# Design and Construction of the SH58 Ramp A Flyover Bridge over IH70

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## ABSTRACT:

*The SH58 Ramp A bridge in Golden, CO is the latest on a series of projects in Colorado that utilize new applications of precast concrete technology in complex interchange projects.*

*The project clearly demonstrates the advantages of using commercially precast concrete products to construct cost-effective, complex long span structures in high profile applications where aesthetics and urban geometrics are significant design consideration. The success the Ramp A bridge and similar projects in Colorado demonstrates that precast concrete can be considered an established design option for complex and long span bridges.*

*Ramp A was complete and open to traffic in November 2008. The paper will describe the design and construction challenges and the solutions that were successfully implemented during construction.*

**Keywords:** Girders, Post-tensioning, Falsework, Spliced, Erection, Design, Construction

## INTRODUCTION

The IH70 / SH58 Ramp A bridge is connector ramp that allows eastbound IH70 traffic to access westbound State Highway 58 in Golden Colorado. The new bridge provides greater highway access to developing in areas of east Golden. Ramp A was the fifth of six bridges in Colorado designed using curved precast girder construction.

The project presented numerous design and construction challenges in difficult urban site conditions. The ten span bridge crosses over Clear Creek, a bike path and three traffic openings, east and westbound Interstate 70 and eastbound SH58. The bridge was redesigned as a Value Engineering effort initiated by the General Contractor after the project was awarded..

Fig. 1: SH58 Ramp A Bridge

The Colorado Department of Transportation has promoted precast concrete as a viable alternate to steel and cast-in-place construction which has typically been used for complex interchange projects. Ramp A is the fifth bridge of this type that is currently open to traffic. Ramp A incorporates a number of innovative design details for precast concrete construction. Many of these details were utilized on previous projects in Colorado and were further developed and refined during design. Ramp A represents the latest state of the art in the use of curved precast bridge girders in Colorado. The construction of Ramp A and other similar projects in Colorado is that they clearly demonstrate the economical viability and design flexibility inherent in the use of precast U girders for long span bridges in complex urban applications.

## BRIDGE CONFIGURATION

The Ramp A bridge begins at Abutment 1 on the north end of the project where traffic exits on the right side of IH 70 and is carried over the east and westbound lanes of IH 70 then crosses over eastbound SH58 and returns to grade at Abutment 11, at the beginning of westbound SH58. All traffic crossings are high volume roadways that required night and weekend erection and lane closures during construction.

Fig. 2: Abutment 1 access to SH58 Ramp A Bridge

The roadway consists of a 38' deck that currently accommodates one traffic lane and two large shoulders, but was designed for three traffic lanes. The roadway alignment consists of a spiral curve with an 809'radius that transitions to a tangent section at the end of the bridge. Bridge grades vary from +5.0% to -5.0% and cross falls vary from +6.0% to -2.0% along the length of the structure.

The bridge consists of a spliced, post-tensioned, precast concrete superstructure with two girder lines that is divided into three units. Ramp A has the longest span in Colorado using constant depth, precast U girder construction to date. Unit 1 consists of 4 continuous spans (153’, 205’, 235’ and 186’) that cross over Clear Creek, a bike path and eastbound and westbound IH70. Unit 2 has 3 three spans (147.5’,205’ and 186’) that crosses over eastbound SH58. Unit 3 consists of four spans (187.5’, 200’, 200’ and 188’). The roadway in Unit 3 transitions from a spiral curve to a tangent section on a -5.00% grade where it returns to grade at Abutment 11.

Construction of the project commenced in Feb 2007. The redesign of the bridge began in April 2007 and continued through March 2008. Precasting of girders and deck panels began in October 2007 and was completed in April 2008. Girder erection began in December 2007 and was completed in April 2008. The bridge was opened to traffic in November 2008. Close cooperation between the Contractor, Designer, Owner, fabricators, suppliers and sub-contractors was essential to successfully maintaining the project schedule.

Fig. 3: Ramp A, Units 2 & 3 at Abutment 12

## SITE CONDITIONS

As previously discussed, the bridge crossed live traffic, a creek and a bike path which required temporary shoring that could accommodate numerous traffic openings during construction. Significant heavy shoring and large cranes were necessary to erect and temporarily support precast concrete girders weighing up to 265 kips during construction with minimal disruption to traffic. The majority of erection occurred at night during road closures.

## SUBSTRUCTURE DESIGN FEATURES

The superstructure is supported on manufactured expansion bearings at the abutments and interior expansion piers at each end of the superstructure units. Abutments are supported on a single line of 36” diameter caissons. Abutments were designed using a traditional cap and back wall design. Expansion piers, 13’ wide x 6’ thick are supported on footings and a group of 4 – 48” diameter caissons.

Fixed interior piers were founded on two, side by side drilled shafts 48” in diameter to balance strength and longitudinal flexibility. Substructure flexibility and soil/structure interaction in the foundations was considered in design thus eliminating the need for bearings at interior piers while accommodating creep and thermal movements. Drilled shafts varied from 65 to 80’ long with a minimum of 25’ of embedment into bedrock. Fixed interior piers were designed using 13’ x 4’ rectangular shafts with 48” semi circular edges. Pier heights varied from 16’ to 45’. Pier reinforcing steel varied from 1% to 2% of the gross concrete area.

Integral pier caps were utilized for all fixed interior piers to solve clearance issues and to present a lighter, consistent look to the bridge. All integral pier caps were transversely post tensioned and fully fixed to the superstructure. Expansion piers utilized a conventional hammerhead cap that was post tensioned to enhance durability and provide for a shallower design that blended aesthetically with appearance of the integral interior pier caps.

Fig. 4: Ramp A, Expansion and Interior Piers

## DESIGN AND FABRICATION OF PRECAST GIRDERS

The superstructure consisted of two lines of 86" deep modified CDOT U84 girders which were spliced near the ¼ points of the typical span. The bridge begins in a spiral curve in Unit 1 which continues through Unit 2 and transitions in Unit 3 to a straight section ending at the up station end of the bridge. The first and last two pairs of girders in the spiral curve were cast at varying radii to form the beginning and end of the spiral curve. The remaining girders in the central curve were cast with an 809' radius for both girder lines. The straight girders in Unit 3 were cast in a conventional girder bed.

The superstructure contains 38 precast girders (30 curved and 8 straight) and 265 precast deck panels. The precast girders and deck panels were fabricated in a commercial precast plant in Denver, CO. All curved girders were cast in special curved forms that conformed to the design radii. The forms were designed in discreet panels that had break points at each end that were adjusted to provide the necessary curvature. Girder lengths varied from 93'-2" to 119'-7" and weighed 220 to 265 kips each.

Fig. 5: Precast U Girder Curved Forms

The curved girders were cast with typical mild reinforcing and small quantities of longitudinal mono strand post-tensioning to control cracking when they were removed from the casting beds and placed in storage. Girders were stored at the 2/10th point from each end to minimize cracking in storage prior to applying permanent post-tensioning and to prevent rolling of severely curved sections.

The girders were designed using with varying levels of prestress in the bottom slab for handling and erection loadings. Curved girders used post-tensioning tendons and straight girders were designed with conventional pretensioning. Bottom slab prestress varied from 14 to 28 - 0.6" diameter strands. Bottom slab tendons in curved girders were stressed and grouted in the casting yard prior to shipping to the jobsite.

Fig. 6: Typical Girder Cross Sections

All girders were cast with diaphragms with access openings at each end. The diaphragms provided anchorage locations for intermediate and bottom slab tendons. In addition these diaphragms provided a strengthened section for handling, temporary support and torsional bracing during erection. Midspan girders were cast with 3' thick diaphragms to accommodate post-tensioning anchorages. Pier girder end diaphragms were 1' thick. Cast-in-place splices, which matched the shape of the diaphragm section, were cast between ends of the girders.

Fig. 7: End Diaphragm and Top Flange Tendon Details in Unit 1

The primary longitudinal post-tensioning was placed in parabolic profiles along the full length of each unit. Ducts were centered in the precast girder webs and continued through the cast-in-place closures. Typical longitudinal post-tensioning consisted of 4 – 12 x 0.6" tendons per web which were anchored in cast-in-place diaphragms at the abutments and expansion piers. In addition, 19 strand tendons were placed in Unit 1 in the top flange over the piers on either side of the 235' span to increase the negative moment capacity. The top flanges were thickened in the typical section to provide room for 4" diameter ducts for the 19 strand negative moment tendons.

Negative moment tendon anchorages were placed in the inside face of the end diaphragms of the precast girders. The top flange tendons were placed through the cast-in-place closures and additional reinforcing steel was added to resist anchorage forces. The 8 ¼" bottom slab was thickened over the piers to 21" to improve the section efficiency and provide a larger compression block for ultimate strength.

Following erection, the precast girders were cast into the pier caps at all interior piers. Ducts were placed through the webs of the girders over the piers to provide access for transverse post-tensioning of the caps. Shear keys were placed in both faces of the girders over the piers to enhance shear transfer in the interior pier diaphragms.

Fig. 8: Precast Girder with "Tongue" Section at Abutment 12

The precast girder sections at the end of each unit were notched to allow placement of a cast-in-place diaphragm at the abutments and expansion piers. A concrete diaphragm, 1' thick with an access opening is used to transition from a 8 ¼" bottom slab thickness to a 21" section at the notch. This thickened "tongue" serves to anchor the bottom slab post-tensioning in the curved girders and to provide support for the girder during erection. Embedded bearing plates are precast into the bottom of the "tongue" section to facilitate bearing installation when the girders are erected.

## ERECTION OF SUPERSTRUCTURE

The girders were shipped to the site on high capacity trailers and set on the falsework with large capacity hydraulic and crawler cranes. The girders were shipped and erected as open cross section. Diaphragms at each end of the girders provided the only internal bracing necessary during shipment and erection. The diaphragms also provided a location for support on temporary bearings during erection and torsional bracing to the falsework. One of the advantages of using precast girders is that for the majority of situations only vertical shoring is necessary, even in severely curved areas.

Fig. 9: Precast Girders Set on Falsework with Cranes

Falsework supporting the girders was designed to accommodate a variety of site conditions. Site conditions at Clear Creek and the bike path required benching into the existing stream bank to provide foundations for shoring towers. Three straddle bents were designed to support the girders at traffic openings over IH70 and SH58 due to the sharp skews at these locations. All falsework was designed to support the weight of precast girders, wind loads, construction live load and provide torsional stability until the superstructure was self-supporting. Temporary shoring of existing bridges over Clear Creek was required in order to set a number of girders where it was necessary to place cranes on the bridges during erection.

Fig. 10: Precast Girders Set on Straddle Bent and Falsework at Traffic Opening

Once the girders were erected the interior pier caps, closures and expansion pier and abutment diaphragms were cast. In addition, the precast girder cross section was closed by setting precast deck panels between the webs and placing a cast-in-place closure strip along the full length of the girders over the top flanges. Mild reinforcing steel extended from the top flanges of the girders and the ends of the precast panels into the closure strips to provide continuity of the connection. By closing the cross section, the torsional strength and stiffness of the girder lines was greatly increased and the potential for undesirable deflections and girder cracking was practically eliminated as the primary post-tensioning was stressed and the superstructure became self- supporting.

Primary post-tensioning tendons were anchored in cast-in-place diaphragms at each end of the unit. The tongue section at the notched ends of the precast girders allowed for the placement of a continuous diaphragm across the width of the bridge as shown before. The end diaphragms were 4' thick and mildly reinforced. The diaphragms transversely connected the two girder lines at the abutments and expansion piers. The cast-in-place diaphragms became integral with the girder lines when longitudinal post-tensioning was stressed.

The precast girder "tongue" section in the bottom slab at the end of each supported the weight of the precast girders on the permanent bearings when erected. This detail greatly simplified erection and eliminated the need for shoring towers at the abutments and expansion piers. The expansion pier diaphragms were designed to allow stressing access with a short stroke ram when both sides of the bridge were erected. After placement of pier caps, closures, diaphragms and lid slabs, the superstructure became a continuous closed cell box for the full length of each unit that was ready for post tensioning.

Fig. 11: Cast-in-place End Diaphragm at Abutment 1

After all longitudinal stressing was complete, tendons were grouted, all of the falsework was removed and the girders were prepared for casting the deck slab.

Precast panels were set between the girder lines and overhang forms were installed to prepare for casting the deck slab. Conventional mild reinforcing was placed in the deck slab. Two separate sets of deck cambers were calculated to facilitate placement of the deck. One set of cambers was used to set the lid slab deck panels prior to post-tensioning the girders and another set of cambers was used to place the deck panels between the girder lines and overhang forms after post-tensioning.

The superstructure was designed to support the fluid weight of the deck slab in an unshored condition. This design condition was imposed to reduce deck cracking in negative moment regions and to provide for the possibility of a full deck replacement in the future if necessary.

Fig. 12: Shoring is Removed after Post-tensioning before Casting Deck Slab

After placement of the deck slab, the permanent barriers were cast and the bridge was painted and prepared for opening to traffic in November 2008.

Fig. 13: Ramp A Opened to Traffic, November 2008

## SUMMARY

The Ramp A bridge incorporated a number of innovative design solutions for long span structures that maximized the use of precast concrete products. The project was constructed in challenging site conditions where maintenance of existing traffic was essential. The success of this project and similar ones constructed in Colorado over the last five years has continued to validate the Colorado Department of Transportation’s vision of developing precast concrete as a viable option for complex, long span interchange construction. Further the Department has emphasized the use of standardized, commercially produced, precast concrete products to further enhance the future economy and sustainability of this concept. Ramp A clearly demonstrates that precast concrete can be used to provide a cost effective design for long span bridges in high profile applications where aesthetics, environmental impact and urban geometrics are a significant design considerations.