

## **DESIGN AND CONSTRUCTION OF THE BIJOU AVENUE BRIDGE OVER MONUMENT CREEK**

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### **ABSTRACT:**

*The new Bijou Avenue Bridge is a gateway structure and the major access into downtown Colorado Springs. The bridge spans from IH25 over Monument Creek and the Union Pacific rail yard into the downtown area. The bridge has several innovative design features that were developed to facilitate a shallow structure depth over active rail lines with an accelerated construction schedule.*

*The design utilized a spliced, post-tensioned, precast concrete superstructure with 7 girder lines in 4 continuous spans. The design used innovative prestressing layouts and variable cross sections to accommodate a unique erection methodology under an accelerated construction schedule.*

*This paper will describe the design and construction challenges and the solutions that were successfully implemented during the construction of this signature project.*

**Keywords:** Bridge, Precast, Concrete, Girders, Prestress, Post-tensioning, Falsework, Spliced, Erection, Design, Construction, Formwork,

## **INTRODUCTION**

The new Bijou Avenue Bridge is a gateway structure and the major access into downtown Colorado Springs. The bridge is part of the COSMIX design/bridge project and spans from IH25 over Monument Creek and the Union Pacific rail yard into the downtown area. The bridge has several innovative design features that were developed to facilitate a shallow structure depth over active rail lines with an accelerated construction schedule. Complex geometric considerations required limited profile grades to maintain sight distances and a roadway width that varies from 88' to 168'.

The design utilized a spliced, post-tensioned, precast concrete superstructure with 4 continuous spans to accommodate a crossing over Monument Creek and a 155' clear span over the rail yard. The superstructure was designed using 7 continuous girder lines that vary in spacing from 12'-6" to 22'-0" to fit the deck width. Girders were kinked at closure joints to accommodate the varying spacing.

Precast concrete girders were designed to cantilever beyond interior piers and support the free end of the adjacent girder during erection. An innovative combination of debonded pre-tensioning, post-tensioning and internally thickened section of the webs and bottom slab was used to accommodate cantilevered construction. Strongbacks were used at girder splices to eliminate the need for temporary shoring supported in the creek or the rail yard during construction. The bridge was fully post tensioned between abutments after splices were cast and prior to placing the deck slab.

Fig. 1: Bijou Avenue Bridge

The City of Colorado Springs allowed a full closure of the existing bridge to accelerate the construction schedule. The existing bridge was closed and demolition began in early January 2007. The new bridge was complete and open to traffic in late September 2007, ahead of schedule. Many innovative uses of precast concrete technology were successfully implemented during the design and construction of this signature project.

## **SITE DESIGN CONDITIONS**

The City of Colorado Springs wanted a bridge that would relieve congestion and accommodate multiple movements of traffic into and out of the downtown area, as well as provide access to the west side of town which is bisected by IH25. The bridge matches the lanes from the new IH25 overpass to provide 3 continuous lanes of traffic into the downtown area, two lanes across IH25 into west Colorado Springs, two left turn lanes to provide freeway access and sidewalks and bike lanes in both directions.

Fig. 2: Bijou Avenue Bridge Roadway Looking West

The profile of the bridge deck transitions from the at grade roadway in the downtown area

to a crossing over the combined BNSF and UPRR rail lines, then spans over Monument Creek and blends into the IH25 ramps and overpass bridge. The City wanted to improve user safety by increasing using a more gradual vertical curve to increase the site distance on both bridges. This severely limited the vertical depth of the structure to provide adequate clearance over the rail yard.

In addition, the railroad wanted to limit foundations and construction access in the rail yard. A main span of 148'-3" was agreed upon to provide ample clearance for all current and future active tracks. A pier was located in the rail yard such that it isolated only one obsolete storage track on the west side of the rail yard. Access to the rail yard was limited to construction equipment. Temporary support of bridge girders was not allowed in the rail yard.

The interior pier in Monument Creek was located to accommodate hydraulic design conditions that accounted for severe flooding events. The pier was located on the east bank of the normal creek channel. Movement of the pier was severely limited by the channel flow during an extreme event. The existing west

Fig. 3: Bijou Bridge over Rail yard

abutment provided a vertical wall that served as a channel liner for Monument Creek. The new west abutment would have to provide the same vertical surface and dovetail with the retaining walls on either side of the bridge. The existing retaining wall was over 30 high and consisted of a combination of counter fortified retaining walls and infill tie back walls that were forty to eighty years old.

The design of the new abutment called for a 3'-0" thick wall pier that was cast against the existing retaining walls. The new wall encased the existing retaining walls in the back fill behind the new abutment and avoided the need for demolition. Holes were drilled through the existing abutment wall and tie backs were anchored in the new abutment and to dead men anchors in the back fill.

Fig. 4: West Abutment and Span over Monument Creek

## **SUPERSTRUCTURE DESIGN**

### **DEVELOPMENT OF STRUCTURAL FRAMING PLAN**

Preliminary designs for the Bijou Bridge that were used to bid the project consisted of a steel plate girder superstructure with a cast in place concrete deck to accommodate the structure depth limitations over the rail yard. Since the bridge was part of a larger design/build project, the Contractor requested that a precast concrete girder alternate be investigated. The span over the rail yard was shortened to accommodate a pier-to-pier erection method using 60" deep, precast concrete U girders. During preliminary studies, the deflections and stresses in the longer spans were found to be excessive and a spliced, post tensioned option with temporary shoring was adopted.

Due to site constraints in the rail yard, a strong back system that would suspend the precast girders over the live tracks was investigated. The drop in girders would be supported at splice locations from cantilevered sections of the adjacent girders on each side of the rail yard. By using this erection scheme the girder stresses and deflections became more manageable and the problem of temporary supports in the rail yard was solved. The strongback system was also adopted at the west interior pier in Monument creek to eliminate all ground supported shoring.

Using this erection scheme, the end spans were erected from each abutment and cantilevered 15' past the first interior pier at each end of the bridge. Girders in Span 2 spanned from a splice, 15' up station of Pier 2 and cantilevered 15' past Pier 3, at the center of the bridge, into the west side of the rail yard. Drop in girders were supported over the rail lines from the girders cantilevering over Pier 3 from the west and Pier 4 from the east side of the rail yard.

Fig. 5: Erection of Precast Girders in Spans 1 & 2 over Monument Creek

The unsupported ends of precast girders at the splice locations were suspended from steel strong backs that were attached to the cantilevered ends of the

Fig. 6: Erection of Precast Girders in Span 3 over Rail Yard

adjacent girders. At each splice, the unsupported end of each girder was suspended from the strongbacks by 2 – 1 3/8" diameter post tensioning bars. The girders were designed with extensive debonding of the pretensioning in the bottom flange and a post tensioning tendon, in the top flange of each web, over the piers to accommodate stresses due to erection loadings.

The large degree of variation of the bridge deck width made using continuous girder lines difficult. The final framing scheme consisted of seven continuous girder lines that accommodate the variations in deck width by using a combination of splayed girder alignments, kinks at splices and variation of the overhangs.

Fig. 7: Girder Framing Plan

The final configuration consisted of a four span bridge with spans of 107', 135', 148' and 88' with a deck width that varied from 179' at the west abutment to 95' at the entrance to downtown. To accommodate this variation, the girder spacing varied from 22.75' to 13.20'. The typical deck slab overhangs varied from 2.50' to 3.50'. The overhangs increased to a maximum of 17.40' on each side of the bridge at the west abutment curved turn lanes for the on and off ramps from IH25.

Fig. 8: Girder Layout in Spans 2 to 4, Looking at West Abutment

## DESIGN OF PRECAST GIRDER SECTIONS

The design of the precast girders incorporated features that would be necessary for erection. The design of the girders was developed with the Joint Venture's Precaster to utilize existing forms. To accommodate the cantilevered erection scheme, post tensioning tendons were placed in the webs near the top flange. A thicker web and tapered bottom flange were designed using forms that were used on a previous project.

Fig. 9: Cantilevered End of Precast Girder

A 30' long section with 10" webs was centred over the interior piers and had a tapered bottom slab that varied from a standard 8" thickness to a maximum 20" thickness over the pier. At the end of the 30' section, standard forms were used to transition to a typical 7 1/2" web. The non-stressing end of the top flange tendons were placed at the interior end of the transition.

Four bays of seven girders were used. Three bays had cantilevered sections and the railroad drop in girders had a typical section from end to end. The girder lengths in each bay were 121.5', 133.0', 114' and 102'.

Fig. 10: Precast Girder at Abutment and Interior Pier Diaphragms

## CONNECTION TO SUBSTRUCTURE

A continuous 6'-0" thick cast-in-place diaphragm section was designed over the interior piers and the abutments. Four columns of ducts were placed in the webs to provide a continuous reinforcing cage, through the girders, at the interior pier diaphragms. The girders were notched at the abutments to provide for a continuous cast-in-place diaphragm and anchorage zone for the longitudinal web tendons. A thickened bottom slab section was designed to temporarily support the girder reaction at the abutments.

The girders were placed on 3/4" neoprene pads at the interior piers and the east abutment when they were erected. The girders were set on expansion bearings at the west abutment. After they were erected, prior to casting the splices between the girders, the interior pier and east abutment diaphragms were cast to provide continuity with the foundation.

The pier diaphragms were connected to the pier caps below with a single line of dowels running along the center of the diaphragm between the girders. A 12" wide continuous layer of isolation material was placed on each face of the diaphragms the interface between the pier and diaphragm to prevent spalling due to rotations of the superstructure and provide an effective pinned connection between superstructure and foundations.

Fig. 11: Cast-In-Place Abutment and Interior Pier Diaphragms

## PRESTRESS DESIGN

The longitudinal prestress design used a combination of pre-tensioning and post-tensioning. The pre-tensioning was designed to optimize the prestress force in the positive moment regions. Prestressing consisted of 20 to 39 - 0.6" diameter strands in the bottom flange. Up to 2/3 of the pretensioning was debonded in the cantilevered section to minimize top flange tensile stresses. A 7 x 0.6" tendon was anchored in the top of the each web in the cantilevered section and deviated to minimum cover over the piers. The top flange tendons were stressed and grouted prior to being shipped and erected.

Parabolic web tendons were placed in the webs and ran the full length of the bridge. The web tendons were stressed after the abutment and pier diaphragms and closures were cast and cured. The deck was placed after all post tensioning was stressed and was designed to be fully replaceable.

## BRIDGE DECK DESIGN

The bridge deck was designed using an 8" cast-in-place deck in spans 2 to 4 where the girder spacing varied from 13.2' to 20.5'. The slab had clear spans of 4.20' to 11.50'. Girder spacing in span 1 varied from 20.50' to 22.75' with clear slab spans of 11.50' to 13.75' and a maximum overhang at the west abutment of 17.40' at the turnout lanes for the IH25 ramps. The deck slab was conventionally reinforced for the entire length of the bridge.

Fig. 12: Continuous Girders at Stressing of Longitudinal Post-Tensioning

## SUBSTRUCTURE DESIGN

The substructure design utilized the flexibility of the piers and foundation to minimize the need for manufactured bearings. The foundation consisted of drilled shafts at the interior piers and the west abutment wall pier. Piling was used to provide for the design of a flexible abutment at the east end of the bridge.

The interior bents had 4 and 5 columns depending on the width of the bridge. Each column was 4' x 8' and was founded on a single 42" drilled shaft. Pier heights varied from 21' to 37'. Bedrock was typically 10' to 15' below grade at the interior piers and very close to grade at the west abutment. A reinforced concrete, pinned connection was designed for the superstructure to substructure interface at the east abutment and all interior piers. The superstructure was set on expansion bearings at the west abutment.

The most remarkable feature of the substructure was the design of the west abutment. The abutment consists of a 40' tall wall pier that is 180' wide. The superstructure was set on bearings at the top of the wall pier and a back wall was added and backfilled after the superstructure post tensioning had been stressed. An expansion joint was placed between the superstructure and approach slab at the back wall.

The wall pier varies in thickness from 3'-6" to 2'-0". The top of the wall is supported laterally by 19 reinforced concrete tie beams that anchor into dead man anchors 35' behind the back face of the pier in the backfill. The wall pier was cast against the retaining wall of the existing bridge. Holes were cut through the existing walls to accommodate the tie beam connection to the new wall pier. No structural contribution from the massive existing retaining wall was considered in the design of the new abutment. The back fill was also reinforced with a geotextile grid.

Fig. 13: Dead Man Anchors and Tie Beams at West Abutment Wall Pier

The abutment wall had full height MSE wall panels on either side that tapered back to existing retaining walls. The completed abutment and adjoining retaining walls form a channel liner for Monument Creek at flood stage as well as provide support for the bridge and roadway above.

Fig. 14: Completed West Abutment

## **CONSTRUCTION SCHEDULE**

The City of Colorado Springs allowed a full closure of the existing bridge during construction to accelerate the schedule. The existing bridge was closed on January 2, 2007. The agreed upon schedule provided for the complete demolition and removal of the existing bridge and opening of the new bridge to traffic by Thanksgiving of 2007. The Bijou Bridge provided the major access to the downtown area from IH25 and any delay in reopening the bridge prior to the holiday season would have seriously affected the local merchants.

Fig. 15: Existing Bijou Bridge Prior to Demolition – January 2007

Demolition of the existing structure started on January 4 and took two months to complete. The substructure was constructed and girder erection took place in April. The bridge was reopened to traffic in late September, two months ahead of schedule.

Fig. 16: Completed Bridge Open to Traffic – September 2007

## **SUMMARY**

The Bijou Bridge over Monument Creek is a major gateway into downtown Colorado Springs. The bridge has a high profile and the aesthetics were a major consideration in its design concept. What is remarkable about the Bijou Bridge is that it incorporates so many existing design technologies in innovative ways to produce an aesthetically pleasing, concrete structure that satisfied all of the numerous design requirements.

The concept for the structural design was developed with careful consideration given to the existing conditions, erection methodology, available precast plant capabilities, and roadway requirements. The result is a signature structure that was completed ahead of schedule that will serve the people of Colorado Springs for many years to come.

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