Colorado Demonstration Project: Reconstruction of the I-25 Bronco Arch Bridge

Final Report
July 2015

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

U.S. Department of Transportation
Federal Highway Administration

FOREWORD

The purpose of the **Highways for LIFE (HfL)** pilot program is to accelerate the use of innovations that improve highway safety and quality while reducing congestion caused by construction. **LIFE** is an acronym for **L**onger-lasting highway infrastructure using **I**nnovations to accomplish the **F**ast construction of **E**fficient and safe highways and bridges.

Specifically, HfL focuses on speeding up *the widespread adoption* of proven innovations in the highway community. “Innovations” is an inclusive term used by HfL to encompass technologies, materials, tools, equipment, procedures, specifications, methodologies, processes, and practices used to finance, design, or construct highways. HfL is based on the recognition that innovations are available that, if widely and rapidly implemented, would result in significant benefits to road users and highway agencies.

Although innovations themselves are important, HfL is as much about changing the highway community’s culture from one that considers innovation something that only adds to the workload, delays projects, raises costs, or increases risk to one that sees it as an opportunity to provide better highway transportation service. HfL is also an effort to change the way highway community decision makers and participants perceive their jobs and the service they provide.

The HfL pilot program, described in Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) Section 1502, includes funding for demonstration construction projects. By providing incentives for projects, HfL promotes improvements in safety, construction-related congestion, and quality that can be achieved through the use of performance goals and innovations. This report documents one such HfL demonstration project.

Additional information on the HfL program is at www.fhwa.dot.gov/hfl.

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16. Abstract

As part of a national initiative sponsored by the Federal Highway Administration under the Highways for LIFE program, the Colorado Department of Transportation was awarded a grant to help replace the Bronco Arch Bridge carrying I-25 over the South Platte River in Denver to demonstrate the use of proven, innovative technologies for accelerated bridge removal and replacement. This report documents accelerated bridge construction technique using precast bridge elements and systems (PBES), with virtually no disruption to daily traffic of over 200,000 vehicles that use this portion of the interstate.

The 60-year-old original structure was a steel arch that local residents dubbed the Bronco Arch because of the site's proximity to Mile High Stadium where the Denver Broncos play football. The new structure is shorter and wider than the original structure (371 feet long by 197 feet wide versus 384 feet long by 158.5 feet wide). It has a five-span layout, 71 feet-30 feet-118 feet-30 feet-119 feet. Eight lines of girders support an 8-inch full-depth precast concrete deck system. Each girder line consists of three precast concrete pretensioned and posttensioned 72-inch-deep U girders cast in lengths of 95.0, 136.5, and 133.5 feet.

The new bridge is designed as a rigid frame with integral connections between the substructure and the superstructure. The distinctive-looking piers simulating the look of arches were precast at the site and placed immediately following caisson construction, eliminating the need for forming and pouring, resulting in reduced construction time. The use of PBES reduced construction time by more than 2 months, avoiding an estimated 58 crashes at this location.

The contractor maintained preconstruction lane capacity during construction, virtually eliminating impacts on traffic.

Because of the success of this project, Colorado plans to accelerate bridge construction using PBES on future projects, where this innovative technology is feasible and appropriate for conditions.

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Highways for LIFE, accelerated bridge construction, PBES, distinctive piers, integral superstructure and substructure connection, innovative construction, high traffic volume, minimal traffic disruption.

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SI* (MODERN METRIC) CONVERSION FACTORS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
(none)	mil	25.4	micrometers	µm
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela per square meter	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	Newtons	N
lbf/in^2 (psi)	poundforce per square inch	6.89	kiloPascals	kPa
k/in^2 (ksi)	kips per square inch	6.89	megaPascals	MPa
		DENSITY		
lb/ft^3 (pcf)	pounds per cubic foot	16.02	kilograms per cubic meter	kg/m^3

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
µm	micrometers	0.039	mil	(none)
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela per square meter	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	Newtons	0.225	poundforce	lbf
kPA	kiloPascals	0.145	poundforce per square inch	lbf/in^2 (psi)
MPa	megaPascals	0.145	kips per square inch	k/in^2 (ksi)

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ABBREVIATIONS AND SYMBOLS

ABC	Accelerated Bridge Construction
ADT	Average Daily Traffic
DOT	Department of Transportation
FHWA	Federal Highway Administration
HfL	Highways for LIFE
OSHA	Occupational Safety and Health Administration
PBES	Precast Bridge Elements and Systems
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users

INTRODUCTION

HIGHWAYS FOR LIFE DEMONSTRATION PROJECTS

The Highways for LIFE (HfL) pilot program, the Federal Highway Administration's (FHWA) initiative to accelerate innovation in the highway community, provides incentive funding for demonstration construction projects. Through these projects, the HfL program promotes and documents improvements in safety, construction-related congestion, and quality that can be achieved by setting performance goals and adopting innovations.

The HfL program—described in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)—may provide incentives to a maximum of 15 demonstration projects a year. The funding amount may total up to 20 percent of the project cost, but not more than $5 million. Also, the Federal share for an HfL project may be up to 100 percent, thus waiving the typical State-match portion. At the State's request, a combination of funding and waived match may be applied to a project.

To be considered for HfL funding, a project must involve constructing, reconstructing, or rehabilitating a route or connection on an eligible Federal-aid highway. It must use innovative technologies, manufacturing processes, financing, or contracting methods that improve safety, reduce construction congestion, and enhance quality and user satisfaction. To provide a target for each of these areas, HfL has established demonstration project performance goals.

The performance goals emphasize the needs of highway users and reinforce the importance of addressing safety, congestion, user satisfaction, and quality in every project. The goals define the desired result while encouraging innovative solutions, raising the bar in highway transportation service and safety. User-based performance goals also serve as a new business model for how highway agencies can manage the highway project delivery process.

HfL project promotion involves showing the highway community and the public how demonstration projects are designed and built and how they perform. Broadly promoting successes encourages more widespread application of performance goals and innovations in the future.

Project Solicitation, Evaluation, and Selection

FHWA has issued open solicitations for HfL project applications since fiscal year 2006. State highway agencies submitted applications through FHWA Divisions. The HfL team reviewed each application for completeness and clarity, and contacted applicants to discuss technical issues and obtain commitments on project issues. Documentation of these questions and comments was sent to applicants, who responded in writing.

The project selection panel consisted of representatives of the FHWA offices of Infrastructure, Safety and Operations; the Resource Center Construction and Project Management team; the Division offices; and the HfL team. After evaluating and rating the applications and supplemental information, panel members convened to reach a consensus on the projects to recommend for approval. The panel gave priority to projects that accomplish the following:

1. Address the HfL performance goals for safety, construction congestion, quality, and user satisfaction.
2. Use innovative technologies, manufacturing processes, financing, contracting practices, and performance measures that demonstrate substantial improvements in safety, congestion, quality, and cost-effectiveness. An innovation must be one the Applicant State has never or rarely used, even if it is standard practice in other States.
3. Include innovations that will change administration of the State's highway program to more quickly build long-lasting, high-quality, cost-effective projects that improve safety and reduce congestion.
4. Will be ready for construction within 1 year of approval of the project application. For the HfL program, FHWA considers a project ready for construction when the FHWA Division authorizes it.
5. Demonstrate the willingness of the State to participate in technology transfer and information dissemination activities associated with the project.

HfL Project Performance Goals

The HfL performance goals focus on the expressed needs and wants of highway users. They are set at a level that represents the best of what the highway community can do, not just the average of what has been done. States are encouraged to use all applicable goals on a project:

1. **Safety**
    a. Work zone safety during construction—Work zone crash rate equal to or less than the preconstruction rate at the project location.
    b. Worker safety during construction—Incident rate for worker injuries of less than 4.0, based on incidents reported via Occupational Safety and Health Administration (OSHA) Form 300.
    c. Facility safety after construction—Twenty percent reduction in fatalities and injuries in 3-year average crash rates, using preconstruction rates as the baseline.
2. **Construction Congestion**
    a. Faster construction—Fifty percent reduction in the time highway users are impacted, compared to traditional methods.
    b. Trip time during construction—less than 10 percent increase in trip time compared to the average preconstruction speed, using 100 percent sampling.
    c. Queue length during construction—A moving queue length of less than 0.5 mile in a rural area or less than 1.5 miles in an urban area (in both cases at a travel speed 20 percent less than the posted speed).
3. **Quality**
    a. Smoothness—International Roughness Index measurement of less than 48 inches per mile.
    b. Noise—Tire-pavement noise measurement of less than 96.0 A-weighted decibels, using the onboard sound intensity tests method.
4. **User Satisfaction**
    a. User satisfaction—an assessment of how satisfied users are with the new facility compared to its previous condition and with the approach used to minimize

disruption during construction. The goal is a measurement of 4-plus on a 7-point Likert scale.

REPORT SCOPE AND ORGANIZATION

This report documents accelerated bridge construction (ABC) techniques used to reconstruct the Interstate 25 Bronco Arch Bridge over the South Platte River in Denver's high-traffic Central Business District (with virtually no impacts on traffic). The report describes:

1. The use of innovative precast bridge elements and systems (PBES) to speed construction.
2. Construction phasing and traffic management during construction, which ensured that the same number of lanes were open to traffic *during* construction as *prior to* construction.
3. A design that maintains the unique aesthetic elements of the original structure.

The report presents project details relevant to the HfL program, including innovative construction highlights, features of value engineered design, HfL performance metrics measurement, and lessons learned.

The contractor was required to complete the project in 550 work days. The notice to proceed was issued on April 27, 2011, with the expectation that it would be completed in late August 2013. However, using value engineering, the contractor presented alternatives based on constructability and use of PBES which was accepted by the Colorado Department of Transportation (DOT). The alternate approach reduced construction time by more than 2 months, virtually eliminated traffic disruption, and was completed within budget as well.

PROJECT OVERVIEW AND LESSONS LEARNED

PROJECT OVERVIEW

The I-25 Bronco Arch Bridge over the South Platte River is located in the city of Denver adjacent to Sports Authority Field at Mile High (formerly Mile High Stadium). I-25 is a major north-south route through Colorado and intersects I-70 in the Denver area. I -25 at this location is one of the most congested sections of freeway, with average daily traffic (ADT) of over 206,000 vehicles. Traffic congestion at this location is caused by the proximity to the Central Business District and a variety of athletic and cultural events that take place at Mile High Stadium, Elitch Gardens, several universities and junior colleges, and a variety of museums.

The bridge has been a landmark since its construction and became known as the Bronco Arch Bridge since the Denver Broncos started playing football at Mile High Stadium in 1960. Figure 1 shows the bridge's location in relation to downtown Denver and Mile High Stadium. Figure 2 provides an aerial view of the project area.

Figure 1. Photo. Aerial view of Denver showing location of the Bronco Arch Bridge (courtesy: Colorado DOT).

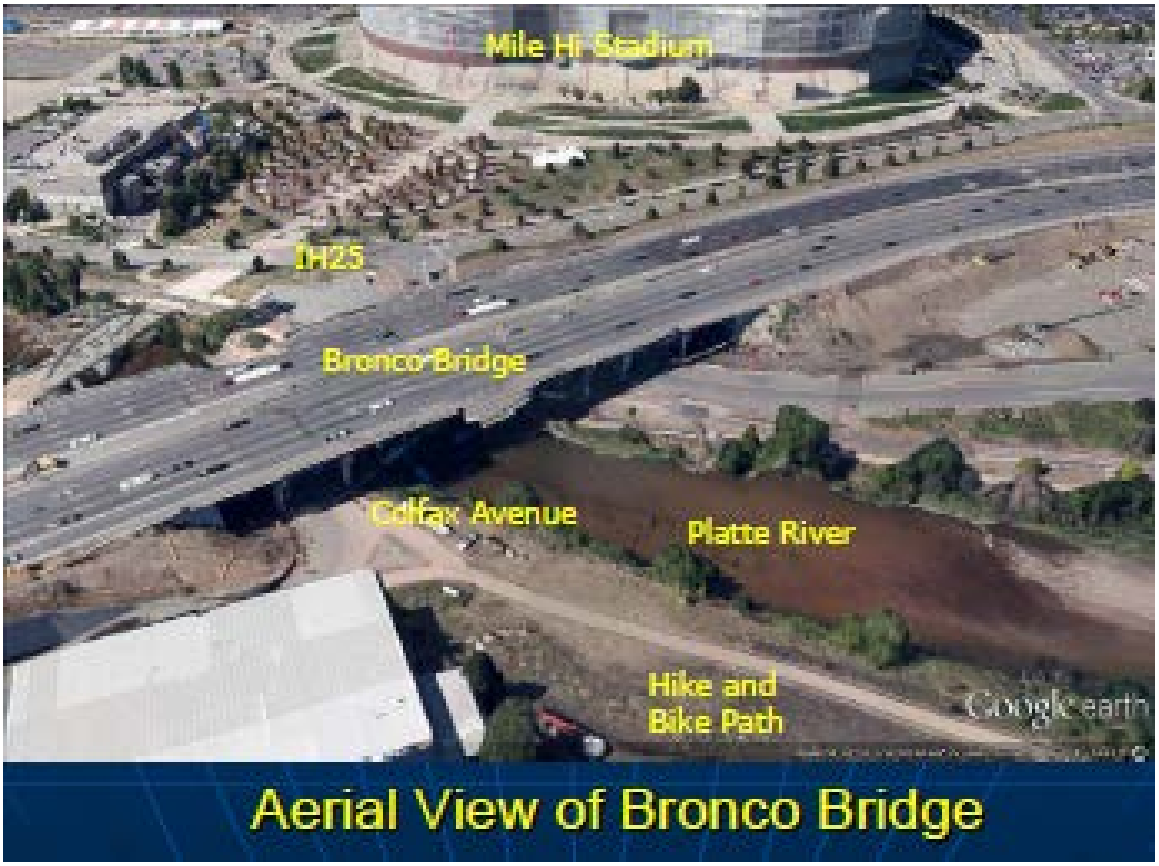


Figure 2. Photo. Aerial view of project site (courtesy: Colorado DOT).

The crossing is skewed to the highway centerline by 56 degrees to match the course of the South Platte River and carries four lanes of traffic and a lane for entry and exit ramps in each direction (see figure 3). The bridge was originally constructed in 1951 as two separate structures with the main spans being steel arches, as shown in figure 4. The structures were widened and connected in 1961 by closing the 38-foot median area between them. The bridge was widened again in 1971 in both directions to accommodate increased traffic volumes.

Figure 5 shows fatigue cracking in the floorbeams and floorbeam connection plates, leaking joints, and extensive corrosion that contributed to the structure being rated as structurally deficient (sufficiency rating of 24.5), easily meeting the funding criteria for replacement.

Using evaluation criteria that included environmental, aesthetics, constructability, in-service maintenance, in-service inspection, construction cost, and schedule factors, Colorado DOT considered rehabilitation and replacement options. The rehabilitation option had greater aesthetic value, but the replacement option had a significant cost advantage. Of the different structure types and span options, the least expensive was bulb tee construction for a three-span configuration. Colorado DOT selected the replacement option with a commitment to make every attempt to maintain the unique aesthetic elements of the bridge in the final design.

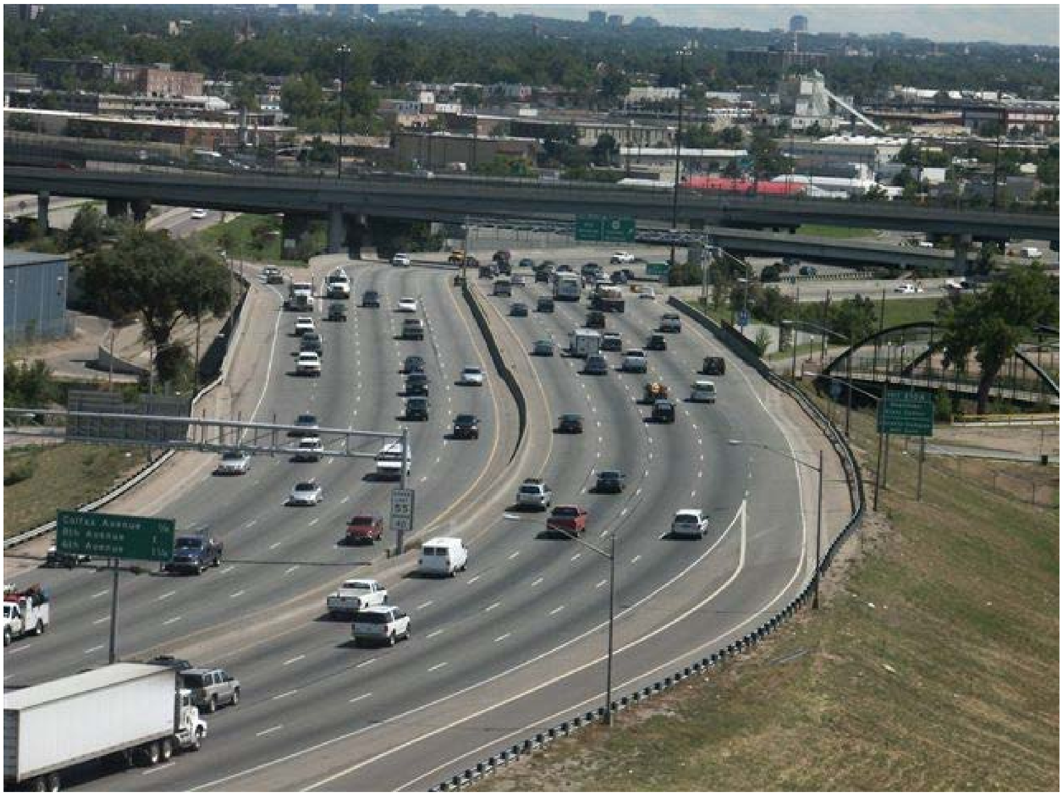
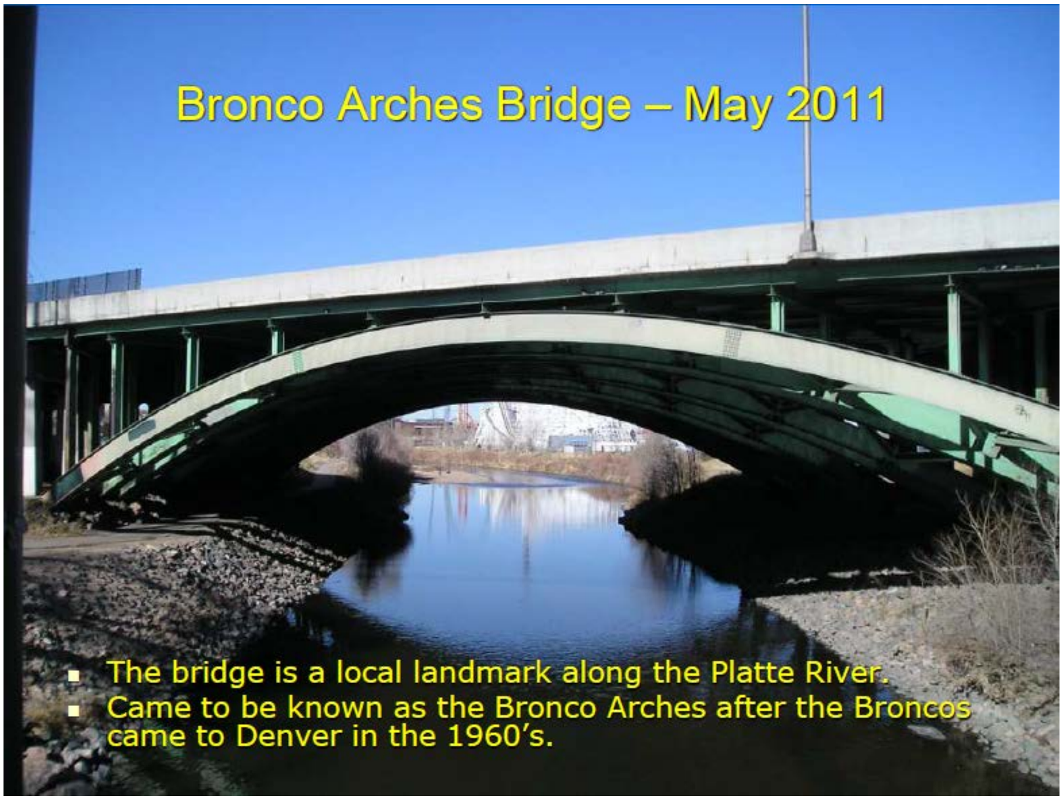


Figure 3. Photo. Four lanes and entry/exit ramp in each direction (courtesy: Colorado DOT).



Bronco Arches Bridge – May 2011

- The bridge is a local landmark along the Platte River.
- Came to be known as the Bronco Arches after the Broncos came to Denver in the 1960's.

Figure 4. Photo. Original bridge (courtesy: Colorado DOT).

Figure 5. Photos. Deterioration of original structure (courtesy: Colorado DOT).

The Colorado DOT decided to use ABC to compress construction time, minimize traffic impacts, improve worker/road user safety, and advance ABC knowledge in the State. The agency applied for and successfully obtained HfL funding.

Colorado DOT designed a new bridge, 371 feet long and 197 feet wide with the utilization of a full depth precast deck, and opened bidding in March 2011 with the requirement that the construction be completed in 550 work days. Although full depth precast decks had been used prior, this was the first transverse phased use of the technology and maximized the length and connects for transverse construction. The low bidder on the project, a contractor from Littleton, was issued the notice to proceed on April 27, 2011. The contractor asked the DOT to consider a value engineering proposal to the original ABC design that was cost neutral but included changes that would reduce disruption to travel and further compress the construction schedule. Key proposed changes were:

1. Use of H piling to support bridge abutment in lieu of caissons. Piling would be installed under the existing structure using a low overhead pile driver during daytime working hours. The new integral abutments would eliminate construction joints and would be completed before traffic was impacted for the bridge demolition phase. Avoidance of impact of the piling on a historic sewer, an important consideration for Colorado DOT, was analyzed and ensured.
2. Cast-in-place retaining walls in lieu of mechanically stabilized earth walls. The cast-in-place walls would be installed and backfilled underneath the existing bridge prior to the phasing of the traffic.
3. Redesign of bridge girders. The new design retained the original number of eight girder lines and girder spacing. The new bridge was designed as a rigid frame with integral connections between the substructure and the superstructure. The U girders were optimized to be lighter and could be handled in longer lengths, reducing the number of splices and easing erection challenges.
4. Redesign of pier columns. The original design of the piers were all identical to prepare for a precast option. The new design would slim down the piers, reducing the mass of concrete. The piers would be precast at the site and placed immediately following caisson construction, eliminating the need for forming and pouring the piers in place per the original design. Similar to the original design, the concrete piers simulated the look of the arches they replaced (see figure 6).
5. Widening the full-depth, 8-inch deck panels from 8 feet to 11 feet, which would reduce the number of transverse deck joints and reduce the number of closure pours by as much as 25 percent. This widening capability was due to the contractor’s casting bed.
6. Reducing the number of construction phases from five to four with some additional engineering and bracing. The contractor was able to combine phases 2 and 3 as originally proposed (see figure 7). This reduced striping quantity, project duration, and night work. Phase 3 would have needed to be completed almost exclusively at night due to its location on I-25. Figures 8 through 12 show the phased construction for the new bridge.

Colorado DOT accepted the value engineering proposal with the requirement that the redesign had to be accomplished within the overall construction schedule. The value engineering proposal removed 53 work days, or about 2.5 months, from the contract time.

New Bronco Bridge – March 2013.

- Project bid in March 2011.
- Lawrence Construction was low bidder at $14.2M.
- Awarded May 2011.
- Project Schedule of 550 working days.
- Completion anticipated in August 2013.

Figure 6. Photo. Elevation view of new structure (courtesy: Colorado DOT).

Figure 7. Drawing. Construction phasing as originally envisioned (courtesy: Colorado DOT).

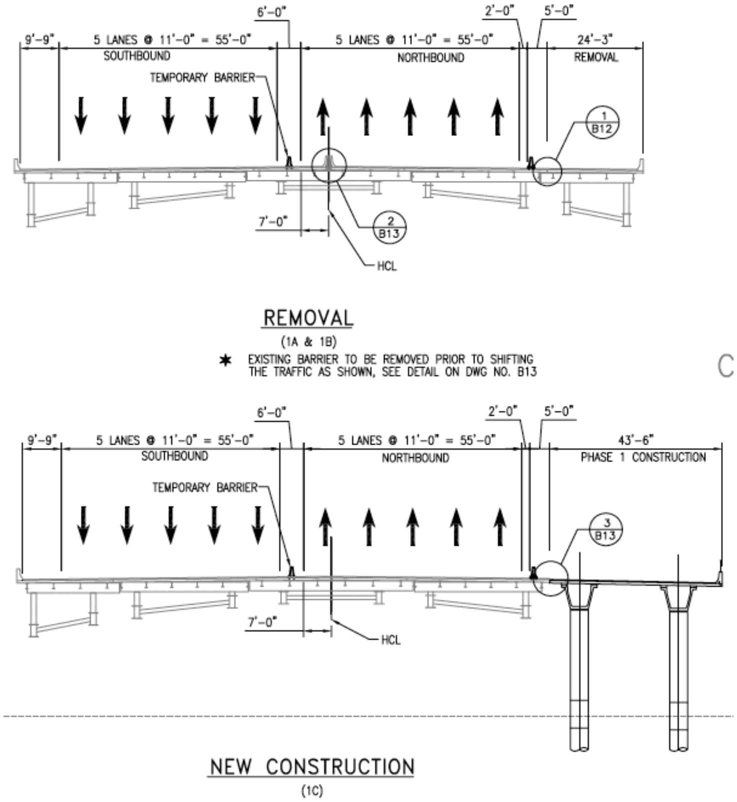


Figure 8. Drawing. Phase 1 construction (courtesy: Colorado DOT).

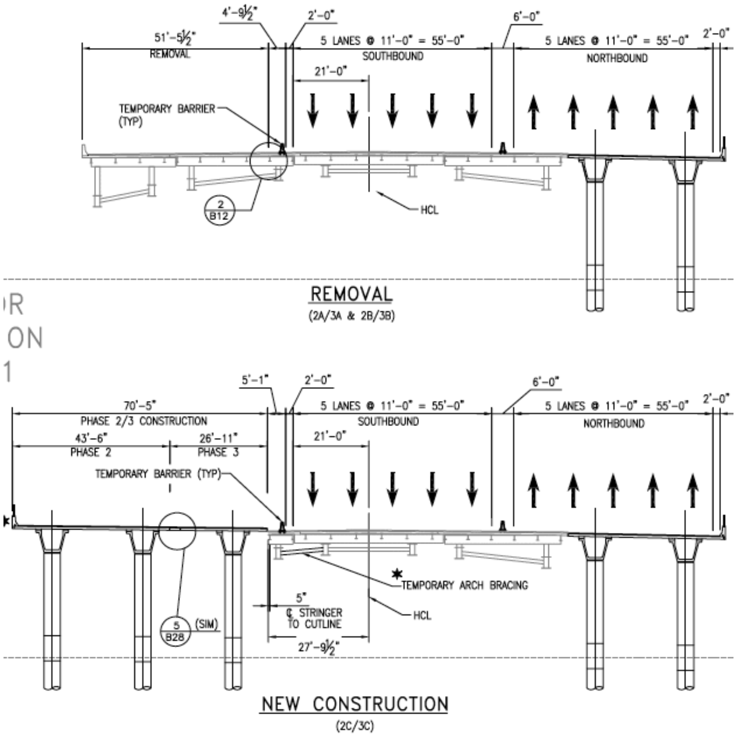


Figure 9. Drawing. Phase 2 construction (courtesy: Colorado DOT).

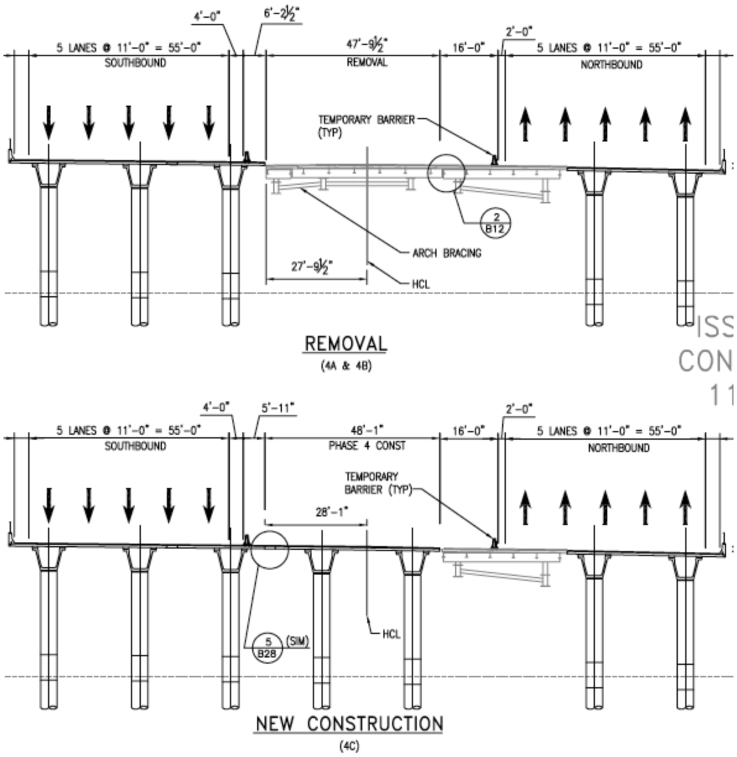


Figure 10. Drawing. Phase 3 construction (courtesy: Colorado DOT).

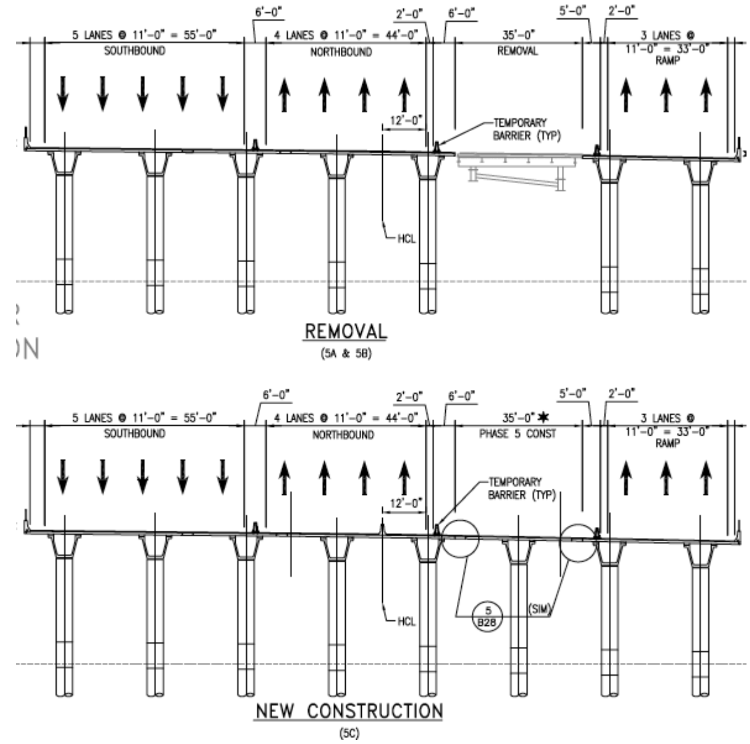
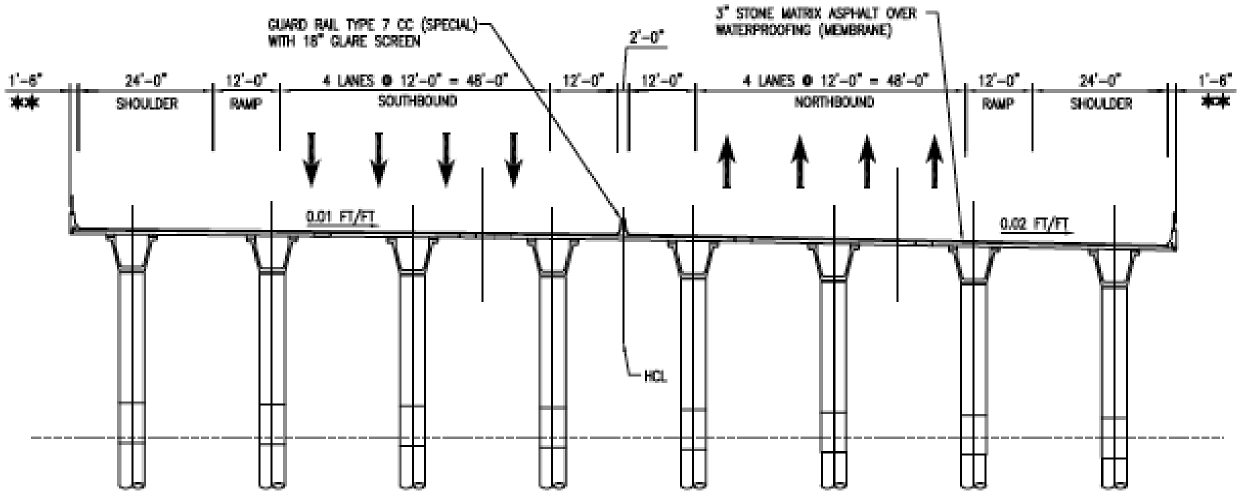


Figure 11. Drawing. Phase 4 construction (courtesy: Colorado DOT).

Figure 12. Drawing. Final phase and typical section



(courtesy: Colorado DOT).

The new bridge is 38 feet wider to accommodate the traffic phasing and provides additional lane capacity for future expansion. It consists of precast concrete curved piers and integral abutments; spliced precast, pretensioned and posttensioned 72-inch-deep U girders, and 8-inch full-depth precast concrete deck panels. The deck panels were pretensioned transversely and posttensioned longitudinally.

This report describes the safety, construction congestion and quality characteristics of the project to demonstrate how the use of innovative features helped the project team achieve the HfL performance goals in these areas.

First, with regards to safety, there were no worker injuries or motorist incidents reported during construction, which means that Colorado DOT exceeded the HfL requirements for worker and motorist safety. This success can be attributed to the preventive actions that the DOT took, which included:

1. Detailed Phasing Plans with the use of input from local jurisdictions in detailed development of traffic control plans.
2. Use of traveler information concerning traffic management changes and changing roadway conditions at the site during construction. The Colorado DOT made information available through newspapers, radio, television, the agency’s website and 511 system, and changeable message signs along the corridor.
3. A requirement that the contractor develop a project safety management plan. The minimum elements of this plan included designation of a safety officer to conduct regular safety meetings and job site safety reviews and reporting of violations.

The new bridge, designed to current standards, also eliminated the substandard shoulder widths and barriers that existed at this location. Furthermore, by reducing the construction duration, Colorado DOT reduced the potential for worker injuries and injury to travelers due to construction exposure.

Based on crash experience at the site, it is projected that by reducing the construction time, about 58 crashes were avoided, 13 of which could have been injury-related.

In addition to the safety-related benefits, building the bridge piers, superstructure, and deck away from traffic enabled easy construction access and improved quality.

With the use of PBES and four lanes available in each direction of travel, trip time through the project site was virtually unaffected by the construction, and there were no significant queues formed due to construction, easily meeting the HfL goals on trip time and queue lengths.

A formal user satisfaction survey was not performed on this project. However, with most work being performed below the roadway surface and with virtually no traffic impacts, this project was dubbed the "invisible project," embodying HfL goals on construction congestion in this high traffic volume environment.

LESSONS LEARNED

Through this project, Colorado DOT gained valuable insights on the innovative processes used, both those that were successful and those that need improvement in future project delivery. Observations and lessons learned include:

1. The closure periods for the demolition of the old structure and replacement with the new structure for each phase of the project were adequate. The contractor became more proficient with PBES with each advancing phase.
2. Public outreach efforts and pre-event and during event communications with stakeholders were effective.
3. Having a public relations person on the contractor's team is effective and is recommended for projects of this size and complexity.
4. Value engineering worked well, thanks to the cooperative effort between the Colorado DOT, the contractor, and the contractor's designer. The contractor's innovative ideas culminated in innovative end products and a project that was built faster with no additional costs.
5. Large cranes tend to be used to erect large precast elements. Although not a problem on this project, space for equipment and accessibility are important factors that must be considered during the planning stages.
6. Time spent on constructability review is time well spent.
7. Despite challenges due to bridge skew, the deck panel installation went very well.
8. Building abutment and walls for the entire structure, prior to demolition in phases, worked well and minimized traffic disruption.
9. Innovative use of precast elements reduced construction time, enabling early completion of the project.
10. The precast slabs didn't save too much time since they were not on the critical path. CDOT estimates that they could save about a month per phase due to the curing time but if it is not combined with precast approach slabs it may not save much time.

PUBLIC INVOLVEMENT

Throughout the project Colorado DOT incorporated an intensive public relations campaign to help inform motorists of changing roadway conditions. Colorado DOT requires that contractors develop and execute a public involvement plan for projects over $1.0 million. This program has worked well for Colorado DOT. In addition to communicating information about traffic phasing, the program provides information on other impacts like noise, nighttime lighting, and construction-related dust and debris.

CONCLUSIONS

The Colorado DOT gained important knowledge and experience using the innovative techniques on this project. This experience will aid in identifying future projects for which these techniques can be leveraged to provide schedule, quality, and safety benefits. From users' perspective, by successfully removing and replacing the structure with minimal impact even in a high-traffic corridor, Colorado DOT has shown it is among the leaders in implementing innovative technology and has undoubtedly raised expectations on project delivery in the future.

From the standpoint of construction speed, motorist and user safety, cost, and quality, this project was a success and embodied the ideals of the HfL program. Colorado DOT learned that careful planning, along with the use of PBES and ABC technologies during bridge construction, can result in projects that serve as watershed events in the way they are delivered to the public with minimal disruption to their travel due to work zones.

Because of the success of this project, Colorado DOT plans to consider PBES and ABC technology as viable tools in its toolkit on all future projects.

PROJECT DETAILS

BACKGROUND

The Bronco Arch Bridge project is located in Denver between mileposts 210.3 and 210.8 of I-25. Traffic phasing extended the limits of the project approximately 1,000 feet on either end of the bridge. The new bridge is wider than the original structure and has out-to-out roadway width in each direction of 96 feet, 20 feet wider than the old structure. With the median barrier and the exterior Type 7 Bridge Rail, the total out-to-out bridge width is 197 feet.

The bridge carries the highway over the South Platte River, an intermittent-use trolley line, bike paths, and two city streets. The South Platte River trails are popular walking and biking areas. Mile High Stadium is located just west of the bridge site. 17th Avenue is located under the northern end spans and is a primary access to the Stadium to the west.

The existing surrounding topography is generally flat and is in the 100-year flood plain of The South Platte River. The I-25 grade was raised in the vicinity of the bridge approximately 30 feet to maintain the proper roadway and railroad clearances during the original construction in 1951.

The bedrock surface elevations range from 35 to 40 feet at the pier locations and about 60 feet below the abutment locations with groundwater elevations approximately similar to the river surface.

PROJECT ENGINEERING

The new bridge was designed with integral connections between the superstructure and substructure and assuming flexible foundations. The abutments are supported by steel piling and the interior piers by 54-inch drilled shafts. Figure 13 shows a drawing of the bridge plan and elevation, and figure 14 shows the continuous cap of the integral abutment supporting the girders.

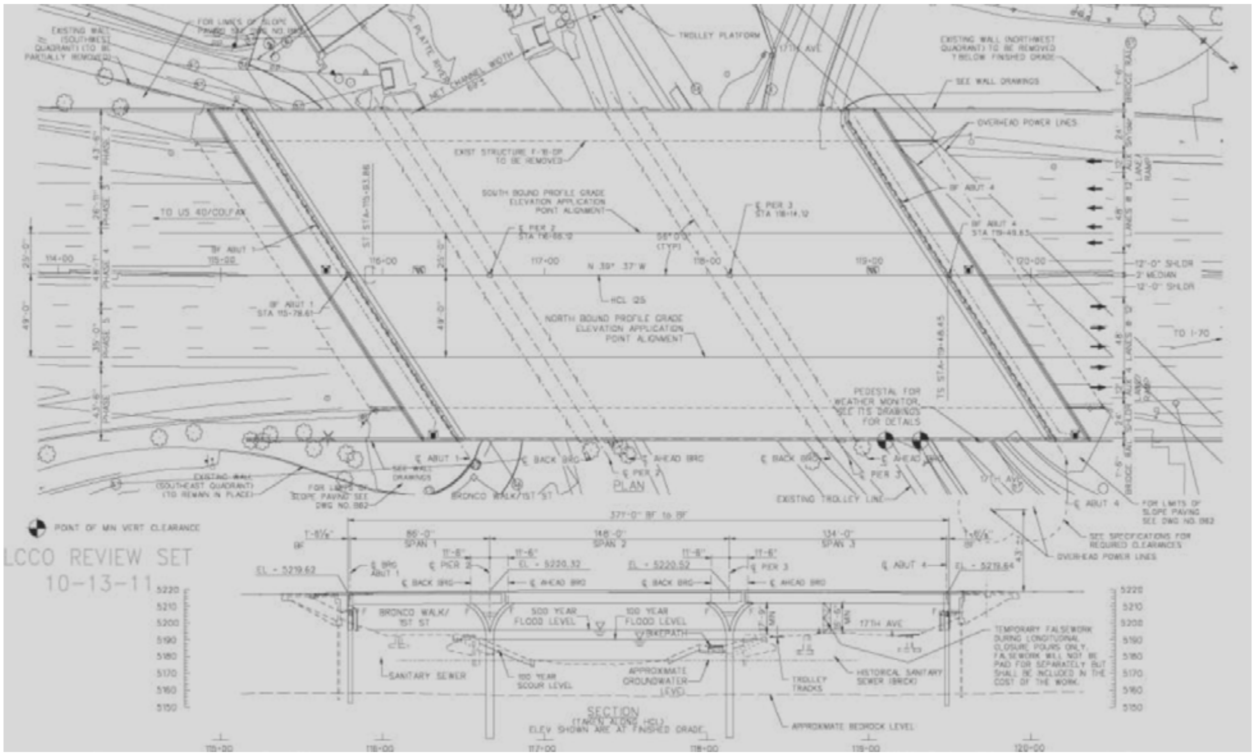


Figure 13. Drawing. Bronco Arch Bridge plan and elevation (courtesy: Colorado DOT).

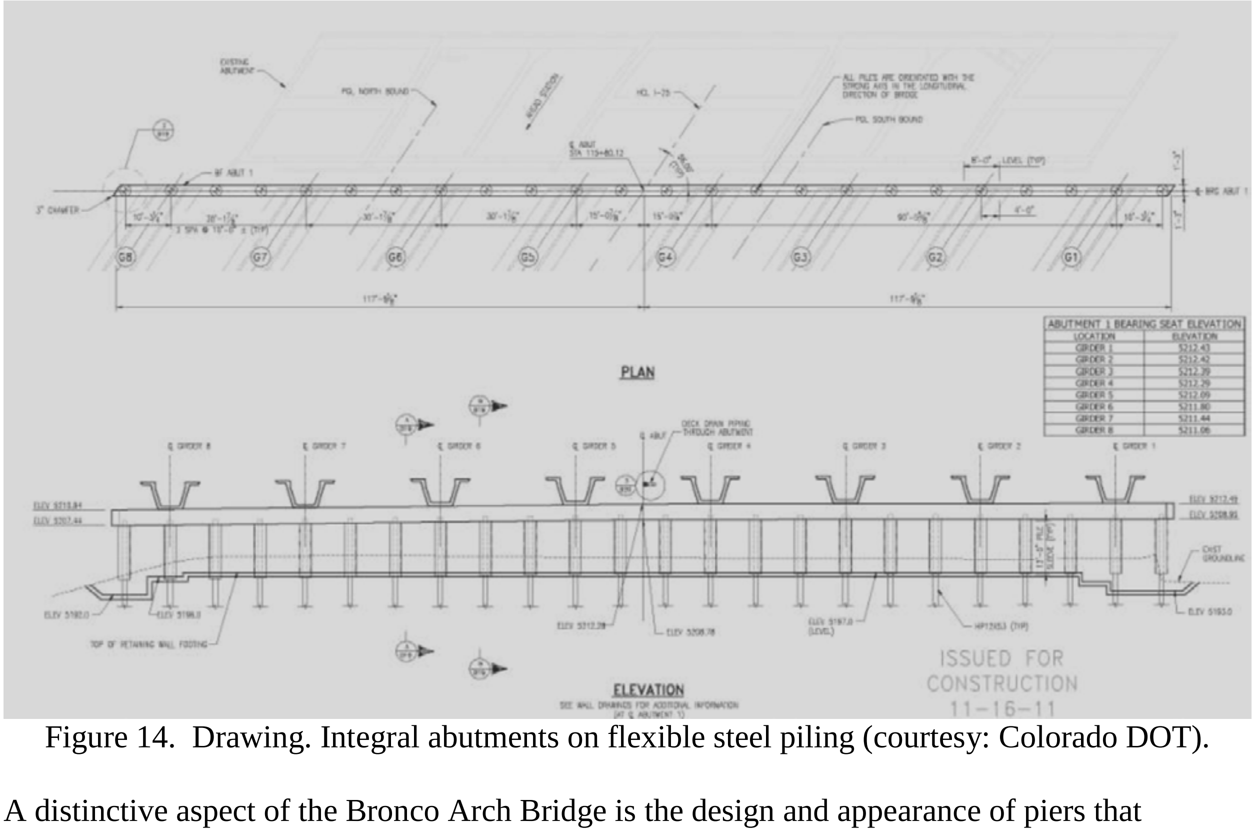


Figure 14. Drawing. Integral abutments on flexible steel piling (courtesy: Colorado DOT).

A distinctive aspect of the Bronco Arch Bridge is the design and appearance of piers that simulate the look of arches. Figure 15 shows one of the 16 identical piers precast for the project. Note the slender, arched shafts that are connected at mid height by a concrete strut, reducing the bending moments in the pier shafts. This helped reduce the overall weight of the piers to 100 kips, making handling and erection possible.

Figure 15. Photo. Arch shaft pier (courtesy: Colorado DOT).

Figure 16 shows the reinforcement details for each pier. The pier is connected to the foundation with a cast-in-place concrete pedestal and to the girders through a capital at the top of each pier shaft.

The piers were cast horizontally in the contractor's yard adjacent to the bridge site on a smooth finished concrete mud slab. As cast, the piers were 34 feet tall and 33 feet across at the top with 54-inch-wide shafts that varied in thickness from 24 inches at the base to 30 inches. at the capitals.[1]

The girders on the project are standard Colorado DOT U72 precast concrete girders 72 inches deep. They were cast with self-consolidating concrete with design compressive strength of 8.5 ksi. The girders were cast in lengths of 95.0, 136.5, and 133.5 feet, and their weights ranged from 170 kips to 210 kips. They were spliced with concrete between adjacent girder ends. The diaphragms connecting the girders to the piers and abutments were cast in place.

Figure 17 shows a drawing of a sample girder. The designer developed unique prestressing patterns for each of the three different girders for construction and service loadings using a combination of straight, draped, and debonded strands. The girders were posttensioned after they were spliced and connected to the substructure.

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[1] Gregg A Reese, "The Bronco Arch Bridge Design and Construction of the replacement for the I-25 Bridge over the South Platte River, ASPIRE, Summer 2013.

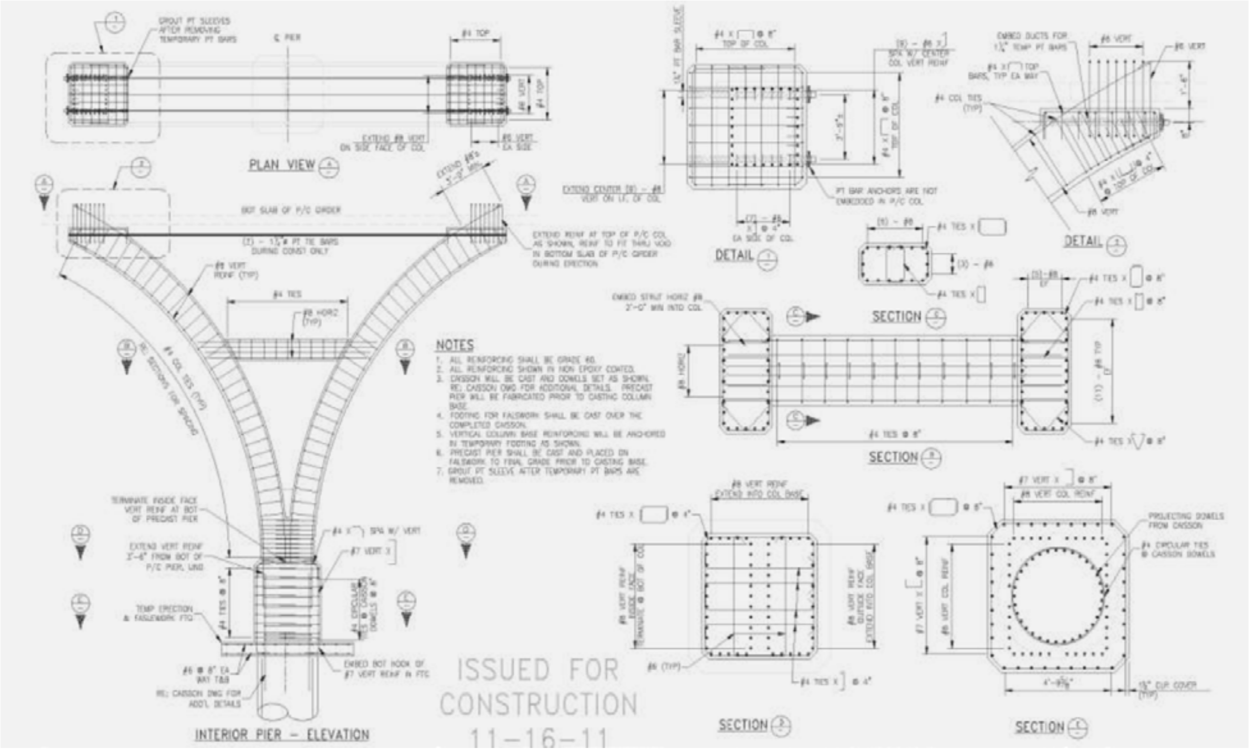

Figure 16. Drawing. Reinforcement details for pier (courtesy: Colorado DOT).

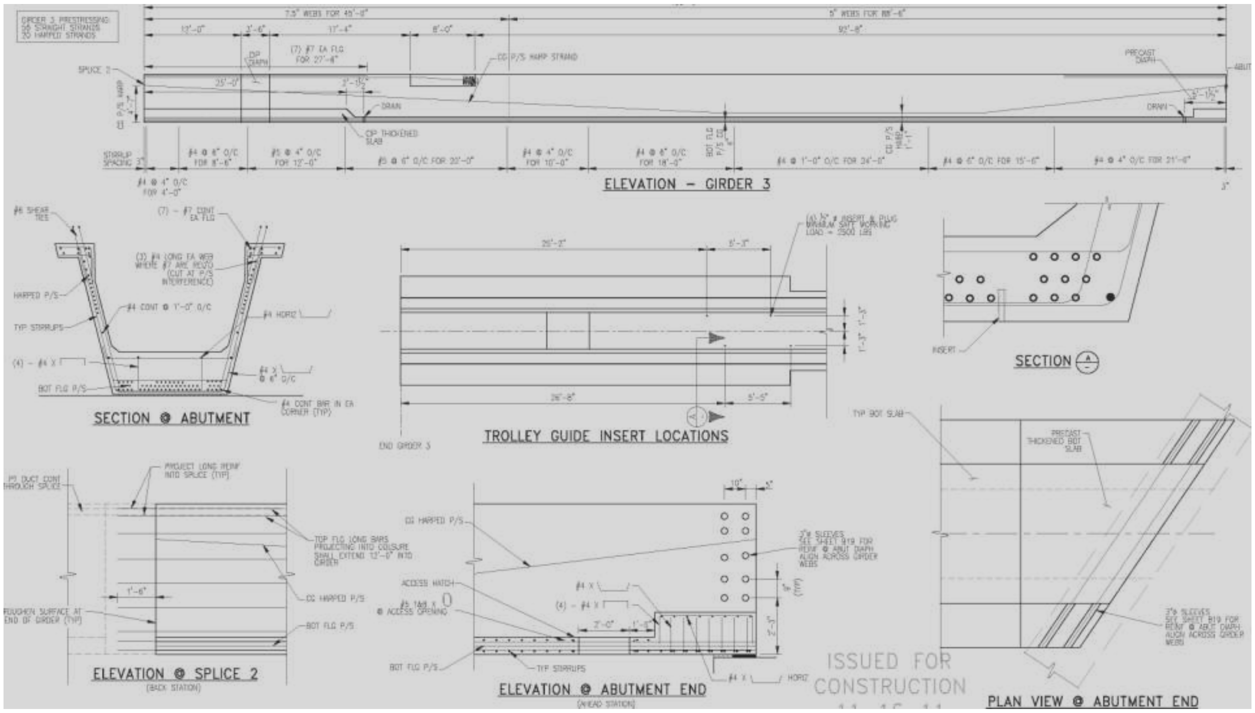

Figure 17. Drawing. U72 girders used on project (courtesy: Colorado DOT).

Once the girders were erected, 8-inch-thick deck panels were set in place using a 240 ton crane. The deck panels were made composite with the precast concrete girders. The panels were then posttensioned longitudinally after the concrete had attained design strength.

The project was built in phases, as was shown in figure 8 through 12. The phasing lines needed to correspond to the original construction and widening in 1961 and 1971 to keep the structure stable. The contractor used additional engineering and bracing when the original Phases 2 and 3 were combined into a single phase.

PROJECT CONSTRUCTION

The construction timeline on the $16.3 million project was as follows:

1. Phase 1 (164 calendar days):
    1. Phase 1 demolition started – November 22, 2011.
    2. Phase 1 construction completed and traffic switched – May 4, 2012.
2. Phase 2/3 (104 calendar days):
    1. Phase 2/3 demolition started – May 7, 2012.
    2. Phase 2/3 construction completed and traffic switched – August 19, 2012
3. Phase 4 (102 calendar days):
    1. Phase 4 demolition started – August 23, 2012.
    2. Phase 4 construction completed and traffic switched – December 3, 2012.
4. Phase 5 (121 calendar days):
    1. Phase 5 demolition started – December 4, 2012.
    2. Phase 5 construction completed – April 4, 2013.

In August 2011 (prior to any traffic phasing), the contractor started building the foundation for the new structure abutments and walls in their entirety. The walls were supported on footings and the abutment caps on steel piling. Because of the low clearance due to work being performed under the existing structure, the contractor used low clearance hydraulic pile hammers to drive 15-foot sections of piles. The piles were driven in front of the existing abutments. Figure 18 shows pilings for an abutment completed full width and piling being encased in 30-inch corrugated pipe.

All foundation work and walls on footings were formed and cast under and alongside the existing bridge and backfilled and compacted without disrupting traffic. Figure 19 shows compacted backfill around pilings under the existing bridge.

The contractor was able to complete a significant amount of construction work before commencing the demolition work for Phase 1 on November 22, 2011.

Figure 18. Photo. Piling for new bridge abutment (courtesy: Colorado DOT).

Figure 19. Photo. Walls backfilled and compacted around piling (courtesy: Colorado DOT).

Once the deck and upper framing was removed, work started on demolition of the steel arches. Figure 20 shows the center section of the arch being removed in manageable pieces while tension rods hold the lower sections in place. The demolition process using this method was slow. However, the contractor was able to obtain and use a crane with 500 ton capacity at the site, which enabled lifting a full arch pair basically intact, and this method made the demolition process go much faster in subsequent phases.

Figure 20. Photo. Cener portion of the original steel arch being removed (courtesy: Colorado DOT).

Pier foundation construction began once the demolition for Phase 1 was completed. The two interior piers for each line of girders are supported on 54-inch drilled shafts. Footings, 12 inches thick for pier shorings, were then cast in place prior to the placement of the prefabricated piers cast in the contractor’s yard adjacent to the project site. Figure 21 shows the piers already cast stacked and stored in the contractor’s yard. All piers were cast horizontally on mud slab using conventional wall forms. Four piers for Phase 1 were then shipped on flatbed trailers, lifted, and set into shoring tower on the cast-in-place footings as shown in figure 22. After each pier was set, a connection pour was made between the caisson and the pier. Meanwhile, six girders for Phase 1were fabricated. Once the piers were ready to receive them, the girders were set on pier pedestals and abutments on 0.75-inch neoprene level pads. Figure 23 shows a girder being set on a pier shaft and abutment. Girder splices and diaphragms over piers and abutments were then field cast and the girders connected to the substructure. Following posttensioning of girders, the superstructure was ready for placement of deck panels.

Figure 21. Photo. Prefabricated piers stacked in adjacent yard (courtesy: Colorado DOT).

Figure 22. Photo. Pier being set on footing (courtesy: Colorado DOT).

Figure 23. Photo. U72 girder being set in place (courtesy: Colorado DOT).

Like the piers and girders, deck panels were precast well in advance of when they were needed. Five widths of deck panels were cast for different phases. Panels were transversely prestressed and equipped with leveling screws to set each panel to correct grade as it was being placed. Figure 24 shows a precast panel in the process of being placed, figure 25 shows panels set with pockets over shear reinforcing in girder top flanges, and figure 26 shows panels set from abutment to abutment, ready for haunch and transverse joint casting. Haunches, pockets, and joints were filled with the same mix as panels, batched at the plant, transported, and pumped into place. Once the haunch and closure concrete reached design strength, the deck panels were posttensioned longitudinally.

Key work prior to traffic phasing included forming and pouring the approach slab with expansion joint, constructing the bridge rail, waterproofing the deck, placing the stone matrix asphalt overlay, and striping the pavement.

The contractor continued to provide four lanes of traffic in each direction as the project moved into each subsequent phase, limiting interruptions to the traveling public to an absolute minimum. A photograph of the completed bridge with its unique aesthetic elements is shown in figure 27.

The contractor was given an additional time of 63 work days primarily due to unanticipated field conditions. As a result, the project was completed on September 20, 2013, instead of early June. Again, throughout the construction duration, even with the extension, there was virtually no disruption to the travelers on the interstate.


Figure 24. Photo. Placement of deck panels (courtesy: Colorado DOT).


Figure 25. Photo. Panels set with pockets over shear reinforcing in girder top flanges (courtesy: Colorado DOT).

Figure 26. Photo. Panels in place from abutment to abutment (courtesy: Colorado DOT).

Figure 27. Photo. Photograph of completed structure (courtesy: Colorado DOT).

DATA ANALYSIS

The primary objective of acquiring data is to provide sufficient performance information to support the feasibility of the proposed innovations and to demonstrate that ABC technologies can be used to do the following:

1. Achieve a safer work environment for the traveling public and workers.
2. Reduce construction time and minimize traffic interruptions.
3. Improve quality.

This section discusses how well the Colorado DOT project met the HfL performance goals related to these areas.

SAFETY

Use of precast bridge elements enabled the substructure, superstructure, and deck elements to be fabricated off site, away from the high volumes of traffic on the interstate. This improved the safety of the workers in the work zone and the safety of motorists as well, as they were not exposed to typical work zone hazards. Also, work could be performed at off-site locations during the day and night without interruptions throughout the construction process.

The HfL performance goals for safety include worker and motorist safety during construction. During the construction of the Bronco Arch Bridge project, no worker injuries were reported, which means Colorado DOT exceeded the HfL goal for worker safety (incident rate of less than 4.0 based on the rate reported on OSHA Form 300).

Colorado DOT's safety study for the project area found that there were 2,771 crashes during the 3-year period between January 1, 2002, and December 31, 2004, averaging 77 crashes per month. Of these, 22 percent (about 17) were injury-related and 78 percent (about 60) were property-related. Less than 1 percent of the accidents were fatal. It is estimated based on national studies that average crash rate increases by approximately 30 percent due to construction.[2] Assuming that the same would have occurred at this location, the average crash rate during construction is estimated to have increased by:

77 * 0.30 = 23 crashes per month.

Therefore, with the estimated reduction in construction time of 2.5 months, it is projected that the use of innovative construction methods reduced the number of crashes by at least 58:

23 * 2.5 = 58 crashes.

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[2] Bhajandas, A and Mallela, J., *I-84 Bridge over Dingle Ridge Road Replacement using Superstructure Slide-In Technology*, Draft Report, December 2013

Furthermore, based on Colorado DOT's crash rate experienced at the site, approximately 22 percent of these crashes would have resulted in injuries. Therefore, it can be projected that about 13 (0.22 * 58) injury-related crashes were avoided by faster construction.

Re-engineering the original design also reduced the number of construction phases by one, which means one fewer phase change during construction, contributing to greater safety for both motorists and construction workers.

CONSTRUCTION CONGESTION

The HfL performance goals for construction congestion are shown here again:

1. Faster construction—Fifty percent reduction in the time highway users are impacted, compared to traditional methods.
2. Trip time during construction—less than 10 percent increase in trip time compared to the average preconstruction speed, using 100 percent sampling.
3. Queue length during construction—A moving queue length of less than 0.5 mile in a rural area or less than 1.5 miles in an urban area (in both cases at a travel speed 20 percent less than the posted speed).

The construction time on the project was reduced by at least 2 months. However, during the entire construction duration of the project of about 24 months, the contractor maintained the same number of lanes for traffic as normally available to travelers prior to construction. Therefore, the project not only easily met, but easily exceeded HfL goals, as there were virtually:

1. No impacts on traffic.
2. No increase in trip time during construction.
3. No queues during construction.

QUALITY

This project primarily involved bridge replacement. The only roadway work was to tie the new construction to the existing approach roadways and to elevate the asphalt pavement grade to accommodate current design vehicle speed. Colorado DOT used stone matrix asphalt as the paving material on this project, which is known to provide improved durability and reduced tire/pavement noise. Users are likely to note these benefits as they drive on the new, smoother surfaces of the approaches and the new bridge deck, which are undoubtedly a great improvement over the surfaces of the old bridge.

Building the piers, beams, and deck panels of the bridge away from traffic enabled easy construction access and improved quality, avoiding any damage by traffic-induced vibrations. The controlled environment allowed longer concrete cure times, better material staging areas, and smoother assembly, all of which contributed to improved quality.

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