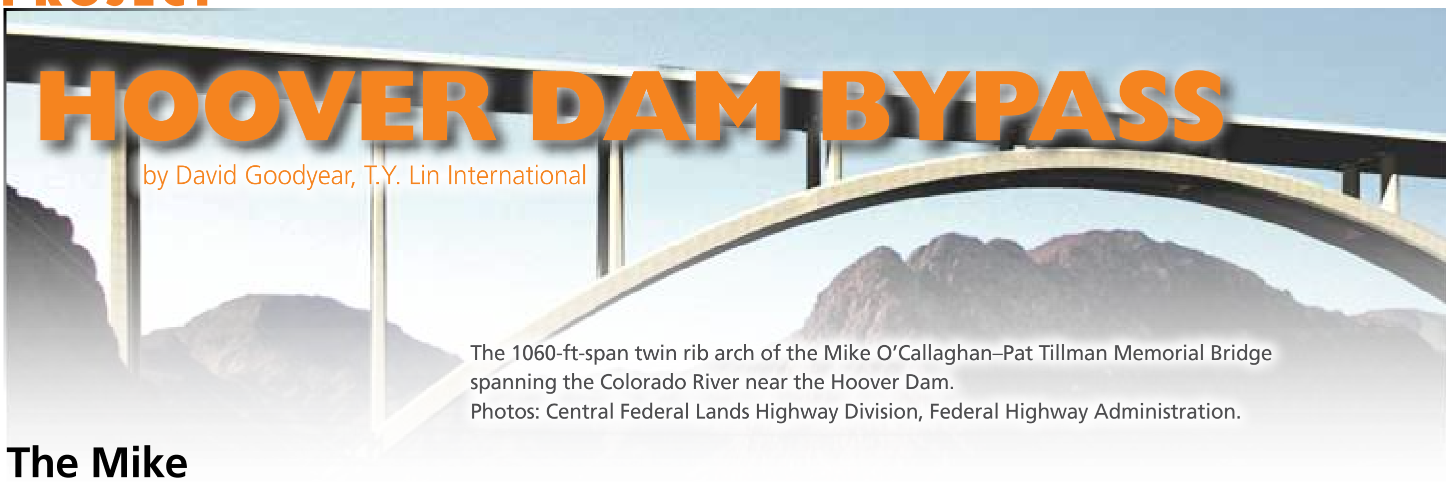
HOOVER DAM BYPASS

by David Goodyear, T.Y. Lin International



The 1060-ft-span twin rib arch of the Mike O'Callaghan–Pat Tillman Memorial Bridge spanning the Colorado River near the Hoover Dam.
Photos: Central Federal Lands Highway Division, Federal Highway Administration.

The Mike O'Callaghan–Pat Tillman Memorial Bridge at Hoover Dam set to open Fall 2010

A project team of five U.S. government agencies, lead by the Central Federal Lands Highway Division of the Federal Highway Administration (CFLHD) collaborated to develop a highway bypass to the existing U.S. Highway 93 over the Hoover Dam. The existing highway route over the dam mixed the throng of tourists for whom the dam is a destination with heavy highway traffic and commercial trucking. The blend of these two created hazards and hardships for both, and served as a bottleneck for commerce along this major north-south route.

Project Development

A consortium of firms working under the moniker of HST (HDR, Sverdrup, and T.Y. Lin International) teamed with specialty sub-consultants and CFLHD to deliver the final design for 1.6 km (1 mile)* of approach roadway in Arizona, 3.5 km (2.2 miles) of roadway in Nevada, and a major 610-m (2000-ft) -long Colorado River crossing about 450 m (1475 ft) downstream of the historic Hoover Dam.

Bridge Type Screening Process

With the selection of an alignment so close to Hoover Dam, the new bridge will be a prominent feature within the Hoover Dam Historic District, sharing the view-shed with one of the most famous engineering landmarks in the United States. The environmental document set a design goal to minimize the height of the new bridge crossing on the horizon when viewed from both the dam and Lake Mead. The State Historic Preservation Officers for both Nevada and Arizona—both members of the Design Advisory Panel—emphasized the need to complement and not compete with the architecture of the dam.

** The Mike O'Callaghan–Pat Tillman Memorial Bridge at Hoover Dam was designed using SI units. Conversions are included for the benefit of the reader.*

CFLHD took full advantage of prior studies and public processes to focus on the alternatives that met all the design objectives. As a result of this screening process, the type study proceeded with only deck arch options.

Major Design Features

The final design went through an evolution of form dictated by the engineering demands on the structure to arrive at the twin rib-framed structure. At the outset of design it was assumed that earthquake loading would control the lateral design of the bridge. A project specific probabilistic seismic hazards analysis was conducted in order to assess the range of ground motion associated with return periods appropriate for design. A 1000-year return period was selected resulting in a design basis peak ground acceleration of 0.2g.

Wind was also a major environmental loading condition from the outset of design. During the preliminary design phase, a site wind study was conducted to correlate the wind speeds at the bridge site with those at the Las Vegas Airport in the valley. With this correlation, the long-term statistics from the airport were used to develop site wind speeds for design. As

profile

MIKE O'CALLAGHAN–PAT TILLMAN MEMORIAL BRIDGE (HOOVER DAM BYPASS, COLORADO RIVER BRIDGE) / BOULDER CITY, NEVADA

BRIDGE DESIGN ENGINEER: T.Y. Lin International, Olympia, Wash., in collaboration with HDR Engineering, Omaha, Neb.

CONSTRUCTION ENGINEERS: OPAC, San Francisco, Calif., and McNary Bergeron, Denver, Colo.

PROJECT DELIVERY: Central Federal Lands Highway Division, Federal Highway Administration, Denver, Colo.

PRIME CONTRACTOR: Obayashi PSM, JV; San Francisco, Calif.

CONCRETE SUPPLIER: Casino Redi-Mix, Las Vegas, Nev.

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

BRIDGE BEARINGS: R.J. Watson, Buffalo, N.Y.

A consortium of firms teamed with specialty sub-consultants and Central Federal Lands Highway Division to deliver the final design.

a result, the 3-second wind speed of 56 m/sec (125 mph) was used. Dynamic studies resulted in a gust loading factor of 2.4, which collectively resulted in wind controlling the design for lateral forces. Therefore, the ensuing design for seismic resistance was based on essentially elastic criteria.

Arch Framing

The 1060-ft-span, 70 MPa (10,100 psi) concrete arch is an efficient element for gravity loads in its final form. There were two aspects of design that resulted in twin ribs instead of a typical single box section for this arch. The first is one of practical construction. A single box would be almost 20 m (66 ft) wide, and weigh approximately 30 metric tons/m (20 kip/ft). This section size would rule out a precast segmental option.

The second aspect is the matter of performance under extreme lateral forces. At the time the framing plan was devised, the level of seismic ground motion had not been determined. A single arch rib would leave no opportunity for tuning stiffness or for providing for frame ductility, whereas twin ribs could provide an excellent means of creating ductile Vierendeel links that could otherwise fully protect the gravity system of the arch.

Spandrel Framing

The composite steel-concrete superstructure was selected for speed of erection and to reduce the weight on the arch. The spacing of spandrels was an extension of the concept to erect the bridge using a highline (tramway) crane system. Above 100 kips, there is a jump in highline cost, so the decision was made to target a 100 kip maximum weight for major superstructure elements. The span was set in the range that a high-line crane could deliver the steel box sections, which resulted in a nominal 37-m (121-ft) span. This span also allows steel girders to be set within the range of most conventional cranes, if an alternative erection system had been selected. The statical system includes sliding bearings for the short, stiff piers over the arch crown, and similar piers near the abutments. This was necessary due to the large secondary moments developed in these piers from creep deflections of the arch, and also produced a more even distribution of longitudinal seismic forces among the piers.

Following closure of the arch, the spandrel columns were set using the high-line crane. Superstructure girders are shown being erected.

Pier Cap Framing

Integral concrete pier caps were selected over steel box cap sections. These provided lateral bracing of the spandrel columns and ultimate stability to the flexible columns in the longitudinal direction. Concrete was selected over steel due to the higher maintenance and inspection costs associated with fracture critical steel diaphragms, even though steel caps might have a lower first cost.

Open Spandrel Crown

An open spandrel crown was selected over the option of an integral crown. A special consideration was that the

CAST-IN-PLACE CONCRETE SEGMENTAL ARCH WITH PRECAST CONCRETE SEGMENTAL COLUMNS / NEVADA AND ARIZONA DEPARTMENTS OF TRANSPORTATION, OWNERS

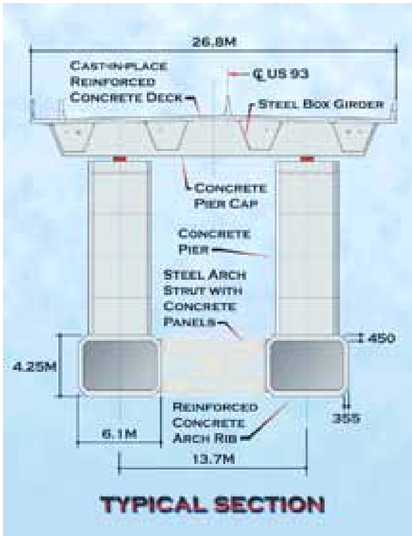
REINFORCEMENT SUPPLIER: Harris Rebar, Phoenix, Ariz.

FORM TRAVELER: NRS, Bangkok, Thailand

BRIDGE DESCRIPTION: A 1900-ft-long bridge over the Colorado River at Hoover Dam, with a 1060-ft-long concrete arch main span, up to 302-ft-tall precast concrete segmental columns, and cast-in-place concrete deck.

STRUCTURAL COMPONENTS: The arch is a twin rib hollow box section with Vierendeel struts connecting the twin ribs. Columns are twin precast concrete segmental box structures. The roadway deck is a steel-concrete composite box girder frame with integral post-tensioned, cast-in-place concrete pier caps.

BRIDGE CONSTRUCTION COST: $114 million



This is a typical section through the twin-rib arch and roadway showing the piers and integral pier cap.

composite steel deck would result in a very abrupt, mechanical looking connection with an integral crown. Equally significant was the high rise of the arch. When studied in either concrete or steel, an integral crown solution looked blocky and massive at the crown, and ran counter to the architectural goal of lightness and openness when viewed from Lake Mead.

Cross Section Forms

The height of the tallest tapered spandrel columns is almost 92 m (302 ft). Wind studies included considerations of drag and vortex shedding on the main structural sections exposed to the long canyon fetch from over Lake Mead. Studies showed that substantial advantage could be gained both in terms of vibration and drag by chamfering the corners of both the columns and the arch. While this adds somewhat to the complexity of construction, the benefit in terms of reduced demand and material savings were substantial.

Construction Methods

As with any large bridge structure, the dead load design is dominated by the assumptions of a construction scheme. The typical approach in the United States is to select an erection scheme, but to show it in the plans only schematically, and defer responsibility for both the scheme and the details to the contractor. The design management team decided that this structure was so unique that the typical approach could prove counterproductive in several respects. A substantial length of time for reviewing and approving an erection scheme might delay the project. The management team also believed that more informed bids could be developed if there was a more complete erection scheme shown with the plans. Therefore, the decision was made to show a complete erection scheme for dead load on the plans and allow the contractors to use that scheme or their own.

Both precast and cast-in-place concrete methods were permitted for the arch and spandrel columns. The contract was written to allow alternative methods of erection, however the columns across the entire bridge were to be of a single type (precast or cast in place) in order to conform to the time-dependent assumptions inherent in design.

Construction

The first challenge for the construction team was creating a foothold for foundation construction. Climbing on the side of the cliff 800 ft over the river below was difficult enough, but excavating (and doing so within the loss limits in the specification) was an incredible challenge. The subcontractor who met this challenge was Ladd Construction from Redding, Calif. They not only met the tight schedule for this work, but completed the excavation allowing about half of the rockfall into the river that was permitted.

Initial bridge construction began with footing and abutment work, and in the precast yard outside of Boulder City where the contractor set up their own facility to precast the columns. Column segments were trucked to the site as needed for erection, and set into place using both the high-line crane and conventional cranes located at the highway hairpin in Nevada.

The first precast pier segment, supported by the high-line crane is erected on its footing.

Four form traveler headings were operated in concert for the cast-in-place concrete arch. After an initial learning curve, the contractor reached a reliable cycle of 2 weeks, and often exceeded that on segments that did not contain a temporary stay for erection.

The arch was closed in August 2009 within an impressive ¾-in. tolerance at closure. Spandrel columns were erected using the high-line crane, and superstructure girders continue to be set. The bridge is scheduled for opening in the Fall 2010.

David Goodyear is senior vice president at T.Y. Lin International, Olympia, Wash.

Progress on construction and additional background can be viewed online at www.hooverdambypass.org.

The tallest of the tapered spandrel columns is almost 92 m (302 ft) tall.

An illustration to show the use of cable stays to construct the arch segments and the position of the high-line crane.