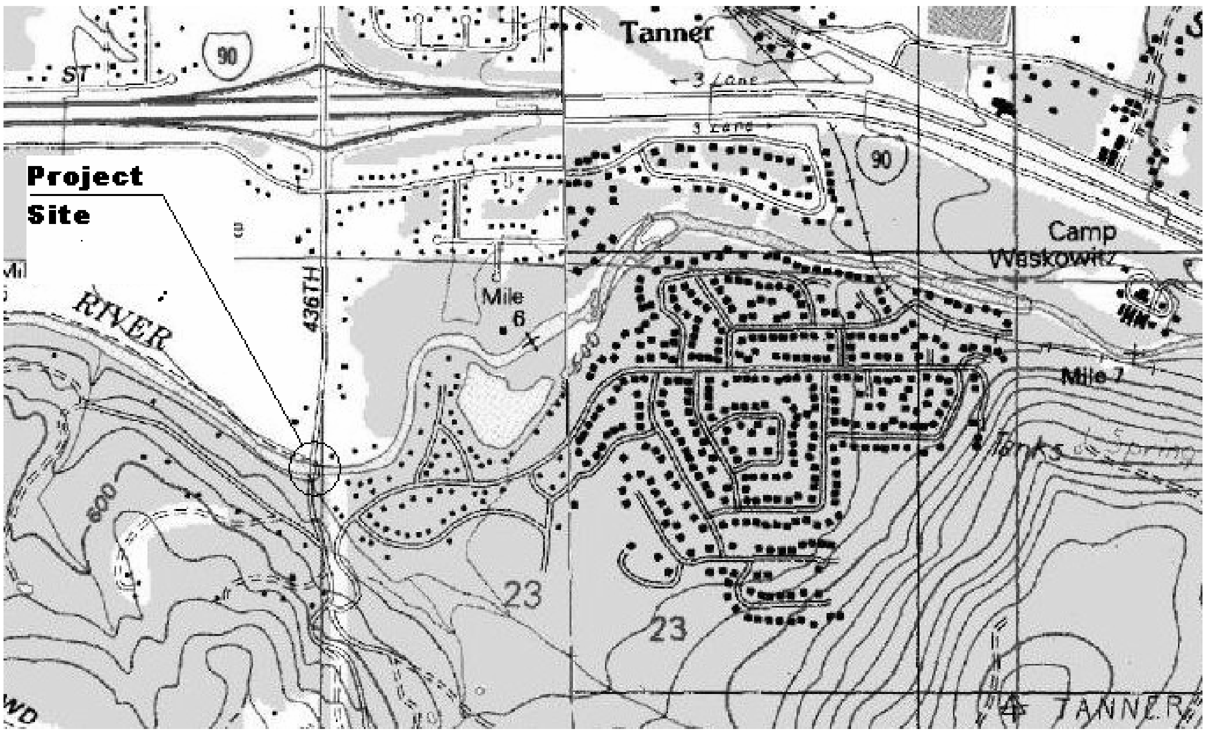


Figure 2

Brissack Bridge previously had three-foot-wide shoulders that included a 2-foot curb with a side-mounted steel guardrail along each side. Although these narrow shoulders served as pedestrian sidewalks, the lack of adequate separation of pedestrians from traffic was cause for safety concerns. The location of the bridge on the river is a popular point for river access by canoeists and kayakers. To address safety concerns, a 5-foot-wide, raised sidewalk was added on the west side of the bridge.



Tanner, Washington
Figure 3

A key aspect of this project was that the road could not be closed during the construction. The neighborhood shown in Figure 3 has only one access road in and out. Neighborhood access is dependent on this single road that crosses the South Fork Snoqualmie River at Brissack Bridge.

Design Alternatives

Multiple alternatives were considered for solving this challenge. A significant factor that affected the design process is the state designation of the stream flowing underneath the bridge as a sensitive area, or Class I stream, capable of providing habitat for salmon and other aquatic life.

One option to add room for pedestrians was to shift the roadway alignment within the existing roadway width (see Figure 4). Due to steep side slopes, this meant that the approach fills would need to be realigned and the new fill would encroach within the designated riparian setback area. This would have set in motion several permitting processes that would increase cost and lengthen the project schedule.

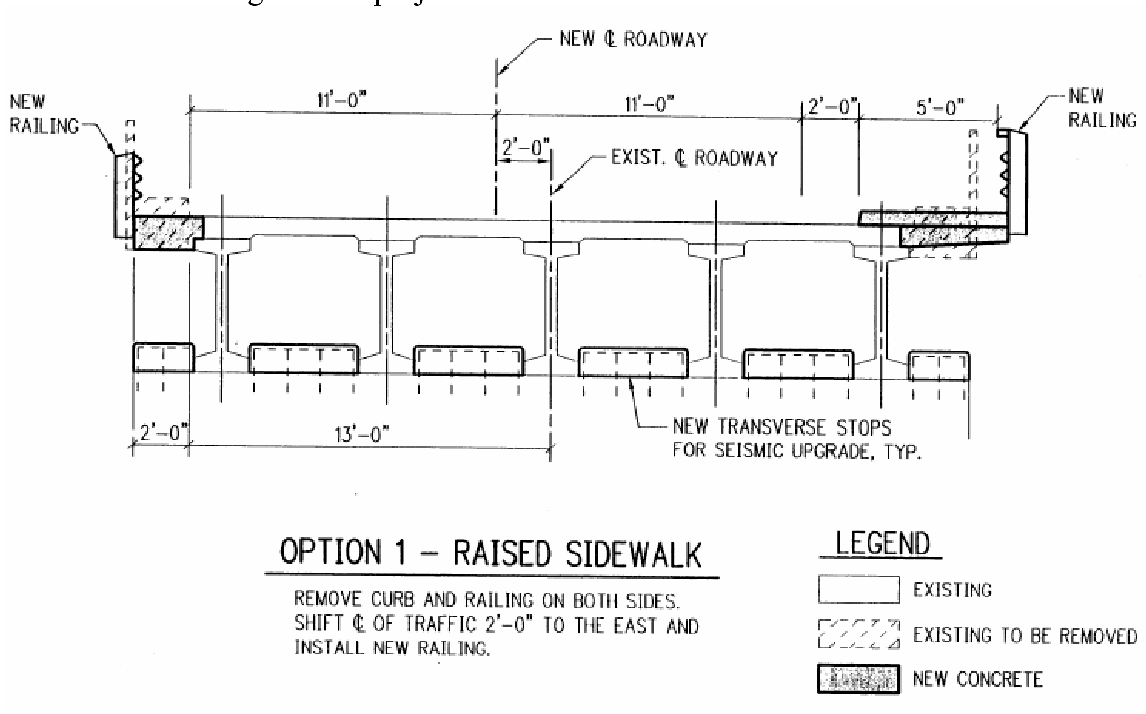


Figure 4

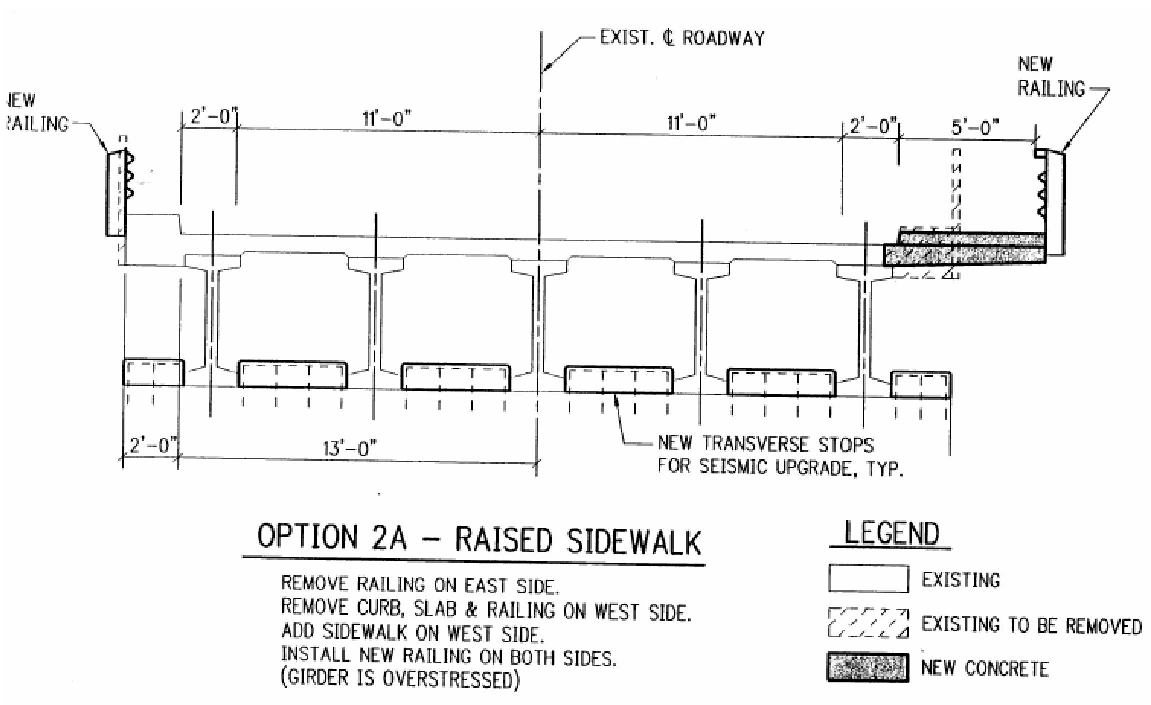


Figure 5

Another variation on this option (see Figure 5) was to add the new raised sidewalk and allow the exterior girder to be overstressed. This was not pursued for obvious reasons.

Figure 6 illustrates the option of separating pedestrians from vehicular traffic with a steel safety barrier and then adding the sidewalk by casting a lightweight concrete sidewalk on a steel frame. Issues of concern with this option included future maintenance and aesthetics. Utilizing the steel framework would have added future maintenance requirements for the County. The area is relatively pristine, and a clunky steel framework below the bridge deck would detract from the surrounding beauty as viewed by users of the river.

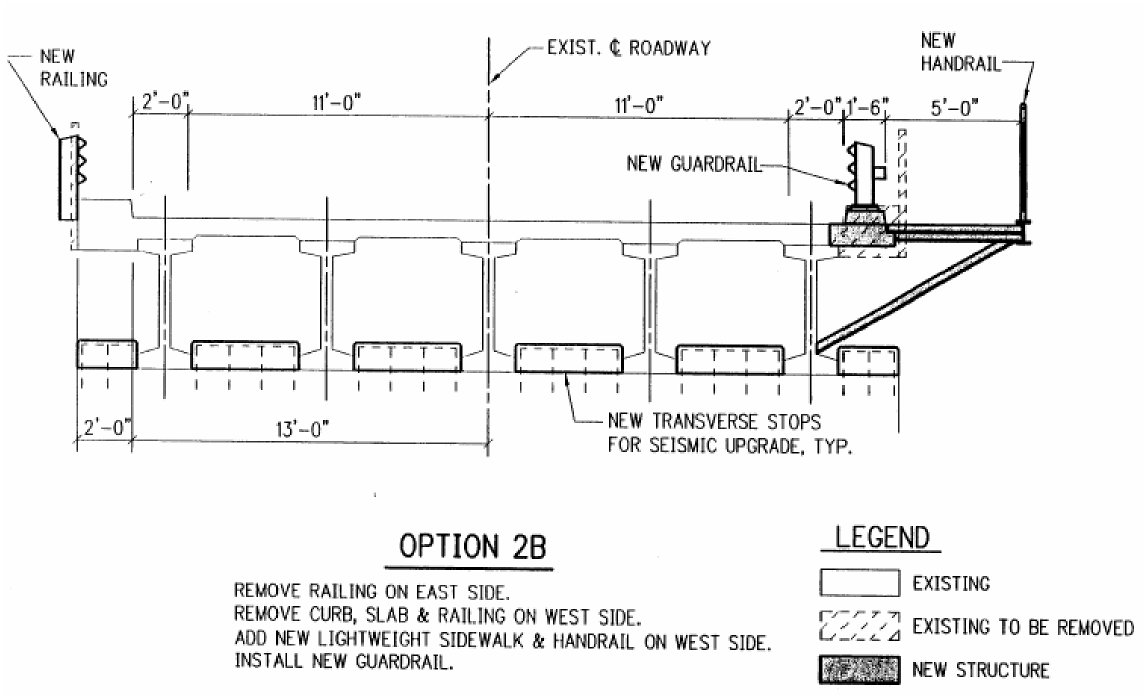


Figure 6

The next option considered was to remove a portion of the bridge deck and the exterior girder (see Figure 7). This would allow for a new sidewalk and girder combination that could be designed exclusively for the new loading condition. This option would have required additional demolition, reduced roadway width for staging construction, involved extensive work above the stream, and added construction costs.

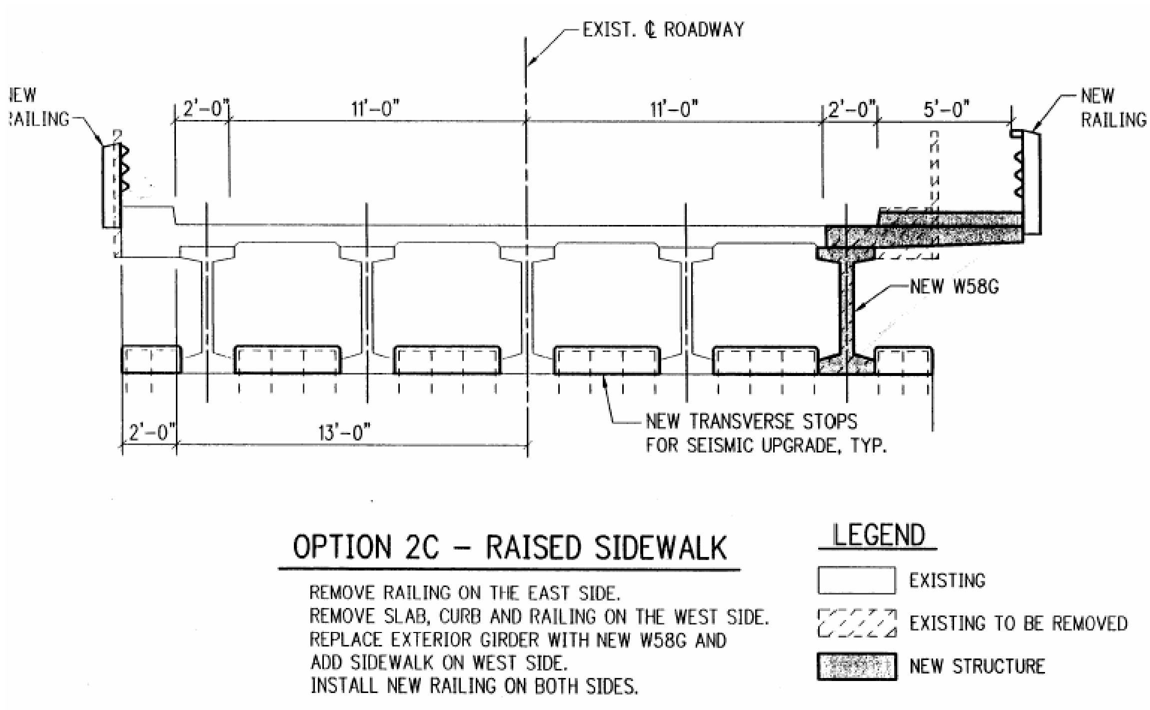


Figure 7

The preferred alternative was to remove a portion of the bridge deck slab but not the exterior girder and build a new raised sidewalk (see Figure 8). To eliminate the overstress on the exterior girder, the girders were externally post-tensioned.

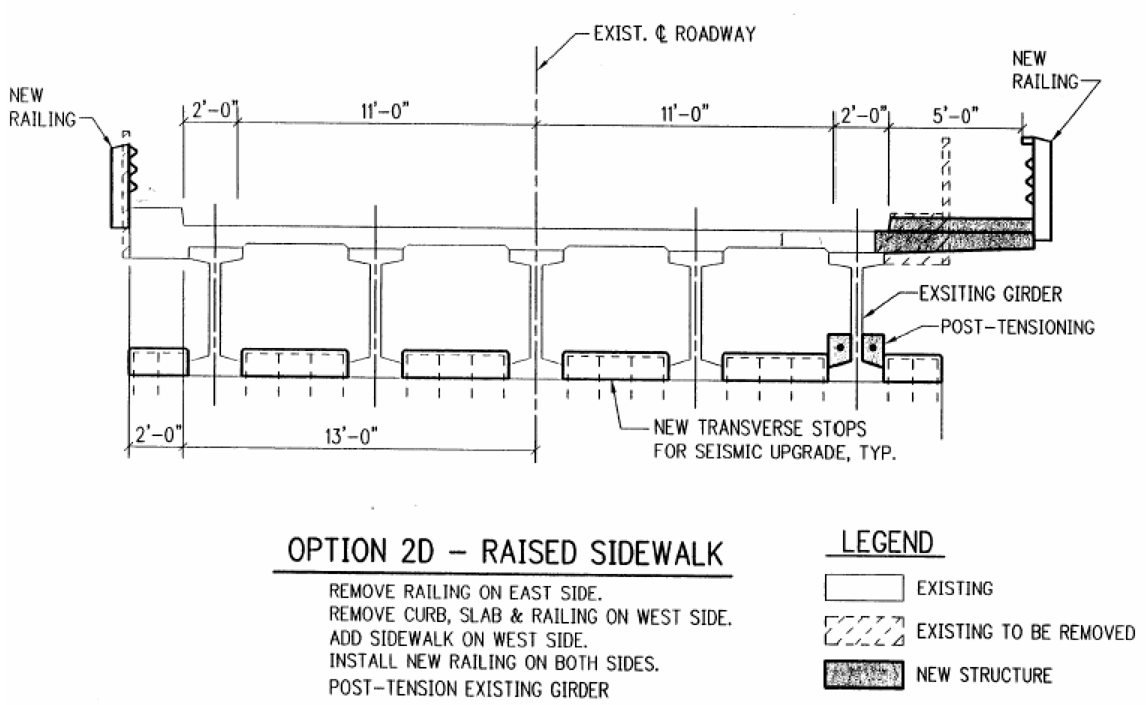


Figure 8

Externally Post-Tensioning Existing Girders

Externally post-tensioning the existing girders posed the following challenges:

- Design – the need to create an anchor block adequate to transfer the post-tensioning force within the strength capacity of the existing girders.

- Construction – the need to transfer the post-tensioning force in the allotted area available between the existing girders' harped strands, the girder end blocks, and the space between the girders.

Design

The design team's first challenge was to define the dimensions, reinforcement, and prestressing of the existing girder. The type of girder used on the bridge is no longer used in Washington State for bridge construction. Luckily, King County had historic standard plans for these vintage 1960s prestressed girders. By matching the overall dimensions of the girder and the spans of the bridge with a design chart on the standard plans, the team was able to define the type and probable design criteria for the girders. The standard design charts provided the probable number and location of harped and straight strands along with girder reinforcement. The general notes on the plans stated that the concrete should have a compressive strength of 6,000 psi.

Another feature of the existing structure that worked in favor of the design team was that each end of the girder was bearing on elastomeric pads. If the end of a girder was fixed to the foundation, the post-tensioning forces could be transferred to the supports rather than the girder. With the elastomeric bearings at each end of the girder, the post-tensioning applied to the girders would be directly transferred to the girders.

The next step was to determine the amount of post-tensioning required to upgrade the existing girders for their new loading conditions. First, the team calculated existing stresses for the non-composite and composite conditions. A 1.5-inch asphalt overlay had been added to the bridge deck since its original construction, so the stresses related to this additional dead load were added to the original composite condition. The existing dead load stresses with the overlay were 1,930-psi compression at the top of the members and 740-psi compression at the bottom of the members.

To install the new widened sidewalk, portions of the existing bridge deck slab and the entire sidewalk were to be removed. These reductions in the dead load were calculated and the corresponding stresses subtracted from the original conditions.

A new 5-foot-wide sidewalk replaced the existing 2-foot-wide sidewalk. The new composite dead load increased the compressive force in the top of the girders to 2,070 psi and reduced the compressive stresses in the bottom of the girders to 440 psi.

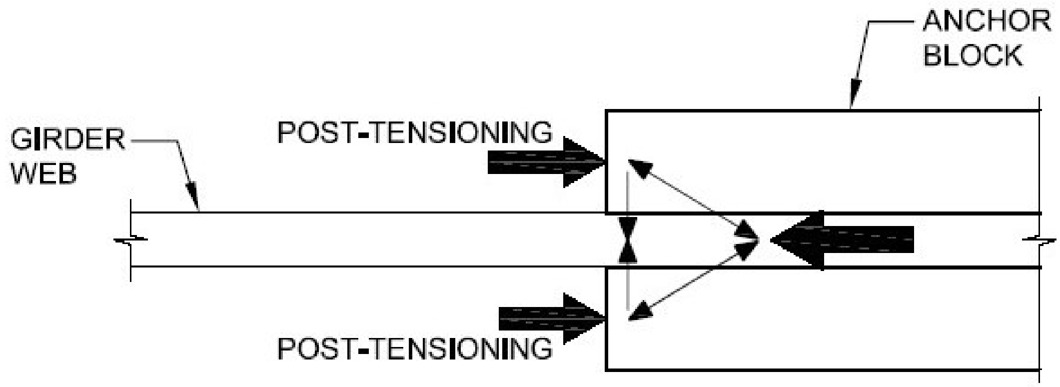
Finally, two live loading conditions were analyzed, one with the traffic in the typical traffic lane and a second with an HS20 load on the sidewalk. With traffic within the traffic lanes, the final stresses were 2,420-psi compression in the top of the members and 490-psi tension in the bottom of the members. Traffic on the sidewalk resulted in total stresses of 2,650-psi compression in the top of the members and 1,110-psi tension in the bottom of the members.

Both the compressive stresses and tensile stresses were above the allowable values of 465 psi and 2,400 psi respectively. Adding post-tensioning would have only increased the compressive stresses, so the post-tensioning needed to be fine-tuned to bring down the tensile stresses while not increasing the compressive stresses to an unacceptable degree. In addition to the more common allowable final stresses at service load, the Washington State Department of Transportation (WSDOT) does not allow any tension in the precompressed tensile zone.

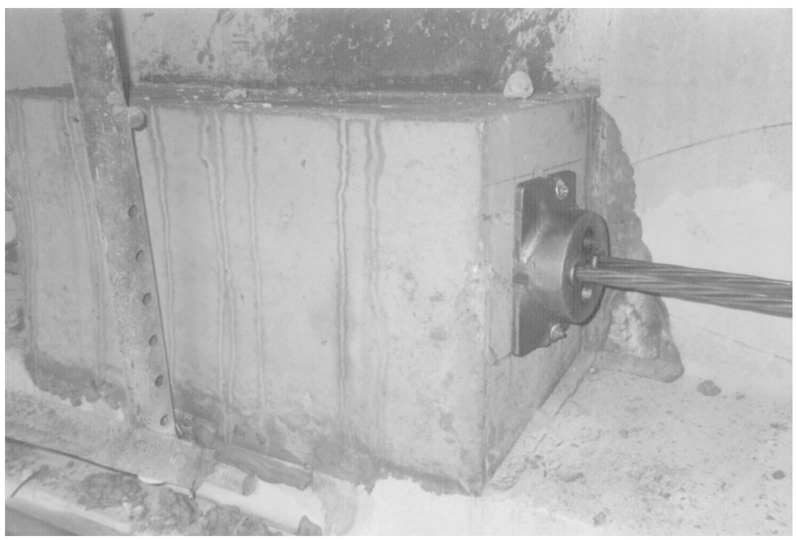
Eight 0.6-inch diameter low relaxation strands were used per girder to deliver a total of 310 kips to the 100-foot girders. The strands were stressed to 75 percent of the allowable stress and approximately 15-percent losses were assumed. This resulted in tensile stresses in the top of the members of 330 psi, which is below the 465-psi allowable by the industry, but higher than that allowed by WSDOT. The compressive stresses increased to 2,710 psi, which is above the allowable 2,400-psi value. It was determined that the event of a truck actually getting onto the sidewalk was remote enough to be comfortable with this 12 percent overage in compression and the WSDOT tensile requirements were waved.

The compressive force is transferred to the girders via an external anchorage block attached to each end of the girders. The team designed the anchor block utilizing research done by David H. Sanders and John (Jack) E. Breen of the University of Texas at Austin. Their study verified the use of the strut-and-tie model approach for designing anchorage zones. The team used reinforcing ties within the anchor blocks in accordance with the strut-and-tie design method to accommodate the bursting forces at the face of the anchor blocks (see Figure 9).

The anchor blocks were sized to fit above the bottom flange of the girder while allowing enough area to adequately handle the bearing stresses from the post-tensioning anchor plate. The post-tensioning forces were design to be transferred into the girders via shear friction between the concrete anchor block and the precast girder along with shear through reinforcement that was placed through holes drilled in the girder webs. An epoxy resin was used to bond the reinforcement in the holes in the girders, then the rebar cage was encased within the anchor block.



Strut-and-Tie Model
Figure 9



Anchor Block with Post-tensioning Strands
Figure 10

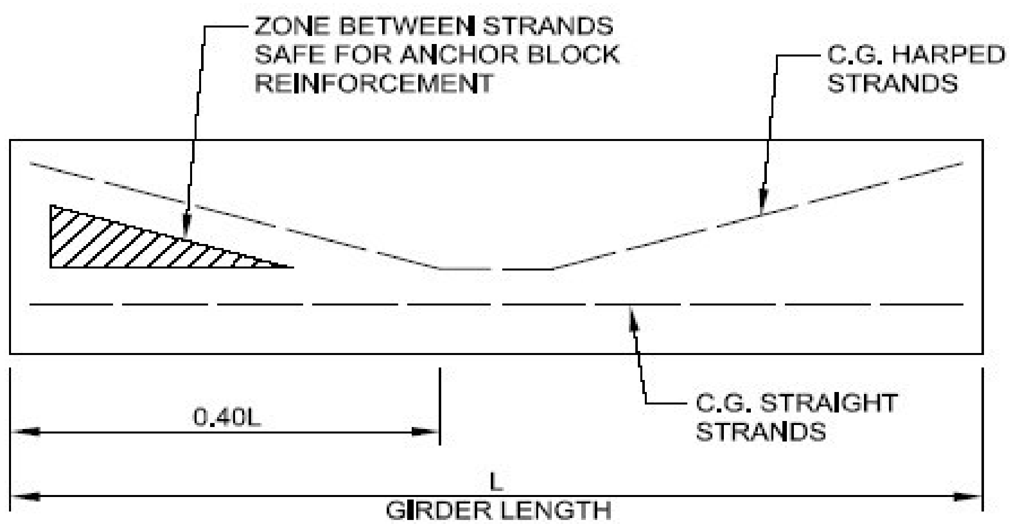
<u>Construction</u>

The construction process was as follows:

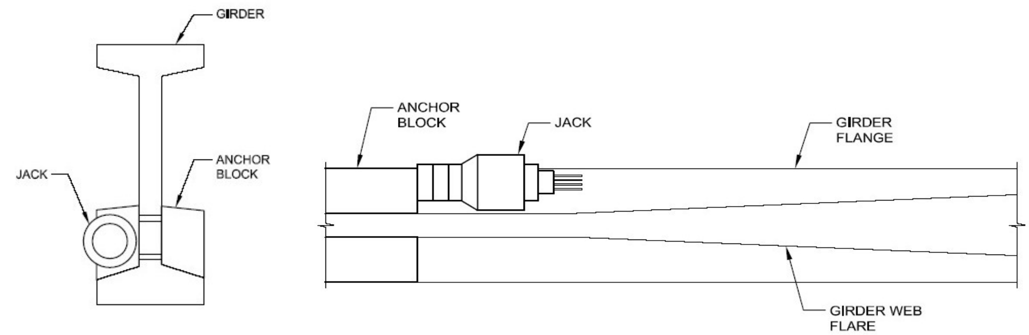
1. Remove existing sidewalk and portion of deck slab
2. Install anchor blocks, post-tension strands and duct
3. Post-tension strands by tensioning one strand at a time and alternating sides
4. Encase and grout ducts
5. Install new portion of deck and sidewalk
6. Install bridge railing

When post-tensioning the existing prestressed girder, it was critical to protect the existing internal prestressed strands while installing the anchor blocks. The reinforcement for attaching the post-tensioning anchor blocks had to be drilled into the girders in a way that does not damage the prestressed strands. The existence of harped strands makes locating the existing tendons particularly challenging (See Fig. 11). The reinforcement had to be accurately placed between the harped strands and the straight strands in the girder.

Further complicating the post-tensioning process was that the girder webs flare at each end of the girders. The flare of the web encroaches on the required space needed for the jacking system to be placed on the external strands. The contractor must have enough clearance from the girder web to get the jack onto the post-tensioning strands (See Fig. 12). Through discussions with local post-tensioning contractors, it was determined that 30 to 36 inches of un-flared web were needed behind the anchor block to enable the contractor to post-tension the strands. This effectively pushed the post-tensioning zone toward the mid-span of the girders and into the narrowing area between the existing harped and straight prestress strands.



Harped Strands
Figure 11



Elevation and Plan of Jack Clearance Requirements
Figure 12

The strands were stressed one strand at a time on alternating sides of the girders. By staging the jacking in this way, eccentricity of the applied loads was kept to a minimum.

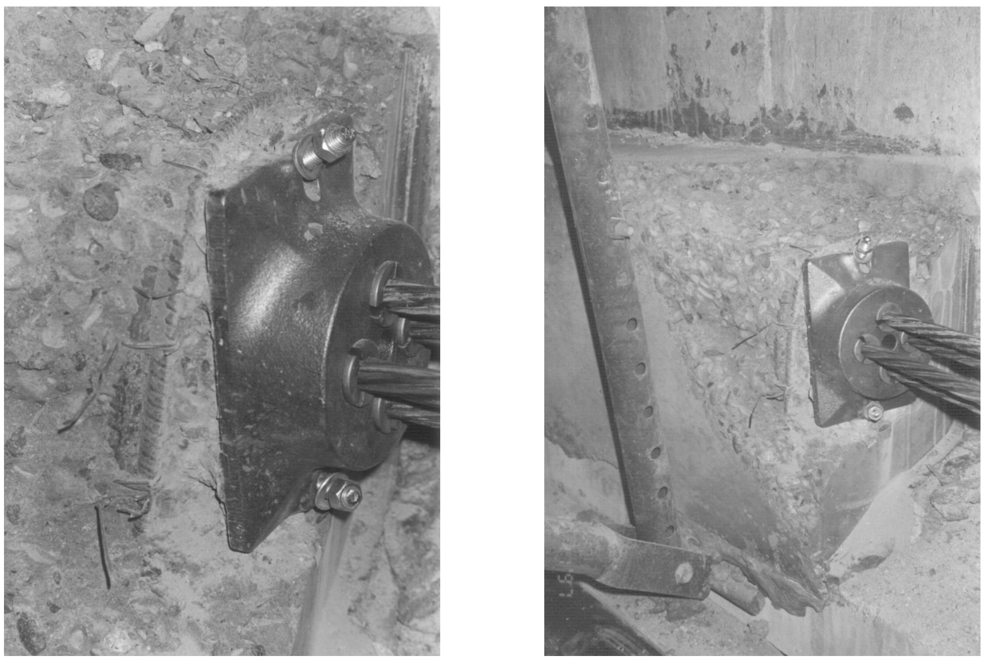
Camber was calculated during the design phase and found not to be a critical issue. The added post-tensioning resulted in an upward 3/8-inch camber. After losses were considered, the total upward camber is only 1/4 inch. The contractor monitored the camber, and no issues occurred because of it.

For protection from the elements and to safely encapsulate the tendons, the strands were placed inside a corrugated metal duct and the duct was grouted. Additionally, after the girders were post-tensioned, the duct itself was embedded in concrete its full length between anchor blocks. This additional measure help to protect the duct not only from the elements but also from people hanging on it and to further confine the strands in case of a failure.

Lessons Learned

During installation of the post-tensioning strands, the contractor mistakenly assumed that the anchors for the 100-foot girders were the same as the 70-foot girders. Accordingly, the anchor plates for the post-tensioning were sized for the 70-foot girders. The plates were therefore sized for a load approximately half of the actual load.

In addition to the undersized plate, the concrete had not attained the minimum initial compressive strength for the post-tensioning process. Consequently, the anchor failed by crushing the concrete beneath the anchor plate. It is interesting to note that the failure stopped at the reinforcement of the anchor block, and only minor repairs were necessary.



Anchor Failure
Figure 13

CONCLUSION

The ability to add capacity by post-tensioning the existing girders saved time, potential environmental impacts, and construction dollars. The time required for work above the sensitive river was reduced, thereby allowing construction to take place without the need for time-consuming permitting processes. The post-tensioning solution costs were 20 percent less than the next closest option.

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