PROJECT

FOOTHILLS BRIDGE NO. 2

Filling in the "Missing Link"

by John Corven, Corven Engineering Inc., in cooperation with the Eastern Federal Lands Highway Division, Federal Highway Administration

Durability for 100+ Years

Enhanced durability measures used on Foothill Bridge No. 2 included the following:

- Post-tensioning design for no longitudinal or top slab transverse tension under service loads
- Concrete with a high cementitious materials content including fly ash for reduced permeability
- Post-tensioning details and corrosion protection system to enhance durability
- Post-tensioning system installed, stressed, and grouted by certified technicians
- High-performance concrete overlay for an additional layer of protection

The Foothills Parkway was authorized by Congress in 1944 to provide beautiful vistas of the Great Smoky Mountains National Park from the Tennessee side of the park. The *missing link* of the Foothills Parkway is a particularly rugged 1.6-mile stretch of the Foothills Parkway traversing steep mountain-sides that overlook Wears Valley, Tenn.

Foothills Bridge No. 2, is located in Blount County, Tenn., approximately 10 miles west of the north entrance to the Great Smoky Mountains National Park. Construction of this bridge is instrumental to completing the missing link in that it crosses the most difficult terrain and is needed to access the construction of the missing link.

Project Development

The Eastern Federal Lands Highway Division (EFLHD) bridge staff prepared the preliminary design for the Foothills Bridge No. 2. The design envisioned a precast concrete segmental, single-cell, box-girder bridge, built with minimum disruption to the site. The Recovery and Reinvestment Act of 2009 provided needed construction funding for the project, and the National Park Service (NPS), Federal Highway Administration (FHWA), and EFLHD moved to develop the project in a design-build format.

Bridge Layout

The new Foothills Parkway Bridge No. 2 is a 790-ft-long precast concrete segmental bridge built using the balanced cantilever method of construction. Lengths of the five spans of the bridge are 125 ft, three at 180 ft, and 125 ft. The bridge follows an S-shaped alignment with curve radii of 262 and 650 ft. Superelevations vary from 7.8% (right) to 5.8% (left) over the length of the bridge. The vertical profile of the bridge begins at a +6.75% grade and transitions through a vertical curve to a +8.02% grade.

The superstructure of the bridge is a 9-ft-deep single-cell, precast concrete segmental box girder with a top slab width of 36 ft 10 in. The width of the segment bottom slab is 16 ft. The slope of the 1-ft 4-in.-thick webs is one horizontal to three vertical. The thickness of the top slab is 9 in. at the cantilever wing tips and in the middle of the top slab, and 1 ft 6 in. at the faces of the webs. The top slabs of the segments were transversely post-tensioned in the casting yard with two tendons consisting of four 0.6-in.-diameter strands.

profile

FOOTHILLS BRIDGE NO. 2 / BLOUNT COUNTY, TENNESSEE

BRIDGE DESIGN ENGINEER: Corven Engineering Inc., Tallahassee, Fla.

PRIME CONTRACTOR: Bell and Associates Construction, Brentwood, Tenn.

CIVIL AND ENVIRONMENTAL ENGINEER: Palmer Engineering, Winchester, Ky.

GEOTECHNICAL AND FOUNDATION ENGINEERING: Dan Brown and Associates, Sequatchie, Tenn.

PRECASTER: Ross Prestressed Concrete Inc., Knoxville, Tenn., a PCI-certified producer

SEGMENT ERECTION AND POST-TENSIONING CONTRACTOR: VSL, Hanover, Md.

Precast segments were cast using the short-line casting method. All photos: Federal Highway Administration.

The segments were trucked 40 miles from the casting yard to the bridge site.

The typical segment length for the project is 8 ft 8 in. The resulting weight of the typical segments is 45 tons. Pier and abutment segments are 5 ft long. This shorter length along with the added weight of the diaphragm concrete produces a segment weight of 40 tons. A total of 92 segments were required. Special effort was expended to produce a consistently dark tinted concrete color to match the desire of the NPS for the segments to blend into the mountainside.

The piers of the new Foothills Parkway Bridge No. 2 also were comprised of precast concrete segments. The typical cross section of the pier is a 6 ft 6 in. by 10 ft oval. At the top of the piers, the width of the oval increases from 10 to 16 ft to match the width of the bottom slab. The wall thickness of the typical precast concrete column segments is 1 ft. The heights of the column segments vary from 5 to 7 ft. Twenty substructure segments were required.

The precast concrete segmental piers are supported by 5-ft-thick, 20-ft-diameter, circular reinforced concrete footings. The footings of the bridge are elevated and exposed to reduce rock excavation. Sub-footing concrete cast to follow tiered excavation provides a working platform for drilling micropiles and constructing the footings. The exposed faces of the sub-footing and footings are faced with granite matching parkway standards.

The foundations of the proposed bridge consist of $9\frac{5}{8}$-in.-diameter micropiles. Twenty micropiles, each with a capacity of 160 tons, are used to support each pier and are arranged in a circular pattern with a 17 ft diameter. Inclined tie-backs are installed at piers 1 and 2 to resist lateral earth pressures related to potential downslope movement of soils overburdening stable rock.

Two elastomeric bearings are used to support the superstructure at each pier. Disc bearings are used at the abutments.

Bridge Construction

Site access only from the beginning of the bridge and steep terrain along the entire length of the alignment would have suggested progressive segment erection similar to that used on the Linn Cove Viaduct. Unfortunately, this strictly linear approach to construction would not permit the bridge to be completed within the project schedule. A new approach to construction was required that allowed various aspects of construction to be performed concurrently.

The resulting construction methodology incorporated a unique temporary work trestle that provided access along the entire bridge alignment. The work trestle was unique in that it could be reconfigured as work shifted from foundation and pier work to superstructure segment erection.

In the superstructure erection configuration, a specialized segment walker placed segments in balanced cantilever, significantly increasing erection speed over one-direction progressive placement methods.

The supports of the work trestle were rigid frames comprised of two steel pipe columns and a transverse steel girder. Each pipe column was supported by three, 7-in.-diameter micropiles and a precast concrete triangular footing. Longitudinal members of the temporary

NATIONAL PARK SERVICE, OWNER

BRIDGE DESCRIPTION: 790-ft-long, five-span, single-cell, precast concrete segmental bridge built using the balanced cantilever method of construction

STRUCTURAL COMPONENTS: 92 precast superstructure segments, 20 precast substructure segments, cast-in-place footings and micropiles, and cast-in-place concrete deck overlay

The temporary work trestle construction advances from right to left. A secondary crane provides access for foundations and pier construction.

View below the temporary work trestle, as pier 1 footing is formed on top of the sub-footing concrete.

work trestle consisted of two rows of paired steel girders. The transverse spacing of the girder pairs was adjusted depending on the configuration of the work trestle.

During trestle construction, the girder pairs were spaced closer together to support the tracks of the crawler crane that erected the gantry. The spacing of the girder pairs was increased during superstructure segment placement to support the segment walker designed to pass the already constructed portions of the bridge.

Bridge construction began with the building of abutment 1. From there, the trestle erection crane placed drilling equipment at the first work trestle support and micro-piles were installed. The crane then placed the precast concrete footings, support frames, and longitudinal girders. Crane mats were placed over the longitudinal girders to form the deck of the work trestle. The crane then crawled forward, and this sequence was repeated until the 22 spans of the trestle were complete.

When work trestle construction had advanced beyond pier 1, sections of the crane mat over pier 1 were set to the side and a secondary, tire mounted 60-ton crane lowered excavation equipment to make the tiered cut for the sub-footings. When complete, the sub-footing was formed and cast. The secondary crane then lowered the equipment to drill through the sub-footing concrete for the micro-piles that support the pier. Inclined tie-backs, used to provide slope stability were also drilled through the sub-footing. Footing construction followed the installation of the micro-piles and tie-backs.

The secondary crane also placed the pier segments. Individual segments were epoxy-joined and stressed together with four, $1^3/_8$-in.-diameter, 150 ksi post-tensioning bars. All segments of the pier with the exception of the pier cap were erected at this time.

Pier cap placement and balanced cantilever construction began once all typical segments of pier 1 were placed using the segment walker. The segment walker also placed the four-legged cantilever construction stability tower on the footing of pier 1.

Cantilever construction continued until all 20 of the precast concrete segments of the balanced cantilever were erected. The segments were epoxy-joined and stressed to the cantilever with three, 1¼-in.-diameter, 150-ksi post-tensioning bars. Two of the bars were anchored in blisters cast with the segments, and could be removed and reused. The bottom bar was internal and became a part of the permanent post-tensioning system. Once each segment was assembled, the cantilever post-tensioning consisting of two tendons with twelve 0.6-in.-diameter strands each were stressed. Cantilevers at piers 2, 3, and 4 were constructed in similar fashion.

Superstructure continuity was made between cantilevers with cast-in-place concrete closure joints and continuity post-tensioning tendons. Ten tendons with twelve 0.6-in.-diameter strands each (eight bottom and two top tendons) were stressed across each closure joint. End spans were completed by placing three additional typical segments and the abutment segments, casting closure joints, and stressing continuity tendons.

The segment walker places a segment at pier 3.

Completed construction of the major bridge elements.

The innovative design-build approach successfully achieved the goals of the NPS, FHWA, and EFLHD. Environmental impacts were limited to selective tree toppings and minimized disturbance of fragile top soils. Remaining work, including railing and overlay, was completed in September 2012.

John Corven is president and chief bridge engineer at Corven Engineering Inc., Tallahassee, Fla.

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