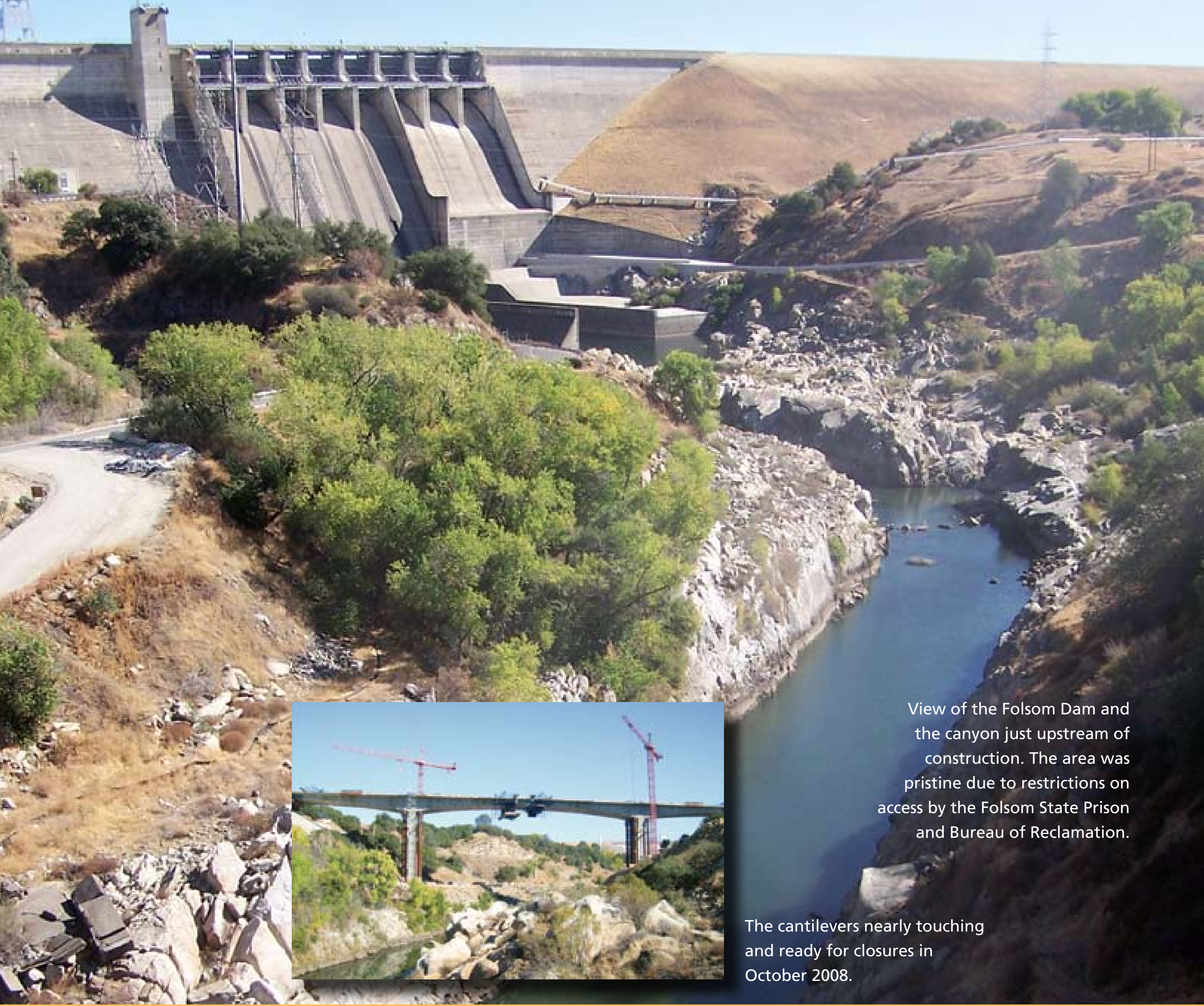
Design and Construction –

Folsom Lake Crossing

by Hans Strandgaard, Alex Harrison, Jeff Aldrich, and Jeff Thomure, CH2M HILL



View of the Folsom Dam and the canyon just upstream of construction. The area was pristine due to restrictions on access by the Folsom State Prison and Bureau of Reclamation.

The cantilevers nearly touching and ready for closures in October 2008.

profile

FOLSOM LAKE CROSSING / FOLSOM, CALIF.

CONTRACTING AGENCY: U. S. Army Corps of Engineers, Sacramento District, South Pacific Division

ENGINEER: CH2M HILL/URS Joint Venture, Sacramento and Roseville, Calif.

CONSTRUCTION ENGINEER: McNary Bergeron and Associates, Broomfield, Colo.

PRIME CONTRACTOR: Kiewit Pacific Co., Vancouver, Wash.

CONCRETE SUPPLIER: A & A Ready Mixed Concrete, Inc. Newport Beach, Calif.

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

Folsom Dam Road, located on the crest of Folsom Dam, near the city of Folsom, Calif., was operational from the time of the dam's construction in 1956, until it was closed to public traffic in 2002, as a result of national security concerns. The road was an important regional transportation artery, with 18,000 vehicles using it daily as a link between Sacramento, El Dorado, and Placer counties. Following the 2002 road closure, traffic across the American River was detoured to other downstream bridges, often resulting in gridlock within the city of Folsom. In response to local congestion concerns, plans for a new crossing of the American River near Folsom Dam were fast-tracked by local and state officials. When federal funding for a new crossing was appropriated in 2006, along with additional funding from the city of Folsom and the State of California, the project had adequate resources to begin at once.

In response to the community's desire to open the new crossing to traffic as quickly as possible, the U.S. Army Corps of Engineers (USACE) and the project development team adopted an aggressive design and delivery schedule that included preparing the environmental documentation in parallel with the engineering studies, design, and right-of-way acquisition for the new roadway and bridge.

The USACE selected the CH2M HILL/URS joint venture to prepare designs for the bridge and approach roadways. As the bridge designer, the CH2M HILL project team's mission was to produce a design to be constructed on a fast-track schedule, within a limited budget, while maintaining the required level of quality, constructability, and acceptance from a broad range of stakeholders.

Kiewit made dual use of the struts to act as falsework for the pier table and then to strut the pier tables to reduce rotation and construction stresses as the cantilevers were constructed.

Site Features and Constraints

The selected river crossing site, approximately 1/2-mile downstream of the dam, presented multiple challenges for the bridge design and construction. Limitations on the maximum roadway profile grade resulted in the vertical alignment that crossed the canyon approximately 200 ft above the river. Existing access into the steep inner canyon was very limited. In addition, the California Department of Corrections and Rehabilitation (CDCR) expressed security concerns related to increasing site accessibility next to Folsom State Prison—a high-security facility—located adjacent to the alignment.

Project Coordination Challenges

The tight project schedule and the simultaneous development of the design and the environmental document were identified as being major constraints to the design team; however, weekly meetings and continuous exchange of information expedited project coordination and delivery.

Key concerns among the various stakeholders involved security issues, as well as maintenance of dam operations during and after construction of the new bridge and roadway. Property acquisition was required from the CDCR, the California Department of Parks and Recreation, and the U.S. Bureau of Reclamation, as well as from private land owners. While other alignments may have resulted in a more favorable bridge layout, it could not accommodate the required schedule. In addition, relocating the existing Folsom Dam powerhouse access road was unacceptable, as it would potentially disrupt the only access to this critical facility.

A cast-in-place concrete segmental box girder was the most appropriate structure type.

CAST-IN-PLACE SEGMENTAL BOX GIRDER BRIDGE / CITY OF FOLSOM, OWNER

SPHERICAL BEARINGS: Lubron Bearing Systems, Huntington Beach, Calif.

ROCK ANCHOR HOLES: Drilltech Systems Drilling and Shoring Inc., Antioch, Calif.

BRIDGE DESCRIPTION: Three-span, cast-in-place, segmental box girder, 970 ft long with 430-ft main span and 270-ft approach spans

BRIDGE COST: $38,378,000 (as bid)

PROJECT COST: $73,294,000 (as bid)

Bridge Type Selection

The bridge type selection study conducted during the preliminary design phase investigated a range of bridge types and span arrangements, as well as alternative bridge construction materials. It was determined that a minimum main span length of approximately 350 to 400 ft was required to span the inner portion of the canyon and keep the pier foundations above the flood elevation.

The design team identified a cast-in-place concrete box girder as the most appropriate structure type for this crossing. Box girder bridges are the most widely constructed highway bridge type in California. Local contractors have a long record of successfully constructing this bridge type, and the design team understood that competitive bids could be obtained and potential schedule delays reduced as a result of the familiarity of the local construction market with this structure type. From the owner's perspective, concrete box girder bridges have a solid record of long-term performance and low maintenance in the Sacramento environment. Further, the seismic behavior and design features of this structure type are relatively well defined in California.

One project issue related to concrete box girder construction was the feasibility of using falsework for construction. While falsework has been used in California for construction of tall three- and four-level freeway interchanges, the 200-ft height above the river canyon posed significant problems. Further, the use of falsework required supports to be placed in the American River, which introduced a high level of risk in the event of flooding, and long-span steel truss falsework was cost prohibitive. The design team identified cast-in-place segmental construction as being the only practical method of box girder bridge construction for this site. Several alternative bridge structure types were considered including arch, extradosed, steel plate girder, and spliced precast concrete girder bridges.

Following consultation with constructability resources and preparation of cost estimates for these alternatives, the design team recommended a cast-in-place concrete segmental box girder with integral piers.

Span Arrangement and Bridge Layout

The selected three-span bridge has a main span of 430 ft with equal side spans of 270 ft. Given site geology and topography, this span arrangement accommodates a feasible foundation configuration, and allowed construction to proceed in four simultaneous headings from two pier tables, which shortened the schedule. The symmetrical span arrangement simplified both design and construction details, and provided for maximum repetition. The overall bridge length was well suited to the site topography, which resulted in minimal abutment heights or fills.

A variable-depth box girder was selected with a total depth that varied between 10 ft at midspan to 26 ft at the piers. Exterior webs were sloped to minimize the piers' cross-sectional width, and to provide for improved aesthetics. The 82-ft-wide bridge deck will accommodate four traffic lanes with a 4-ft-wide median. In addition, a 12-ft-wide regional trail located on the north side of the roadway will provide for an unprecedented and dramatic view of the dam.

Superstructure Design

The box girder cross section has two cells with a deck slab that spans approximately 28 ft between web centerlines and has 12-ft-long deck cantilevers. This arrangement optimizes the deck slab thickness while providing for an adequate cross section at the tops of the webs to locate cantilever post-tensioning ducts and anchorages. The deck slab is transversely post-tensioned to minimize slab thickness and control cracking. The design team selected the segment arrangement to be within the capacity of available traveling forms while minimizing the number of segments to be cast on each cantilever. A segment length of 12 ft adjacent to the piers and 15.5 ft away from the piers was selected.

Design of the Folsom Lake Crossing utilized three-dimensional analytical modeling. While traditional practice for transverse design of segmental bridges has been to use an elastic plate analysis in conjunction with two-dimensional frame models, this approach has practical limitations on variable depth girders. Sections with shorter webs have a greater bending stiffness and develop larger live-load web moments than sections with deeper webs. While this effect can be accounted for in two-dimensional models, development of a three-dimensional model allowed for more accurate determination of internal cross-section forces. In addition, the three-dimensional model was used to study shear lag effects over the length of the cantilevers.

Kiewit lifted concrete from the pier bases in 4 yd^3 buckets to a remixer/pumper located at the top of the pier table. Segments were cast full depth in a single placement.

The cantilevers progressing in September 2008.

Form traveler for cast-in-place segmental construction advancing from the pier table. Portions of the travelers were last used on the nearby Benicia-Martinez Bridge project.

Substructure Design

The pier configuration consisted of a "dogbone" cross section column extending from the spread footings to a transition element at the top of the column. This prismatic column cross section provided sufficient ductility under transverse seismic loadings, and allowed the use of repetitive details and maximum reuse of column forms. One aesthetic feature incorporated into the substructure design was a truncated pyramid transition element that provided for a smooth visual and structural transition from the columns to the superstructure soffit. Spread footings were used on top of the granite bed rock.

Seismic Design Considerations

Seismic design is a major consideration for any bridge built in California, and particularly for a long-span, relatively heavy concrete bridge with tall columns. With an estimated peak horizontal ground acceleration of 0.4 times gravity, the site is considered a moderate seismic zone. Finite element analysis was used to determine elastic acceleration response spectrum (ARS) analysis forces and structure displacements.

The structure was designed in accordance with California Department of Transportation (Caltrans) design standards to manage the formation of plastic hinging in the piers in a completed configuration. These plastic hinging forces are resisted by "joint" regions in the pier table and footing. These are designed to remain essentially elastic, as are the superstructure and the footings. The pier table joint region required particular attention due to the steel required to sustain the joint forces in combination with the heavy reinforcement and tendon density driven by segmental construction. Caltrans' design criteria were verified with complex cracked concrete three-dimensional block finite element analysis to verify the design reinforcement configuration. Integrated drawings were developed for this region to eliminate potential interference and enhance detailing of the reinforcement. Similarly, the footings were designed to transfer the pier plastic moments through the footing and into the rock foundation using post-tensioned tie-downs.

A horizontal construction seismic load of 10% of gravity was considered for the balanced cantilever construction configuration, prior to completion of closure pours and before the spans were connected. Both the pier and spread footings were evaluated in this analysis to ensure that there is not a collapse if a moderate earthquake occurs during construction.

The bridge is expected to open in spring 2009.

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Kiewit constructed a liquid nitrogen plant to lower the initial temperatures of the concrete for mass concrete placements.

Looking from the Pier 3 cantilever towards Pier 2, shows the height of the structure over the water and the reconstruction efforts required for the slope

Pier 3 in June 2008.

The cantilevers starting in August 2008.

Bar reinforcing at one of the pier tables was very dense due to seismic requirements.