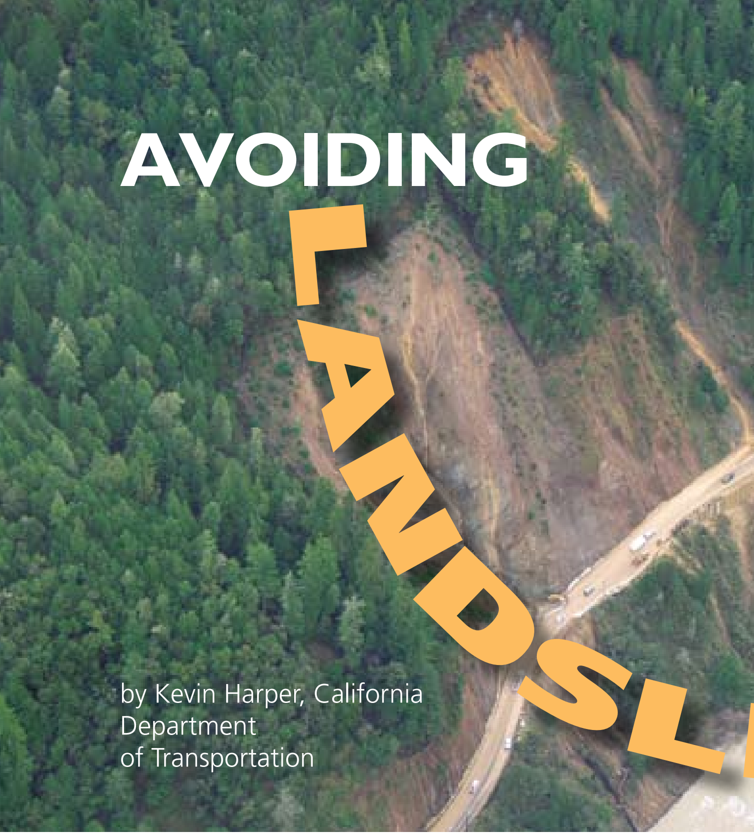


AVOIDING LANDSLIDES

by Kevin Harper, California Department of Transportation

The emergency project relocates a portion of U.S. Route 101 away from a large landslide requiring two large bridges over the South Fork Eel River.

The large landslide extends over 1000 ft above the river enveloping the current highway. The slide is approximately 3000 ft wide. Photos: © Caltrans.

The relocation of U.S. Route 101 required two high-level bridges over the Eel River

An emergency project to relocate a portion of the Pacific Coast Highway (U.S. Route 101) away from a large landslide in northern California required two large bridges to span the South Fork Eel River. Although the bridges are within a quarter mile of each other, they are dramatically different structures. The difference in the bridge types resulted from the vastly different terrains at the two crossings of the South Fork Eel River that snaked along in the shape of a giant "U" with a bridge over each leg. The southern leg of the river, with its wide banks, required a 1355-ft-long, three-span, segmental concrete bridge that was 275 ft above the river. The northern leg of the river, which passed through a narrow rock walled canyon, required a 581-ft-long, three-span, cast-on-falsework concrete arch bridge that sits 150 ft above the river.

Route 101 is the primary route that provides direct access to California's north coast for commercial trucking and recreational traffic. North of the San Francisco Bay area, this highway is considered the "lifeline of the California's north coast." There has been a recurring problem of landslides around Confusion Hill over the last decade, resulting in frequent road closures and high maintenance costs. When a major landslide occurs that closes both lanes, the traffic south of Confusion Hill may have to backtrack and detour an additional distance of 250 miles. During the past 10 years, over $33 million has been spent on slide repairs.

The project involves relocating approximately 1.5 miles of U.S. Route 101 away from the active landslide. The large ancient rockslide complex extends

profile

SOUTH FORK EEL RIVER BRIDGES (CONFUSION HILL BRIDGES) / LEGGETT, CALIF.

ENGINEER: California Department of Transportation, Sacramento, Calif.

PRIME CONTRACTOR: MCM Construction Inc., North Highlands, Calif.

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

CONCRETE SUPPLIER: Mercer-Fraser Company, Eureka, Calif.

FORM TRAVELER SUPPLIER: AVAR Construction Systems Inc., Campbell, Calif.

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

REINFORCING STEEL SUPPLIER: Fontana Steel, Stockton, Calif.

upwards from the river for more than 1000 ft, enveloping the current highway that is benched into the mountain about 240 ft above the river. The landslide area is approximately 3000 ft wide. Geotechnical studies have concluded that the slide is progressively losing strength and there is a high probability that the complex will continue to move in the future. This highway relocation project is an emergency project that is fully financed with federal emergency relief funds. The expedited delivery of this $65.7 million dollar project only took 28 months from the initial planning study phase until award of the construction contract.

The complete project includes two bridges, two tieback retaining walls, and a large cut between the two bridges. The bid for the structures work was $49.4 million. The contractor started work in June of 2006 and is expected to complete the project in 2009.

North Bridge

The smaller north bridge is a concrete inclined leg frame arch with a 229-ft center span and 175-ft end spans. This bridge type fits this particular site well by meeting the requirement to keep the piers out of the ordinary high water limits of the river while still maintaining balanced span ratios. This configuration actually kept the piers out of the higher 100-year water level, which simplified the environmental process even more. The river at this site was contained within a relatively narrow canyon with steep rock walls, which provided suitable foundation material to anchor the inclined piers. The superstructure of the bridge is a cast-in-place, post-tensioned, two-cell box girder with sloping exterior webs. The box varies in depth from 13.8 ft at the piers to 5.9 ft at the ends and midspan. The deck width is 42.8 ft and the bottom slab width varies from 16.8 ft at the piers to 24.7 ft at the ends and midspan. The bridge was cast on falsework that was up to 140 ft tall. The solid concrete tapered piers are anchored into the mountain in 17.5-ft-wide by 6.9-ft-high by 80-ft-deep mined shafts to develop the full probable plastic moment of the piers during a seismic event. The shafts were excavated through very hard rock that required blasting, as well as weathered and fractured rock regions that required rock bolting for stability.

Concrete compressive strength was specified as 6100 psi for the superstructure and 5100 psi for the piers. The concrete strength required at time of post-tensioning was 3600 psi. The total post-tensioning jacking force applied at abutment 1 for the full-length tendons was 8776 kips. The tendons consisted of 0.6-in.-diameter, 270 ksi, low relaxation strands.

South Bridge

The larger south bridge uses a cast-in-place, segmental concrete box girder with normal weight concrete. Like the north bridge, the piers were not only outside the required ordinary high water limits of the river, but also the 100-year flood levels. The south bridge was selected to be segmental because its height above the river was too high for economical construction using falsework. The span lengths of the bridge are 348 ft, 571 ft, and 436 ft.

The south bridge, which is 275 ft above the river is a cast-in-place concrete segmental box girder constructed by the balanced cantilever method. Photos: © Jon Hirtz, Caltrans.

The north bridge, which is approximately 150 ft above the river, was built as a cast-on-falsework post-tensioned concrete box girder. The lower portion of the falsework (table top) can still be seen below the bridge as well as the temporary access trestle behind the bridge.

SEGMENTAL CAST-IN-PLACE CONCRETE / CALIFORNIA DEPARTMENT OF TRANSPORTATION, OWNER

DRILLING SUBCONTRACTOR: Pacific Coast Drilling, Petaluma, Calif.

EARTH WORK AND MINED SHAFTS: Ladd & Associates, Redding, Calif.

BRIDGE DESCRIPTIONS: Three-span, segmental cast-in-place concrete single cell box girder constructed by the balanced cantilever method and three-span, cast-on-falsework post-tensioned concrete two cell box girder with inclined piers

STRUCTURAL COMPONENTS: South Bridge: 68 concrete segments in spans of 348 ft, 571 ft, and 436 ft. North Bridge: Cast-in-place on falsework with spans lengths of 175 ft, 229 ft, and 175 ft

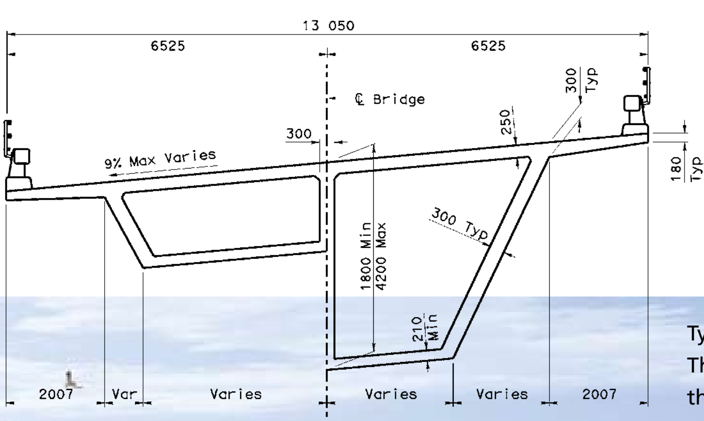
BRIDGE CONSTRUCTION COST: South Bridge—$37 million; North Bridge—$9 million

Looking south at segmental construction of the south bridge pier 2 cantilever with form travelers. Abutment 1 can be seen in the background. Photo: © Jon Hirtz, Caltrans.

For both bridges, the piers were located outside the 100-year flood levels.

The superstructure varies in depth from 31.5 ft at the piers to 11.5 ft at the ends and midspan. The single cell, box girder cross section has vertical webs and is post-tensioned longitudinally and transversely. The box girder has a deck width of 42.8 ft and a bottom slab width of 23.8 ft. The bridge is being built by the balanced cantilever construction method from each pier and casting on falsework near the abutments. The contractor is utilizing one set of conventional form travelers, constructing the pier 2 cantilever first and then moving the travelers over to pier 3 to construct the final cantilever. The cantilevers on each side of the piers consist of 17 segments. The first four heavier segments are 13.1 ft long while the remaining 13 segments of each cantilever are 15.4 ft long. The closure segments are 12.5 ft long. The heaviest segment weighs 200 tons. The pier table length is 45 ft and is 7.5 ft out of balance toward the center span side of the pier so that during segment production the cantilever will not be more than one-half of a segment out of balance. The first segment cast is on the end span side of the piers.

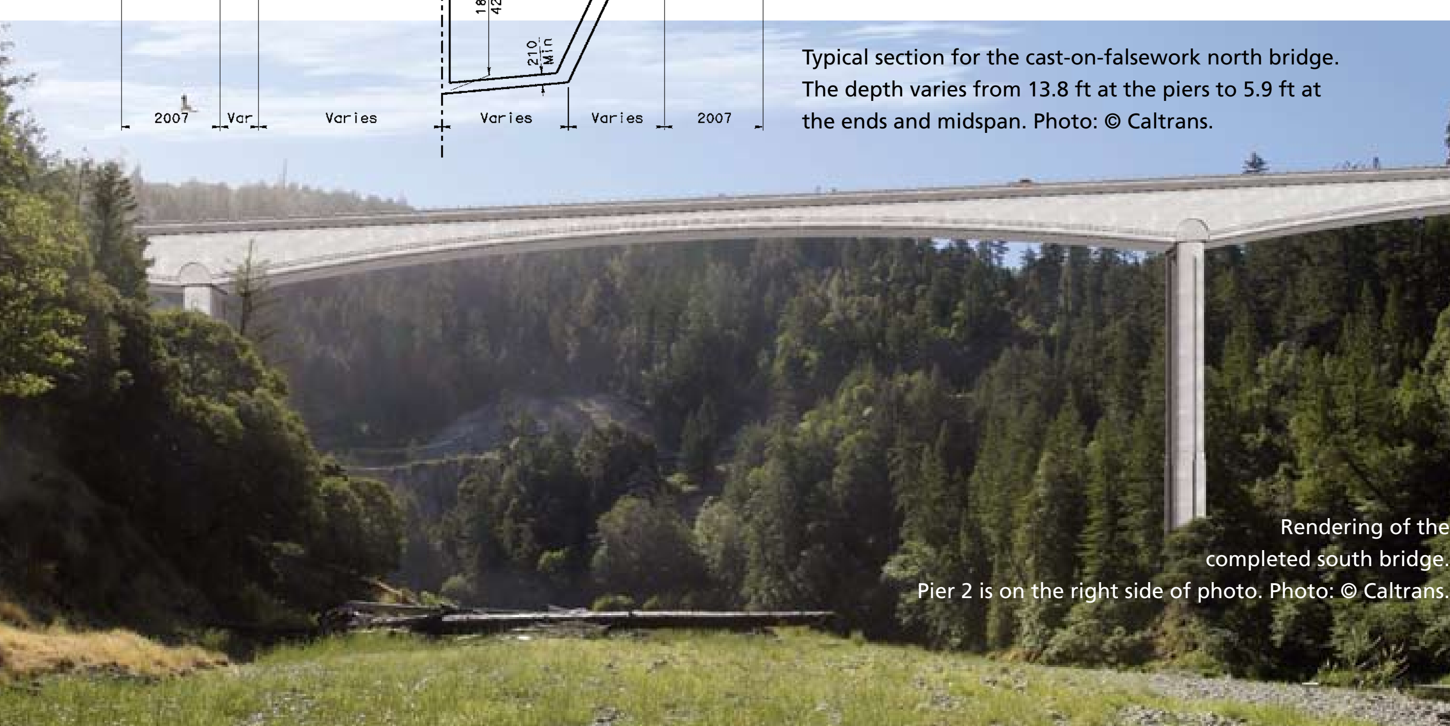
The heights of the piers from top of the footing to the top of the bridge deck are 200 ft. Because of this height, it was determined that it was more economical to use a hollow pier section. The hollow piers have heavily confined corner elements using welded No. 10 reinforcing hoops spaced at 4-3/8 in. on centers to get the necessary ductility to meet the California Seismic Design Criteria. The solid pier footings and caps were classified as mass concrete and required chilled water to be pumped through the elements to keep the heat of hydration below specified limits. The footings incorporated eleven 5-ft-diameter cast-in-drilled hole piles. The piles are up to 136 ft deep and have a nominal compression resistance of 4382 tons per pile. The footing dimensions are 36 ft long by 49 ft wide by 10.5 ft deep.



Typical section for the cast-on-falsework north bridge. The depth varies from 13.8 ft at the piers to 5.9 ft at the ends and midspan. Photo: © Caltrans.

Construction of the superstructure began at the pier 2 table in October 2007. Early on, the contractor was able to achieve two segments per week per pair of travelers on the first cantilever. The contractor has plans to increase segment production to three segments per week prior to completing this first cantilever. The bridge deck incorporates an integral overlay in which an additional 1 in. of cover has been provided to the deck reinforcement for profile grinding. The bridge has also been designed to carry a future wearing surface.

The design of the bridge utilized the 1990 CEB-FIP Model Code for Concrete Structures to model the time-dependent creep and shrinkage characteristics of the bridge. Testing of the contractors mix surprisingly showed that the actual shrinkage was twice that predicted in the



Rendering of the completed south bridge. Pier 2 is on the right side of photo. Photo: © Caltrans.

Protecting the Environment

The project is located at the north end of Mendocino County. It is within the majestic redwood forests near Standish-Hickey State Recreation Area, approximately 10 miles north of the town of Leggett where State Route 1 terminates and joins U.S. Route 101. Several tourist attractions are nearby including the adjacent Confusion Hill Mystery Spot from which the landslide gets its name.

The South Fork Eel River is federally designated as a "Wild and Scenic River." Because of this designation, all bridge piers were required to be outside of the "ordinary high water" level of the river in order to expedite the environmental process on this emergency project. This requirement caused the bridges to have relatively large center spans over the river. Both bridges are three-span structures that carry two lanes of traffic and have see-through concrete barriers along each edge of the deck.

CEB model. Consequently, a shrinkage-reducing admixture was added to the mix to cut the concrete drying shrinkage in half. The shrinkage results of the mix at the Devil's Slide segmental bridges were similar (see article in Winter 2008 *ASPIRE*™), and a shrinkage-reducing admixture had to be incorporated into that mix as well.

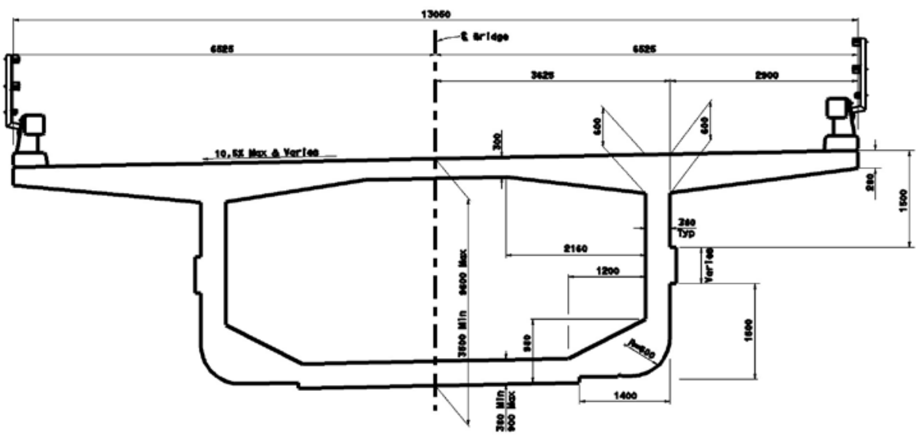
The project is progressing on schedule and within budget. The north bridge was completed in January 2008. The contractor is currently trucking excavated material from the large cuts between the two bridges over the north bridge. The south bridge pier 2 cantilever is expected to be completed in July, at which time the form travelers will be moved over to pier 3. The closure between the cantilever tips is scheduled to be placed in early 2009.

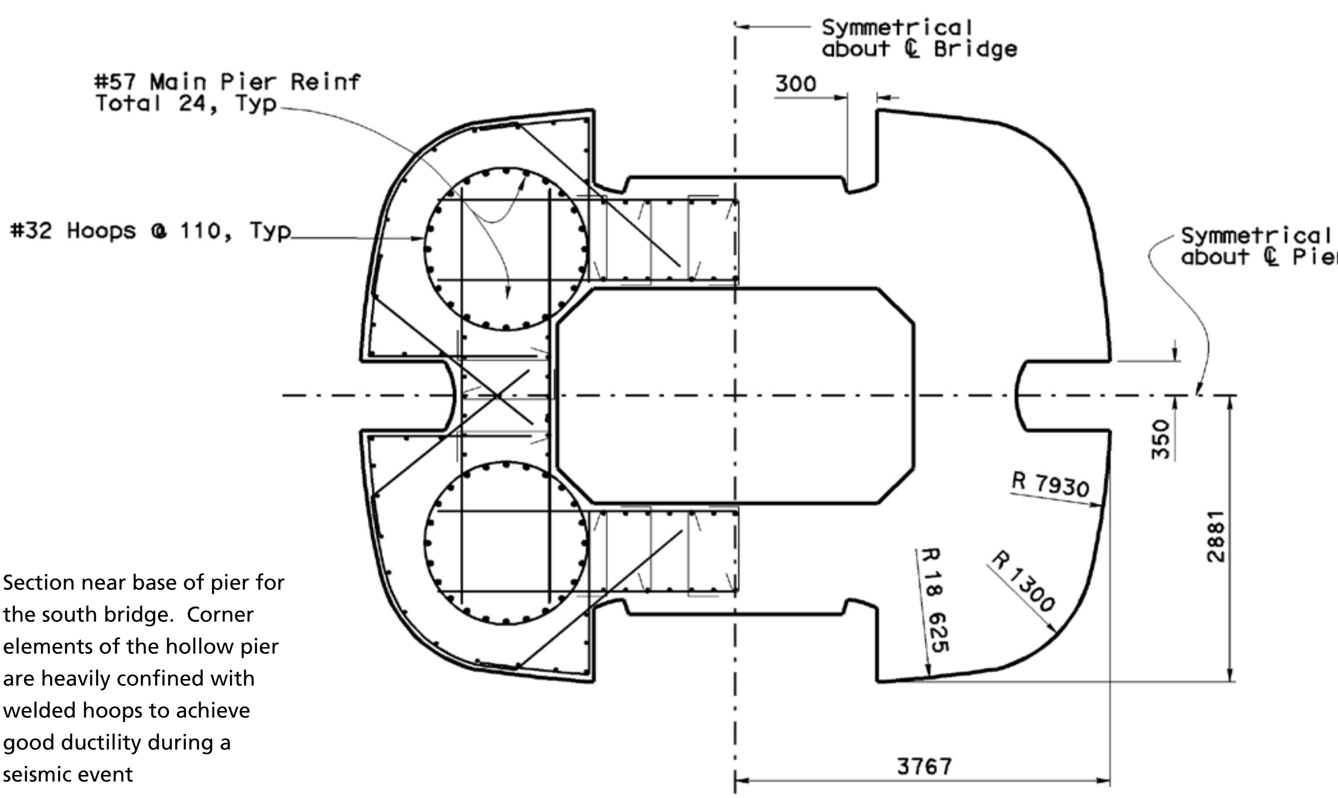
Kevin Harper is a senior bridge engineer with the California Department of Transportation, Sacramento, Calif.

For more information on this or other projects, visit www.aspirebridge.org.

Advertisers Index

Photo: ©Caltrans.





Section near base of pier for the south bridge. Corner elements of the hollow pier are heavily confined with welded hoops to achieve good ductility during a seismic event

Photo: ©Caltrans.

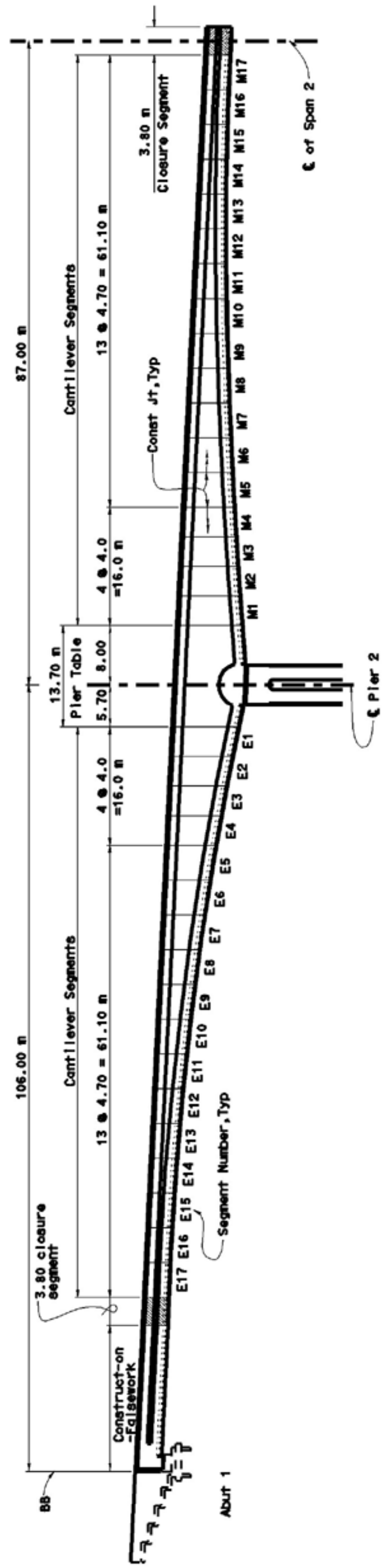


Photo: ©Caltrans.