COLORADO CREATES UNIQUE SOLUTION FOR RURAL BRIDGE

by Peter Montoya and Trever Wang, Colorado Department of Transportation

Constant-depth bottom flanges on precast concrete U-girders were converted to a variable depth at the site to reduce fabrication and transportation costs

The Richmond Hill Bridge in Conifer, Colo., creates a separate grade crossing and enhanced safety for nearby mountain residents plus safer access to and from the adjacent fire station. It is part of a larger project to widen U.S. 285 from two to four lanes for approximately 2 miles and create a new animal crossing at the site. Goals for the project included creating a signature design and providing an attractive, cost-efficient structure to inspire later designs along this highway and elsewhere in the state. Achieving these goals required value-engineering the original plan and creating a unique approach in which precast concrete U-girders made with constant-depth bottom flanges were converted into variable-depth flanges at the site.

Initial bids on the widening project as designed by the Colorado Department of Transportation (CDOT) were rejected because they exceeded the allowable maximum bid established by CDOT's cost-estimating engineers. Presented with this challenge to their design, CDOT's designers placed the entire project before an independent value-engineering team to find cost-effective alternatives and reduce the cost.

An initial in-house, value-engineering effort changed the original cast-in-place, variable-depth, parabolic-girder concept to a precast concrete design with constant-depth U-girders and variable-thickness bottom flanges. This allowed the girders to resist large negative moments over the piers. As a result, the owner and engineer could save time and money.

The independent value-engineering team subsequently suggested two minor deletions: eliminating a textured finish

profile

RICHMOND HILL BRIDGE / CONIFER, COLORADO

ENGINEER: Colorado Department of Transportation, Denver, Colo.

CONCRETE PIER CONSULTANT: HDR Inc., Denver, Colo.

PRIME CONTRACTOR: Lawrence Construction Co., Littleton, Colo.

PRECASTER: Plum Creek Structures, Littleton, Colo., a PCI-certified producer

AWARDS: *Best Owner-Designed Bridge, Co-Winner, Precast/Prestressed Concrete Institute's 2008 Design Awards*

The Richmond Hill Bridge in Conifer, Colo., features a striking design that is enhanced by the use of precast concrete components, including trapezoidal U-girders and full-depth deck panels. The V-legs at each end reduce the span length without encroaching on the roadway.

on the girders and a flared-web detail at the post-tensioning anchor plates. But otherwise, they determined that the bridge design, having undergone intensive design reviews previously, was as cost effective as possible. These changes lowered the precast concrete girder costs, but they did not provide the significant overall project-cost reductions required. Subsequently, the team found significant savings in other areas of the project, including modifying roadway geometry and eliminating retaining walls. These changes allowed the project to meet the budget and move forward.

Prior to beginning construction, design engineers created a virtual 3-D model, while the contractor built a full-scale mock-up of the pier leg-to-girder connections. These are both unusual steps for a modest project. Because this project was far from typical, the models provided a better understanding of how the components worked for this signature bridge.

Six prestressed, post-tensioned trapezoidal U-girders, 60 in. deep, were used for the superstructure.

The 215-ft-long bridge features a superstructure composed of all precast concrete components. Six prestressed, post-tensioned trapezoidal U-girders, 60 in. deep, along with 27 prestressed, variable-thickness deck panels were used on the project.

Variable-Depth Flanges Created

Creating the bridge as a precast concrete structure posed a significant challenge, in that the original design featured a parabolic girder with variable-depth bottom flanges to resist the high negative moments over the piers. To accomplish this economically, the precaster took the project's variable-depth bottom flanges and substituted constant-depth precast flanges with the additional thickness provided by cast-in-place concrete hidden inside the girder.

The precaster was allowed to create the constant-depth design as long as horizontal shear reinforcement was provided at the plane between the precast and cast-in-place concrete. However, rather than have shear reinforcement project above the top of the bottom flange, which would have been very difficult due to the steel form at that location, the precaster provided transverse grooves that were form-cast in the interior of the tub. The grooves provided an alternative shear-friction plane. By keeping the bottom flange at a constant depth in the casting yard, fabrication costs and shipping weights were reduced. This was a significant factor, as the girders, with a weight of about 104 tons apiece, were near the handling limits for typical cranes.

215-FT-LONG BRIDGE WITH PRECAST CONCRETE TRAPEZOIDAL U-GIRDERS / COLORADO DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Four cast-in-place pier columns, six, 60-in.-deep trapezoidal U-girders, and 27 precast, prestressed concrete, variable-thickness full-width deck panels

BRIDGE CONSTRUCTION COST: \$1.354 million (\$170.18/ft^2)

Precast concrete deck panels were set over studs on steel plates embedded in the girders.

The V-legs that provide a striking silhouette for the project take their shape and dimensions from the precast concrete U-girders.

In addition, numerous inserts were specified in the webs and top flanges of the U-girders to facilitate the hidden pier cap, the hidden thickened bottom flange, and the end diaphragms at the abutments. Weldable A-706 steel reinforcement was allowed in the girder so that inserts could be positioned in congested areas where there was little or no room for wire ties.

Upon arrival at the site, an additional mat of steel reinforcement was placed at a slope inside the U-girder. Field-placed concrete produced variable-depth bottom flanges that were completely hidden inside the box.

V-Legs Reflect Girders

The V-legs that provide a striking silhouette for the project take their shape and dimensions from the precast concrete U-girders. The width at the top of each pier leg was sized to slightly exceed that of the bottom girder flange. Moreover, the webs in standard precast Colorado U-girders are sloped at a ratio of 4:1 and this slope was allowed to flow into the pier legs, defining the V-shape. As a result, the legs echo the exterior precast concrete girder faces. Sun falling on the piers and on the girders reflects at the same angle, casting shadows of equal intensities on the pier and girders, visually smoothing the transition between these connecting elements.

The aesthetic design produced by the two precast girder lines was superior to that of a single, flat bottom flange that would have been provided in a cast-in-place superstructure. Because the interior cells would have been hidden behind a single flat bottom flange, the cast-in-place approach would have produced a visually undesirable tunnel effect. The transition between each of the two supports at the top of the slant-Vs into two precast concrete girder lines provided a more visually unified appearance than if it consisted of a single bottom flange.

Precast Deck Panels Selected

Full-width precast concrete deck panels were chosen, with a cast-in-place alternative offered as well. The girders were fitted with steel plates embedded in the top flanges. The required numbers of studs were field-welded onto the plates at locations lining up with blockouts in the precast concrete deck panels. Foam board was carefully sized and glued in place along the top flange to contain the concrete used to fill the blockouts and spaces between the tops of the beams and the bottoms of the panels.

The concrete deck panels were delivered from the casting yard, lifted onto the girders, and fitted up. They were adjusted for height with leveling screws and clamps. A concrete mix that was virtually self-consolidating with a spread of approximately 22 in., was used to fill the spaces. This mix exceeded all strength requirements and did not require internal vibration. Using this flowable mix ensured that any congested spaces between the deck panels or within the hidden pier cap were completely filled.

The deck joints were cured under insulated blankets. High-strength post-tensioning rods were inserted into the ducts running longitudinally through the deck. Jacks were positioned, and the rods were tensioned. Finally, all shoring towers (those supporting the girders and the V-legs) were dismantled, leaving a freestanding structure.

To complete the bridge's aesthetics, orange paint highlighted the bridge's face. Painted lines on the exterior webs mimic the angles of the internal strands of the girders.

In addition to the emphasis placed on achieving a high-quality design with innovative thinking, designers also emphasized construction safety. This was also reinforced by the use of precast concrete components, as local precasters have a proven safety record.

The result of this creative thinking by the entire design and construction team was that Colorado received a signature bridge with all visible components sharing elegant proportions, symmetry, unity, openness, and a use of materials that allows for maximum creativity. The work also was completed safely and provided low final costs. It is expected that the bridge will remain durable for a 100-year service life, and initial experience with the finished project indicates that it has more than enough resilience to meet this challenge.

Peter Montoya is a bridge designer and Trever Wang is a bridge engineer and supervisor with the Colorado Department of Transportation, Denver, Colo.

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