PROJECT

BLACK CANYON ROAD BRIDGE

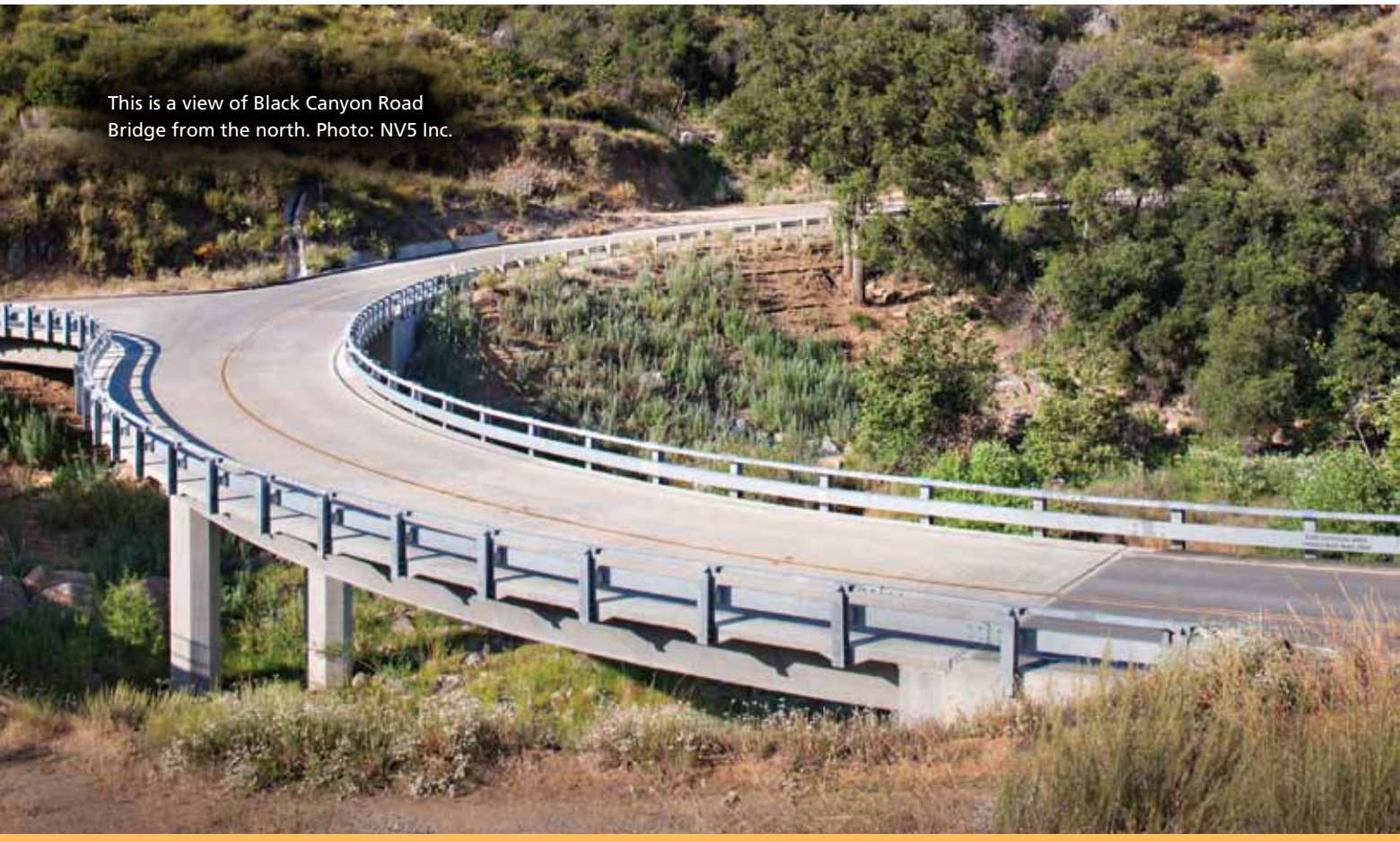
by Christopher Krier and Jack Abcarius, NV5 Inc.

Black Canyon Road passes through Cleveland National Forest in San Diego County, Calif., and serves as the main access point between the Mesa Grande Band of Mission Indians Reservation and the unincorporated community of Ramona. The Black Canyon Road Bridge spans a steep canyon over Santa Ysabel Creek downstream of Sutherland Dam and provides an aesthetically pleasing structure.

Geometry

Black Canyon Road Bridge is a two-span, cast-in-place, conventionally reinforced, concrete box girder bridge that carries two lanes of traffic on a tight 150-ft-radius horizontal curve. It is 175 ft long, typically 28 ft wide, and has no sidewalks. The midpoint pier consists of two 4-ft-wide, octagonal columns with a clear height of about 20 ft. The columns are supported by two 8 ft 6 in.-square by 3-ft-thick footings that are formed into the underlying rock layer.

Five, 3-ft-diameter, cast-in, drilled-hole (CIDH) piles support each abutment, and the extension at abutment 1 is supported by an additional four, 3-ft-diameter CIDH piles. The CIDH piles have nine, two-bar bundles of No. 8 longitudinal bars and No. 5



This is a view of Black Canyon Road Bridge from the north. Photo: NV5 Inc.

profile

BLACK CANYON ROAD BRIDGE / SAN DIEGO COUNTY, CALIFORNIA

BRIDGE DESIGN ENGINEER: NV5 Inc., San Diego, Calif.

CIVIL DESIGN ENGINEER: Southern California Soil & Testing Inc., San Diego, Calif.

PRIME CONTRACTOR: Weir Construction Corporation, Escondido, Calif.

CAST-IN PLACE CONCRETE SUPPLIER: Vulcan Materials Company, Chula Vista, Calif.

Looking north at the completed Black Canyon Road Bridge and the original structure. The original structure will be used by non-motorized traffic. Photo: County of San Diego.

From below, shown is the framing between Sutherland Dam Road and Black Canyon Road. Photo: County of San Diego.

hoops at 6 in. on center for transverse reinforcement. The west wingwalls at both abutments are supported by a 2-ft-diameter CIDH pile due to their length, while the east wingwalls are typical cantilever-type wingwalls. The bridge is also located on the sag of a vertical curve and is superelevated with a 2% cross slope.

The 4-ft 9-in.-deep box girder consists of three bays with a maximum center-to-center web spacing of 7 ft. The box girder web thickness is 10 in. typical, and the top slab and soffit slab are 7½ in. and 6 in. thick, respectively. The exterior web on the east edge of the bridge flares to 12 in. where it intersects the dual 12-in.-thick deck extension girders. Concrete for the substructure had a specified compressive strength of 3.6 ksi and the superstructure concrete was specified for 4.0 ksi.

The owner designed the approach roadway using the smallest-allowable cross-sectional width per AASHTO standards to minimize the impact on the environment.

A California Environmental Quality Act clearance with a Mitigated Negative Declaration document was processed and approved. The mitigation required the owner to obtain the necessary U.S. Army Corps and State Fish and Game Permits, and specified certain items for mitigation.

One item in particular was the Visual Impact Assessment recommendation for the use of an open railing design to maintain an unobstructed view of the surroundings. The design team worked with Caltrans reviewers to allow the use of an open rail system using a Type 18 railing with modifications to make the system comply with today's FHWA standards.

Maintaining History

The bridge replaces an existing true three-hinged arch structure that was built in 1913. It is one of only a handful of remaining three-hinged arch structures, so the original bridge is considered to be a local historic landmark. For this reason, the original structure was left in place and can be enjoyed by non-motorized traffic at all times.

The initial replacement design was completed by the County of San Diego in the mid 1990s prior to the establishment of the Caltrans Seismic Design Criteria (SDC). The design plans were set aside until the project was funded. In 2007, when funding was secured, the engineer was tasked to incorporate all requirements of the SDC, while maintaining the layout and configuration of the initial design to the maximum extent possible. This allowed the owner to avoid the preparation of a new environmental document.

In order to maintain the original bridge footprint, engineers were creative in their approach to the design. They worked with the owner and Caltrans to develop special criteria for this rural road because the existing site constraints

Intersection of Black Canyon Road and Sutherland Dam Road. Photo: County of San Diego.

COUNTY OF SAN DIEGO, OWNER

BRIDGE DESCRIPTION: Two-span, 175-ft-long, variable width, three-cell, cast-in-place, conventionally reinforced box girder bridge

STRUCTURAL COMPONENTS: 4-ft 9-in.-deep box girders; 4 ft 0 in. octagonal columns on spread footings; seat type abutments on CIDH piles; and concrete deck extension with two, 1-ft 0-in.-wide by 3-ft 9-in.-deep deck extension girders

BRIDGE CONSTRUCTION COST: $1.672 million ($301/ft^2)

AWARDS: American Society of Civil Engineers San Diego Chapter, 2011 Outstanding Project of the Year Award; American Public Works Association San Diego Chapter, 2011 Honor Award

on the proposed geometrics did not allow for the use of the Public Road Standards and Bridge Design Standards. Using the agreed upon layout, the main structure was designed with a 150 ft radius ending at the southern abutment with a 30 ft reversing curve to tie into Sutherland Dam Road.

To minimize the impacts even further, the abutments were placed as close to the channel as possible. Because of this, the abutment piles were designed to be exposed and web walls were proposed and designed to be constructed between the piles. These web walls were doweled into the piles and support the abutment backfill to maintain structural integrity of the abutment systems.

Deck placement using special concrete screed. Photo: County of San Diego.

Challenges

The bridge profile had ample freeboard available so the engineer also recommended the use of a conventionally reinforced concrete, box girder bridge rather than the post-tensioned concrete box girder proposed in the initial design. This revision eliminated potential challenges with post-tensioning on a very tight radius and precluded special detailing of the girders to avoid "bursting" forces during and after post-tensioning.

Engineers also proposed changing bent 2 from a fixed, single column with a massive footing to a two-column bent configuration. This enabled the design of a pinned connection at the base of the columns, which greatly reduced the size of the footings. In turn, this reduced the amount of earthwork in the channel, which was going to be very difficult due to the rocky terrain, and greatly reduced the overall construction cost.

The most interesting design feature was the deck extension at abutment 1. Black Canyon Road intersects Sutherland Dam Road immediately adjacent to that abutment. In order to connect Black Canyon Road and Sutherland Dam Road, abutment 1 and the bridge deck surface had to be extended to the east with a reversing curve. That portion of the bridge deck was designed using two, 3-ft 9-in.-deep, concrete T-girders that extend from the exterior girder of the concrete box to the diaphragm of the extended portion of abutment 1. This deck extension support system prevented a major change in the bridge layout, but in order to meet the design schedule and satisfy all of Caltrans bridge requirements, a unique deck extension design criterion that was agreeable to the design reviewers was created.

A live load trace envelope was used to determine the critical location of the design vehicle on the deck extension. Then, rather than distributing the dead load and live load from the deck extension equally among all four main bridge girders, the special criterion considered a larger proportion of those loads to act on the exterior girder of the bridge. This resulted in a special reinforcement detail for the exterior girder nearest the deck extension.

The radius of the structure also required some extra attention while detailing the longitudinal deck reinforcement and the shear reinforcement for the girders. Because the bridge girders on the interior of the radius are shorter than those on the exterior, a unique reinforcement arrangement was required for each girder. Special reinforcement details were also required for the intersections of the deck extension girders, the abutment diaphragm extension, and the exterior bridge girder.

During construction, the existing rock profile at abutment 1 varied significantly from that expected. This resulted in some piles being much longer or shorter than anticipated. The engineer quickly performed a revised foundation analysis and a rigidity analysis to account for force concentrations in the shorter piles, and then coordinated with the geotechnical engineer to determine new pile demands. The necessary details for the supplemental reinforcement were prepared without delay to the contractor to avoid potential claims.

Other construction issues included challenges caused by the reversing curve at abutment 1. The contractor had to use a special screed during placement of the concrete deck because the setup of the standard mechanical screed machine on rails would not work with the tight radii and varying deck width. The contractor also had to construct special formwork to accommodate the deck extension and the intersection between the deck extension girders and the exterior bridge girder.

All Ends Well

When Caltrans designated the original bridge as structurally deficient with an overall sufficiency rating of 16.5, and the approach roadway geometrics did not meet current design standards, a replacement structure was needed. The new Black Canyon Road Bridge provides a functional solution, and also serves as a focal point in an area known for hiking, bird watching, horse-riding, and other outdoor activities.

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