PROJECT

The Bronco Arch Bridge

Design and construction of the replacement for the I-25 Bridge over the South Platte River

by Gregg A. Reese, Summit Engineering Group Inc.

The new Bronco Arch Bridge spans the South Platte River near Mile High Stadium in Denver, Colo. All Photos: Summit Engineering Group Inc.

The I-25 Bridge over the South Platte River has been a Denver landmark structure since its initial construction in 1951. The steel arches, supporting the bridge superstructure, became known as the Bronco Arches after the Denver Broncos began playing football in the adjacent Mile High Stadium in 1960.

Today the bridge carries over 200,000 vehicles per day. After many years of service the bridge deck, superstructure, and supporting arches became seriously deteriorated resulting in the bridge having one of the lowest sufficiency ratings in Colorado.

A new replacement bridge, designed by the Colorado Department of Transportation (CDOT), was bid in March 2011. The new bridge is 371 ft long and 197 ft wide to accommodate four through lanes of traffic in each direction as well as acceleration lanes and on and off ramps. The superstructure consists of three spans with eight parallel girder lines with skewed abutments at each end.

Value Engineering Proposal

The contractor requested that CDOT consider a number of value-engineering proposals that would enhance the design of the bridge, reduce the number of stages of construction, shorten the schedule, and greatly reduce the impact on existing traffic. CDOT recognized that the value-engineering proposals suggested by the contractor would result in less disruption and a shorter schedule and allowed them to proceed.

Because the project was bid prior to performing any preliminary value engineering, the designs had to be accomplished within the overall project construction schedule to avoid delays. To accomplish this, a design schedule was established with priorities driven by the construction schedule.

profile

BRONCO ARCH BRIDGE / DENVER, COLO.

BRIDGE DESIGN AND CONSTRUCTION ENGINEER: Summit Engineering Group Inc., Littleton, Colo.

PRIME CONTRACTOR: Lawrence Construction Co., Littleton, Colo.

PRECASTER: Plum Creek Precast, Littleton, Colo., a PCI-certified producer

POST-TENSIONING CONTRACTOR: VSL, Denver, Colo.

The piers are arched to simulate the look of the original arch bridge.

Structural Concept

The new design retained the original number of girder lines, girder spacing, cross section, and the full-depth precast concrete deck system. Heights and locations of all retaining walls remained the same.

The new bridge structure was designed as a rigid frame with integral connections between the substructure and superstructure and assuming flexible foundations. All permanent bearings were eliminated. The revised superstructure framing consisted of a transversely pretensioned and longitudinal post-tensioned, precast concrete deck slab supported on continuous, post-tensioned girder lines during construction. The use of a rigid frame enhanced the structural efficiency and stiffness of the system while optimizing the use of precast, prestressed concrete elements.

Design and Casting of Interior Piers

The most distinctive architectural features of the Bronco Arch Bridge are the interior piers. Concrete piers simulate the look of the arches they replaced. Each of the 16 precast, reinforced concrete piers consists of a pair of slender, arched shafts that converge into a square base. The pier shafts are connected with a concrete strut at mid-height. The piers connect to the drilled shaft foundation with a cast-in-place, reinforced concrete pedestal. A capital at the top of each pier shaft supports the precast, prestressed concrete girders.

Concrete piers simulate the look of the arches they replaced.

As cast, the piers were 34 ft tall and 33 ft across at the top with 54-in.-wide shafts that varied in thickness from 24 in. at the base to 30 in. at the capitals. The base section was 54 in. square. The addition of the strut reduced bending moments in the pier shafts by 60%. This, in turn, resulted in a more slender design that reduced the overall weight of the piers to 100 kips, which made precasting, handling, and erection possible.

All the precast, reinforced concrete piers are identical. They were cast in the contractor's yard adjacent to the bridge site. The piers were cast on their side in a simple casting bed consisting of conventional curved wall forms on a smooth finished concrete mud slab. Casting of the piers commenced during construction of the walls and abutments.

Interior Pier Construction

Each pier foundation consists of a single, 54-in.-diameter drilled shaft. This foundation provides the necessary strength to resist all design loads while providing the flexibility to accommodate longitudinal movements.

The pier foundations were designed for a minimum concrete compressive strength of 4 ksi and approximately 1.5% vertical reinforcement, which extends 4 ft into

Precasting the interior piers.

The precast concrete interior piers were cast and stored horizontally.

The piers were cast horizontally, rotated, and threaded into the shoring towers.

COLORADO DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: A 371-ft-long, three-span, rigid frame consisting of precast concrete deck panels; spliced precast, pretensioned and post-tensioned U-girders; precast concrete curved piers; and integral abutments

STRUCTURAL COMPONENTS: Sixteen precast, reinforced concrete piers; 24 precast, prestressed concrete, 72-in.-deep, U-girders with lengths of 95, 136.5, and 133.5 ft; and 8-in.-thick, precast, full-depth, concrete deck panels, pretensioned transversely and post-tensioned longitudinally

BRIDGE CONSTRUCTION COST: $14.2 million the column pedestal above. Drilled-shaft penetrations into the siltstone bedrock, approximately 30 ft below existing grade, varied from 14 to 18 ft.

A square footing cast on top of each drilled shaft supported a temporary shoring tower that was used to support the precast concrete piers during erection. Once the foundations were complete, the precast concrete piers were loaded in the storage area on to conventional trailers that were retrofitted with transverse support beams. Two cranes lifted the piers at locations at the top of the cross strut and at lifting loops embedded in the end of the pier base.

Erection required the piers to be rotated from a horizontal to vertical position and threaded into the shoring towers. A special head frame at the top of each shoring tower supported the pier. Jacks on the head frame were used to adjust the piers into their final alignment.

After the piers were secured on the shoring towers, the reinforcement and forms for the support pedestal were set in place and the pedestals were cast. Pedestal concrete had a minimum design compressive strength of 4.5 ksi. Superstructure girders were erected 8 to 14 days following erection of the precast concrete piers.

Superstructure Design

The superstructure framing consists of eight continuous girder lines supporting a composite precast concrete deck slab and an integral connection to the substructure. The girders are standard CDOT U72 precast concrete girders with a depth of 72 in. and 5- and 7½-in.-thick webs. The girders were cast with self-consolidating concrete with a design compressive strength of 8.5 ksi.

Each girder line consists of three precast concrete U72 girders cast in lengths of 95.0, 136.5, and 133.5 ft. Girder weights varied from 170 to 210 kips. Span lengths are 84, 148, and 134 ft. When erected, the girders are spliced with concrete between adjacent girder ends and connected to the piers and abutments with cast-in-place concrete diaphragms.

The simple-span girders were spliced and post-tensioned together and connected to the piers and abutments.

Unique prestressing patterns were developed for each of the three different girders using a combination of straight, draped, and debonded strands. Once the girders were spliced and connected to the substructure, they were post-tensioned with twelve 0.6-in.-diameter, 270 ksi strand tendons in each of the girder top flanges over each interior pier. The design creates a combination of pretensioning and post-tensioning that resulted in a fully prestressed, continuous girder line prior to setting the bridge deck panels.

The deck slab consists of full-depth, transversely pretensioned, 8-in.-thick, precast concrete deck panels with a concrete design strength of 7.4 ksi. Once erected, the deck panels are made composite with the precast concrete girders with a continuous haunch placement and a series of transverse closure placements. Once the haunch and closure concrete reached design strength, the deck panels were post-tensioned longitudinally. The deck post-tensioning consisted of four 0.6-in.-diameter strand tendons spaced at 2 ft 6 in. and located at the mid-depth of the precast concrete panels.

Accelerated Construction

The construction of the Bronco Arch Bridge was completed within budget and ahead of schedule. More importantly, construction was accomplished with minimal disruption to existing traffic considering it was a full replacement of a busy section of interstate highway over a waterway in a downtown urban area with a high volume of daily traffic.

To minimize the impact on traffic, the contractor built all retaining walls and abutments before commencing the first stage of demolition and bridge construction. Precast concrete piers, girders, and deck panels were all fabricated well in advance of the time they were needed. An efficient set of operations was repetitively executed minimizing the time necessary for each stage of construction.

Summary

The design and construction of the Bronco Arch Bridge is an excellent example of accelerated bridge construction. A signature structure was built within budget and schedule. New and innovative technologies and construction methods were developed and successfully executed and all of this was accomplished with a minimum amount of inconvenience to the citizens of Colorado.

The success of the Bronco Arch Bridge was largely due to the close cooperation that existed between CDOT, the contractor, the engineer, and all the various subcontractors and suppliers who worked on the project. An open, cooperative environment that encourages innovation has resulted in a number of nationally recognized bridges, and the Bronco Arch Bridge is another example.

Gregg A. Reese is president of Summit Engineering Group Inc. in Littleton, Colo.

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