PROJECT

Innovative Precast Concrete Trough Bridge for SMART's San Rafael Creek Crossing

by Brian Olp, STV

The Sonoma–Marin Area Rail Transit (SMART) system has been expanding rail service along the Highway 101 corridor since 2017, including a major design-build extension from San Rafael to Larkspur, Calif. The Larkspur terminal enables convenient connections to the Golden Gate Ferry and transit into San Francisco, making the final 2.1 miles of track a key link in the regional network.

Among the most technically challenging components of the extension was the San Rafael Creek crossing, which is located just south of the San Rafael Station and adjacent to Second Street. Tight geometric constraints, corrosive soils, a high-skew channel, and a narrow construction window demanded an unconventional approach. The SMART request for proposals originally envisioned a shallow concrete trough (U-shaped) bridge, a concept driven primarily by the need to avoid the use of steel in the corrosive tidal environment and to maintain a low profile between existing roadway elevations.

A traditional cast-in-place (CIP) concrete solution, however, was impractical. Environmental restrictions prohibited in-channel falsework, and the short summer construction window limited the feasibility of time-intensive CIP operations. Given these constraints, a precast concrete trough superstructure emerged as the most efficient and constructable solution. The owner's preference for ballasted track for ease of long-term maintenance was another reason to select an economical, shallow, and robust precast concrete section.

Design Development

Following contract award, the design-build team explored several precast concrete alternatives for the trough configuration. Early concepts used a traditional box girder with a ledge to support double-tee floor beams. As the design was refined, the design-build team transitioned to prestressed concrete rectangular voided-slab floor beams and eliminated the girder ledge, instead opting for a CIP longitudinal closure joint between the beams and edge girders.

The final design consisted of the following:

- Two precast, prestressed concrete voided-box edge girders
- Precast, prestressed concrete rectangular voided-slab floor beams
- A CIP longitudinal edge joint to tie floor beams and girders together
- Two levels of transverse post-tensioning (PT) to engage all elements into a unified trough
- Longitudinal PT in the floor beams to ensure shear continuity

This configuration created a fully integrated superstructure with no tension in the concrete permitted, in accordance with requirements of the American Railway Engineering and Maintenance-

Sonoma–Marin Area Rail Transit (SMART) system map. All Figures: STV.

profile

BRIDGE 16.86 OVER SAN RAFAEL CREEK / SAN RAFAEL, CALIFORNIA

BRIDGE DESIGN ENGINEER: STV, San Francisco, Calif.

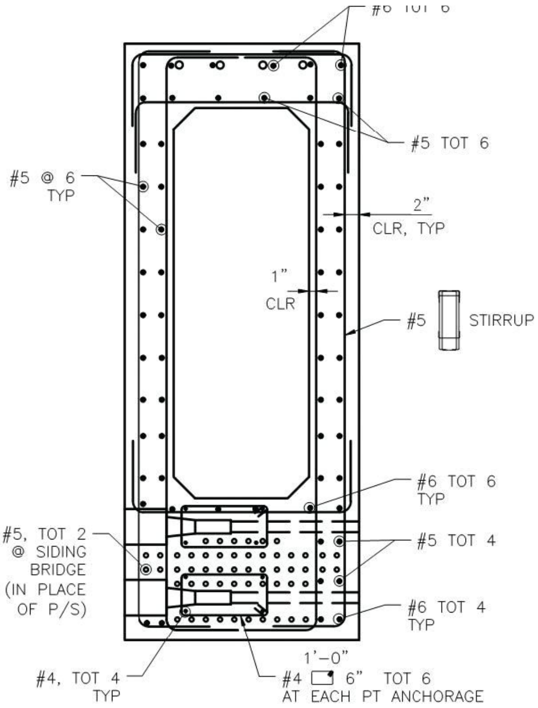
GEOTECHNICAL ENGINEER: HDR/WRECO, Roseville, Calif.

PRIME CONTRACTOR: Stacy Witbeck, Alameda, Calif.

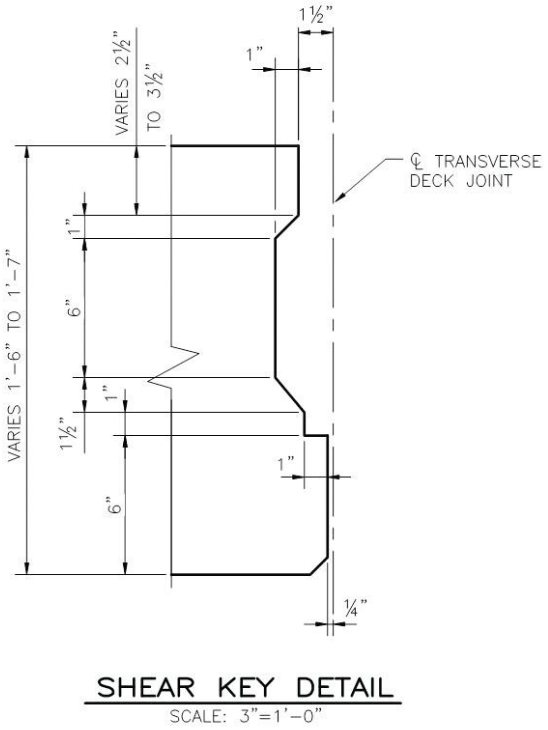
CONCRETE SUPPLIER: Shamrock Materials, San Rafael, Calif.

PRECASTERS: Kie-Con Inc., Antioch, Calif.—a PCI-certified producer, and Con-Fab California, Lathrop, Calif.—a PCI-certified producer

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



Cross section of a prestressed concrete edge girder showing reinforcement.



Floor beams have recessed shear keys along their longitudinal edges.

of-Way Association (AREMA). The design team used specialized structural design software to model staged construction, time-dependent effects, and temporary support conditions.

Geometry and Loads

The project design followed the *SMART Design Criteria Manual*[1] and *AREMA Manual for Railway Engineering*[2] for a 100-year design life. Loads included Cooper E50 maintenance trains and SMART's four-axle diesel multiple unit (DMU) with 46.7-kip axle loads. Owing to the significant skew of the channel, two separate, straight bridges were designed for the mainline and siding tracks. The bridge for the mainline tracks has a final span of 76 ft ½ in., while the final span of the siding-tracks bridge is 64 ft ¼ in. For each bridge, two edge girders and floor beams are used to create the trough shape. Clear spacing between edge girders is 18 ft 8 in. for the mainline tracks and 18 ft 0 in. for the siding tracks.

The bridge depth from the top of rail to soffit was held to 3 ft 6 in. despite the use of ballasted track. Compared with the elevation specified in the request for proposals, this depth provides a 6 in. raise in the soffit of the bridge, providing crucial vertical clearance over the waterway crossing.

Foundation and Superstructure Corrosion Protection

Site borings revealed highly corrosive soils, with chloride concentrations more than 10 times the limit set by the California Department of Transportation (Caltrans). To address this issue, the design team specified the following:

- Precast, prestressed concrete piles with a water–cementitious materials ratio of 0.37
- Calcium nitrate inhibitor at 3.5 gal/yd^3 of concrete
- Epoxy-coated reinforcement in the abutment caps and all superstructure elements
- Increased concrete cover (3.5 in. for abutments; 2 in. for girders)

Precast concrete piles are approximately 35 ft long, with a specified distance to below-grade surface of 34 ft, to penetrate weak bay mud and reach competent-bearing strata. Sheet piles were used to slightly adjust abutment locations and minimize structure length.

Design Details

Each prestressed concrete edge girder is a 2-ft 9-in.-wide and 7-ft 0-in.-tall voided box designed to house two levels of transverse PT tendons, with

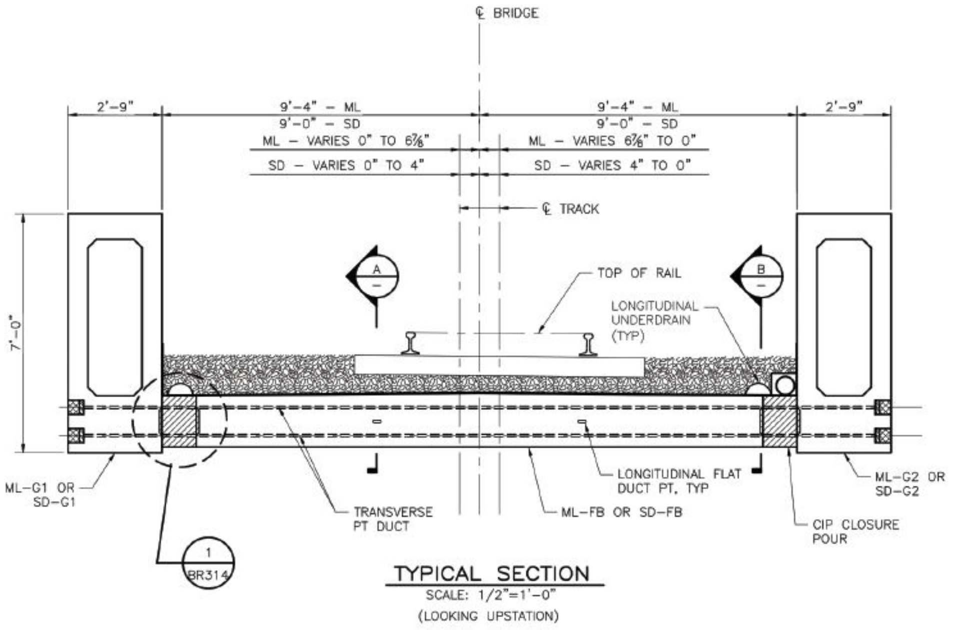
SONOMA–MARIN AREA RAIL TRANSIT (SMART), OWNER

OTHER MATERIAL SUPPLIERS: Sheet piles: National Pipe & Piling; abutment reinforcing bars: Harris Rebar, Livermore, Calif.; bearing pads: Scougal Rubber, McCarran, Nev.

BRIDGE DESCRIPTION: Two single-span, single-track precast, prestressed and post-tensioned concrete trough railroad bridges.

STRUCTURAL COMPONENTS: Four precast, prestressed concrete edge box girders; thirty-five precast, prestressed concrete floor beams; cast-in-place edge joint and abutments; thirty-eight 14-in.-square precast, prestressed concrete piles.

BRIDGE CONSTRUCTION COST: $1.5 million



Typical cross section of the trough (U-shaped) bridges.

View from beneath an edge girder. No falsework was permitted in the creek, so the team developed a temporary support system to support the floor beams during construction. The supports were later repurposed to facilitate installation of the bridge's transverse post-tensioning. All Photos: Stacy Witbeck/Herzog.

a solid 3 ft 10 in. length at each end. The concrete compressive strength at transfer was 5 ksi, with a final design compressive strength of 8 ksi. Longitudinal reinforcement in the edge girders consists of straight longitudinal prestressing strands, a portion of which was debonded at the girder ends, and transverse PT to connect the girders with the floor beams. Mainline girders and siding girders used 58 strands and 46 strands, respectively, of 0.6-in.-diameter low-relaxation prestressing steel that was initially tensioned to $0.75f_{pu}$.

Recessed shear keys and overlapping hooked dowels connect each girder to the floor beams within the CIP longitudinal joint. The surface of the edge girders at the joint was form finished, not intentionally roughened. A small-aggregate, 5-ksi concrete was used to ensure flowability; the concrete also includes a corrosion-resistance admixture. The girders are supported at the abutments by 3-in.-thick, steel reinforced elastomeric bearing pads. Dowels were connected by a form-saver cast into the girder, with a U-bar cast into the floor-beam ends that extend into the CIP concrete joint.

The 18-in.-deep, approximately 4-ft-wide precast concrete floor beams were prestressed with eight 0.6-in.-diameter strands each. These beams vary in thickness from 19 in. at the center to 18 in. at the end, and they are topped with a slight cross slope for drainage. Concrete for the floor beams was designed for an initial compressive strength of 4 ksi, and a design compressive strength of 5 ksi. Each beam has recessed shear keys along their longitudinal edges that were grouted with 5-ksi non-shrink grout after placement, and ducts for longitudinal PT connecting the entire floor system. The floor beams were connected by PT before the longitudinal closure joint was placed.

The CIP closure joint between the floor beams and edge girders required dense reinforcement and staggered mild-steel reinforcement couplers to maintain constructability. Detailed analysis ensured that even in a hypothetical tendon-loss scenario, which was used to check for redundancy in case any one strand was compromised, shear and flexural capacity would remain adequate. Transverse PT

AESTHETICS COMMENTARY

by Frederick Gottemoeller

Not every bridge is a landmark bridge like the Corpus Christi Harbor Channel Crossing featured in the Winter 2026 issue of *ASPIRE*®. Many bridges, particularly those used for rail or transit like the Sonoma–Marin Area Rail Transit's (SMART's) San Rafael Creek crossing, are background bridges. They do not have a prominent scenic location; they are not meant to attract attention. However, that is not an excuse for designers to be careless about the appearance of such structures. These background bridges can still be part of important urban or rural scenes. They are aesthetic elements that can affect the overall visual quality, enjoyment, or even economic success of their surrounding communities. The SMART bridge located close to the San Rafael Station and Second Street performs that role in San Rafael.

With background bridges, visual simplicity is especially important. The SMART bridge's rectangular box girders are as simple as it gets. No shadow lines, texture, or splashes of color have been added. None are needed. The soffit (which would be important if the bridge were crossing a street) displays only the lines dividing the precast concrete slabs, and a relatively light, reflective color is used to brighten the space below the bridge. Again, this is as simple as it gets.

Although the designers selected the bridge components for structural and constructability reasons, not for visual quality, the San Rafael Creek crossing is yet another example of a "twofer," when a decision made for reasons of efficiency and economy also improves appearance. Neither a park nor a commercial establishment nearby would have any reason to complain about the detrimental effect of the appearance of the SMART bridge.

A tandem crane pick is used to place a 154-kip mainline track edge girder on the abutments.

Crew members use a single, 400-ton crane to install one of the prestressed concrete edge girders for the bridge of the siding track on the south side of the creek.

Timber struts provide bracing to mitigate the inward rotation of the edge girders during installation of the floor beams. After each floor beam is set, the shims at the strut ends are adjusted.

with four 0.6-in.-diameter strands per duct was the final operation, fully engaging the girders and floor beams into a rigid monolithic trough.

Two local precasters fabricated the precast concrete; one supplied the piles and the other provided the edge girders and floor beams. Because no falsework was permitted in the creek, the team developed a specialized temporary support system in which steel, hollow-structural-section (HSS) brackets embedded into the underside of the precast concrete box girders supported the floor beams during placement. This system allowed crews to set all the beams from above without any temporary supports in the channel.

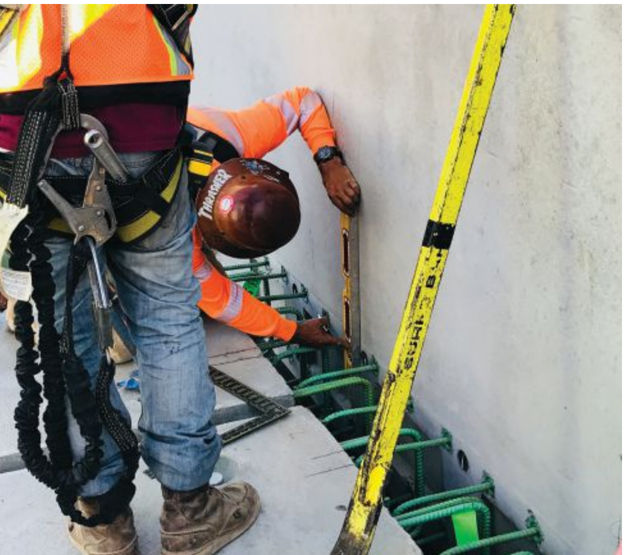
Construction Sequence and Challenges

Construction required careful staging to accommodate the brief environmental window (June 15–October 15), roadway constraints at Francisco Boulevard West, and overhead utilities that had to be moved underground.

Pile and Abutment Work

Sheet piles were first installed using a vibratory hammer. High tides overtopped the sheets on the south side, requiring frequent dewatering—an issue later mitigated by driving taller steel sheet piles with sealed interlocks on the north side. Precast concrete piles were driven with a diesel hammer and cut to elevation before CIP abutment caps were placed. 35-ft-long precast concrete piles were selected for the highly corrosive site. Pile caps are 5 ft wide, 4 ft 6 in. thick, and 26 ft 8 in. long, with a 1-ft

A worker verifies the post-tensioning duct alignment between floor beams and edge girder.



As the precast concrete floor beam is placed, the shear key and blockouts for the bridge's longitudinal post-tensioning are visible.

Epoxy-coated reinforcement (green) and post-tensioning ducts (red) are visible in the floor beam–to–girder joint before placement of the closure pour.

backwall on top of each cap. Shear keys at the end of the pile caps were designed to remain elastic under AREMA level 1 loading but fail under higher loading levels to protect the foundations.

Installation

The 154-kip, 76-ft-long edge girders required a tandem pick using two cranes with lifting capacities of 400 and 350 tons positioned on opposite sides of the creek. The girders were initially set on dunnage to allow the handoff between the cranes, and then set on bearings.

As previously noted, the team developed a specialized, temporary support system using HSS brackets embedded in precast concrete box girders. This allowed the floor beams to set without temporary supports in the creek.

Because the floor beams initially imposed eccentric loading, each edge girder was anchored to the abutment with pipe bracing to maintain plumbness during erection.

Alignment of PT ducts between each floor beam and the girders required precise layout. To mitigate the inward girder rotation under the asymmetric load, the team installed full-length timber struts across the top of the girders before placing any beams. After each beam was set, crews adjusted shims at the struts to keep the girders plumb.

Grouting and Post-Tensioning

Blockouts in the floor beams allowed the bridge's longitudinal PT ducts to be connected before grouting. After the longitudinal PT was tensioned, the CIP edge joint was placed. This step was particularly demanding because of the tight reinforcing bar spacing and coupler congestion.

Because the pockets for the transverse PT were located above the creek, using traditional lifts for the jacking operation was not feasible. The team ingeniously repurposed the HSS temporary brackets, installing lumber and planking to create a suspended walkway for PT operations that was compliant with Occupational Safety and Health Administration requirements.

Conclusion

The San Rafael Creek Bridge demonstrates how innovative precast, prestressed concrete solutions can overcome severe site constraints and environmental limitations. By integrating precast concrete edge girders, prestressed voided-slab floor beams, and a fully PT trough structure, the team delivered a highly durable, corrosion-resistant structure with accelerated bridge construction methods and minimal impact to the sensitive channel.

This project showcases the adaptability of precast, prestressed concrete to complex railroad applications and highlights the value of collaborative design-build delivery in achieving both performance and constructability goals.

References

1. Sonoma–Marin Area Rail Transit (SMART). 2012. *SMART Design Criteria Manual*. Rev. 2. Petaluma, CA: SMART.

2. American Railway Engineering and Maintenance-of-Way Association (AREMA). 2025. *AREMA Manual for Railway Engineering*. Landham, MD: AREMA.

Brian Olp is principal and senior project engineer for STV in Denver, Colo.

Crew members tension the transverse post-tensioning tendons from a temporary platform supported by the repurposed support system used during the installation of the floor beams.

View of the two completed trough bridges. The mainline track is on the right, and the siding track is on the left.