PROJECT

Petaluma River Bridge Replacement on US 101

Project aims to lessen traffic congestion north of San Francisco, California

by Walt LaFranchi, AECOM

Completed northbound side of the Petaluma River Bridge. Photo: Caltrans.

This bridge replacement project will ultimately reduce traffic congestion in the infamous bottleneck area of US 101 north of San Francisco, Calif., known locally as the Marin Sonoma Narrows (MSN). In this area, US 101 narrows to a four-lane expressway with multiple access points from neighboring properties. The proposed MSN project will improve a 16.1-mile-long segment of this congested area with improvements that include constructing high-occupancy vehicle (HOV) facilities, widening and realigning portions of the highway, constructing new interchanges, upgrading drainage systems, and constructing new frontage roads and bikeways. The Petaluma River Bridge Replacement project is one of the key high-profile projects in this segment.

Bridge Setting

The existing bridge consists of a nine-span, 886-ft-long twin structure that utilized a cast-in-place reinforced concrete box-girder bridge with a drop-in precast concrete girder span over the navigable Petaluma River. The existing twin structures were each 6 ft deep, 32 ft-4½ in. wide, and were supported on single column bents. A former rock quarry lies south of the bridge, allowing the existing structure foundation to be supported on spread footings. However, worsening soil conditions at the northern end of the existing bridge required the use of driven concrete piles. All supports were on an approximately 36-degree skew. The existing bridge had a minimum vertical clearance of approximately 70 ft over the mean high-water level and a horizontal clearance requirement of 100 ft from the United States Coast Guard (USCG). Seismicity for the site has an anticipated peak acceleration response spectrum of 1.4*g* from an earthquake with a magnitude of 7.1 and 0.6*g* peak rock acceleration.

Bridge Type Selection

One goal for the Petaluma River Bridge Replacement project was to replace the existing twin structures with one single structure that is 117 ft wide and 907 ft long. The replacement bridge accommodates three lanes of traffic in each direction plus standard-width shoulders. The number of spans is reduced to five with a bridge span layout of 113, 180, 212.5, 212.5, and 169 ft.

Right-of-way restrictions on either side of the bridge, design speed requirements of the freeway, line of sight requirements for vehicles (limited height to raise the highway), and marine vessel vertical clearance requirements restricted the location of the replacement bridge to be in basically the same location as the existing bridge. Therefore, one of the main challenges of this project was determining how to stage the construction of the new bridge.

During bridge-type selection, it was anticipated that three stages of construction would be needed, with the first stage of the replacement bridge (both superstructure and substructure) to be constructed between the existing twin structures. The existing northbound bridge could then be removed and construction of the new northbound side of the bridge (stage two—both superstructure and substructure)

profile

PETALUMA RIVER BRIDGE REPLACEMENT ON US 101 / PETALUMA, CALIFORNIA

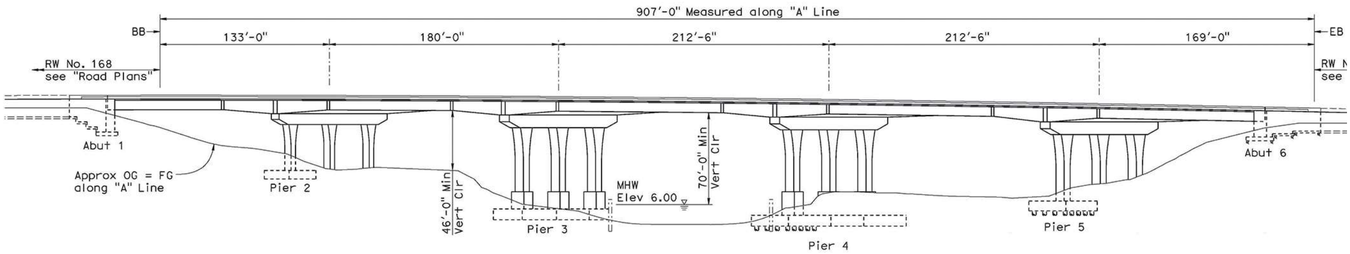
BRIDGE DESIGN ENGINEER: AECOM, Sacramento, Calif.

PRIME CONTRACTOR: Ghilotti Bros. Inc., San Rafael, Calif. (prime contractor) and C. C. Myers Inc., Rancho Cordova, Calif. (bridge contractor)—a joint venture

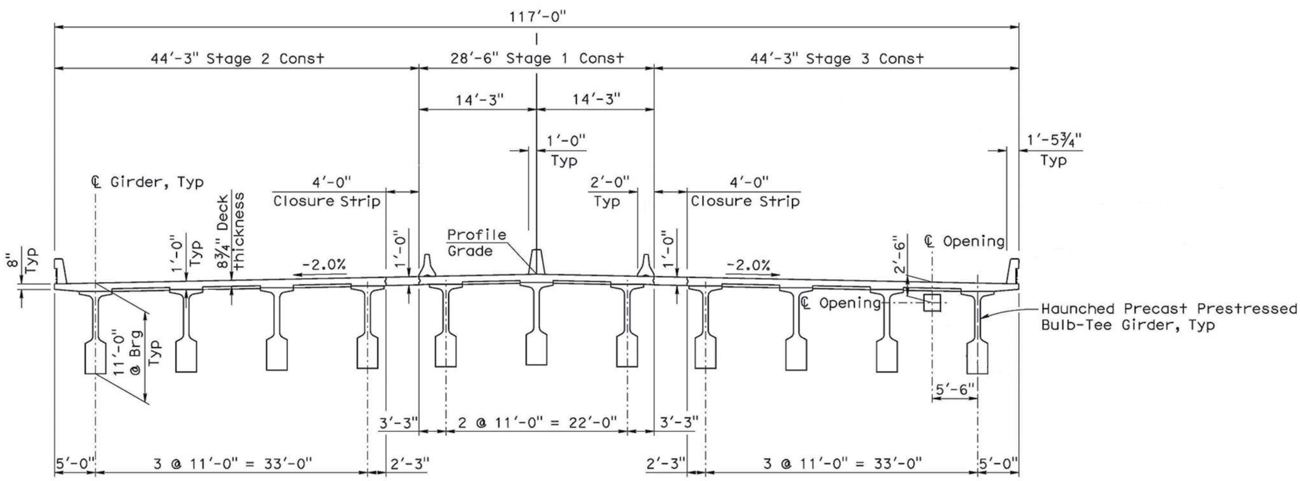
PRECASTER: Con-Fab California Corporation, Lathrop, Calif.—a PCI-certified producer

POST-TENSIONING CONTRACTOR: DYWIDAG-Systems International, Long Beach, Calif.

ERECTION CONTRACTOR: Bigge Crane & Rigging, Stockton, Calif.



Elevation showing the bridge spans and configuration. Drawing: AECOM.



Typical section at pier. Drawing: AECOM.

could begin. A similar staging would occur for the southbound side of the bridge. All of this construction would take place in very restricted areas for access and working room. However, the contractor was able to develop a construction scheme that allowed all of the replacement piers to be constructed in their entirety (without staging) under the existing twin structures, even with very limited head room.

Various superstructure types were considered during the type selection process for this bridge. The two types of bridges considered for final design were

- a cast-in-place, prestressed concrete box-girder bridge with precast concrete bulb-tee girders over the river, and
- a spliced, precast concrete haunched bulb-tee girder bridge.

The first thought was to utilize a similar structure type as the existing bridge, that is, a cast-in-place, box-girder bridge with a span of precast concrete girders over the river. The span of precast concrete girders was required because the use of falsework would be problematic for this span. Although this type of bridge would have been similar to the existing bridge and the estimated construction cost was the least of the alternatives at $27,786,000, it was not selected.

The bulb-tee girder option used 81-ft-long, haunched precast concrete girder segments at each pier that were spliced with constant-depth girders to complete each span. The constant depth girders were 7 ft deep and the haunched pier segments varied in depth from 7 to 10 ft. There were 99 precast concrete segments in the superstructure. The longest constant-depth segments weighed 79.5 tons each and the variable-depth pier segments weighed 87 tons each. The overall staging of the construction of the spliced-girder option would be


Contractor was able to construct entire pier under existing twin bridges. Photo: Caltrans.

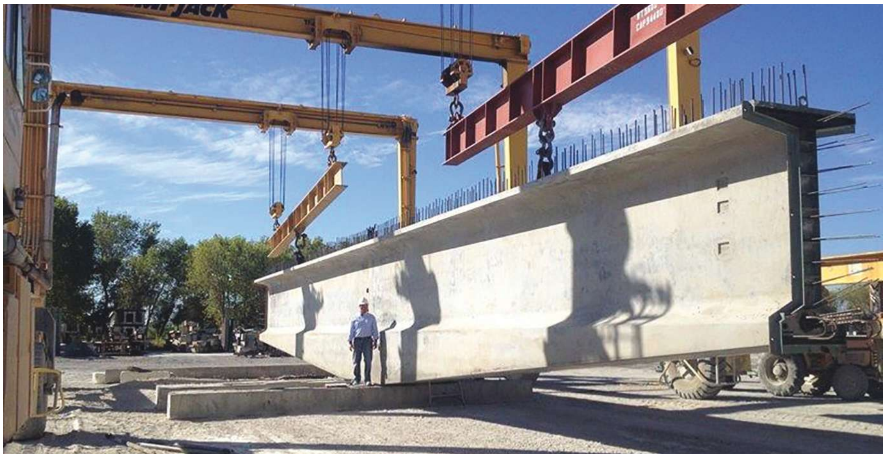
CALIFORNIA DEPARTMENT OF TRANSPORTATION, OWNER

SPONSORING AGENCY: Sonoma County Transportation Authority, Santa Rosa, Calif.

BRIDGE DESCRIPTION: A five-span, 907-ft-long, 117-ft-wide bridge with haunched, spliced, precast, prestressed concrete girders with main spans of 212 ft 6 in.

STRUCTURAL COMPONENTS: Ninety-nine precast concrete bulb-tee segments including 44 haunched pier segments and fifty-five 7-ft-deep constant depth segments; an 8¾-in.-thick composite deck; 7000 linear feet of 36-in.-diameter, cast-in-drilled-hole concrete piles

BRIDGE CONSTRUCTION COST: $25.5 million ($243/ft^2)



Pier girder segment in precast concrete plant. Photo: Caltrans.

similar to the concept for the drop-in span of the box-girder option. The proposed construction sequence for each stage of construction for the spliced-girder option was as follows:

- Erect the haunched pier segments over piers 2, 3, 4, and 5 and stabilize the segments with temporary falsework bents in the back spans
- Erect end-span segments in spans 1 and 5 between the abutments and temporary falsework bents
- Erect span 2 and 4 segments with strongbacks on one end of the girder resting on pier segments and the other end supported by temporary falsework bents
- Erect the span 3 segment over the Petaluma River with strongbacks on both ends resting on pier segments
- Place concrete for the girder splices, then post-tension the girders
- Remove temporary falsework bents and place concrete for the deck
- Perform final post-tensioning, then place barriers and joint seals

Even though the engineer's estimate of construction cost with this type selection was slightly higher at $28,142,000, using this method of construction eliminated all the falsework in the river area, provided a single continuous structure type, and reduced the construction schedule, which lessened the impact on US 101 traffic. It also allowed Caltrans to gain more experience with long-span precast concrete girders.

Design Challenges

The bridge deck was supported by 11 lines of haunched, precast, prestressed concrete bulb-tee girder segments spaced 11 ft apart. The bridge was constructed in three stages. Design challenges included the high skew, the long continuous bridge length, and the staged construction. The girder segments were pretensioned at the fabrication yard utilizing 0.6-in.- diameter strand on a straight alignment with debonding. Post-tensioning of the girders in the field used five tendons (in 3½-in.-diameter ducts) in the webs and two tendons (in 1⅞-in.-diameter ducts) in the each flange for the span segments; for the haunched segment an additional tendon was utilized in the bottom flange (in a 3⅞-in.-diameter duct). Due to the length of the tendon paths, two-end stressing was utilized for the phases of post-tensioning. The first phase was performed after the diaphragms at the abutments and piers and the girder splices were placed and cured. The second phase was performed after the intermediate diaphragms and deck slab was placed. The third phase was performed on the pier diaphragms in the transverse direction. Other design challenges included time-dependent analysis and deflection control to ensure compatibility between stages.

To lighten the cap weight and reduce the seismic loads on the bridge, the dropped bent caps were originally designed with rectangular voids. The contractor requested that round voids be used for easier construction and better concrete placement. A wave pattern with fractured rib texture, similar to that used on the concrete bridge barriers for the US 101 corridor in this segment of the highway, was utilized on the side faces of the pier caps. Columns also had the fractured rib texture.

Three of the piers were supported by three, 8 by 8-ft columns with 24-ft-high,

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one-way column flares with an 8 by 10 ft in cross section. Columns were fixed at the top and bottom at all pier locations except for the southerly pier. At the base of the columns adjacent to the river, an enlarged section (12 by 12 ft) was utilized for the additional strength needed for the seismic and barge-impact loads. The most southerly pier of the bridge was much shorter than the other piers. Thus, due to high thermal, creep, and shrinkage loads, a reduced cross section of 6 by 6 ft and smaller column flares were utilized in conjunction with a sliding bearing at the top of the pier cap.

During design, a fender replacement system study was performed. Due to the nature of the varying soil subsurface and the resulting significant costs needed for replacing the existing fender systems for this site, it was decided to not utilize a fender system. Instead, marine vessel collision loads were designed to transfer directly into the substructure of the piers on each side of the river. Working with the USCG and barge users on the river, the design barge used was 260 by 55 by 15 ft with a bow rake of 30 ft, an empty weight of 750 tons, a loaded weight of 4600 tons, a tug weight of 300 tons (with a maximum tug velocity of 6 knots), and a design impact speed of 11.3 knots resulting in significant lateral design loads applied to the bottom portion of the piers. The resulting footing sizes became large, but instead of three separate footings for the columns at each pier, a continuous strip footing was utilized.

Spread footings were utilized at the south end at abutment 1 and pier 2; 36-in.-diameter, cast-in-drilled-hole concrete piles were utilized at piers 4, 5, and 6; and 14-in.-square precast concrete piles were utilized at abutment 7.

Construction Challenges

Installation of cofferdams on either side of the river was necessary for construction of the replacement bridge and removal of the old bridges. A temporary falsework platform and trestle system was utilized to remove the existing bridges and construct the new bridge.

All spans utilized two girder splices except the end spans that utilized only one splice. Vertical support for the girder loads at the splice locations was provided by temporary falsework where feasible, such as the end spans, span 2 adjacent to Petaluma Boulevard North, and one of the splices in span 4. At piers 3 and 4 (adjacent to the river), falsework could only be erected on the land side (the side away from the river) of each pier. Consequently, the contractor installed tie-downs to counter the load of the girders for the span over the river. The tie-downs consisted of 1⅜-in.-diameter, high-strength threaded rods drilled and bonded 50 ft deep into the ground. Each rod was load tested to a capacity of 90 tons for pull-out load verification. For stage 1 construction in the median of US 101, two tie-downs were required on each side of the river (four total); for stages 2 and 3 (northbound/southbound portions) three tie-downs were used on each side of the river (six total).

Using couplers, each threaded rod was extended up to the back side (away from the river) of the haunched girders at piers 3 and 4. At the girder level, the extended threaded rods connected via a custom made brace to a W14×145 strongback placed transversely across all girders in that stage. This arrangement provided enough capacity to counter the load of the girders in the span over the river while providing the ability to place the girders during the allowable lane closure hours. Strongbacks on each girder were utilized in the two splices in the span over the river (span 3) and one splice in span 4.

The contractor utilized a 300-ton crane for the placement of the precast concrete girder segments. Girders for the span over the river required approximately 85% of the crane's lifting capacity.

To support the crane and girder weight adjacent to the river, the contractor constructed temporary crane pads at each quadrant. The reinforced concrete pads were 55 by 85 by 2 ft and were thickened to 3 ft at each of the pile locations. The sixty-five, 200-ton piles for each temporary pad were driven 60 ft deep at pier 4 and 40 ft deep at pier 3.

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Walt LaFranchi is the northern California transportation group manager for AECOM in Sacramento, Calif.

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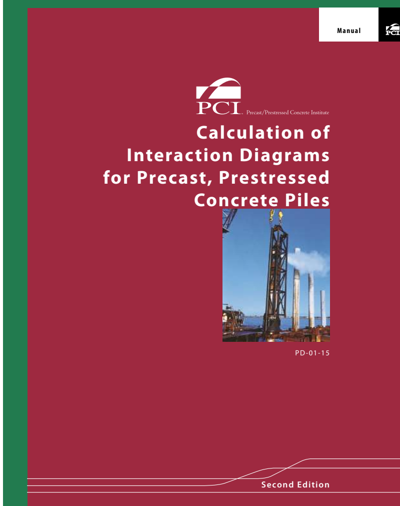

This free eBook, *Calculation of Interaction Diagrams for Precast, Prestressed Concrete Piles*, provides context and instructions for the use of the 2015 revised version of the Microsoft Excel workbook to compute pile stresses, plot interaction diagrams, and compute lifting points of precast concrete piles.

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