PROJECT

ANTLERS BRIDGE

by Jason Lynch, California Department of Transportation

In Northern California, Interstate 5 follows a historical route through the Sacramento River Canyon, and the new Antlers Bridge is one of its significant structures. The 1942-ft-long bridge crosses Shasta Lake, near the community of Lakehead, on a new alignment to replace an aging truss. For the California Department of Transportation (Caltrans), the $131 million project improves a critical link for the movement of people and goods in the West. For the general contractor, it presented a host of challenges, requiring innovation and flexibility.

Replacement Needed

The structure replaces a narrow steel deck truss built during the construction of Shasta Dam in 1941. Its active structural-steel fatigue cracks and a deteriorating deck made the existing bridge an annual drain on the state's maintenance resources. The approach highway lacked shoulders and had a steep, tightly curved alignment that could drive like a luge run.

Vehicles on the new bridge and the final days of the old truss. All Photos: California Department of Transportation.

New Design

Seeking to improve safety and reduce long-term costs, the state realigned the roadway and opted for the durability and ease of maintenance of a cast-in-place, prestressed concrete box-girder bridge. The height of the bridge and the challenging site access discouraged California's typical falsework construction, driving the project to the balanced-cantilever, segmental method.

Designers located the piers to miss the greatest depth of the lake and a recreational hot spot fronting the Antlers public boat ramp. The result was a bridge with five continuous spans and a 591-ft-long main span. Symmetry in the layout and the box-girder dimensions helped to economize on equipment and formwork costs. The design followed the *AASHTO LRFD Bridge Design Specifications*, supplemented by project-specific criteria. For bridge trivia buffs, the effort holds the inconsequential distinction of being the last California bridge designed in metric units and among the first using the load-and-resistance-factor design method.

Design Challenges

Caltrans's *Seismic Design Criteria* requires ductility and resilience of all California bridges, particularly for operationally important structures. With a two-lane detour more than 100 miles long, this lifeline structure needs to perform. But performance would come

profile

ANTLERS BRIDGE / LAKEHEAD, CALIFORNIA

BRIDGE DESIGN ENGINEER: California Department of Transportation (Caltrans), Sacramento, Calif.

PRIME CONTRACTOR: Tutor-Saliba Corp., Sylmar, Calif.

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

CONTRACTOR'S ENGINEER: Finley Engineering Group, Tallahassee, Fla.

at a steep price, the amount of extra pier-table reinforcement needed.

One sees a panoramic view of Shasta Lake from those pier tables. It is the largest reservoir in California, filling the Sacramento and two other river canyons above Shasta Dam. The dam's original function was salinity control for the agricultural delta off San Francisco Bay, but its modern roles include water supply and flood protection, competing objectives that cause the lake's surface to fluctuate vertically as much as 50 ft in a normal year.

Unfortunately, after five years of a state-wide drought, normal years have been quite the anomaly. At the construction site, 20 miles from the dam, the Sacramento River changed from deep lake to trickling stream—and back again—with only 120 ft between its extremes.

Anticipating the challenge, the designers sought a foundation type that was both constructible and visually appealing in either high or low water conditions. Potential high water conditions precluded traditional cofferdams, and low water would make an eyesore and boating hazard out of any suspended pile cap. The design team turned to 12-ft-diameter drilled shafts extending between 95 and 140 ft to the superstructure. The shafts were a versatile solution, but constructing them required much time and money.

In November 2009, the contractor cleared staging areas and drove trestle piles in the dry conditions of a nearly empty Shasta Lake. It was an enthusiastic start, but heavy rains flooded the site, overtopped the temporary works, and pushed activity to higher elevations. A combination of barges and even loftier trestles—up to 95 ft tall—provided access to subsequent work.

Massive columns are monolithic with the heavy pier cap.

Drought left the access trestle high and dry.

Shaft construction began with a sacrificial 14-ft-diameter construction casing vibrated 25 to 60 ft into the canyon's sloping, degraded rock. Ribbed with 6-in. angles above ground, the 1-in.-thick casing would ultimately serve as a 90-ft-deep cofferdam for the dry placement of column concrete. In the drilling phase, its primary functions were to control turbidity, to increase the precision of the shaft position, and—when the lake went dry—to provide hydraulic head over the drilling tools.

After excavating within the construction casing, the contractor used reverse circulation drilling to advance the shaft up to 70 ft into more competent rock. To reduce the risk of caving in the open hole, several operations were conducted in quick succession after the drill string was removed. A sonic caliper assessed

CALIFORNIA DEPARTMENT OF TRANSPORTATION (CALTRANS), OWNER

OTHER SUPPLIERS: Harris Salinas Rebar Inc., Livermore, Calif.; Shaft Drillers International, Mt. Morris, Pa.; Spec Form Liner, Santa Ana, Calif.; and Stimpel-Wiebelhaus Associates, Redding, Calif.

BRIDGE DESCRIPTION: Five-span continuous, post-tensioned, cast-in-place, segmental concrete box-girder bridge, 104 ft wide and 1942 ft long, with a 591 ft main span, all founded on 12-ft-diameter drilled shafts

STRUCTURAL COMPONENTS: 212 box-girder segments 13 to 15 ft long, 12 to 30 ft deep; 63 by 104 by 36 ft deep pier tables supported by 12-ft-diameter drilled shafts; and transversely post-tensioned, cast-in-place concrete deck

BRIDGE CONSTRUCTION COST: At least $131 million

Construction casings and access trestles were built when the lake was full but are exposed when the lake is low.

Falsework was used near the bridge abutments.

the hole for plumbness, and a miniature drilled shaft inspection device verified the bottom cleanliness. Prefabricated, 80-ft-long reinforcing cages were then lowered into the shafts, followed by tremied concrete with a 6-ksi strength requirement. Caltrans tested the hardened concrete for homogeneity using gamma-gamma density logging. Of the 12 shafts, six contained minor anomalies that were repaired by grouting.

On to the Pier Tables

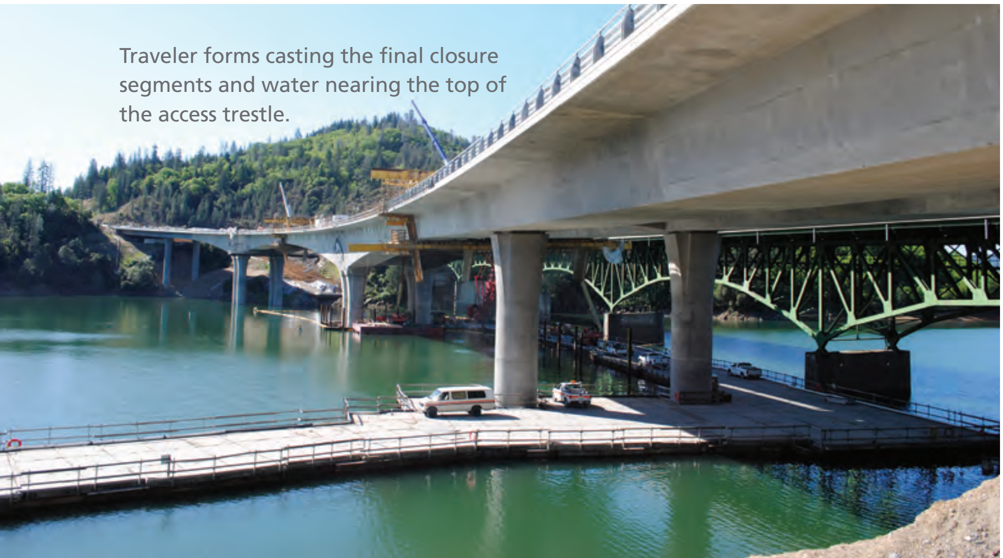
As the foundations were completed, and each shaft extended upward as a column, attention turned to the 63 by 104 by 36-ft-deep pier tables. At the main piers just one of these massive elements would consume 4350 yd^3 of concrete from an on-site batch plant. Architectural details required complicated, curving formwork. Brackets embedded in the bridge columns supported an impressive falsework system above the water line. Seismic design required nearly one million pounds of reinforcing steel in each of the main pier tables. The congestion and scale prompted the contractor to use self-consolidating concrete, placing three separate lifts over the course of several weeks. Individual concrete placements lasted up to 20 hours. Mass concrete specifications required cooling pipes and thermal monitoring during and after concrete placement.

Segments

Once a pier table was finished, the contractor erected four 1200-kip form travelers to support the cast-in-place concrete segmental construction. The 212 superstructure segments were 13 to 15 ft long and weighed up to 400 kip. After an initial learning curve, construction settled into a routine of casting four segments per week. Each segment was prestressed 18 to 24 hours after it was cast, once an on-site lab broke test cylinders at a minimum of 3.6 ksi.

The superstructure cross section is a double-box girder, each box being 50 ft wide and 12 to 30 ft deep and connected by a 4 ft longitudinal closure strip. The overall width is 104 ft on a 4% cross slope, carrying five lanes of traffic between open steel barriers. The asymmetric traffic layout—owing to a southbound truck climbing lane up the 6% grade—drove the decision to connect the otherwise symmetrical boxes.

Longitudinal prestressing tendons—twenty-five 0.6-in.-diameter strands in each box-girder web—keep the superstructure in compression under live load. Some segments were vertically prestressed with high-strength bars to manage principal stresses.



Traveler forms casting the final closure segments and water nearing the top of the access trestle.

Durability for the Future

After decades of maintenance on the fatigued and ailing truss, durability and long life became touchstones of the Antlers Bridge project. The no-tension requirement is one of several strategies to that end. Transverse post-tensioning, epoxy-coated reinforcement, 2.5-in. concrete cover, and a polyester concrete overlay also contribute to the durability of the new deck.

The bridge went into service in late 2016, and demolition of the old truss is nearly complete. After seven years of construction, boaters can look forward to open water while motorists will enjoy an open road. Caltrans expects the new Antlers Bridge to last in excess of 100 years.

Jason Lynch is a senior bridge engineer with the California Department of Transportation in Sacramento.