Colorado Demonstration Project:

I-70 Tower Road to Colfax Avenue GRS-IBS Bridge Replacement Project

Final Technical Brief

August 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. Such "innovations" 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 a part of the Highways for LIFE initiative, the Federal Highway Administration provided a $2,000,000 grant in support of the Colorado Department of Transportation effort to replace two structurally deficient bridges on I-70 over Smith Road and Union Pacific Railroad. The existing bridges were on a horizontal and vertical curve and consist of welded steel girders with a cast-in-place concrete deck. Each bridge had an out-to-out width of 43.0 feet and accommodated two lanes with 8-foot shoulders on either side.

This project involved removing the two bridge structures and replacing them with wider (60-foot) structures. The key innovation on the project was the use of geosynthetic reinforced soil-integrated bridge system (GRS-IBS) for the construction of the bridge abutments. This is the first project in the nation to utilize the GRS-IBS technology on a multi-span, high-speed interstate roadway.

Phase 1 of the construction, which involved the replacement of the westbound bridge, is completed. Phase 2 is underway. The westbound bridge is performing very well, with no settlement observed to date.

With the experience gained during Phase 1, it is anticipated that the second phase of construction in the eastbound direction will be carried out more efficiently.

17. Key Words	18. Distribution Statement
Highways for LIFE, geosynthetic reinforced soil, integrated bridge system, GRS-IBS	No restriction. This document is available to the public through the Highways for LIFE website: http://www.fhwa.dot.gov/hfl/

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSIONS FROM SI UNITS

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)

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

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ABBREVIATIONS AND SYMBOLS

AADT	annual average daily traffic
ADT	average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
CDOT	Colorado Department of Transportation
DOT	department of transportation
EDC	Every Day Counts
FHWA	Federal Highway Administration
GRS	geosynthetic reinforced soil
HfL	Highways for LIFE
IBS	integrated bridge system
IRI	International Roughness Index
MSE	mechanically stabilized earth
MVM	million vehicle miles
OBSI	onboard sound intensity
OSHA	Occupational Safety and Health Administration
PDO	property damage only
RCC	roller compacted concrete
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
UPRR	Union Pacific Railroad

INTRODUCTION

HIGHWAYS FOR LIFE DEMONSTRATION PROJECTS

The Highways for LIFE (HfL) pilot program, the Federal Highway Administration (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 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 annually 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 applicant department of transportation (DOT) 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 on 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 miles 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 (IRI) measurement of less than 48 in/mi.

b. Noise—Tire-pavement noise measurement of less than 96.0 A-weighted decibels (dB(A)), using the onboard sound intensity (OBSI) test 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 or more on a 7-point Likert scale.

REPORT SCOPE AND ORGANIZATION

This technical brief documents the Colorado Department of Transportation (CDOT) HfL demonstration project for replacing two bridges located on the westbound and eastbound routes of I-70 near Aurora. The innovation on this project is the use of geosynthetic reinforced soil-integrated bridge system (GRS-IBS) for the construction of the bridge abutment. The technical brief presents the available project details, project innovations, and HfL performance metrics measurement.

PROJECT DETAILS

BACKGROUND

This CDOT project involved reconstructing I-70 between Tower Road and Colfax Avenue, in Adams County. As shown in Figure 1, the project is located to the west of Aurora, with the approximate limits shown in Figure 2. This project is located to the east of the I-70 exit to Pena Boulevard and Denver International Airport, between mileposts 285.09 and 289.12.

This portion of I-70 is a major corridor for commerce, and the westbound roadway serves as one of the primary access routes to Denver International Airport for the public in the eastern plains. The 2012 average daily traffic (ADT) for this portion of I-70 was 39,817 vehicles, with 20 percent truck traffic.

Table 1 summarizes the traffic, number of accidents, and accident rates for the 3 years prior to construction. Also included within the project limits are the twin bridges (E-17-JW and E-17-JX) over Smith Road and the Union Pacific Railroad (UPRR) at approximately milepost 268.8. These bridges were determined to be structurally deficient.

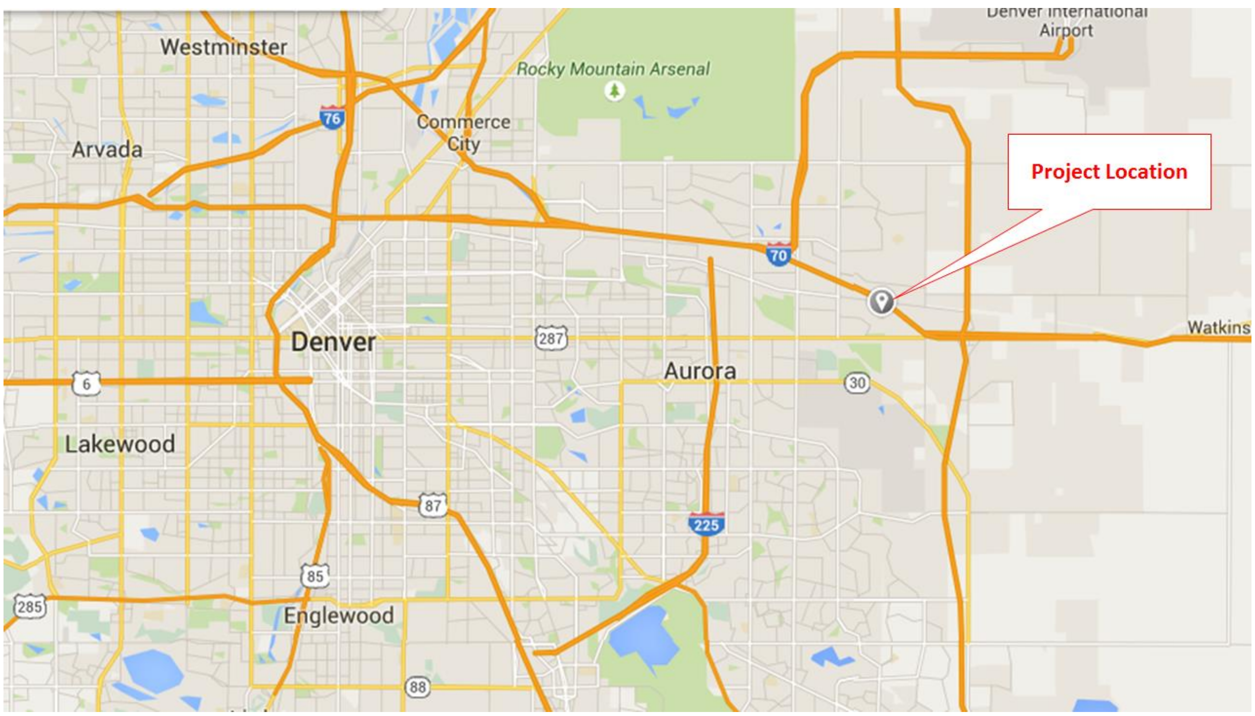

Figure 1. Map. Approximate location of CDOT's I-70 reconstruction project.

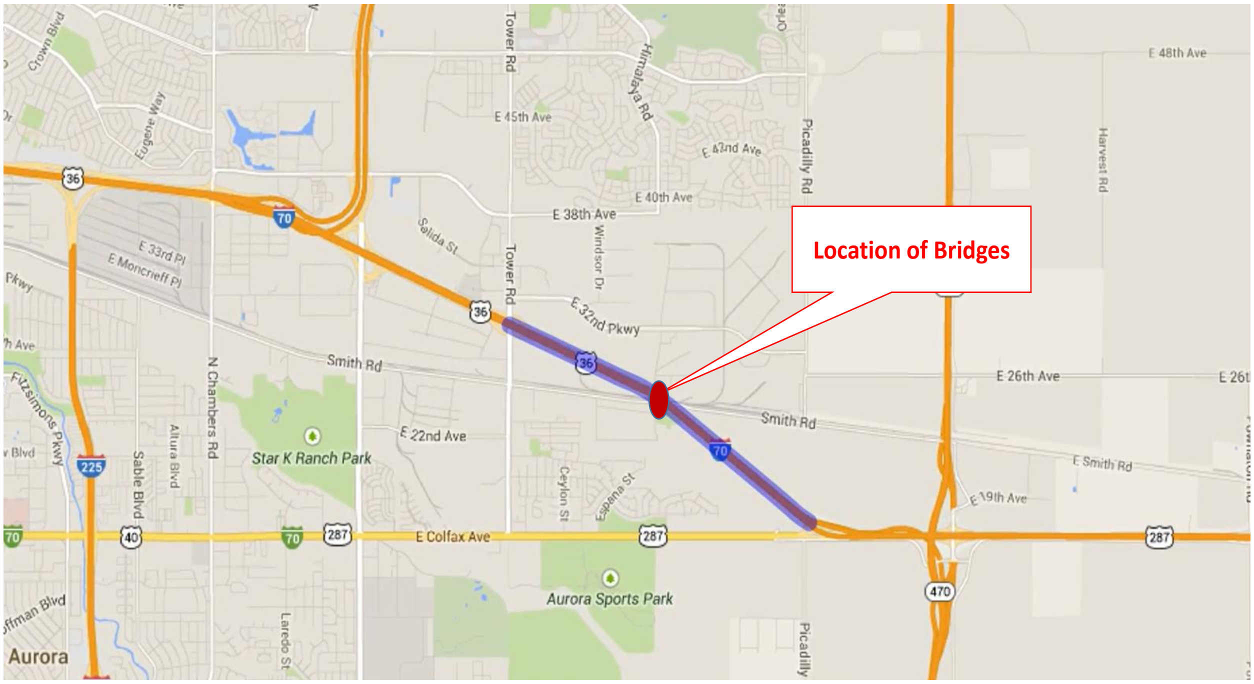

Figure 2. Map. Approximate limits of the I-70 project and location of deficient bridges.

Table 1. Traffic, number of accidents, and accident rates for I-70.

Year	AADT	Accidents				Accident Rates (per MVM)			
		PDO	Injury	Fatal	Total	PDO	Injury	Fatal*	Total
2012	39817	54	16	1	71	0.72	0.21	1.33	0.94
2011	39817	52	12	0	64	0.69	0.16	0.00	0.85
2010	43565	46	11	0	57	0.57	0.14	0.00	0.70
Total	**41053**	**152**	**39**	**1**	**192**	**0.65**	**0.17**	**0.43**	**0.83**

AADT = annual average daily traffic; PDO = property damage only; MVM = million vehicle miles.
*Fatality rates shown are per 100 MVM.

Project Goals and Scope

Following are the goals of this CDOT project:

1. To replace and widen the outdated structurally deficient highway bridge structures over the UPRR and Smith Road.
2. To reconstruct and widen portions of I-70 between Tower Road and Colfax Avenue.
3. To improve safety for all project stakeholders and the traveling public.
4. To improve the overall flow of traffic through this important highway corridor.

The reconstruction work included the following:

1. Widening I-70 to accommodate two full-width shoulders (12 feet each) and two 12-foot through lanes in each direction with 11 inches of concrete pavement. The widened shoulders will allow for one future highway travel lane in each direction of travel.

2. Reconstructing the existing section of I-70 with 7.75 inches of roller compacted concrete (RCC) pavement.
3. Removing the two bridge structures, E-17-JW and E-17-JX, and replacing them with wider (60-foot) structures (E-17-AEJ and E-17-AEK).

Existing Bridge Information

The existing bridges are shown in Figures 3 and 4. These bridges are on a horizontal and vertical curve and consist of welded steel girders with a cast-in-place concrete deck. Each bridge has an out-to-out width of 43.0 feet and accommodates two lanes with 8-foot shoulders on either side. Both of these bridges were determined to be structurally deficient.

Figure 3. Photo. Bridge E-17-JW (eastbound).

Figure 4. Photo. Bridge E-17-JX (westbound).

Project Innovations

The key innovation on this project is the use of GRS-IBS for reconstruction of the bridge supports. GRS-IBS is an accelerated bridge construction technique that was selected as one of FHWA's Every Day Counts (EDC) initiatives. The GRS-IBS technology provides support to the bridge through the use of alternating layers of compacted granular fill and sheets of geosynthetic fabric reinforcement.

CDOT decided to use the GRS-IBS technology for this project for the following reasons:

1. Reduced construction duration: CDOT anticipated that the GRS-IBS technology will allow for construction of the bridge abutment in 1 week. CDOT's traditional abutment construction typically requires about 1 month to complete.
2. Reduced cost: CDOT anticipated a 25 percent reduction in abutment construction cost through the use of GRS-IBS.
3. Reduced differential settlement: Since GRS-IBS allows for the abutment foundation to settle at the same rate as the approach roadway, it is capable of reducing the differential settlement, or "bump," typically seen in the approach joint of a bridge.
4. Expand their current knowledge of GRS-IBS systems and utilize a different wall facing.

Although the GRS-IBS technology has been used in Colorado as well as in other States, this project is the first in the nation to utilize it on a multi-span, high-volume, interstate highway.

CONTRACT AND BIDDING INFORMATION

This project was let using traditional design-bid-build contracting. A mandatory pre-bid meeting for this project was combined with another CDOT project (IM 0253-222, I-25 North Express Lanes) and was held on July 9, 2013. Nineteen contractors attended the pre-bid meeting, and eight submitted bids for this project. The winning bid was submitted by Ames Construction for $23,821,348.00. Table 2 presents a bid comparison summary.

Table 2. Bid comparison summary.

Bidder	Construction Bid	% Over Low Bid
Estimated Construction Cost	$ 23,361,238.25	-
Winning Bid (Ames Construction)	$ 23,821,348.00	0.0 %
Bid 2	$ 23,987,245.34	0.7 %
Bid 3	$ 24,467,014.34	2.7 %
Bid 4	$ 24,725,708.85	3.8 %
Bid 5	$ 25,212,616.25	5.8 %
Bid 6	$ 25,449,796.23	6.8 %
Bid 7	$ 27,582,158.95	15.8 %
Bid 8	$ 30,352,292.33	27.4 %

NEW BRIDGE SPECIFICATION

The new bridges over Smith Road and UPRR are expected to have three spans with an out-to-out width of 63 feet. As shown in Figure 5, each bridge will consist of two 12-foot lanes, a 12-foot outside shoulder, and a 24-foot inside shoulder for a total curb-to-curb width of 60 feet. The bridges will consist of 8-inch-thick decks that will be placed on top of seven steel plate girders spaced at 9.5 feet center-to-center. Figures 6 and 7 show the general span layout, including the span length, location of bridge abutments and piers, and location of Smith Road and UPRR for E-17-AEJ and E-17-AEK, respectively.

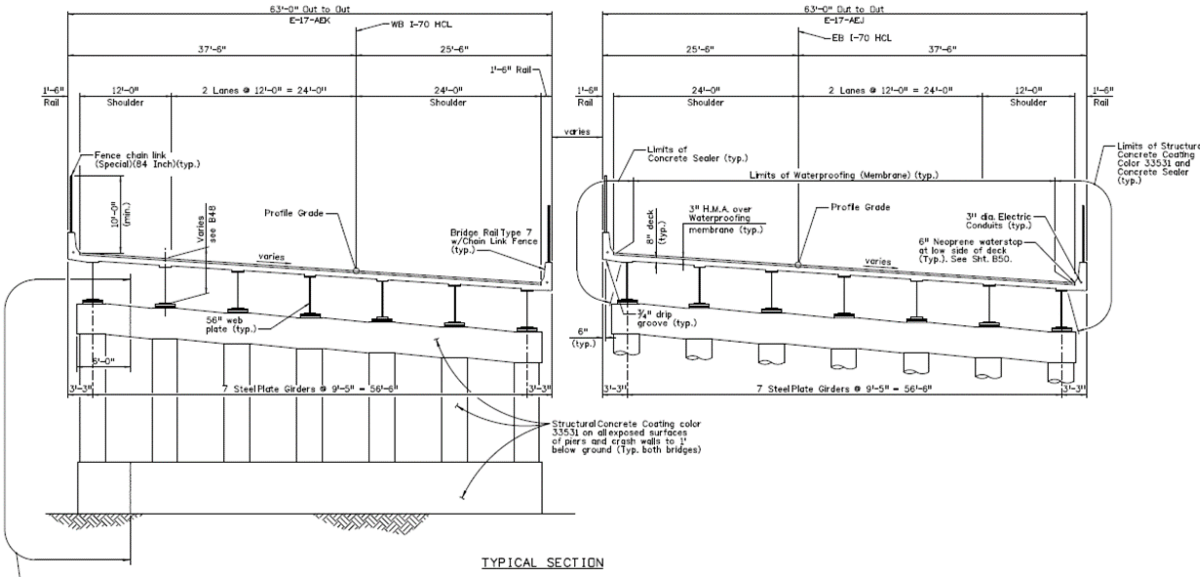

Figure 5. Diagram. Typical section for bridges E-17-AEJ and E-17-AEK.

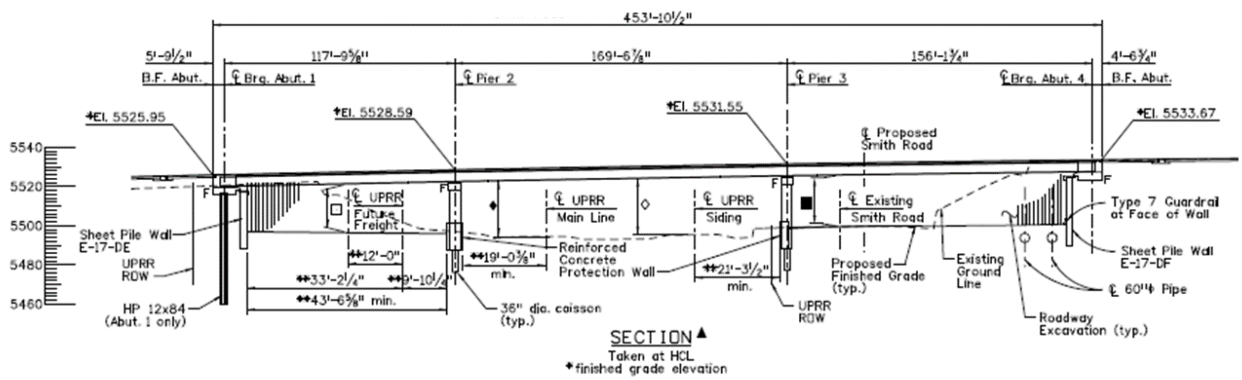

Figure 6. Diagram. General span layout for eastbound bridge E-17-AEJ.

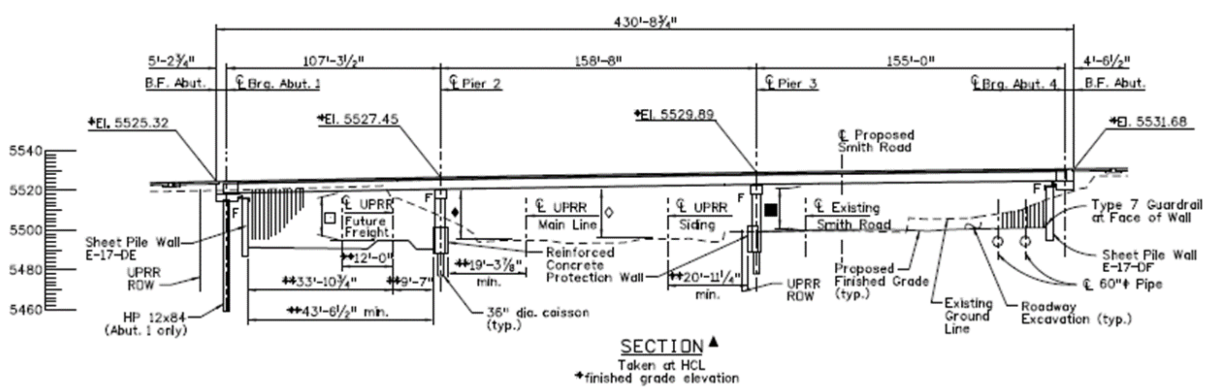

Figure 7. Diagram. General span layout for westbound bridge E-17-AEK.

GEOTECHNICAL DESIGN

A total of 13 borings were made around the bridge construction area, using the method described in American Association of State Highway and Transportation Officials (AASHTO) T 206. The geotechnical investigation revealed that the embankment below the bridges consisted of A-6 sandy clay material and A-7-6 sandy claystone material. The design load for the abutment footer was composed of a service dead load of 1.56 ton/ft^2 and a factored live load 2.27 ton/ft^2. Figures 8 through 10 provide the plan, elevation, and section views of the westbound bridge abutment 4.

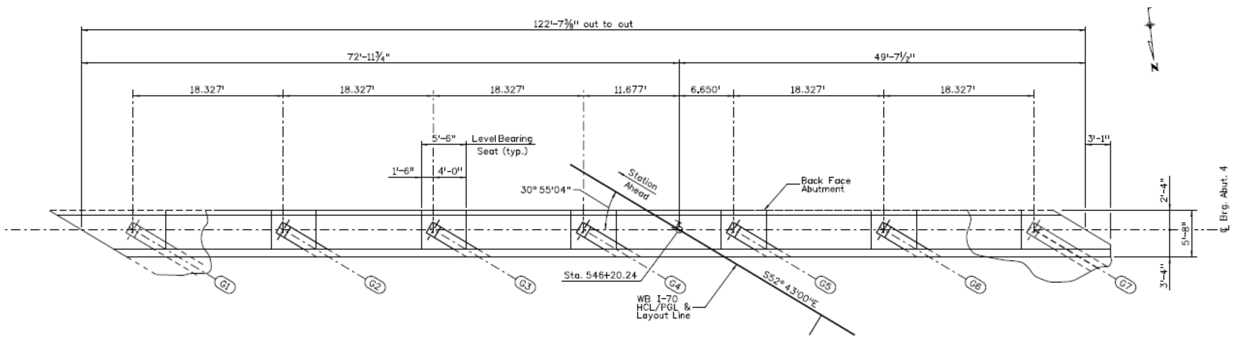

Figure 8. Diagram. GRS abutment plan view of abutment 4, E-17-AEK.

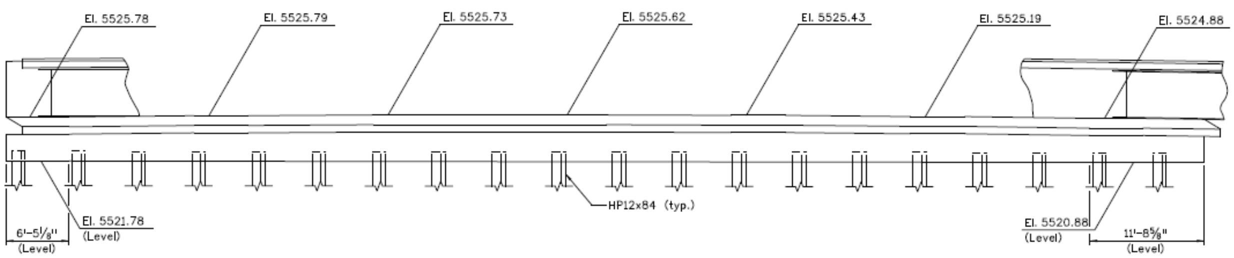

Figure 9. Diagram. GRS abutment elevation view of abutment 4, E-17-AEK.

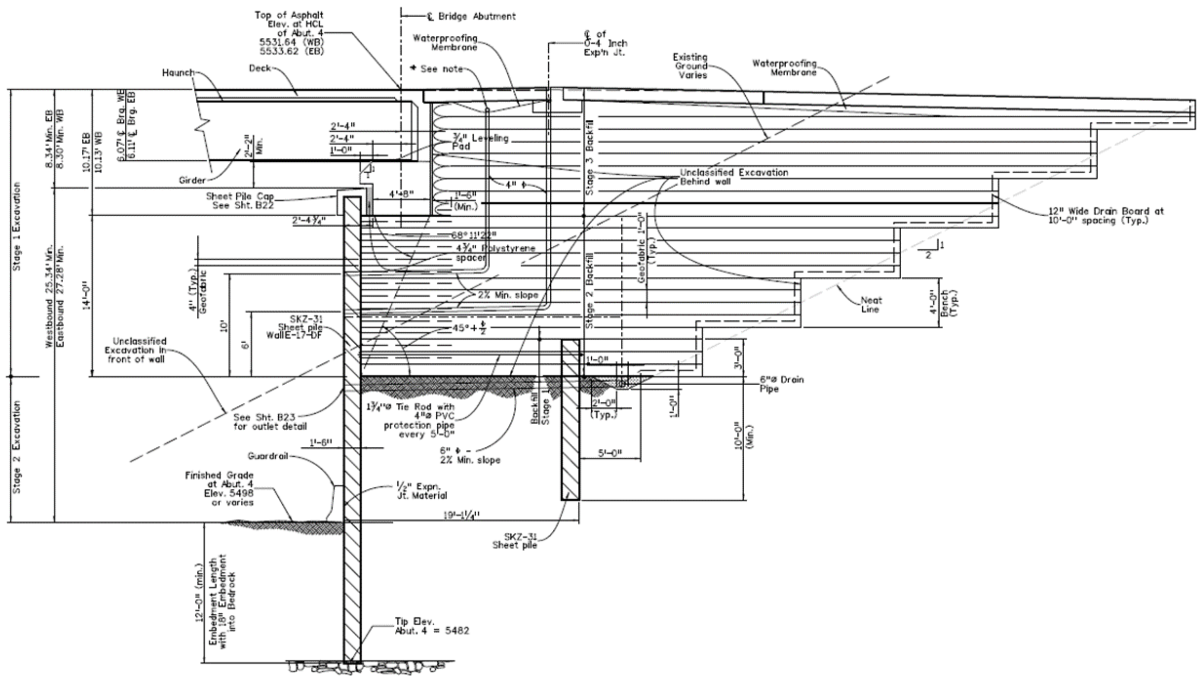

Figure 10. Diagram. GRS abutment section view of abutment 4, E-17-AEK.

GRS-IBS CONSTRUCTION

The construction activity was planned in two phases. Phase 1 involved the reconstruction of the westbound pavement and replacement of the westbound bridge, whereas Phase 2 involved the construction in the eastbound direction. Initially, Phase 1 of the project was designed for abutment 4 of westbound structure E-17-AEK and retaining wall E-17-DJ (located to the north of the east end of E-17-AEK) of the same structure to be constructed using GRS-IBS. Construction and instrumentation of the lower portion of abutment 4 began on July 22, 2014, and was completed by August 14, 2014, at which point instrumentation and construction of the upper portion started and was completed on September 30, 2014. Due to time and budget constraints of the instrumentation task order, retaining wall E-17-DJ was constructed as a typical mechanically stabilized earth (MSE) wall, and the project plan was updated to include one GRS retaining wall for Phase 2. Currently, the construction in the westbound direction is complete, and the GRS-IBS at abutment 4 of E-17-AEK appears to be performing very well. No settlement has been observed to date.

The project plans for Phase 2 are to construct abutment 4 of structure E-17-AEJ and the retaining wall E-17-DH (located to the south of the west end of E-17-AEJ, respectively) using GRS-IBS. Per the latest project schedule, construction of abutment 4 is to begin on July 20, 2015, and will be completed, along with instrumentation, by August 17, 2015. Construction of the retaining wall E-17-DH will begin immediately following and will be completed by September 14, 2015.

Figures 11 through 18 show construction-related photos for this project.

Figure 11. Photo. Old westbound structure, E-17-JX, being demolished.

Figure 12. Photo. GRS-IBS construction of abutment 4, E-17-AEK: placement of geosynthetic fabric.

Figure 13. Photo. GRS-IBS construction of abutment 4, E-17-AEK.

Figure 14. Photo. GRS-IBS construction of abutment 4, E-17-AEK: sheet piling wall E-17-DF shown.

Figure 15. Photo. GRS-IBS construction of abutment 4, E-17-AEK (close-up view).

Figure 16. Photo. Steel girder installation for E-17-AEK.

Figure 17. Photo. New bridge E-17-AEK, March 2015, facing abutment 4.

Figure 18. Photo. Old eastbound bridge being demolished, new bridge E-17-AEK in background, June 2015. E-17-AEK is in service at the time of this photograph.

HIGHWAYS FOR LIFE PERFORMANCE GOALS

The primary objective of acquiring data on HfL performance goals such as safety, construction congestion, and quality is to quantify project performance and provide an objective basis from which to determine the feasibility of the project innovations and to demonstrate that the innovations 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. Produce a high-quality project and gain user satisfaction.

Since this project is still ongoing, the HfL performance goals are yet to be measured. The following subsections provide additional information on some of the significant factors that influence the HfL performance goals.

SAFETY

As mentioned, the construction of this project is being carried out in two phases. During Phase 1, the westbound lanes were closed and westbound traffic was crossed over to the eastbound inside lane, as shown in Figure 19. Similarly, Phase 2 involves closing down the eastbound lanes and moving the traffic over to the westbound inside lane (Figure 20). The speed limit for this stretch of I-70 was reduced from 70 mph to 55 mph during construction. In addition, to limit workers' exposure to live traffic, Smith Road was closed and the traffic was detoured through East 32nd Parkway during construction, as shown in Figure 21.

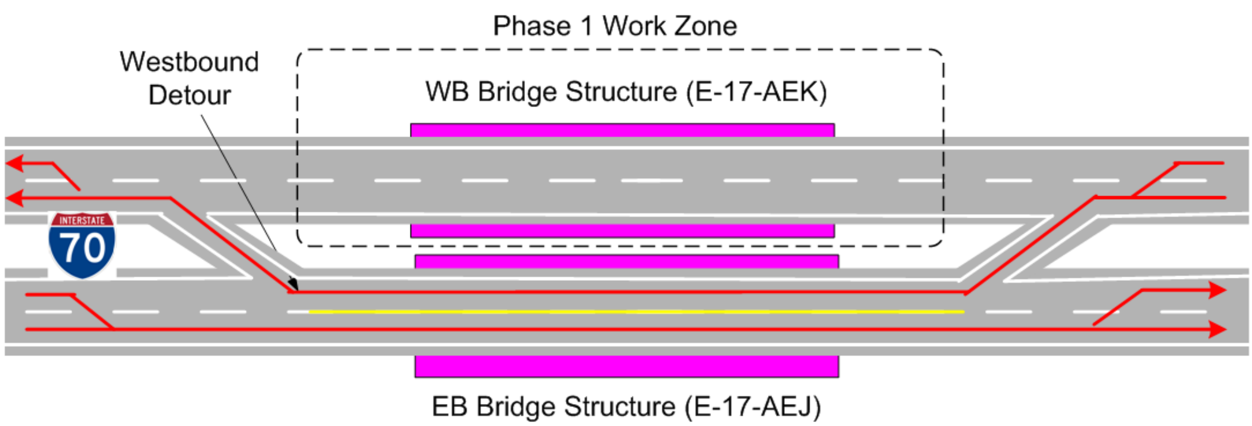

Figure 19. Diagram. Traffic maintenance plan for construction Phase 1 (westbound).

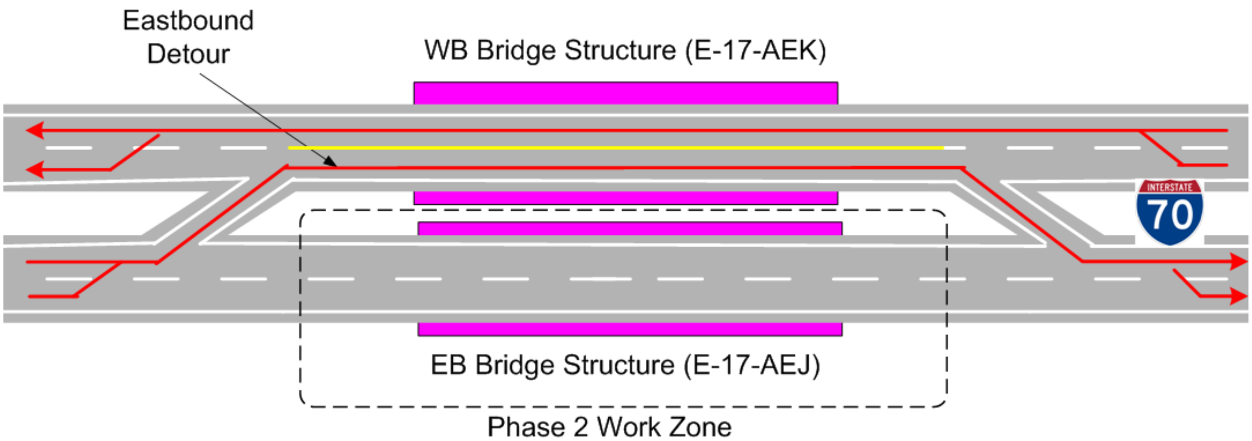

Figure 20. Diagram. Traffic maintenance plan for construction Phase 2 (eastbound).

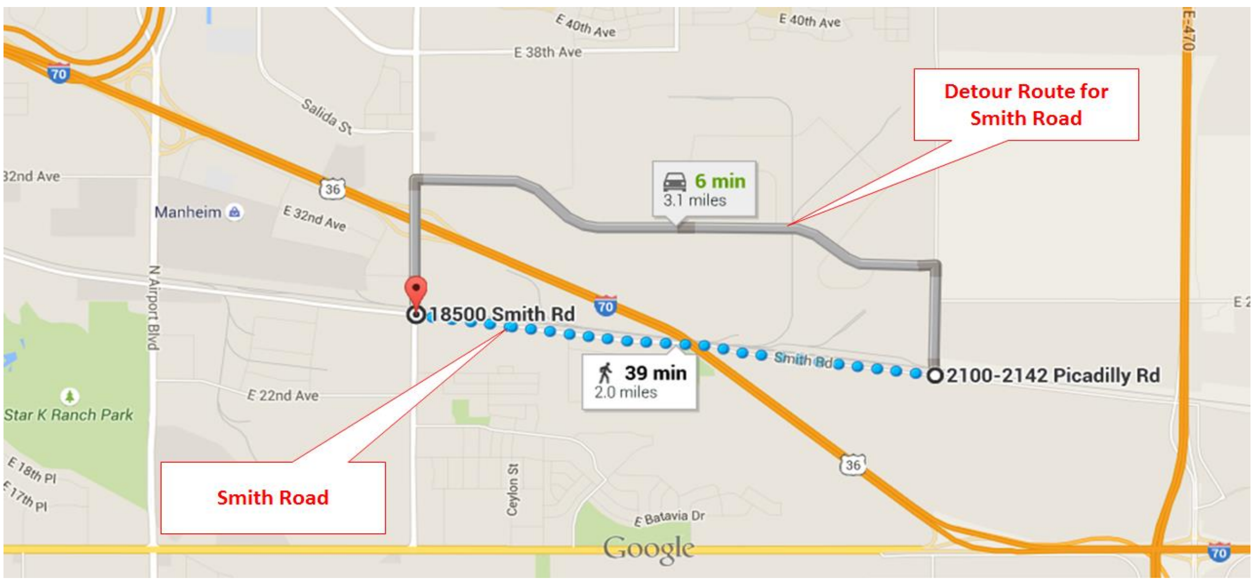

Figure 21. Map. Detour route for Smith Road.

Construction Congestion

Congestion-related data for this project have not been made available. As described earlier, this stretch of I-70, including the bridge structures, is currently being widened to accommodate an additional lane of traffic in each direction.

Noise and Smoothness

CDOT does not plan to collect noise data for this project. It is anticipated that the GRS-IBS will reduce the differential settlement between the bridge abutments and the approaching roadway, which in turn will reduce the bump frequently encountered at the bridge approaches. Elimination of such a bump will improve rideability and reduce the long-term wear and tear on the structure, thereby increasing the life of the bridge joints and reducing the degradation of the approach slabs. CDOT will collect smoothness data for travel lanes in both directions towards the end of construction.

LESSONS LEARNED

As this project is the first in nation to utilize the GRS-IBS technology on a multi-span, high-speed interstate roadway, it presented a significant learning challenge to the contractor. The contractor needed some time to get all the details ironed out in terms of lift thickness, fabric installation, addition of drainage system, and coordination of the instrumentation installation. Consequently, the GRS-IBS took considerably more time to construct than a traditional MSE backfill system would take. However, with the contractor's experience gained during Phase 1, it is anticipated that Phase 2 of the project will experience little to no delay.

The project delivery was expedited to meet funding deadlines resulting in a condensed review. Unfortunately, there were plan errors that caused delay and problems in the field. The lesson learned is to make sure there is adequate review time and resources during the project development.

The project also proved GRS walls exhibit negligible deflections with the wall facing and the reinforced mass for an interstate bridge.

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