PROJECT

In Harmony with Nature

by Fred Doehring, Utah Department of Transportation and Stephen E. Fultz, Figg Bridge Engineers

Construction was completed in December 2010, on the U.S. 191 Colorado River Bridge in Moab, Utah, the state's first concrete segmental bridge. The bridge's sustainable design kept the focus on the natural wonder of the environment. All photos: ©Figg Bridge Engineers.

Utah's first segmental bridge constructed from above to minimize impact on scenic national park

The new U.S. 191 Bridge over the Colorado River in Moab, Utah, blends with the spectacular Canyonlands region and offers a number of features to ensure that the landscape remained pristine during and after construction. The state's first segmental concrete bridge was constructed in a way that allowed continual recreational use of the river and surrounding area during construction. Long spans ensured a minimal bridge footprint, while a unique public involvement process provided a context-sensitive design representative of the community's vision.

The pristine environment surrounding Moab was acknowledged in the solution by the Utah Department of Transportation (UDOT) and Figg Bridge Engineers. The twin, 1022-ft-long bridges consist of cast-in-place, post-tensioned concrete segmental structures built from above using the balanced cantilever method of construction to protect the environment. Piers and abutments were staggered 38 ft to align the substructure with the river-flow direction, which is skewed to the roadway alignment. The bridges are 39 ft 10 in. wide including two 12-ft-wide lanes, a 7-ft-wide outside shoulder and a 6-ft-wide inside shoulder. Pedestrians, mountain bikers, and casual riders are separated from the highway traffic by using a new pedestrian bridge upstream.

Unique Site Characteristics

The bridge is in one of the most high-profile locations in the region, drawing more than 1.5 million visitors a year to its picturesque landscapes. It provides a gateway to Arches National Park, Canyonlands National Park, Dead Horse Point State Park, and the Sand Flats Recreation Area.

Designated wetlands along the south bank required careful consideration. In addition, water levels in the river can vary greatly, historically causing flooding of the Moab Valley. Flows in excess of 100,000 ft^3/sec have been recorded at the bridge site. The design had to accommodate seasonal variations in water-surface elevation of more than 15 ft. A site-specific hydraulic analysis completed for the project ensures that the new bridge

profile

COLORADO RIVER BRIDGE / MOAB, UTAH

ENGINEER: Figg Bridge Engineers, Denver, Colo.

CONSTRUCTION ENGINEERING AND INSPECTION: Figg Bridge Engineers, Denver, Colo.

ROADWAY ENGINEERS: Lochner, Salt Lake City, Utah

SURVEY, ROW, AND GEOTECHNICAL ENGINEERING: RB&G Engineering, Provo, Utah

PRIME CONTRACTOR: Wadsworth Brothers Construction, Draper, Utah

CONCRETE SUPPLIER: Legrand Johnson, Moab, Utah

POST-TENSIONING CONTRACTOR: DYWIDAG-Systems International USA Inc., Bolingbrook, Ill.

will survive the predicted 500-year event. The river also is home to several endangered fish species. Construction activities that disturb the river cannot be conducted during the fish-spawning season of May through August.

Segmental Solution

To meet these challenges, a three-span, segmental bridge was selected using cast-in-place, single cell, concrete trapezoidal box girders. The spans consist of two 292-ft-long end spans and a 438-ft-long main span. The superstructure depth varies from 19 ft 2½ in. to 9 ft 2½ in. The deck varies in thickness from 11½ in. at the center and wing tips to 1 ft 8½ in. over the webs. The deck thickness includes a 2½ in. integral wearing surface. Webs are typically 1 ft 2 in. thick, and the bottom slab varies in thickness from 9 in. at midspan and near the abutments to 3 ft 0 in. at the piers.

The design creates open space beneath the bridge and minimizes its footprint. Only one pier of each structure is located in the river, strategically placed to maintain the navigational channel. The other pier is located well outside the channel and adjacent wetlands, which streamlined the permitting process. Long side spans allow enhanced and new trails beneath the bridge at each end.

Building from above using balanced cantilevers, construction began with 45-ft-long sections of the superstructure atop each pier. These "pier tables" serve as launching points for form travelers that advance horizontally away from each pier to construct segments of the bridge. Casting in an alternating fashion, first on one side of the pier and then on the other, ensured that pier-construction loads remained balanced.

The segmental concrete design eliminated the need for large ground-based equipment, which would have been difficult to place. The river conditions are often less than 5 ft deep in winter and more than 20 ft deep in summer. This would have made construction of other bridge types difficult. UDOT also benefited from the sustainable, low-maintenance nature of this bridge type, which features bi-directional post-tensioning.

Substructures and Materials

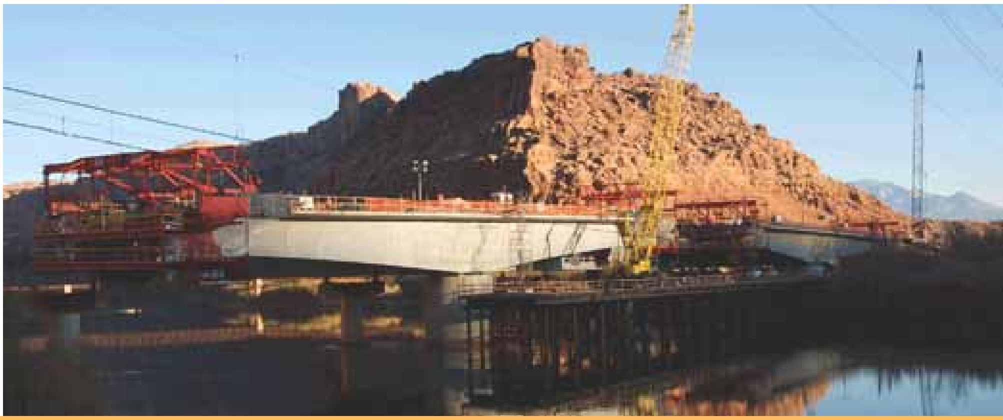
The southbound bridge was constructed adjacent to the existing bridge, which continued in operation during this initial phase. The work began with 7-ft diameter, 150-ft-long drilled shafts for the land pier (Pier 3) using polymer slurry. The 7-ft-diameter, 100-ft-long shafts for Pier 2 in the river were installed after completion of a cofferdam and used oscillator casings.

Footings at the piers are 30 ft square and 8 ft thick. A mass concrete plan ensured controlled thermal stresses arising from the heat of hydration. A 4000 psi compressive strength concrete with Type II cement mixture and 30% Class F fly ash was specified for piers and foundations. Concretes were tested for chloride permeability to make sure they fell within the "low" range for long-term durability.

Features ensured that the landscape remained pristine during and after construction.

Cylindrical columns 24 ft in diameter were selected for aesthetics and to facilitate a four-bearing configuration, eliminating the need for temporary works during cantilever construction. The circular profile also enhanced pier-shape characteristics against the river flow. Piers were cast hollow and filled with concrete flow-fill, eliminating mass concrete concerns. Pier 2 on the south bank is 13 ft tall, while Pier 3 in the river is 33 ft tall.

The construction of a temporary causeway and work trestle over the floodplain and river was completed as the foundation work progressed. It had to be accomplished before the May-to-August restriction on work in the river began due to fish habitat concerns.



Balanced cantilever construction extended out from both sides of the single river pier to create long, arching spans of 438 ft over the water that protected the environment below.

TWIN, 1022-FT-LONG, THREE-SPAN SEGMENTAL CAST-IN-PLACE CONCRETE BOX-GIRDER BRIDGES / UTAH DEPARTMENT OF TRANSPORTATION, OWNER

REINFORCING STEEL: Masco Inc., Centerville, Utah

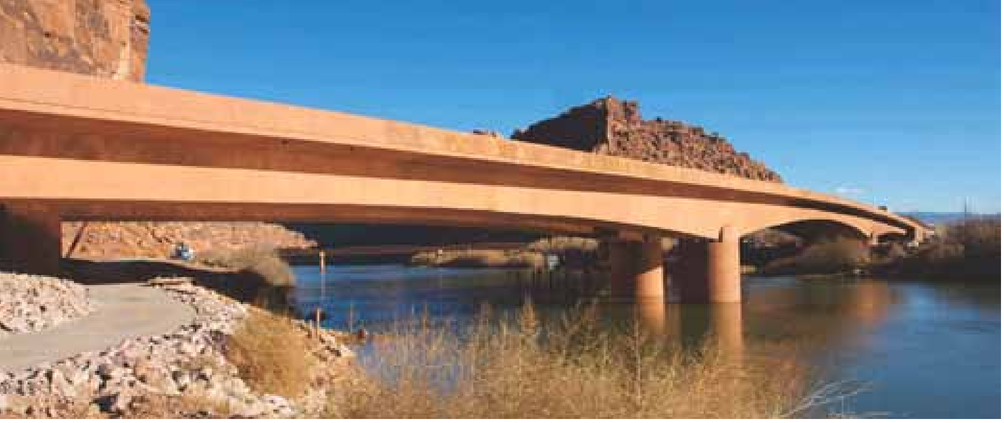
EPOXY-COATED REINFORCING STEEL: Western Coating, Ogdan, Utah

FORM TRAVELERS: NRS-USA, Aventura, Fla.

BRIDGE DESCRIPTION: Twin, three-span, cast-in-place concrete segmental box-girder bridges with end spans of 292 ft and a center span of 438 ft, built with form travelers to minimize impact on the environment

BRIDGE CONSTRUCTION COST: $25.9 million

AWARDS: Roads & Bridges *Top Ten, 2010*



Only one pier of the 1022-ft-long structure is located in the river, strategically placed to maintain the navigational channel preferred by recreational users. The other pier is located well outside the channel and adjacent wetlands.

Superstructure

A minimum concrete compressive strength of 6000 psi was required by the design with high-performance concrete specified to ensure long-term durability. The concrete contained 30% Class F fly ash and was pumped from the shore area and from the work trestle as needed. The segments were 16 ft 6 in. long. Concrete was cured in all weather conditions using curing compound, heating, and insulating blankets. High early strength concrete was critical to the contractor's production schedule, with stressing and traveler-launching strengths achieved in less than 36 hours.

Once the southbound bridge was constructed, the original structure was demolished and the northbound bridge was built in its location, following the same procedure. The form traveler and forms were used for the 6-ft closure segments joining the cantilevers together over the river. End sections of the bridge were cast on falsework at each abutment.

The closure segment in Span 1, on the south side, was completed first, followed by the Span 3 segment on the north side. Finally, the main-span closure was completed in Span 2. Once closures were cast, the continuity tendons were post-tensioned.

Post-Tensioning

Longitudinal top-slab cantilever post-tensioning tendons were embedded in the deck and anchored on each segment face. Fifty 12 x 0.6-in.-diameter strand tendons were used in each cantilever, with 25 over each girder web. Six 27 x 0.6-in.-diameter strand external continuity tendons were used in the box girder, three per web, in each span. Bottom slab continuity tendons consisted of 12 x 0.6-in.-diameter strands embedded in the bottom slab with 6 tendons used in the end spans and 14 tendons used in the main span. Transverse tendons in the deck comprised 4 x 0.6-in.-diameter strands spaced typically at 3 ft $3\frac{5}{8}$ in. centers.

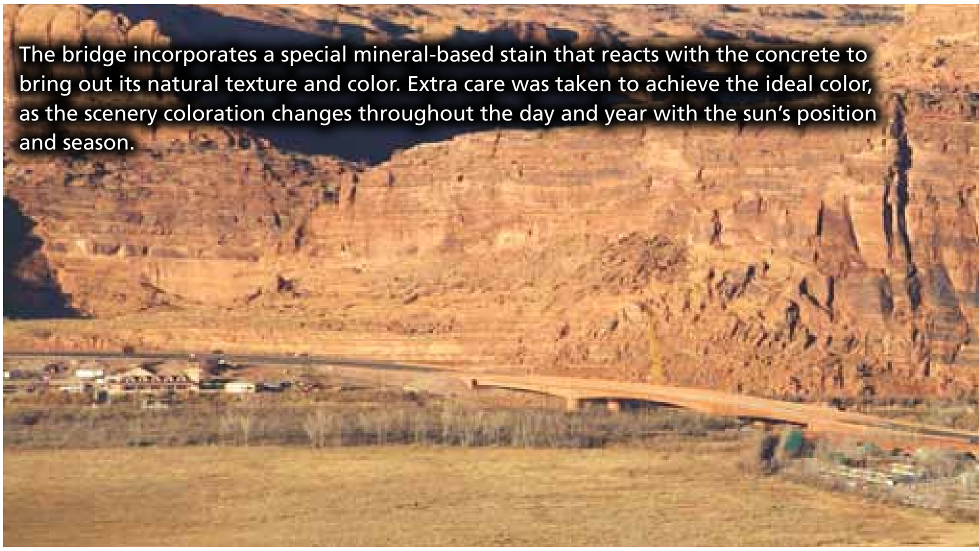
Cost-Effective Design

A cost-plus-time format determined the winning bidder in accordance with UDOT's statewide focus on accelerated bridge construction. The low bid saved UDOT $3.1 million compared to the engineer's estimate. The bid schedule of 659 days was met with 18 days to spare, completing work in early December 2010. That was accomplished despite construction taking place during the coldest Moab winter in more than 40 years, with consistent below-zero temperatures.

Bridge Blends In

The bridge's aesthetic goals were designed to blend the structure with the scenery as much as possible rather than allow it to serve as a focal point. To achieve this, a special mineral-based

Long, sweeping spans, stone textures on the piers, smooth barrier details, and bridge colors were selected by the Moab community during special feedback sessions early in the design process.



The bridge incorporates a special mineral-based stain that reacts with the concrete to bring out its natural texture and color. Extra care was taken to achieve the ideal color, as the scenery coloration changes throughout the day and year with the sun's position and season.

stain that reacts with concrete was used to bring out the natural texture and color of the concrete. Extra care was taken to achieve the ideal color, as the scenery coloration changes throughout the day and year with the sun's position and season. Formliners also were used to create a rock texture on the mechanically-stabilized earth wall panels and piers matching the texture of nearby canyon wall relief, providing a natural rock appearance for river and trail users.

Long concrete spans, efficiently combined with post-tensioned segmental technology, resulted in a delicate footprint, and building from above protected the cherished environment during construction. Balanced cantilever construction allowed for continual recreation on the river, which was important to this region of outdoor enthusiasts. The cast-in-place segmental post-tensioned concrete box girders will offer long service life, resulting in low life-cycle cost for the citizens of Utah.

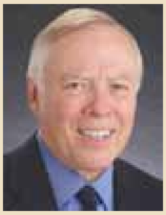
Fred Doehring is deputy bridge design engineer for the Utah Department of Transportation in Salt Lake City, Utah, and Stephen E. Fultz is assistant regional director with Figg Bridge Engineers in Denver, Colo.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

Visual Sensitivity

A guiding theme of "A Bridge in Harmony with Nature" shaped the context-sensitive design. A stakeholder group representing the community guided the design to ensure realization of the community's vision. Stakeholders included in the discussions included city and county leaders, property owners, businesses, the Lions Club, the Bureau of Land Management, the National Park Service (including Arches), and the Moab Trails Alliance.

The arching shape of the variable-depth superstructure reflects the spirit of nearby Landscape Arch, a prominent feature in Arches National Park. Bridge piers were located to avoid the trail network, and overhead construction allowed trail use and many recreational events to continue during construction.



AESTHETICS COMMENTARY

by Frederick Gottemoeller

Low and close to the Colorado River, surrounded by stunning high desert buttes and rock formations, this bridge occupies a very small part of the total visual field. Its designers were wise to design it so that it seems to be an integral part of the topography. Its most obvious feature, its color, captures the color of the surrounding rocks perfectly.

But, there's more. The girder is very well proportioned. The significant difference in girder depth between haunch and midspan, and end spans makes visible the concentration of forces over the piers. The clear desert sunlight causes the overhang to cast a deep shadow across the top of the girder that makes the midspan and end spans seem even thinner. The piers are too short to make a visual statement on their own, so the designer has not made the attempt. Instead, the piers have been designed as simple cylinders. They are notched at their tops and seem to cradle the haunches. As a result, they act as visual foils for the girder. Their visual mass contrasts with the relative thinness of the girder, reinforcing its delicate appearance.

Because the bridge is so low to the water, the view of the bridge interacts with its own reflection, which reinforces initial impressions. Altogether the bridge seems delicate, almost liquid, a fitting contrast to the robust formations in the background.

Bridges don't always have to be foreground elements. Sometimes it is best when they just blend in, become a part of a beautiful scene that was strong before they got there, and is strong still.

Snow covers the mountain landscape in Moab, showcasing the elegant, graceful curves of Utah's longest concrete bridge span.