The Westbound Nalley Valley Interchange

SW Line Flyover Bridge and Temporary Eastbound Bridge

by Jeremy Johannesen, McNary Bergeron & Associates

The Nalley Valley Interchange in Tacoma, Wash., is a major reconstruction of an interchange originally opened to traffic in 1971. It is being redesigned and reconstructed in several design-bid-build packages that will extend over several years. The westbound viaduct is the "jumping off point" for motorists on I-5 heading west to the Tacoma Narrows Bridge and the Olympic Peninsula on State Route 16. Because this SW Line flyover was first bid as a steel box girder bridge and ended up as the Washington State Department of Transportation's (WSDOT) first precast concrete segmental bridge, the project proved to be a "jumping on point" for WSDOT as well. Volatile steel prices at bid time in October 2008 were the primary incentive for Guy F. Atkinson Construction LLC, Renton, Wash., to consider redesigning the two steel bridges on the project. However, this "first" use of a precast segmental bridge would not have happened without the contractor's and owner's desire to advance segmental precast concrete technology in the state. This article describes two redesigns. The second is described in the sidebar.

The SW Line Flyover Bridge nearing completion in the center of the photo. Photo: Guy F. Atkinson Construction LLC.

profile

SW LINE FLYOVER BRIDGE, NALLEY VALLEY INTERCHANGE / TACOMA, WASHINGTON

GENERAL CONTRACTOR: Guy F. Atkinson Construction LLC, Renton, Wash.

VALUE ENGINEERING DESIGN: McNary Bergeron & Associates, Broomfield, Colo.

INDEPENDENT DESIGN REVIEW AND CONSTRUCTION ENGINEERING: Campbell Construction Engineering LLC, Redmond, Wash.

A partially erected cantilever shows the cross section and cantilever post-tensioning. Photo: McNary Bergeron & Associates.

Redesigns can be challenging . . . the pier column had been built in a previous contract.

Seismic Design

Redesigns can be challenging simply because the bulk of the engineering is performed post-bid. The larger challenge on this project was designing a concrete bridge that could be supported on a pier column that was not only designed for a steel bridge, but already had been built in a previous contract.

For this to happen required some amount of luck. First, the end span adjacent to the constructed pier was the shortest span on the bridge and there was some reserve capacity in the original design. Second, the key to the design was making an integral connection to the superstructure in lieu of bearings used in the original steel design. Using an integral connection significantly reduces the moment arm for longitudinal seismic loads. While the concrete bridge was approximately 33% heavier than the original steel design, the double-curvature in the columns resulted in comparable demands. Along with seismic advantages of the integral connection, there was the additional benefit of eliminating the cost and maintenance of the bearings at the interior piers.

Structure Description

In addition to inheriting a pier column, vertical clearances posed another challenge for the redesign. Based on a minimum depth-to-span ratio of 0.04, the required depth is 12 ft; slightly deeper than the original design. It required raising the profile of the bridge and the adjacent approach.

The four-span bridge is 1061 ft long with span lengths of 225, 295, 295, and 246 ft. It has a 43-ft-wide roadway, providing two travel lanes and shoulders. The superstructure consists of a single-cell box with a constant depth of 12 ft. The webs are typically 15 in. thick but increase to 20 in. at the piers. Similarly, the bottom slab transitions from 9 in. to 24 in. at the piers.

To minimize weight and satisfy shear demands in a relatively shallow structure required the introduction of inclined post-tensioning tendons. To increase ductility and continuity for seismic demands, the inclined tendons are located in the webs and anchored at each pier. Most of the precast segments were erected using balanced cantilever methods, allowing the contractor to limit lane closures and minimize falsework. A typical cantilever consists of 15 segments in all. The first five segments from the pier are 8 ft long with thickened webs and bottom slab as well as draped web tendons. The remainder of the segments are 10 ft long, and a portion of these have bottom slab anchorage blisters for the continuity post-tensioning.

The superstructure was constructed using concrete with a design compressive strength of 6000 psi. All the longitudinal tendons use nineteen 0.6-in.-diameter strands except the last three where only 12 strands were required. This provided for up to seven strands for contingency post-

Precast pier shells were erected over the column reinforcing to provide an integral connection. Photo: Guy F. Atkinson Construction LLC.

1061-FT-LONG, FOUR-SPAN, PRECAST CONCRETE SEGMENTAL BOX-GIRDER BRIDGE / WASHINGTON STATE DEPARTMENT OF TRANSPORTATION, OWNER

POST-TENSIONING CONTRACTOR: Schwager Davis Inc., San Jose, Calif.

SEGMENT FORMWORK: Aluma Systems, Kent, Wash.

BRIDGE DESCRIPTION: Four-span, single-cell, precast concrete segmental box girder with span lengths of 225, 295, 295, and 246 ft built using the balanced cantilever method

Cantilever construction shown adjacent to an end span. End span segments were supported on shoring designed to support 100 kips per leg. Photo: Guy F. Atkinson Construction LLC.

tensioning during construction. Each of the 15-segment cantilevers contains 14 pairs of longitudinal tendons in the deck slab over the pier. Continuity between the cantilevers is made using five pairs of tendons anchored in blisters and one pair that went from pier to pier to reinforce the bottom slab for seismic loads at the piers. As with the cantilever tendons, space was available in selected tendons to provide contingency capacity.

The overall width of the top flanges is 45 ft. Transverse post-tensioning in each segment consists of four, 0.6-in.-diameter tendons spaced at 30 in. on center to support the 10 ft overhangs. The top mat of deck reinforcement is epoxy coated.

Engineered Construction

Balanced cantilever construction is anything but a novelty. In this case, the contractor's means and methods for casting and handling segments as well as the construction of the pier tables, end spans, and deck corbels dictated the design and required some novel solutions.

Segments were produced using the long-line casting method. This involved beginning at the pier segment and match casting segments toward the middle of the span. Concrete slabs were constructed on which to cast the segments. These slabs defined the profile geometry. A polyethylene sheet and plywood on top of the slab provided a slip plane to separate segments prior to erection. The movable formwork was bolted to the slab at each segment joint. The long-line casting method allowed the segments to be cast and stored in one place and eliminated the need for large handling equipment in the casting yard until segments were loaded for shipment to the bridge.

Match-casting the cantilever segments with the precast pier segments eliminated the need for a cast-in-place concrete joint and associated starter segment brackets during erection. Making the pier segment integral with the pier column was achieved by blocking out the webs and the bottom and top slabs to allow placement of the diaphragm reinforcement. The precast "shell" was erected by lowering it down over the pier column onto supporting brackets. There it could be aligned and made integral by the cast-in-place concrete diaphragm pour. See the Creative Concrete Construction article about pier shells on page 30.

Each segment weighed approximately 70 tons. They were held in place during erection by temporary external post-tensioning bars placed inside of the box. Once a pair of balanced segments was in place, the permanent tendons were installed and stressed and the temporary bars were removed.

Because the columns are integral with the superstructure and the seismic demands require relatively large columns, creep and shrinkage of the bridge superstructure can cause significant shear and bending stresses in the columns. Span jacking was used to offset shortening in the bridge. After making the continuity closures in the end spans, the interior spans were jacked apart with a force of 750 kips at each closure to create a 2 in. deflection in the 8-ft-square columns.

Successful Results

Some say that precast concrete segmental construction is considered to be cost effective for projects having 300 or more segments. While this structure only contained 112 segments, its success can be attributed to the economic alternatives that precast concrete offers and the ability to adapt these designs to suit difficult urban settings. And as this project illustrates, innovation and cooperation between owners and contractors can yield successful alternatives for the most difficult projects.

Jeremy Johannesen is a partner with McNary Bergeron & Associates in Broomfield, Colo.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.


Pier segment shell being loaded on transport equipment in the casting yard. Photo: Guy F. Atkinson Construction LLC.

Temporary Eastbound Bridge

Second Bridge Converted to Concrete

by Phil Marsh, McNary Bergeron & Associates

The temporary eastbound (TEB) bridge was constructed to temporarily bypass a portion of the interchange project for several years until the final construction phase is completed. The original WSDOT designed structure was a steel girder bridge with a composite cast-in-place concrete deck. As with the SW Line Bridge, the contractor proposed an alternative concrete structure to save time and money.

McNary Bergeron & Associates worked closely with the contractor, Guy F. Atkinson Construction LLC, Renton, Wash., and the precaster, Concrete Technology Corporation, Tacoma, Wash. (a PCI-certified producer), to determine the most cost-effective and practical solution for the superstructure. Ultimately, the selected alternative used intentionally-cambered, thin-flange deck bulb-tee girders with variable top flange thickness, generally from 3 in. minimum to as much as 7 1/8 in. Each of the eight simple spans (four spans at 83 ft and four spans at 95 ft) contains six lines of girders spaced at 7 ft on center, for a total deck width of 42 ft and a total of 48 girders. The 6-ft-wide top flange of the interior girders and 7-ft-wide top flange of the exterior girders provided an important advantage of eliminating deck formwork. Girders are a minimum of 50 in. deep at the thinnest deck thickness.

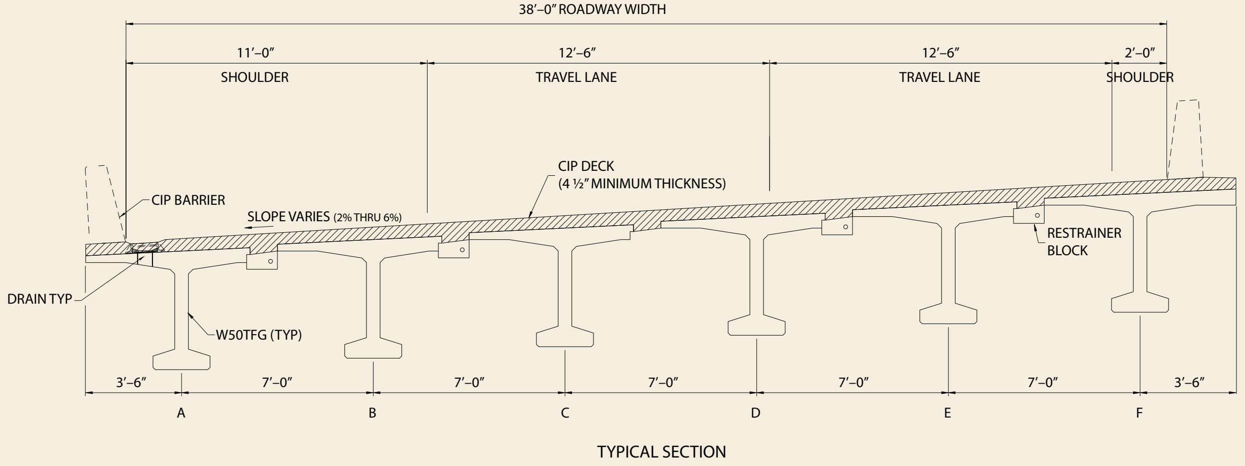
With conventional precast girders, geometric variability and excess girder camber is generally accommodated by increasing the haunch at the girder top flanges. However, in this case the haunch thickness would have required a thickened deck across the entire structure width, adding unnecessary seismic mass and undoing its viability as a cost-effective alternative to steel.

Using specialized articulated forms, the precaster was able to individually camber or sag each girder to the designer's specifications. The bridge has a vertical and horizontal curve, and variable cross slope from 2 to 6%. Much of the geometric variability in the TEB deck profile (including grade, curvature, cross slope, and camber) was approximated by adjusting forms during fabrication, thereby reducing the amount of additional deck thickness needed to achieve the final profile. The formed profile camber varied from +1.5 to – 4.5 in.

The precaster measured the camber of each girder at 28 days from the time of casting. This allowed the designer to fine-tune the bearing pad heights and girder end elevations to produce the optimal deck profile. Though minimized by the articulated forms, it was anticipated that any differential camber between adjacent girders could be problematic. To accommodate any differential, a 1-ft-wide longitudinal closure strip was field cast between adjacent girders during deck placement. These strips had the added benefit of making the top flange reinforcement in the deck bulb tees continuous across the entire deck width. No. 4 reinforcing bars extended 9 in. from the edges of the girder flanges and terminated in 180-degree hooks. The girder flange reinforcement could then be counted on to act as the bottom mat of the deck reinforcement and only the top mat of deck reinforcement needed to be field placed. This allowed for a thinner cast-in-place deck (5.5 in. average), while still providing a total minimum composite deck thickness of 8 in.

All of these challenges, including design, were met in less than a year; from the time the notice to proceed was issued in late 2008 until the bridge opened to traffic in the fall of 2009.

Phil Marsh is a bridge engineer with McNary Bergeron & Associates in Broomfield, Colo.



Typical cross section of temporary eastbound bridge. Drawing: McNary Bergeron & Associates (edited).