SATUS CREEK BRIDGE

Curved, tilted, precast concrete box girders key to replacement project

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Curved trapezoidal girders were used for the Satus Creek Bridge in south central Washington state. All photos: Washington State Department of Transportation Visual Engineering Resource Group.

Satus Creek Bridge is located 25 miles southwest from Toppenish, Wash., where U.S. 97 crosses Satus Creek. It was constructed as part of a $13.4 million project completed in the first part of 2013. It replaced an old, load-restricted timber bridge built in 1942. Washington State Department of Transportation (WSDOT) designed this new, resilient structure to correct design deficiencies with the old timber bridge including vehicular impact and seismic resistance. Several unique features are implemented in the design including horizontally curved and spliced precast concrete girders.

Structural Design

The Satus Creek Bridge is a 180-ft-long, simple-span bridge. This long, single-span bridge was necessary to satisfy environmental constraints to cross the wide section of the creek. The 7.5-in.-thick bridge deck is comprised of conventional, cast-in-place concrete. The shallow foundation also consists of conventional, cast-in-place concrete that is 18 ft tall.

The superstructure is comprised of three open, precast concrete box girders, which are horizontally curved and tilted to match the 8% cross slope of the bridge. The girders are the WSDOT U78PTG5 series. The "78" indicates the height of the webs in inches and the "5" identifies the width of the bottom flange in feet. Bottom flange and web thicknesses are 6 in. and 10 in., respectively.

To achieve this long, simple span across Satus Creek, each girder line consists of three precast concrete girder segments. Falsework towers were used to temporarily support the segments while the deck was cast and subsequent to assembly of the splice sections. Each web has three post-tensioning tendons comprised of nineteen, 0.6-in.-diameter strands with a total estimated jacking force of 2505 kips per web. After post-tensioning was applied, the temporary falsework towers were removed.

Splicing the segments in the field after the deck was made composite increased the span capability, which eliminated the need for an intermediate pier. This was a great cost savings and it satisfied WSDOT's environmental constraints. Another added benefit of the spliced girders was reduced shipping costs. The precast concrete segments are easier to handle and more shipping routes were available to the precaster due to shorter and lighter components.

Each girder segment was precast with a 1290 ft radius in the horizontal plane. In the bridge special provisions, WSDOT allowed the precaster to chord the girder segments at 20-ft intervals to achieve the prescribed horizontal radius. This construction method would have facilitated the use of conventional, less-expensive, flat formwork panels that are readily available. For this particular project, the precaster was able to build a form to the prescribed radius, achieving a smooth face for each girder segment and a smoother transition between segments at time of assembly.

profile

SATUS CREEK BRIDGE / TOPPENISH, WASHINGTON

BRIDGE DESIGN ENGINEER AND ARCHITECT: Washington State Department of Transportation, Olympia, Wash.

GENERAL CONTRACTOR: Franklin Pacific Construction Company, Seattle, Wash.

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

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

Close up of the splice between precast concrete girder segments.

The girders were analyzed as straight segments because:

- the girders are concentric,
- the bearings are not skewed,
- the arc span divided by the girder radius (the central angle) is less than 12 degrees as permitted by AASHTO design requirements, and
- the girder depth is less than the width of the box at mid-depth.

These considerations simplified the analysis of the structure. Three different software packages were used to design the girders: a proprietary software, PG-Splice (developed by WSDOT), and PG-Super (developed by WSDOT). The proprietary software and PG-Splice were both used to verify the validity of each other's results. Both the proprietary software and PG-Splice were utilized to design the main post-tensioning tendons to resist self-weight, superimposed dead loads, live loads, and temperature gradients.

PG-Super was utilized to design the prestressing strands of the individual segments to withstand the stresses induced during the temporary

Falsework towers were used to temporarily support the segments while the deck was cast and subsequent to assembly of the splice sections.

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION, OWNER

PROJECT DESCRIPTION: An 180-ft-long, simple-span bridge with horizontally curved, tilted, spliced precast concrete box girders and a 1290-ft-radius horizontal alignment

STRUCTURAL COMPONENTS: WSDOT U78PTG5 precast concrete tub girders with a 28-day design compressive strength of 8.5 ksi and a cast-in-place concrete deck and foundation

BRIDGE CONSTRUCTION COST: $2.49 million construction stage, which included loads from the deck, diaphragms, and concrete formwork. Additionally, the prestressing strand design was checked to ensure the girders remained within allowable stress limits during shipping and handling of the girder segments prior to assembly.

The post-tensioning tendon paths are parabolic and the post-tensioning losses included:

- friction between the post-tensioning steel and the ducts,
- duct misalignment,
- anchorage slip,
- concrete elastic shortening,
- concrete creep and shrinkage,
- relaxation of post-tensioning steel, and
- stressing sequence.

Earth-tone oxidizing concrete color blends with south-central Washington colors.

Concrete colors and textures complement natural riprap slope protection.

For this particular project, an important aspect in calculating friction losses was the correction for the effects caused by the built-in horizontal curvature. These friction losses introduced by the horizontal curvature were small due to the fairly large radius. Yet the designer could not ignore their effects.

Another interesting design facet for the Satus Creek Bridge is the consideration of out-of-plane and in-plane forces caused by the tendons placed along the webs. These forces are caused by the spreading of the strands within the post-tensioning ducts and by the horizontal and vertical curvatures assumed by the post-tensioning tendons due to the bridge geometry. Small, out-of-plane and in-plane forces may be resisted by the concrete in shear. However, in this project, the addition of stirrups around the post-tensioning ducts along the whole length of the girders provides the necessary resistance to withstand these forces.

Curved trapezoidal girders showing closure concrete placements and diaphragms.

Due to the tremendous forces involved, special attention was given to the end blocks. Two areas of interest were considered: the local zone and the general zone. The local zone is designed to resist the forces introduced by the post-tensioning anchors. The general zone is designed to resist the forces introduced by the jacking forces and the stressing sequence of the post-tensioning tendons. It is not uncommon for end blocks to become fairly large to accommodate the post-tensioning anchors and to provide adequate reinforcement to withstand the forces applied in the general zone.

Architectural Design

This bridge is set in the rural, semi-arid region of south-central Washington state. Except for the creek valley, the area is treeless. Native grasses, sage brush, and basalt rock create colors ranging from golden yellows to reddish browns. The bridge finishes respond to these textures and colors. The abutments and retaining walls are made of cast-in-place concrete with fractured basalt formliners, while the hardened surface is colored with a natural oxidizing agent to blend with the terrain. The barrier and girders are colored and textured for contrast.

The use of curved concrete girders transforms the aesthetic possibilities of precast concrete bridges. Although straight girder sections can be placed on horizontal alignments, there are limits to deck overhangs. These overhangs are invariably changing along the span, creating visual discord. However, with the use of curved girders, the horizontal radius can be less and the deck overhang remains constant.

Lessons Learned

The Satus Creek Bridge is the first horizontally curved, precast, post-tensioned concrete girder bridge to be built in the state of Washington. It is a cost-effective, durable, and resilient structure that is aesthetically pleasing to the eye while satisfying the geometric and environmental constraints of the site.

Satus Creek Bridge was a testing ground for the WSDOT Bridge and Structures Office. The WSDOT team did not encounter significant issues during the design and construction phases of this project. Overall, horizontally curved post-tensioned spliced girders were found to be innovative and cost-effective, while allowing WSDOT to maintain a high level of safety and resiliency in the state's highway bridges.

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