PROJECT

THE ESTRELLA UNDERPASS AT GRAND AVENUE

by John Lange, Stanley Consultants

State Route (SR) 303L is a 40-mile-long new freeway in the western and northwestern portions of the greater Phoenix, Ariz., metropolitan area. Originally known as the Estrella Freeway, it opened in 1992 as a two-lane freeway. Growth and future traffic projections have driven the need to expand SR 303L to an ultimate configuration of six lanes in each direction. This growth in the Phoenix metro area has had a significant impact on bridge design and construction methodology. Bridge widening on existing freeways and over busy urban arterials often requires bridge engineers to explore innovative designs to maintain traffic during major bridge construction activities.

The Estrella Underpass at Grand Avenue bridge carries SR 303L over U.S. 60 (Grand Avenue) and the Burlington Northern Santa Fe (BNSF) Railway. The challenge of maintaining traffic on U.S. 60 during construction was complicated by the limited detour options. High traffic volumes of 24,000 and 12,700 vehicles per day on U.S. 60 and SR 303L, respectively, precluded extended closures with off-site detours. Consequently, the final design of this bridge was driven primarily by the need to maintain both vehicular and railway traffic through this interchange.

Innovating from the Start

The original project design concept report proposed widening on both sides of the existing bridge. This approach created significant constructability and access issues. Large excavations for the deep spread footings impacted U.S. 60, the BNSF Railway, and underground utilities. It also resulted in aesthetic inconsistencies among the bridge substructure elements.

Partially completed bridge ready for drop-in girders over railroad. Construction was paused multiple times each day for railroad traffic to pass through the site. Photo: Haydon Building Corp.

profile

ESTRELLA UNDERPASS AT GRAND AVENUE / SURPRISE, ARIZONA

BRIDGE DESIGN ENGINEER: Stanley Consultants, Phoenix, Ariz.

PRIME CONTRACTOR: Haydon Building Corp., Phoenix, Ariz.

PRECASTER: TPAC, Phoenix, Ariz.—a PCI-certified producer

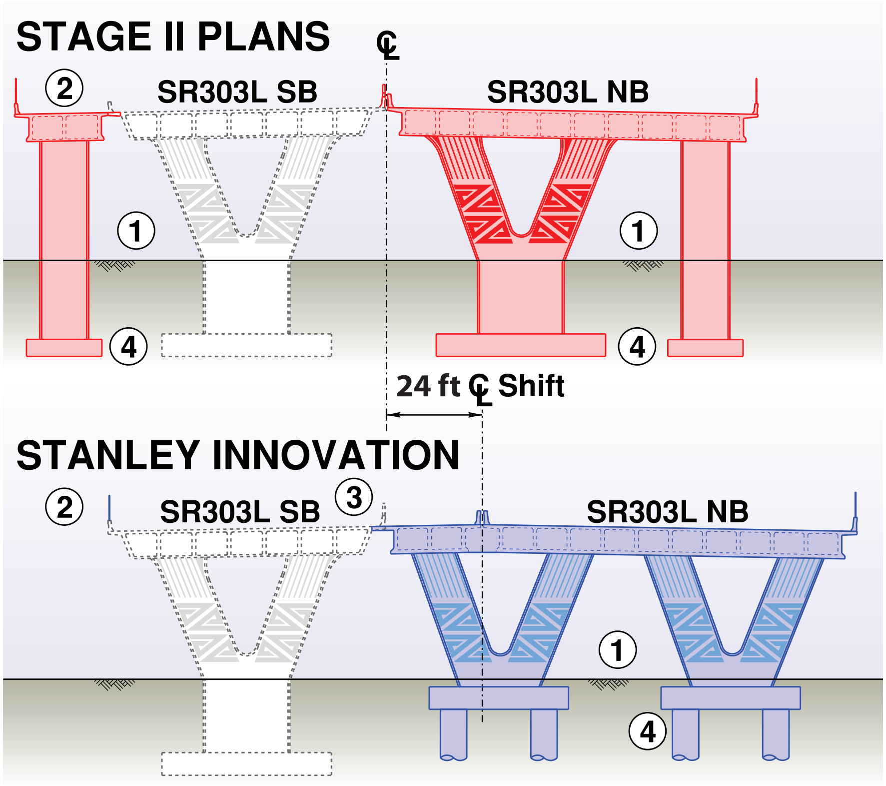
POST-TENSIONING CONTRACTOR: Dywidag Systems International, Long Beach, Calif.

OTHER MATERIAL SUPPLIERS: Reinforcing Bar Producer: Nucor Steel LLC, Kingman, Ariz.; Reinforcing Bar Fabricator: CMC Rebar, Mesa, Ariz.; and Reinforcing Bar Installation: Endo Steel, Gilbert, Ariz.

AWARDS: 2016 CRSI Honors Award and 2016 American Council of Engineering Companies (ACEC) Grand Award

During the proposal phase, the winning proposal was the only team of the twelve competing teams to propose shifting the freeway construction centerline 24 ft east and replacing spread footings with drilled shafts. This innovative concept provided the following advantages (items are keyed to figure to the right):

1. Inconsistent bridge piers were made uniform so aesthetic treatments were a natural extension of the existing bridge.
2. The southbound widening was eliminated, improving construction phasing and access.
3. All new construction was on the east side with only one interface between new and existing bridges.
4. Drilled-shaft foundations reduced the excavation footprint and eliminated associated conflicts.



Project proposal graphic illustrating the constructibility and aesthetic benefits resulting from shifting the roadway alignment 24 ft to the east. Figure: Stanley Consultants.

A Hybrid Option

The existing Estrella Underpass Bridge was constructed in 2000. The bridge is a four-span, 536-ft-long, cast-in-place (CIP), post-tensioned concrete box-girder superstructure with custom Y-shaped columns and integral piers. The structure depth is 7 ft 4 in. and it has a span arrangement of 105, 194, 118, and 114 ft with a precast concrete drop-in span over the BNSF Railway. The project widened the existing bridge about 2½ times its original width, from an out-to-out width of 73 ft 8 in. to 197 ft 1 in. A conventional approach would have been to widen the bridge using an identical CIP post-tensioned concrete superstructure because the proximity of the railroad tracks created ample vertical clearance for falsework over U.S. 60 traffic. In addition, the length of span 2 exceeded the capabilities of pretensioned precast concrete American Association of State Highway and Transportation Officials (AASHTO) girders used in the Phoenix area.

Working with the prime contractor, an improved bridge-widening method was developed that combined AASHTO precast concrete girders with CIP concrete pier tables. Pier locations, span arrangements, and joint locations were all dictated by the existing bridge configuration. CIP concrete was used near and over the piers where demand for structural compatibility was greater. This method eliminated large portions of falsework—most important, falsework over U.S. 60. The two structure types (CIP and precast concrete) were spliced and post-tensioned to provide continuity and comparable structural behavior to the existing bridge. Spliced connections between CIP and precast concrete elements were located where dead load moments were low and where shoring towers could be placed without affecting U.S. 60.

Precast Opens the Way

A critical project requirement was maintenance of traffic on U.S. 60 during bridge construction. CIP construction on falsework over traffic is invariably disruptive to traffic below. At span 2 and over U.S. 60, 120-ft-long precast, pretensioned concrete girders were spliced with 37-ft-long CIP pier tables. Prior to post-tensioning the superstructure, the precast, pretensioned concrete girders were temporarily supported on shoring towers. This created an available clear opening of almost 100 ft for U.S. 60

ARIZONA DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: 536-ft-long, four-span, post-tensioned superstructure combining AASHTO precast concrete girders with cast-in-place concrete pier tables on integral Y-shaped piers

STRUCTURAL COMPONENTS: Twenty 60-ft-deep, 36-in.-diameter drilled shafts in a double row at each abutment; four 70-ft-deep, 96-in.-diameter drilled shafts at each pier line; cast-in-place (CIP) Y-shaped piers, pier tables, and abutments; and 56 AASHTO Type Super VI precast concrete girders with a 9-in.-thick cast-in-place concrete deck. Frame A is 316 ft long and comprises spans 1 and 2 plus a 20-ft 3-in. CIP beam ledge at pier 2 cantilevered into span 3. In frame A, three post-tensioning tendons were used per web with a total jacking force of 32,605 kip applied at hinge 1. Frame B is 123 ft long and comprises span 4 plus a 12-ft 3-in. CIP beam ledge at pier 3 cantilevered into span 3. In frame B, two post-tensioning tendons were used per web with a total jacking force of 19,685 kip applied at hinge 2.

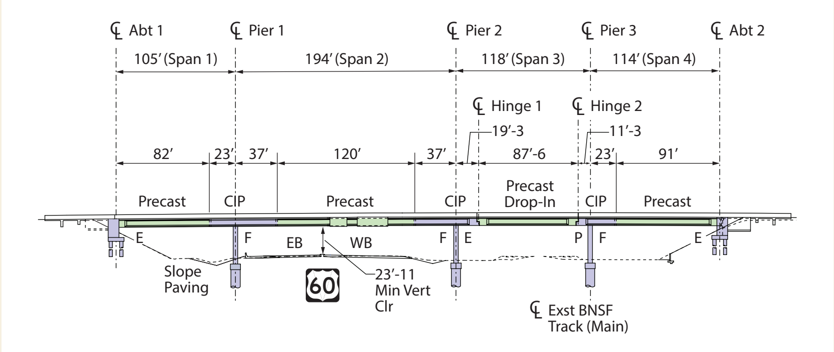
BRIDGE CONSTRUCTION COST: $7,300,000 (approximately $110.28/ft^2)

Completed piers 2 and 3 showing Y-shaped columns and the interface of the cast-in-place concrete pier tables with the precast concrete girders. Photo: Stanley Consultants.

Span 2 Precast Concrete Girder Data

f'_c = 6.5 ksi
f'_{ci} = 5.25 ksi
Strands = Grade 270, low relaxation

Number of strands = 28 (straight)
Prestressing force = 1230 kip
Length = 120 ft



Elevation view of bridge depicting span arrangement and orientation of precast and cast-in-place concrete segments. Figure: Stanley Consultants.

traffic. This large opening, with high vertical clearance, easily accommodated two lanes of traffic in each direction plus a turn lane. This solution improved public safety, provided flexibility during construction, and permitted traffic shifts to accommodate construction phasing.

To provide a structure similar in depth to the existing bridge, 6-ft 6-in.-deep AASHTO Type Super VI girders were used, spaced at 9 ft on center. These deep girders, combined with the short interim span lengths (span between shoring towers prior to post-tensioning), allowed for minimal pretensioning to accommodate the interim construction loads. All precast concrete girders were designed for two-stage stressing: an initial pretensioning for dead loads, and post-tensioning on top of pretensioning for final loads. It was desirable to minimize initial camber in the precast concrete girders to allow for the additional camber resulting from the second-stage post-tensioning and to control screed grades. The girders utilized only 0.6-in.-diameter straight strands to carry the self-weight of the girder, the deck concrete while fresh, and a nominal construction load. Harped strands could not be used due to the draped post-tensioning (PT) ducts in the girder webs. After concrete placement for the deck, the minimal initial pretensioning produced about 0.5 in. of upward camber in the girder prior to post-tensioning.

Erection of the precast concrete girders coincided with the construction of the CIP box-girder webs. This simultaneous construction reduced overall construction time and ensured proper alignment of the PT ducts. A 2-ft-wide closure pour was provided between the ends of the precast concrete girders and the ends of the CIP concrete box-girder webs to allow for splicing of the PT ducts. This end diaphragm also accommodated the end rotation of the precast concrete girders resulting from the deck concrete placement. The superstructure was post-tensioned once the deck and splice/closure pour concrete reached adequate strength.

This tied the precast and CIP concrete superstructure elements together to provide continuity, mimic the structural behavior of the existing bridge, and carry the live loads.

The bridge is composed of two frames. Frame A (abutment 1 to hinge 1) is approximately 318 ft long and Frame B (hinge 2 to abutment 2) is approximately 125 ft long. The 87-ft-long precast concrete drop-in span connects the two frames. Each tendon comprised either sixteen or eighteen 0.6-in.-diameter, Grade 270 low-relaxation strands. Frame A required three 18-strand tendons per girder, whereas Frame B required only two 16-strand tendons per girder. Jacking operations took place from the hinged ends of each frame. Post-tensioning from the hinge anchorages took advantage of friction losses, thus reducing the jacking forces in the precast concrete girder anchorage zones at the opposite ends.

The BNSF Railway has strict guidelines and restrictions concerning bridge construction within its right-of-way and over existing tracks. One key restriction prohibits falsework over existing railway tracks. As such, a portion of span 3 used precast, prestressed concrete drop-in girders.

The CIP concrete box girder cantilevered 19 ft 3 in. ahead and 11 ft 3 in. behind piers 2 and 3, respectively. The precast concrete girders were supported on CIP hinges (that is, beam ledges) and the ends of the girders were dapped to maintain a uniform structure depth. The webs of the precast concrete girders were flared at the ends to provide the necessary width for bearing and to provide the shear capacity needed as a result of the reduced depth at the dapped end. To provide visual continuity between CIP and precast concrete, the exterior webs of the CIP ledges were formed to match the end flares of the precast concrete girders' dapped ends.

Saving Time and Money

The existing bridge was widened about 120 ft, which equates to approximately 64,000 ft^2 of new bridge deck. Using precast concrete girders eliminated approximately 31,800 ft^2 of falsework, saving an estimated $954,000. In addition to the tangible monetary savings, another benefit was time savings. The worker hours required to erect and break down falsework could be directed toward other activities. There were also time savings associated with the concurrent construction of different bridge elements. Portions of the superstructure were no longer dependent on the completion of the falsework, thus allowing for the simultaneous construction of bridge substructure elements and the fabrication of precast concrete girders.

Conclusion

The widening of the Estrella Underpass at Grand Avenue bridge demonstrated that the usually obvious approach of "widen in-kind" is not necessarily the best approach.The hybrid concrete system used in the project provided a cost-effective solution to address common challenges encountered during urban freeway construction today. The prestressed and post-tensioned concrete superstructure provides durability, long service life, and low maintenance, essential properties necessary for the high traffic volumes—particularly truck traffic—this bridge will experience over its design life.

Construction of new Y-shaped columns at pier 3 with existing bridge pier 2 in the background. Photo: Haydon Building Corp.

John Lange is a senior engineer with Stanley Consultants in Phoenix, Ariz.

AESTHETICS COMMENTARY

by Frederick Gottemoeller

The first notable aspect of this project is the willingness of the design-build team to open their minds to all the options, not just the obvious ones, when addressing the myriad traffic maintenance and construction requirements of this complicated site. The second notable aspect is their willingness to consider good aesthetics as a legitimate criterion to be achieved at the same time as all of the functional requirements. Too often there is an unspoken assumption that achieving good aesthetics is an either/or proposition: we can solve all of the functional requirements or we can have good aesthetics, but we can't have both. This project proves that assumption to be untrue.

As one example of their open mind, let's take the team's decision to do all of the widening on one side, rather than symmetrically about the original centerline. The layout geometry is often presented to bridge engineers as if it were carved in stone, not to be adjusted no matter what opportunities it forecloses. By moving off the original centerline and widening all to one side, the team not only solved major traffic maintenance and construction problems, it allowed the original piers to be replicated, thereby ensuring that the new lanes would look integrated with the old as opposed to tacked-on additions.

As a second example of their open minds, let's take the team's decision to integrate precast concrete girders with cast-in-place concrete pier tables. Not only did this resolve serious construction issues and reduce cost, it also allowed the depth and shape of the original bridge to be emulated in the new construction. Recognizing that the precast concrete girders would inevitably look different from the cast-in-place concrete pier tables, the team even extended its concern for appearance to the details of the fascia girders at hinges and splices to ensure visual continuity across the whole bridge. This kind of attention to detail requires more care by the designers and builders, but its additional construction costs are not significant, while its aesthetic benefits are crucial. Urban underpasses like these are major components of our everyday lives. It is encouraging to see a design team make the effort to get one right aesthetically as well as functionally.