Innovative Design for Colorado's West Vail Pass Bridges

by Chad Hammond, RS&H

The Interstate 70 (I-70) West Vail Pass auxiliary lanes project included updating the roadway curvature to current standards, widening the lanes and shoulders, and replacing the eastbound and westbound bridges over Polk Creek. See the Project article on page 20 of the Winter 2026 issue of *ASPIRE*®. for general information about the bridges and construction. This article covers some of the unique design aspects of the project in detail.

Structure Type Study

The design of the twin bridges required innovative ideas and collaborative solutions from the design team with input from the construction manager/general contractor, the Colorado Department of Transportation (CDOT) as the owner, and other stakeholders. The bridges are approximately 575 ft long with an out-to-out width of 55 ft and a constant 1680-ft radius horizontal curve along their entire lengths. Based on the aesthetic criteria for the project, the bridge girders had to be curved and girder shapes were limited to tub or box girders. The Structure Type Study evaluation determined that a simple-made-continuous, precast concrete tub girder option offered cost and schedule advantages. Therefore, this option was carried through to final design.

Final Design

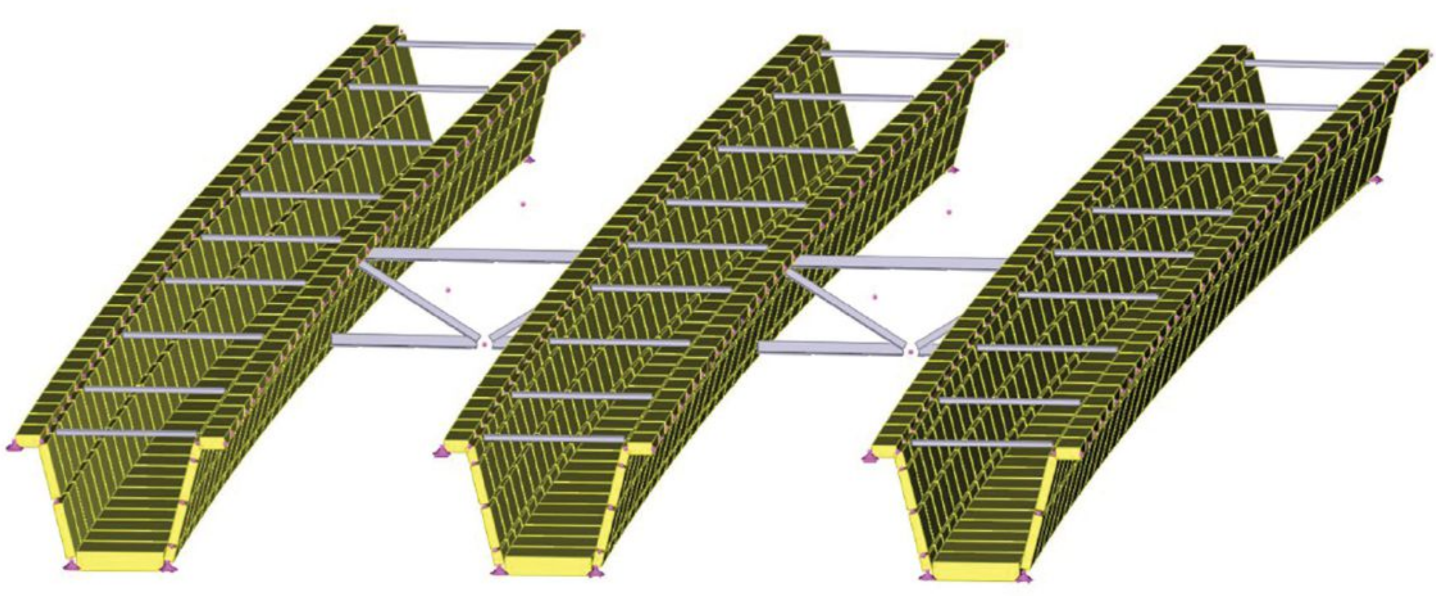
For the simple-made-continuous design, the precast concrete tub girders are assumed to behave as simple spans for noncomposite loads applied before the deck cures, but continuous for loads applied to the composite section (that is, superimposed dead and live loads).

The final design of the precast concrete tub girder alternative used the typical references for CDOT bridge designs and a few specialty resources:

- The American Association of State Highway and Transportation Officials' *AASHTO LRFD Bridge Design Specifications*, 9th edition[1]
- The *CDOT Bridge Design Manual*[2]
- PCI's *Guide Document for the Design of Curved, Spliced Precast Concrete U-beam Bridges*[3]
- The California Department of Transportation's *Bridge Design Memo 5.26: Anchorage Zone for Cast-in-Place Prestressed Box Girder Bridges*[4]
- National Cooperative Highway Research Program Report 356, *Anchorage Zone Reinforcement for Post-Tensioned Concrete Girders*[5]

Three finite element models were used in the analysis of the bridge. The first model was a time-dependent line-girder model used to track stresses and forces in the superstructure at various stages of construction. Results from this

A three-dimensional finite-element plate model of the longest span was used to evaluate torsion and distortion in the girder before and during deck placement. Temporary and permanent bracing was designed based on the results of these analyses. All Figures: RS&H.



The difference in width and curvature between the original Interstate 70 (I-70) over Polk Creek bridges (left) and the nearly completed westbound bridge (right) is clear in this photo. By widening traffic lanes and shoulders and modifying existing curves to meet current federal design standards, the project improves safety and operations on I-70 for the traveling public. Photo: Dennis Humphrey, Cirque Civil.

model were used for the superstructure longitudinal design, prestressed concrete stress checks throughout construction, shear and moment design of the composite girder, camber and dead-load deflections, time-dependent effects, creep, shrinkage, prestress losses, and restraining moments due to continuity.

The second model was a three-dimensional plate and member model of the full bridge—superstructure and substructure—which was used to look at girder torsion for the closed section after deck placement and for substructure and bearing reactions. The pier diaphragms are detailed to perform as pinned connections. The girders sit on leveling pads at the piers and vertical reinforcing bar dowels run along the centerline of the piers to create a pinned connection.

At the abutments, the girders are supported by CDOT Type III bearings, which are a disc-style bearing that allows significant movement. The lower sole plate of the bearing assembly slips over a polytetrafluoroethylene surface on the upper bearing plate. The upper bearing plate sits on a urethane disc and is restrained by a steel pin. The center girder uses a guided bearing to prevent transverse movement of the superstructure at the abutments, and all movements were assumed to act along the curve due to the large radius. The boundary conditions for piers and abutments were used in this finite-element model, which allowed the design team to obtain accurate substructure reactions from this model.

The third model was a three-dimensional plate model of the longest span looking at torsion and distortion in the girder before and during deck placement. This model was used to develop the temporary diaphragm design, which was used to limit girder distortion during deck placement. The reactions derived from this model were provided to the contractor for the temporary support of the girder ends.

The project team used guidance from the *CDOT Bridge Design Manual* for the continuity diaphragm design. The manual indicates that when girders are aged at least 90 days, continuity diaphragms should be designed for a positive moment of 1.2 times the girder cracking moment and the negative moment calculated for the specific span configuration. In this case, the negative moments were pulled from the finite-element model and positive restraining moments were compared to the cracking moment to verify that the cracking moment controlled positive moment design at the diaphragms.

The final design uses 6-ft-deep precast concrete tub girders that are 4.5 ft wide at the bottom flange and 9.5 ft wide at the top. The design concrete compressive strengths for the precast concrete girders were 6.5 ksi at transfer and 8.5 ksi at 28 days. All girders have four post-tensioning tendons in the bottom flange. However, there was only room to anchor two tendons at any given location, so one anchorage was placed at the ends of the girders and a second anchorage was placed 12 ft from the ends. The number of 0.6-in.-diameter strands in each tendon was either 12 or 19, depending on the span length. Tendons were grouted after tensioning.

Because the girders were designed as simple spans made continuous, an interesting and unique part of the staging took place at the precast concrete producer's facility. Girders were removed from the casting bed and placed on temporary supports 30 ft from the girder ends—for all the girder lengths—until they were post-tensioned. These support locations were intended to limit the positive moment at midspan before

One of the precast concrete tub girders for span 3 of the westbound structure—with a girder weight of approximately 220,800 lb—is lifted to its final position on the piers. The simple-made-continuous for live-load concept for the Interstate 70 over Polk Creek bridges saved considerable time by eliminating the need for falsework towers. Photo: Kevin Petrillo, RockSol.

Temporary diaphragms were installed between girders to prevent girder distortion during deck placement and ensure stability. The bridge engineer designed temporary diaphragms at midspan (steel K-frames in this photo). The contractor designed temporary diaphragms at girder ends (wood timber and steel rods in this photo). Photo: Kevin Petrillo, RockSol.

post-tensioning and induce upward camber growth. The supports were shifted to the girder ends immediately after post-tensioning.

Design Challenges

One of the design hurdles for the simple-made-continuous option was girder weight. The *CDOT Bridge Design Manual* limits girder weight to 240 kip to ensure that girders can be shipped. The design team made several adjustments to the girders to reduce their weights. The largest girder in the final design was on the eastbound bridge (span 2) and weighed 249,300 lb. To reduce weight, the girder web thickness was minimized and set at 5 in. This revision was possible because the girders by themselves are not continuous over the piers, so post-tensioning is always in the bottom flange for the full length of the girder. Continuity over the piers is established using mild reinforcement cast into the deck along with the cast-in-place continuity diaphragms at each of the piers. Another weight-saving measure was the elimination of the concrete lid slab typically placed on top of curved concrete tub girders after fabrication. To replace the bracing typically provided by the lid slab, steel interior diaphragms were added to support the top flanges and webs for handling and shipping of the girders. A temporary steel diaphragm was installed at midspan between girders to prevent girder distortion during deck placement.

Tendon anchorage for the precast concrete tub girders. There was only room to anchor two tendons at any given location, so one anchorage was placed at the ends of the girders and a second anchorage was placed 12 ft from the ends. Photo: RS&H.

A major consideration during design was girder deflection and distortion due to the curvature in the girders. Addressing this issue was challenging because the girders were not closed sections with a lid slab. As previously discussed, deflections were analyzed using a finite element model of the girders with plate elements. The girder ends were assumed to be fixed. Deflection and twist were checked for two cases—girder self-weight and the girder supporting the wet deck concrete. Temporary diaphragms were added to the model to ensure that the girders would be sufficiently restrained during placement of the deck and to prevent racking of girders that could lead to excessive deck thickness. The plate model used to check deflections also provided end reactions for the girders. These reactions were included in the plans to aid the contractor in the design of girder end bracing.

Construction of the westbound I-70 bridge over Polk Creek was completed in 2023, and feedback about that bridge was incorporated into the final design for the eastbound bridge, which was completed in 2025. The innovative application of simple-made-continuous precast concrete girder concept proved to be cost-effective and saved time in construction. The successful design and construction of this project required innovative solutions and collaboration among the team members. The bridge replacements are an important milestone in the West Vail Pass auxiliary lane project, which is improving safety and operational capacity in the region.

References

1. American Association of State Highway and Transportation Officials (AASHTO). 2020. *AASHTO LRFD Bridge Design Specifications*. 9th ed. Washington, DC: AASHTO.
2. Colorado Department of Transportation (CDOT). 2021. *CDOT Bridge Design Manual*. Denver, CO: CDOT.
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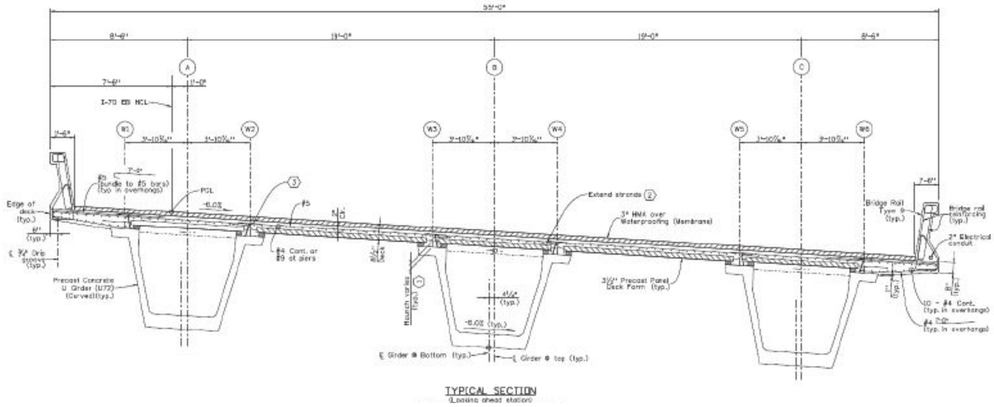
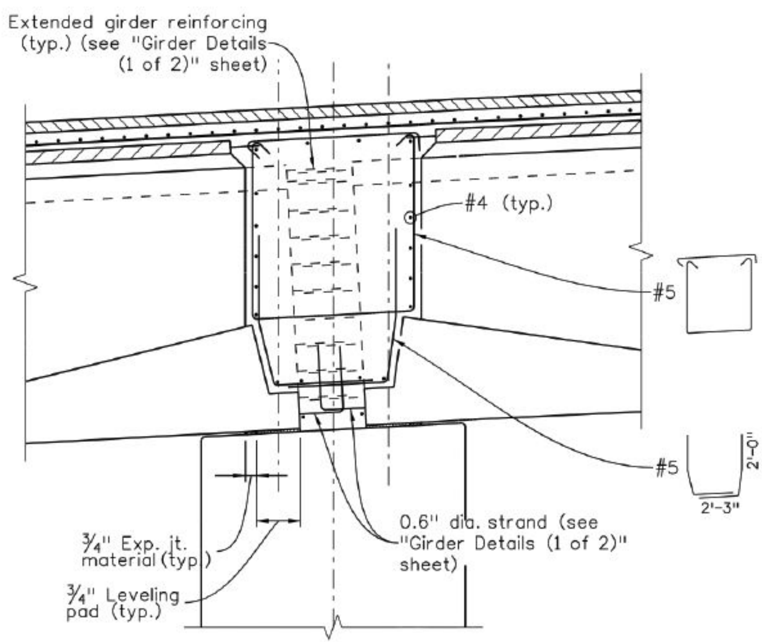


Bridge typical section showing the precast concrete tub girders with partial-depth precast concrete deck panels, cast-in-place concrete topping, and asphalt wearing surface.



Section showing the continuity diaphragms at the piers. The hooks extending from the girder bottom flanges provide a positive moment connection. The reinforcement in the cast-in-place deck provides the negative moment continuity reinforcement.

Document for the Design of Curved, Spliced Precast Concrete U-Beam Bridges. Chicago, IL: PCI. https://doi.org/10.15554/CB-03-20.

4. California Department of Transportation (Caltrans). 2021. *Bridge Design Memo 5.26: Anchorage Zone for Cast-in-Place Prestressed Box Girder Bridges*. https://dot.ca.gov/-/media/dot-media/programs/engineering/documents/bridgedesignmemos/05/202108-bdm0526-anchoragezonedesigncippsboxgirders-a11y.pdf.
5. Breen, J. E., O. Burdet, C. Roberts, D. Sanders, and G. Wollman. 1994. *Anchorage Zone Reinforcement for Post-Tensioned Concrete Girders*. National Cooperative Highway Research Program (NCHRP) Research Report 356. https://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_356.pdf.

EDITOR'S NOTE

A supplement to the Summer 2015 issue of ASPIRE® tracks the development of curved, precast, post-tensioned concrete U-girders. It can be found on the ASPIRE website under the Resources tab at www.aspirebridge.com/magazine/2015Summer/ASPIRESupplementSummer2015.pdf.

Drawing files related to the U-girder can also be found under the Resources tab of the ASPIRE website at www.aspirebridge.com/additionalresources/index.shtml

EDITOR'S NOTE

The West Vail Pass Auxiliary Lanes project has a number of interesting characteristics that make it worth another article in ASPIRE (see the Project article on page 20 of the Winter 2026 issue).

It is said that necessity is the mother of invention, but it is also the mother of innovative engineering. Engineers may not always consider what happens to precast concrete girders while they are stored at the precaster's facility, but that was an important consideration for this project. This project presents some innovative solutions tailored to the challenging site conditions.

The girders for the Polk Creek bridges did not have initial prestressing, so there was no initial camber. Therefore, there was a possibility these girders could develop sag while sitting in the yard before the post-tensioning was applied. To control stress, deflection, and ultimately the camber after post-tensioning, the girder support points (bunking) were moved in 30 ft from the girder ends until the post-tensioning was applied. The supports were then moved to the end of girder.

To accommodate limitations on the girder shipping weight, engineers employed several inventive practices. They chose to use a continuous–for–live load structure for reasons stated in the Project article. That choice in turn allowed for thinner webs, which reduced girder weight.

Engineers also elected to ship and construct without the concrete lid slab attached, making the girders open sections, rather than closed. Curved girders want to twist; the difference in torsional rigidity between an open section and a closed one is usually orders of magnitude. The solution started with analysis of the open one to understand the stresses and distortions that would occur when the deck was placed; those stresses and distortions were controlled by the innovative use of temporary steel frames.