State Route 162/6 Puyallup River Bridge

Successful bridge replacement in Washington State using prestressed, lightweight concrete girder superstructure

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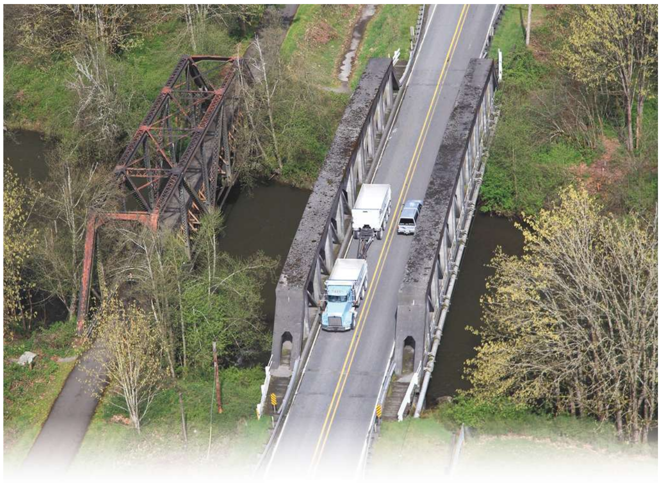


State Route 162/6 existing historical concrete pony truss bridge that was replaced. Photo: Washington State Department of Transportation.

State Route 162 is a two-lane highway that services several rural towns in western Washington. This short section of highway, only 17.5 miles in length, contains 10 separate water crossings. One of these crossings is over the Puyallup River near the town of Orting. A uniquely designed concrete truss bridge had been in service over the river for some 81 years. This historical, existing bridge had reached its functional limitation, which required that a replacement structure be built: the State Route 162/6 Puyallup River Bridge.

The New Bridge

A new roadway alignment was designed to allow the replacement bridge to be constructed adjacent to the existing bridge. This made it possible to maintain traffic during construction. The new alignment required a 3300-ft radius horizontal curve throughout most of the length of the bridge. The replacement bridge contains two spans of prestressed, lightweight concrete girders with a 7.5-in.-thick, cast-in-place, reinforced normal-weight concrete bridge deck supporting concrete traffic barriers at each side. The two spans are 110 and 160 ft for an overall length of 270 ft. A nonsymmetrical span arrangement was chosen to allow the center pier to be constructed out of the river, on the bank, while maintaining an opening large enough to meet the hydraulic requirements of the river. The 40-ft curb-to-curb width allows for two, 11-ft-wide lanes and two 9-ft-wide shoulders.

Prestressed lightweight concrete girders were used for the new bridge. Photo: Washington State Department of Transportation.

Girder Selection

The initial girder choice was to utilize the Washington State Department of Transportation (WSDOT) WF74G girder type, which is a 74-in.-deep girder with a 49-in.-wide top flange. The WSDOT bridge and structures office was looking for a suitable structure to evaluate the use of prestressed, lightweight concrete girders and selected this bridge due to its limited size and medium-length spans. The use of prestressed, lightweight concrete girders had been contemplated in the past, but concerns about girder properties—specifically the modulus of elasticity, creep, and shrinkage values—deterred WSDOT from using them.

Advantages

Weight reductions as a result of using lightweight concrete for the production of girders generally helps reduce substructure sizes. For instance, the depth to which shafts require embedment is controlled by either vertical or lateral loads. The vertical loads are reduced in two ways. The most obvious way is from the reduced girder weights. However, reduced girder weights can also reduce the size of pier crossbeams, which further reduces the dead load. These combined reductions lead to a smaller mass in the superstructure, which can reduce the seismic lateral loads to the foundations. These smaller foundation elements lead to cost savings in construction of the bridge.

Reduced girder weight for a given span length also has the advantage of requiring smaller crane and hauling

profile

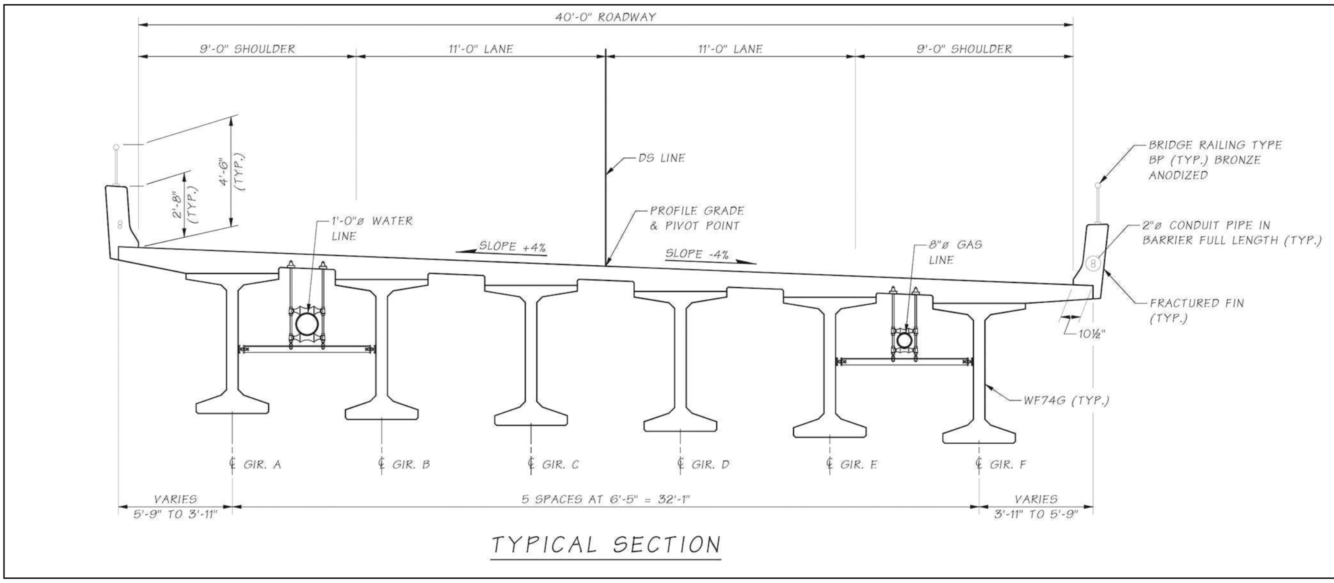
STATE ROUTE 162/6 PUYALLUP RIVER BRIDGE / PIERCE COUNTY, WASHINGTON

BRIDGE DESIGN ENGINEER: Washington State Department of Transportation, Tumwater, Wash.

PRIME CONTRACTOR: Selby Bridge Company Inc., Vancouver, Wash.

PRECASTER: Concrete Technology Corporation, Tacoma, Wash.—a PCI-certified producer

LIGHTWEIGHT AGGREGATE SUPPLIER: Carolina Stalite Company, Salisbury, N.C.



Typical section of the superstructure of the State Route 162/6 Puyallup River Bridge with Washington State Department of Transportation WF74G girder type. Figure: Washington State Department of Transportation.

equipment when compared with normal-weight concrete girders.

For this structure, a weight savings for the entire superstructure was achieved by using the lightweight girders instead of normal-weight girders. This total reduction in dead load was about 300 kips, with half of this reduction being realized at the single column/shaft at pier 2.

Contract Requirements

The contract documents limited the unit weight of the concrete in the girders (when fresh, and not including reinforcement) to 125 lb/ft^3. There was also a limitation placed on the absorption of the coarse aggregate, which was required to be less than 10% when tested in accordance with the American Association of State Highway and Transportation Officials' (AASHTO's) AASHTO T 85, *Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate*. In addition, the coarse aggregate gradation was required to conform to AASHTO M 195, *Standard Specification for Lightweight Aggregates for Structural Concrete*.

Properties

The specified concrete compressive strengths at prestress tranfer and at 28 days were 7.5 and 9.0 ksi, respectively. During the design phase of a project, it is important to be able to predict creep and shrinkage values with some level of accuracy. Too much variation in these values can lead to issues in the construction and final profile of a bridge roadway. For prestressed concrete girder bridges, WSDOT's method of design and resulting constraints on the construction sequence positions the girders vertically far enough below the bottom of the bridge deck to eliminate interference from the top flange of the girder as camber grows prior to construction of the deck. The gap between the top flange of the girder and the bottom of the bridge deck is filled with concrete as part of the bridge deck concrete placement.

If the camber growth of the girder is too large, then the top of the girder can intrude into the bottom reinforcement in the bridge deck. And if the camber growth is too small or negative, then the gap between the top of the girder and the bottom of the deck will create a large added dead load to the bridge.

Determining a reliable unit weight and modulus of elasticity are necessary to calculate creep and shrinkage coefficients that provide reasonable camber estimates. The modulus of elasticity used for the design of the State Route 162/6 Puyallup River Bridge was computed using the *AASHTO LRFD Bridge Design Specifications* equation (prior to the 2015 Interim Revisions) with the density of the sand lightweight concrete and an initial value of 1.0 for the K_1 correction factor for the source of aggregate. Testing of the sand-lightweight concrete suggested a K_1 value of 0.9 was more appropriate.

Comparisons

WSDOT designs for camber presume that the girders will be placed, and the deck cast, within a specific window of time after the girders have been fabricated. Midspan camber values are calculated for two specific elapsed times between girder fabrication and deck placement: 40 and 120 days. The calculated value at 120 days represents the upper-bound limit of the predicted camber at midspan of the girders. The lower bound is simply one half of the calculated midspan camber at 40

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: A two-span, continuous-for-live-load bridge with span lengths of 110 and 160 ft, that used a cast-in-place, normal-weight reinforced concrete deck supported on prestressed lightweight concrete girders.

STRUCTURAL COMPONENTS: Twelve, 74-in.-deep, WF74G prestressed lightweight concrete I-girders; a 7.5-in.-thick, cast-in-place reinforced concrete bridge deck; middle pier, cast-in-place, two-stage crossbeam; and cast-in-place abutments, column, and shafts.

State Route 162/6 Puyallup River Bridge with prestressed lightweight concrete girders (Portion of span 1 and all of span 2 shown). Photo: Washington State Department of Transportation.

days. In general, the longer the span, the bigger the camber values. Span 2 is of most importance for this structure because it controls the total depth of concrete to be placed above the girder flange in order to achieve the final profile. The lower and upper camber values for the majority of the span 2 girders were given in the contract plans as 3.44 and 7.88 in., respectively.

The midspan camber of the lightweight concrete girders was measured periodically between the time of fabrication and the time of deck placement. Three of the girders in span 2 were measured at approximately 40 days after fabrication at 5.5. 6.2, and 6.2 in. These same three girders were measured again at around 55 days with values of 5.7, 6.1, and 6.3 in.

The girders were fabricated at a rate of about one girder per day and stored at the precast facility until the bridge substructure was ready to receive them. There was a difference of 8 days between the ages of the girders in span 2. They were delivered to the project when they were around 55 days old and then the temporary top strands were cut at around 70 days after fabrication.

ESTIMATED CAMBER AND SHORTENING VERSUS TIME

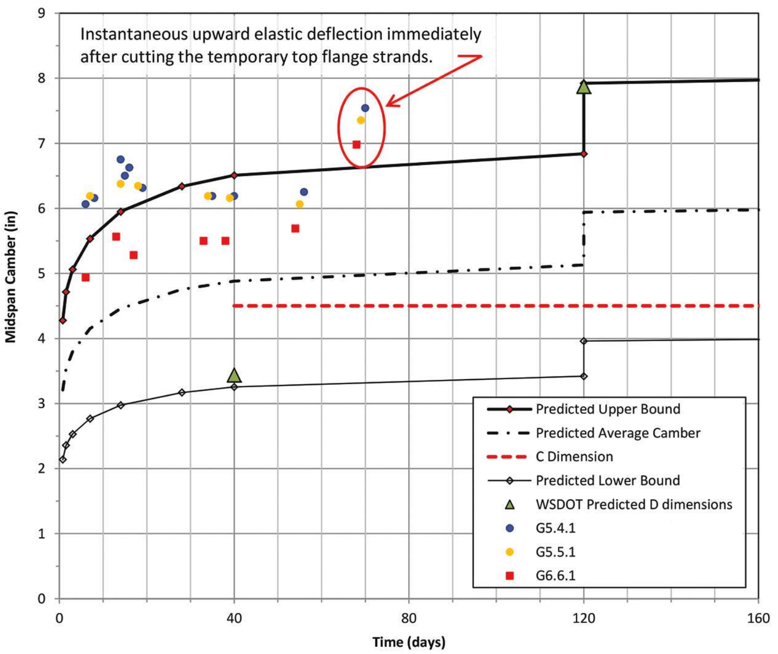
Dims from Contract Documents

D_{40}	=	3.44	inches
D_{120}	=	7.88	inches
C	=	4.50	inches

Estimated Camber Growth

Camber at 120 days, T_1:	6.59	inches
Camber at 365 days, T_2:	6.88	inches
Estimated Growth (T_2-T_1):	0.29	inches
Camber Tol. per 6-02.3(25)K:	1.50	inches

Plot of Camber Versus Time



Notes:

1 Values based on the assumption the girders are supported at 1.5 feet from each end during storage
2 Straight + Harped + Temp Top Strands = (38) + (19) + (6)
3 Release & 28-day Concrete Strengths = 7.1 & 8.2 ksi, respectively
4 Girder Length = 156 ft
5 Elastic D = -0.29 intermediate diaph + 1.37 temp top strand removal = 1.08 inches (UP)
6 The *Predicted Average Camber* equals 75% x the *Predicted Upper Bound*
7 The *Predicted Lower Bound* equals 50% x the *Predicted Upper Bound*

Measured midspan camber for the State Route 162/6 Puyallup River Bridge span 2 girders D, E, and F at various times after girder fabrication. Figure: Concrete Technology Corporation.

Temporary top strands were needed to prevent cracking in the top flange of the girders during shipping. This is a standard practice for medium- and long-span WSDOT girders. These temporary strands are released at the project site once the girders have been placed and the temporary bracing has been installed. The release of these strands increases the camber and the design accounts for this instantaneous growth in camber.

For the span 2 girders, the change in camber at release of the top strands was calculated to be 1.3 in. and was measured in the field to be the same. This additional camber increased the midspan cambers of the three girders to 7.0, 7.4, and 7.6 in., which was just below our calculated maximum value for the 120-day upper bound of 7.88 in. (see the figure to the left—note that calculations assumed release of top strands at a later age). The deck was cast at around 105 days after the date of girder fabrication. No camber growth was measured after the temporary top strands had been cut.

Conclusions

Use of the sand-lightweight concrete in the fabrication and construction of prestressed, lightweight concrete girders for the State Route 162/6 Puyallup River Bridge has been successful. The project demonstrated to WSDOT that it can utilize its standard design and construction methods for lightweight concrete with little to no modifications. Prestressed, lightweight concrete girder designs should follow the AASHTO LRFD specification for lightweight concrete and utilize a K_1 correction factor for source of aggregate of 0.9. (Note: Using the new equation in the AASHTO LRFD Specifications, the factor should be 1.0.) WSDOT absorption and gradation specifications should also be used to achieve predictable camber values for medium-length girders.

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