

PROJECT

I-25 Trinidad Viaduct

Tight curves and variable depths challenge bridge designers

by Matthew Gilbert and Fred Holderness, Tsiouvaras Simmons Holderness Inc.

Interstate 25 (I-25) serves as Colorado's major north-south freeway, extending from the Wyoming state line to New Mexico. The freeway weaves through the picturesque town of Trinidad, located at the base of Raton Pass and just north of the New Mexico state line. I-25 was carried through town on an aging viaduct consisting of a combination of steel and precast concrete girders spanning over a river, three existing rail lines, a future rail line, and four city streets. The girders were corded to meet the roadway's tight curves.

Constructed in the mid-1950s, these bridges were nearing the end of their service life and required replacement. Preliminary design and environmental studies proved that realignment was not an option. The new structures needed to account for varying, highly skewed, substructure elements and complex horizontal geometry combined with reversing superelevated curves.

The reconstruction of I-25 through Trinidad provided some unique challenges. The remote small town of

Trinidad is nearly 200 miles from any major bridge construction industry, has a limited supply of skilled labor, and only one local ready-mixed concrete supplier. Based upon these concerns, the Colorado Department of Transportation (CDOT) elected to include an option for alternate structural design types but maintained the requirement to adhere to strict aesthetic criteria developed during the preliminary design and environmental assessment. A local contractor and engineering firm teamed up to develop a prestressed concrete

The final viaduct created a structure that the community was proud of and greatly enhanced the appearance below the bridges. Photo: Jeanne Sharps.



profile

I-25 TRINIDAD VIADUCT / TRINIDAD, COLORADO

BRIDGE DESIGN ENGINEER: Tsiouvaras Simmons Holderness Inc., Greenwood Village, Colo.

PRIME CONTRACTOR: Lawrence Construction, Littleton, Colo.

CAST-IN-PLACE CONCRETE SUPPLIER: Leone Sand & Gravel & Redi Mix Concrete, Trinidad, Colo.

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

POST-TENSIONING CONTRACTOR: Schwager Davis Inc., San Jose, Calif.

tub-girder superstructure design. The awarded design bid was \$8 million less than the engineer's estimate.

The prime contractor, the precast concrete fabricator, and the contractor's design engineers devised a series of structures to meet the complex geometric requirements and address site-specific constraints. The resulting bridge layouts include four bridges over the river (two bridges for the interstate mainline and two on-and-off ramp bridges), two viaducts carrying the interstate over the city streets and rail lines, and two on-and-off ramps connecting into the viaducts.

Structural Configurations

The four river bridges consist of three-span structures using simple span, precast, prestressed concrete girders made continuous. Each bridge is about 335 ft long with skews of approximately 46 degrees.

The 1985-ft-long northbound viaduct is divided into three units and the 2057-ft-long southbound viaduct into four units. Expansion joints are provided at the end of each unit. The northern-most units NBU 2 and 3 on the northbound viaduct and SBU 2, 3, and 4 on the southbound viaduct, along with the on-and-off ramp bridges, are comprised of simple-span girders made continuous. NBU2, SBU3 and SBU4, and both ramp structures have four spans, while NBU3 and SBU2 are each five spans. These portions of the viaduct were relatively simple and contain spans no longer than 128 ft.

The largest spans, highest skews, and tightest horizontal curvatures all exist at the unit 1 sections of the northbound and southbound viaducts. The highly skewed railroad and city streets—along with the aesthetic requirement of hammerhead piers—created a staggered substructure configuration to support



The staggered piers were necessary to span the city streets and the railroad along the curved freeway alignment. Photo: Jeanne Sharps.

the four-girder-wide superstructures. The five-span northbound unit 1 (NBU1) with a length of 854 ft along the highway centerline has span lengths of 115, 131, 250, 175, and 181 ft for girders 1 and 2 and 115, 181, 256, 121, and 182 ft for girders 3 and 4.

The southbound unit 1 (SBU1) is 486 ft along the highway centerline and has a more balanced, three-span configuration and a slightly shorter span of 232 ft over the railroad. The minimum horizontal radii on the flaring NBU1 and SBU1 structures are 1000 ft and 1700 ft, respectively. These configurations made simple-span, continuous superstructures unfeasible. To create consistency, the engineering team designed a spliced, variable-depth, curved, precast concrete, tub-girder superstructure. This superstructure type, to the best knowledge of the contractor and the design engineer, was the first of its kind.

The spliced, variable-depth unit consists of both constant-depth segments and variable-depth segments; nine girder segments for each girder line are used on NBU1 and five girder segments on SBU1. The variable-depth segments over

the piers are 116 ft long and 78 in. deep at the ends, linearly increasing to a depth of 108 in. at the piers. This linear variation also tapered the bottom flange width of the girder from 54 in. at the ends to 39 in. at the deepest portion of the segment to account for the 4:1 sloping webs of the girder, an aesthetic requirement for the project.

Construction

Customized adjustable forms were constructed to allow the precaster to fabricate segments on varying radii while having the ability to cast both constant-depth and variable-depth segments. Special, drop-in internal forms reduced the weight of the variable-depth segments. The design called for a bottom flange thickness of over 40 in. at the deepest portion of the beams, which were erected over the piers on either side of the long span over the railroad. If the entire flange thickness had been precast, the girder segments would have been heavier than the 240-kips shipping limit. The drop-in forms created a precast concrete segment with a constant thickness flange; then, secondary field concrete placements were utilized to produce the necessary flange thicknesses.

COLORADO DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Two curved, spliced, variable-depth, precast concrete tub girder viaducts with total lengths of 1985 ft northbound and 2057 ft southbound; on-and-off ramps; and four river bridges.

STRUCTURAL COMPONENTS: 156 precast concrete tub girders, of which 16 were variable in depth and some were horizontally curved on radii between 1000 and 1935 ft; 3162 precast concrete deck panels varying between 3 and 3.5 in. thick; 4.5-in.-thick, cast-in-place concrete deck; cast-in-place concrete hammerhead or single column piers; and cast-in-place concrete abutments and pile caps

BRIDGE CONSTRUCTION COST: \$79,528,100

AWARDS: 2012 PCI Harry H. Edwards Industry Advancement Award and Best Bridge with a Main Span Greater than 150 ft



The first curved, variable-depth precast concrete girder segment is lifted into place. The 6% super-elevation of the roadway is evident from the top of the column. Photo: TSH Engineering.

To build the structures, the engineering team developed an erection and post-tensioning sequence to meet the complexities of the structure. Segments were erected onto temporary and permanent piers with the exception of the long spans over the railroad. Temporary piers were not allowed at the railroad, requiring the use of a drop-in section erected onto strongbacks. To do this, the 116-ft-long, variable-depth segments were first erected onto the permanent piers on either side of the railroad while cantilevering out 58 ft over the railroad. The ends of the girders not over the railroad were supported on temporary towers to resist uplift from the large cantilevers. Strongbacks were placed at the ends of the cantilevers to support the drop-in segments, which weighed 260 kips and were 136 ft long.

After setting the drop-in segments, closure diaphragms were cast and the structure was post-tensioned together. Continuity post-tensioning was utilized before and after the deck was placed to reduce the post-tensioning costs. Altogether, over 101 miles of prestressing strand were utilized in the girders for the two unit 1 structures. Stressing consisted of pretensioned strand in the straight segments, internal multi-strand post-tensioning in curved segments, monostrands in the curved variable-depth segments, temporary external post-tensioning in the curved variable-depth segments, and multistrand continuity internal post-tensioning to splice segments together.

Precast, Prestressed Concrete Panels

In addition to the curved, variable-depth girders, one item that assisted with the contractor's winning bid was the use of partial-depth, prestressed concrete deck panels. The panels were used for both the interior panels and the deck overhangs. The deck overhangs varied up to 6 ft and would have required costly formwork, in particular, for the portions of the decks within the curves. The engineers designed the panels to be supported over the exterior girder's

two flanges while cantilevering to match the overhang length. These panels contained reinforcing bar projections for the Jersey-style barrier and pockets in the panels over the exterior web to allow for reinforcing bar projections from the girder to tie into the deck.

Panel layouts, panel shop drawings, and girder shop drawings were closely coordinated to accommodate the varying overhangs and curvature of the deck while meeting tolerances for the barriers. The panels were 3.5 in. thick and had a 4.5-in.-thick cast-in-place concrete deck over the top, for a total deck thickness of 8 in. for the majority of the bridges. Design engineers used self-consolidating concrete to fill in the pockets, ensuring an even bearing below the panels and sufficient connection to the girders.

Economy and Innovation

With bridge replacement funding at a premium, the original project focused on the construction of the northbound structures. Bids were accepted for the southbound structures in anticipation of acquiring additional funds to build the entire project. The economic savings of the redesign and the availability of additional funds allowed CDOT to proceed with the southbound structures. The entire project was made possible through the innovative use of



Curved precast concrete tub girders sit on temporary and permanent piers at the end of northbound unit 1. Photo: TSH Engineering.



Workers set the overhang, partial-depth precast concrete panels on one of the ramp structures. The pockets in the panels, and the use of self-consolidating concrete, create the connection between girders and the deck. Photo: TSH Engineering.

precast concrete and the collaborative design between the contractor, the designers, and the precaster. 

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Matthew Gilbert is a senior bridge engineer and Fred Holderness is a principal, both with Tsiouvaras Simmons Holderness Inc., in Greenwood Village, Colo.



The overhang precast concrete panels reduced the amount of support brackets needed for the deck placement. Photo: TSH Engineering.

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