SH58 Ramp A Flyover Bridge

by Gregg A. Reese, Summit Engineering Group Inc.

Colorado is using curved precast concrete U-girders to create cost-effective, long-span bridges where aesthetics and urban issues are key factors

The SH58 Ramp A Bridge in Golden, Colo., is the state's longest span using constant depth, precast U-girder construction.
Photos: Summit Engineering Group.

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The State Highway (SH)58 Ramp A Bridge in Golden, Colo., features a state-of-the-art design using curved precast concrete bridge girders to overcome serious challenges that arise when creating complex interchange projects. This latest project, the fifth of six projects to date to use this technique in the state, demonstrates the benefits of this approach to construct cost-effective, complex, long-span structures in high-profile locations where aesthetics and urban geometrics are significant design considerations.

The ramp connects eastbound I-70 traffic to westbound SH58. As originally designed by CH2M Hill, the bridge was to feature curved, precast concrete girders with unique detailing. Summit Engineering value-engineered the design to feature details and cross-sections similar to those developed for previous projects. This approach provided efficiencies to both the contractor and precaster, which helped meet the numerous construction challenges presented by the difficult urban site. The 11-span bridge crosses Clear Creek, a bike path, three traffic openings, eastbound and westbound I-70, and eastbound SH58.

The Colorado Department of Transportation (CDOT) has promoted precast concrete as a viable alternative to structural steel and cast-in-place concrete, which typically have been used for complex interchanges. This project shows how that effort can pay off. Many of the innovative precast concrete design details used on Ramp A were devised for earlier Colorado projects and were further developed and refined during design.

The roadway consists of a 38-ft-wide deck that currently accommodates one traffic lane and two large shoulders, but was designed for three traffic lanes. Grades vary from +5.0% to -5.0% and cross slopes vary from +6.0% to -2.0% along the length of the structure.

The project includes the state's longest span using constant depth, precast concrete U-girder construction. Its superstructure features two lines of spliced, post-tensioned, precast concrete girders, divided into three units. Unit 1 consists of four continuous spans (153, 205, 235, and 186 ft) that cross Clear Creek, the bike path, and eastbound and westbound I-70. Unit 2 has three spans (147.5, 205, and 186 ft) that cross eastbound SH58. Unit 3 consists of four spans (187.5, 200, 200, and 188 ft). The bridge begins in a spiral curve in Unit 1, which continues through Unit 2 and transitions in Unit 3 to a straight section at the end of the bridge.

profile

SH58 RAMP A FLYOVER BRIDGE / GOLDEN, COLORADO

BRIDGE ENGINEER OF RECORD: Summit Engineering Group Inc., Littleton, Colo.

PROJECT ENGINEER OF RECORD: CH2M Hill, Englewood, Colo.

PRIME CONTRACTOR: Ames Construction Inc., Aurora, Colo.

PRECASTER: EnCon Bridge Co. LLC, Denver, Colo., a PCI-certified producer

POST-TENSIONING CONTRACTOR (LONGITUDINAL): VSL, Wheat Ridge, Colo.

Substructure Design Features

The superstructure is supported on expansion bearings at the abutments and interior expansion piers at each end of the superstructure units. Abutments, supported on a single line of 36-in.-diameter caissons, were designed as a traditional cap and back wall. Expansion piers, 13 ft x 6 ft, are supported on footings and a group of four 48-in.-diameter caissons.

Fixed interior piers were founded on two, side-by-side drilled shafts 48 in. in diameter to balance strength and longitudinal flexibility. Substructure flexibility and soil-structure interaction in the foundations were considered in the design thus eliminating the need for bearings at interior piers while accommodating creep, shrinkage, and thermal movements. Drilled shafts varied in length from 65 ft to 80 ft, with a minimum of 25 ft of embedment into bedrock. Fixed interior piers consisted of 13 ft x 4 ft rectangular shafts with 48-in.-diameter semi-circular ends. Pier heights varied from 16 ft to 45 ft.

Integral pier caps on all fixed interior piers resolved clearance issues and presented a lighter, consistent visual appearance. All integral pier caps were transversely post-tensioned and fully fixed to the superstructure. Expansion piers used a conventional hammerhead cap post-tensioned to enhance durability and provide a shallower design that blended aesthetically with the interior pier caps.

Precast Girder Designs

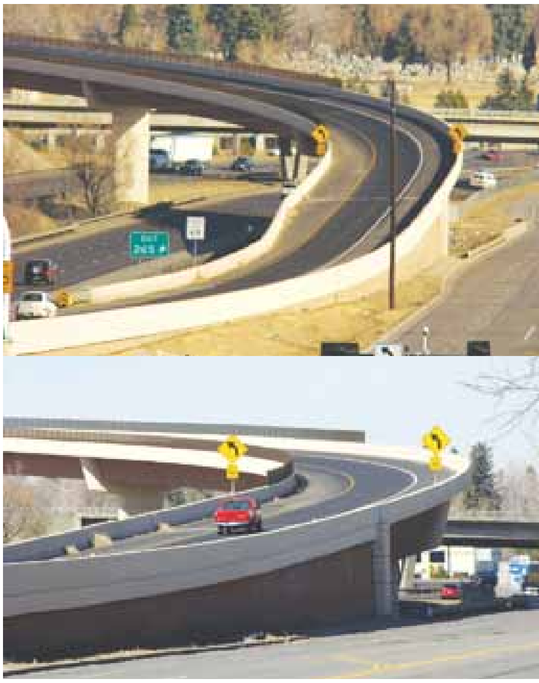
The superstructure consists of two lines of 86-in.-deep modified CDOT U84 concrete girders spliced near the quarter points of the typical span. The first and last pairs of girders in the spiral curve were cast at varying radii. The remaining girders in the central curve were cast with an 809-ft radius for both girder lines. The straight girders in Unit 3 were cast in a conventional girder form.

The superstructure contains 38 precast concrete girders (30 curved and eight straight) and 265 precast concrete deck panels. The curved girders were cast in special curved forms that conformed to the design radii. The forms were designed in discreet panels that had break points at each end adjusted to the necessary curvature. Girder lengths varied from 93 ft 2 in. to 119 ft 7 in. and weighed from 220 kips to 265 kips.

The project represented the third such project cast by EnCon Bridge Co. Vice President Jim Fabinski noted that this project went quite well, as everyone from all of the agencies involved understood the process by now, so they could focus more attention on honing details than on the process of casting the curved girder segments.

The girders were designed with varying levels of prestress in the bottom slab for handling and erection. Curved girders used post-tensioning tendons, while straight girders used conventional pretensioning. Bottom-slab prestress varied from fourteen to twenty-eight 0.6-in.-diameter strands. Bottom slab tendons in curved girders were stressed and grouted in the casting yard prior to shipping.

All girders were cast with diaphragms at each end incorporating access openings. The diaphragms provided anchorage locations for intermediate and bottom slab tendons. In addition, they provided a strengthened section for handling, as a temporary support, and to serve as an anchor location for torsional bracing during erection. Midspan girder segments were cast with 3-ft-thick diaphragms to accommodate top flange longitudinal tendons. Pier girder end diaphragms were 1 ft thick. Cast-in-place concrete splices, which matched the shape of the diaphragm section, were cast between girder ends.



The 11-span bridge, which crosses Clear Creek, a bike path, and three traffic openings, plus eastbound and westbound I-70, and eastbound SH58, features a circular curve with a radius of 809-ft that transitions through a spiral curve to a tangent section.

Integral pier caps on all fixed interior piers resolved clearance issues and presented a lighter, consistent visual appearance.

2115-FT-LONG PRECAST CONCRETE FLYOVER RAMP WITH MODIFIED CDOT U84 CURVED GIRDERS / COLORADO DEPARTMENT OF TRANSPORTATION, OWNER

POST-TENSIONING CONTRACTOR (PIER CAPS): DSI, Long Beach, Calif.

BRIDGE DESCRIPTION: Eleven-span bridge constructed with 30 curved and eight straight precast concrete girders with integral piers, 265 precast concrete deck panels spanning between girder webs, and a cast-in-place concrete deck

BRIDGE CONSTRUCTION COST: $30.8 million

The design provides the option of a full deck replacement in the future.

Post-Tensioning Details

The primary longitudinal post-tensioning tendons were placed in parabolic profiles along the full length of each unit. Ducts were centered in the precast concrete girder webs and continued through the cast-in-place closures. These ducts were difficult to position, Fabinski noted, to ensure clearance to the faces of the webs. To ensure proper alignment of the tendons, the company incorporated a special plastic chair that holds the ducts in the correct position and spacing during casting. That technique improved the casting of these pieces—and will continue to aid future projects.

Typical longitudinal post-tensioning consisted of four tendons of twelve 0.6-in.-diameter strands per web, which were anchored in cast-in-place concrete diaphragms at the abutments and expansion piers. In addition, 19 strand tendons were placed in the top flange of Unit 1 over the piers on both ends of the 235-ft-long span to increase the negative moment capacity. The top flanges were thickened in the typical section to provide room for 4-in.-diameter ducts for these tendons.

Negative moment tendon anchorages were placed in the inside face of the end diaphragms of the precast girders. The top-flange tendons were placed through the cast-in-place closures and additional reinforcing steel was added to resist anchorage forces. The 8 ¼-in.-thick bottom slab was thickened over the piers to 21 in. to improve the section efficiency and provide a larger compression block for ultimate strength.

Following erection, the precast girders were cast into the pier caps at all interior piers. Ducts were placed through the webs of the girders over the piers to provide for transverse post-tensioning of the caps. Shear keys were placed in both faces of the girders over the piers to enhance shear transfer in the interior pier diaphragms.

The precast girder sections at the end of each unit were notched to allow placement of a cast-in-place diaphragm at the abutments and expansion piers. A concrete diaphragm, 1 ft thick with an access opening, was used to transition from an 8 ¼-in.-thick bottom slab to a 21-in. section at the notch. This thickened "tongue" anchored the bottom slab post-tensioning in the curved girders and provided support during erection. Embedded bearing plates were precast into the bottom of the tongue section to facilitate bearing installation during erection.

Superstructure Erection

The girders were shipped on high-capacity trailers and set on falsework with large hydraulic and crawler cranes to handle the pieces with minimal disruption to traffic. The majority of the erection took place during road closures at night.

Falsework accommodated a variety of site conditions, including locations along Clear Creek and the bike path, which required benching into the existing stream bank to provide foundations for shoring towers. Three temporary straddle bents supported the girders at traffic openings over I-70 and SH58 due to the sharp skews at these locations. Temporary shoring of existing bridges over Clear Creek was required to support the cranes used to set the girders during erection.

Primary post-tensioning tendons were anchored in cast-in-place diaphragms at each end of a unit. The tongue section at the notched ends of the precast girders allowed a continuous diaphragm to be placed across the bridge's width. The end diaphragms were 4 ft thick and mildly reinforced. The diaphragms transversely connected the two girder lines at the abutments and expansion piers. The cast-in-place diaphragms became integral with the girder lines after longitudinal post-tensioning.

When erected, the precast girder tongue section supported the girders' weight on the permanent bearings. This detail greatly simplified erection and eliminated shoring towers at the abutments and expansion piers. The expansion pier diaphragms were detailed to allow stressing of both ends of the tendons using a short-stroke ram. After placement of pier caps, closures, diaphragms, and lid slabs, the superstructure became a continuous closed-cell box for the full length of

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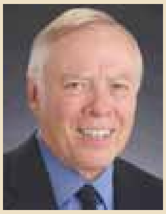
each unit ready for post tensioning. After all longitudinal stressing was complete, tendons were grouted, falsework was removed, and the girders were prepared for the deck slab.

The superstructure girders support the fluid weight of the fresh concrete for the cast-in-place deck in an unshored condition. This approach reduces deck cracking in negative moment regions and provides the option of a full deck replacement in the future.

The success of this project and similar ones in Colorado over the last 5 years validates CDOT's vision of developing precast concrete as a viable option for complex, long-span interchange construction. CDOT has emphasized the use of standardized, commercially produced, precast concrete products to enhance the future economy and sustainability of this concept.

Gregg A. Reese is president of Summit Engineering Group Inc. in Littleton, Colo.



AESTHETICS COMMENTARY

by Frederick Gottemoeller

Large, multilevel interchanges are inherently confusing and stressful. Vehicles of all sizes hurtle along curved ramps in patterns that are unreadable at ground level. Drivers are continually trying to see ahead to what is coming next: sign, ramp, or merging vehicle. Within and contributing to this visual cacophony are the bridges themselves, and their phalanxes of piers.

Improving a confusing and stressful scene requires simplifying it. In the case of interchange bridges that means using fewer girders, fewer piers, and fewer columns within each pier. In addition to reducing the number of elements in the visual field this opens up view corridors through the interchange, so that drivers can anticipate what is coming next, and improves the safety of the interchange. Simplifying the features of the bridge itself further reduces the number of visual elements the driver must absorb. Ramp A brings new techniques and new technology to these goals.

First of all, the torsional stiffness of the U-girders allows only two girders in the ramp cross section. Then, splicing and post tensioning the girders allows for longer spans and fewer piers. Having only two girders to support, the piers themselves can be simple and straightforward. Since the girders are curved they can smoothly follow the curve of the ramp, so that all of the lines of the ramp are parallel to each other. Coloring the girders a darker color emphasizes this consistency, and makes the ramp appear thinner and thus the spaces below seem more open. The open, graceful appearance of this bridge will make this interchange easier and more enjoyable to use.

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The ends of each precast concrete girder section were notched to allow placement of an integral cast-in-place diaphragm at the abutments and expansion piers.