Vermont Demonstration Project: Route 2 – East Montpelier Bridge Reconstruction

Final Report
July 2011

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 decisionmakers 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 Vermont Agency of Transportation (VTrans) was awarded a $540,000 grant to demonstrate the use of proven, innovative technologies to build a high-quality bridge with state-of-the-art design and materials that will last longer than conventional construction.

The structure is located on the National Highway System in rural East Montpelier, VT, on US Route 2 over the Winooski River, approximately 1 mile east of the intersection of US Route 2 and VT Route 14. The replacement structure is a single span integral abutment bridge with weathering steel girders, bare high performance concrete deck reinforced with solid stainless steel, topped with a curbless, pedestal mounted rail. With no joints that can fall into disrepair and leak, no curbs that retain salt-laden runoff and accelerate deck deterioration, no bearings that can corrode and freeze, and no beam paint system that can fail, the project accomplished its goal of designing and building a structure that is reduced to its most basic components, incorporates durable materials, is virtually maintenance free, and has lower life cycle costs than a conventional structure. With wider lanes and ample shoulder widths, the new bridge addresses safety concerns over numerous collisions and "near misses" at the site and easily will accommodate the truck traffic on this National Highway System highway.

VTrans minimized construction congestion and time and worker exposure to traffic through construction of a two-way detour bridge adjacent to the site, which enabled the Agency to complete the project in one season instead of two. A comprehensive economic analysis including the anticipated long-term maintenance costs shows that the project saved $932,800 (or 47 percent compared to traditional methods). The project saved money and demonstrates that the HfL program concepts apply not only to large, complex bridge projects, but also to smaller, rural bridge projects.

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Unclassified	Unclassified	50	

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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)

*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)

ACKNOWLEDGMENTS

The project team would like to acknowledge the invaluable insights and guidance of the Federal Highway Administration Highways for LIFE Team Leader (Mr. Byron Lord) and Program Coordinators Ms. Mary Huie and Ms. Kathleen Bergeron, who served as the Technical Panel on this demonstration project. Their vast knowledge and experience with the various aspects of construction, technology deployment, and technology transfer helped immensely in developing both the approach and the technical matter for this document. The team also is indebted to the Vermont Agency of Transportation engineers Mr. Wayne Symonds, Ms. Kristin Higgins, Mr. Jim LaCroix, and Mr. Chris Jolly for the tireless advice, assistance, and coordination they provided in the conduct of this project. Project designer Mr. LaCroix provided the very helpful project-related information included in this document. The project team also is grateful to the FHWA Division Office, and particularly to Mr. Mark Richter for all the support received.

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ABBREVIATIONS AND SYMBOLS

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ADT	average daily traffic
ADTT	annual daily truck traffic
dB(A)	A-weighted decibel
DHV	design hourly volume
DOT	department of transportation
FHWA	Federal Highway Administration
HfL	Highways for LIFE
HPC	high performance concrete
Hz	hertz
IRI	International Roughness Index
LRFD	Load and Resistance Factor Design
NHS	National Highway System
OBSI	onboard sound intensity
OSHA	Occupational Safety and Health Administration
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SI	sound intensity
SRTT	standard reference test tire
VTrans	Vermont Agency of Transportation

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 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 issued open solicitations for HfL project applications in fiscal years 2006, 2007, 2008, and 2009. State highway agencies submitted applications through FHWA Divisions. The HfL team reviewed each application for completeness and clarity, then 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:

- Address the HfL performance goals for safety, construction congestion, quality, and user satisfaction.
- 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.
- 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.
- 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.
- 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 address all applicable goals on a project:

- **Safety**
  - Work zone safety during construction—Work zone crash rate equal to or less than the preconstruction rate at the project location.
  - 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.
  - Facility safety after construction—Twenty percent reduction in fatalities and injuries in 3-year average crash rates, using preconstruction rates as the baseline.
- **Construction Congestion**
  - Faster construction—Fifty percent reduction in the time highway users are impacted, compared to traditional methods.
  - Trip time during construction—Less than 10 percent increase in trip time compared to the average preconstruction speed, using 100 percent sampling.
  - Queue length during construction—A moving queue length of less than 0.5 mi (0.8 km) in a rural area or less than 1.5 mi (2.4 km) in an urban area (in both cases at a travel speed 20 percent less than the posted speed).
- **Quality**
  - Smoothness—International Roughness Index (IRI) measurement of less than 48 inches per mile.
  - Noise—Tire-pavement noise measurement of less than 96.0 A-weighted decibels (dB(A)), using the onboard sound intensity (OBSI) test method.

- **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 report discusses the Vermont Agency of Transportation (VTrans) HfL demonstration project which consists of reconstruction of a bridge to replace a narrow bridge on the National Highway System (NHS). The report presents the project details of most relevance to the HfL program, including traffic management during construction, innovative design and construction highlights, HfL performance metrics measurement, as well as a return on investment analysis. Also presented are a record of the technology transfer activities that took place during the construction of this project and a summary of the lessons learned.

PROJECT OVERVIEW AND LESSONS LEARNED

PROJECT OVERVIEW

This project includes the replacement of a narrow bridge structure with a new wider structure with minimal approach work on each end of the structure. Key innovations employed on this project include:

- Use of solid stainless steel deck reinforcing steel for increased deck durability.
- Use of high performance concrete bare deck.
- Use of weathering steel to eliminate need for repainting.
- Use of integral abutments to eliminate the need for deck movement joints and bearings at abutments.
- Elimination of membrane and pavement over the deck to eliminate maintenance need to address ruts and potholes.
- Elimination of curbs that retain salt-laden run-off to minimize deck maintenance due to chloride intrusion.
- Use of a two-way temporary bridge and design features that reduce impacts and disruptions to the traveling public during construction and future maintenance.
- Reduction of life cycle costs through design of a structure with 100-year design life incorporating high-quality materials and design details that minimize the need for maintenance.

HFL PERFORMANCE GOALS

Safety, construction congestion, quality, and user satisfaction data were collected before, during, and after construction to demonstrate that innovations can be deployed while meeting the HfL performance goals in these areas.

- **Safety**
  - Work zone safety during construction—The project achieved the HfL goal of keeping the work zone crash rate equal to or less than the preconstruction rate. No work zone incidents were reported during construction.
  - Worker safety during construction—Promoting worker safety by maintaining normal daylight work hours and moving traffic to the temporary bridge and away from the workers helped the contractor to achieve no injuries (OSHA Form 300 score of 0.0, which meets the HfL goal of achieving a score of less than 4.0).
- **Construction Congestion**
  - Faster construction— The innovations adopted on this project helped VTrans meet their accelerated construction schedule with ease. The bridge project was completed in one season despite a 41-day delay caused by the need to straighten and clean the stainless steel reinforcing bars and re-pouring of a portion of the deck whose depth was compromised by rotation of the exterior girders. The bridge was opened to traffic on November 19, 2009. A conventional approach using phased construction would have required two construction seasons.

- Trip time—The decision to divert traffic to a temporary bridge built adjacent to the existing bridge, as opposed to lengthy detour routes, eliminated additional trip time caused by extra mileage. Actual increase in trip time caused by lowering the speed limit from 50 to 35 mi/hr through the short work zone was insignificant. Moreover, no significant congestion-related delays were observed during construction.
- Queue length during construction—Since free flow of traffic was maintained on the temporary bridge, queue length was not a problem during construction. Brief queuing did occur when materials such as the bridge beams and reinforcing steel were delivered. The short interruptions in traffic during deliveries allowed VTrans to distribute satisfaction survey questionnaires to motorists waiting in queue.

- **Quality**
  - Smoothness—The IRI value dropped dramatically from a preconstruction value of 126 to 78 in/mi after construction as a result of the increase in smoothness across the bridge. Although the HfL goal for IRI of 48 in/mi—reasonably attainable on long, open stretches of pavement—was not met on this project, the 48 in/mi drop in IRI value is a reflection of quality construction.
  - Noise—Quality was measured in terms of noise (OBSI), and the data showed a 2.6 dB(A) reduction in noise from a preconstruction level of 99.0 to a 96.4 dB(A) postconstruction level, nearly satisfying the HfL requirement of 96.0 dB(A) or less.
  - User satisfaction— Overall, 96 percent of surved respondents were satisfied with the new bridge compared to the condition of the old structure, and 83 percent gave favorable marks to the approach used to minimize disruption during construction. The response to the questions exceeded the HfL goal of 4-plus on a Likert scale of 1–7 (in other words, 57 percent or more participants showing favorable response).

ECONOMIC ANALYSIS

It is estimated that, with the reduced need for maintenance, the innovative HfL project delivery approach will realize a cost savings of $1,030,450 in current dollars over the 100-year design life of the project. The savings represent more than 40 percent of the contract bid amount of $2,001,500 for traditional construction and exceed the construction cost estimate of the as-built bridge portion of the project of $918,700.

LESSONS LEARNED

Some of the lessons learned from this demonstration project are:

- It demonstrates that the HfL program concepts of realizing the benefits of accelerated bridge construction do not apply only to large, complex bridges or other horizontal infrastructure projects in urban settings but also to smaller rural bridges.
- HfL program concept implementation can result in significant cost savings over the life of the project.
- Tolerances for straightness of stainless steel rebar along with what is acceptable in terms of rebar contamination or rust must be well understood by the rebar manufacturer, fabricator, and contractor.
- Early and frequent interaction with the public on the project resulted in users highly

satisfied with the end product.

Conclusions

This project gave VTrans the opportunity to integrate innovative designs and materials to deliver a safe and durable replacement bridge using less time and money than conventional construction. The innovations played a key role in reaching the HfL performance goals of increasing safety, reducing congestion, and increasing quality. Moreover, the direct experience gained with all the innovations and the long-term performance of this project will give VTrans the confidence to incorporate these innovations in future projects.

PROJECT DETAILS

BACKGROUND

The Vermont HfL project includes the replacement of the US 2 Bridge near East Montpelier. The new bridge was opened to traffic on November 19, 2009. These types of smaller rural bridges form a significant portion of the national bridge inventory. The innovative approaches used in the delivery of this project, if successful, could therefore have a wider deployment potential nationally.

PROJECT DESCRIPTION

The project is located on US Route 2 over the Winooski River, about 1.1 mi east of the US Route 2 & Vermont 14 intersection, in the town East Montpelier, Washington County, Vermont. This portion of Route 2 is part of the NHS and is classified as a Principal Arterial. The bridge is located on a key access route to Montpelier and Barre. The following subsections highlight the innovative features of this project.

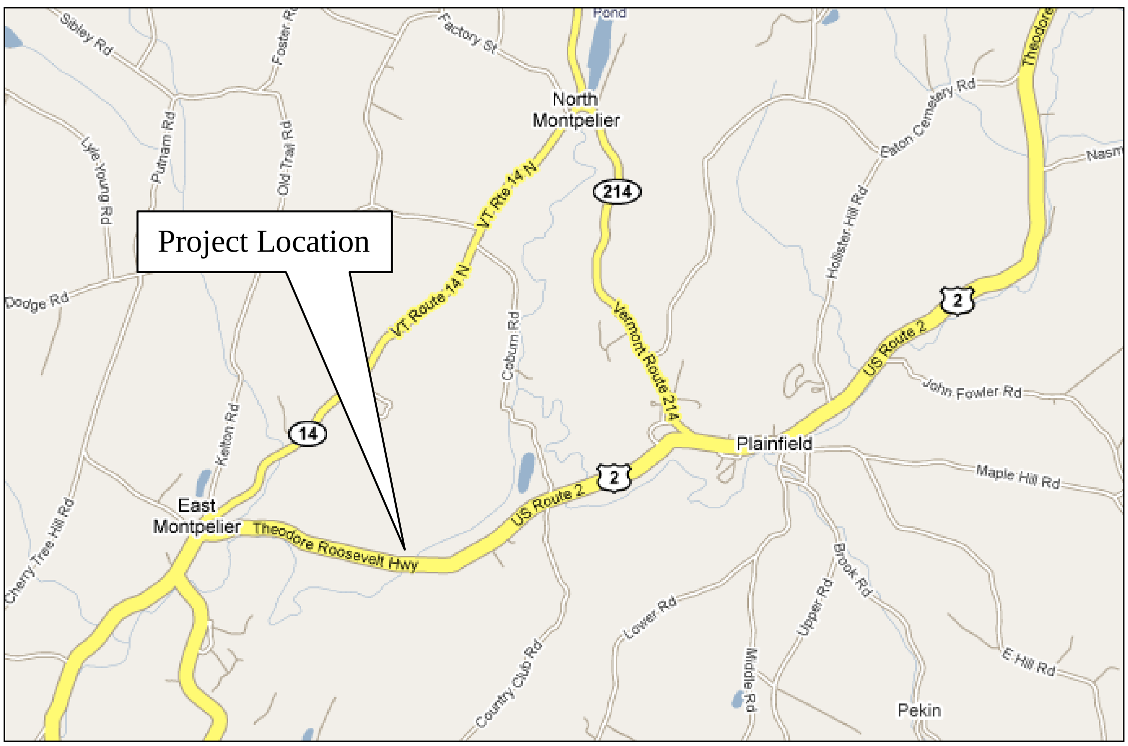


Figure 1. General project location.

The purpose of the project was to replace a functionally obsolete bridge. The average daily traffic (ADT) on the bridge is 8,500 vehicles per day with 5.6 percent trucks. The old bridge (Figures 2 and 3) was narrow, with 20 ft clearance between rail faces, and was the site of regular minor collisions and “near misses” representing a significant safety concern to VTrans and the agency’s stakeholders.

Figure 2. The functionally obsolete existing structure.

Figure 3. Deteriorated bridge deck.

The replaced structure was a three span bridge built in 1930. The superstructure was concrete T beams with a concrete deck. The total span was 140 ft. The concrete beams showed significant deterioration, with large areas of spalling and pop-outs that had exposed the reinforcing steel. Some areas showed substantial section loss. The deck joints at each of the intermediate piers had failed and allowed saturation of the bearings and substructure below.

The substructure consisted of concrete abutments and two intermediate piers. Although the substructure was in fair condition, its capacity could not be increased to accommodate any roadway improvements. The July 2001 scoping report referenced the inspection report that recommended that the structure be rehabilitated or replaced. In addition to the structural deficiencies, the bridge was supported on timber piles, and cofferdams had been installed to reduce scour (see Figure 4).

Notes of a November 8, 1999, Local Concerns Meeting showed concern over the narrow width of the structure and adjacent landowners citing examples of broken mirrors due to vehicles sideswiping on the bridge.

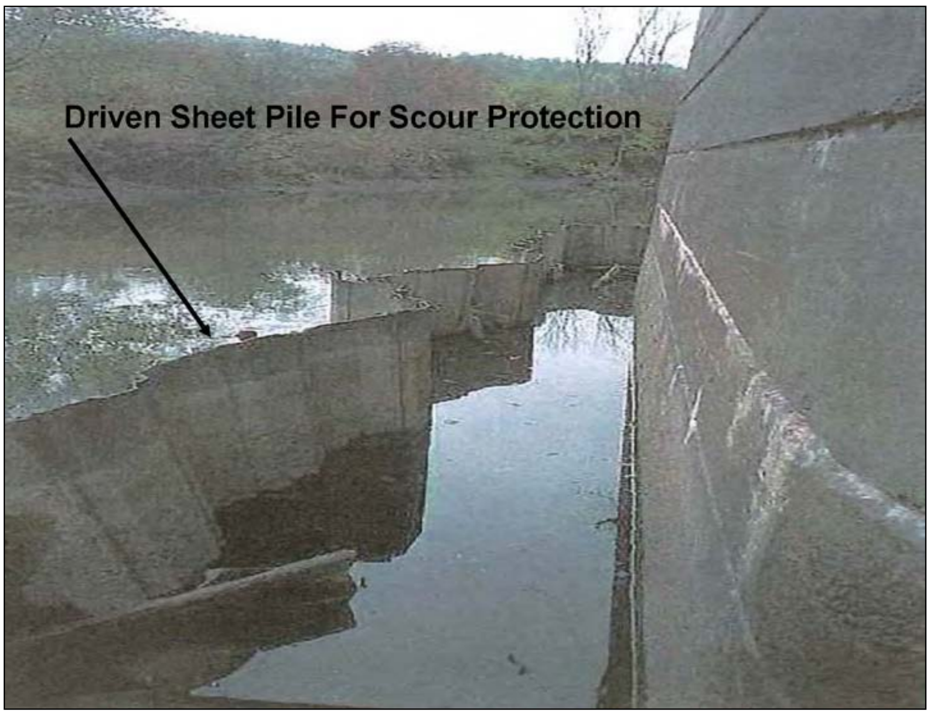


Figure 4. Scour protection at the existing structure.

VTrans considered both replacement and rehabilitation options and decided against the latter because:

- The deck joints at each end of the intermediate piers had failed and allowed saturation of the bearings and substructure during rain events.
- The bearings were rusted and rust scale covered.

- The superstructure width was inadequate for current and future traffic. ADT on the bridge was 8,500, with average daily truck traffic (ADTT) of 480 and design hourly volume (DHV) of 1,000. Design future values for ADT, ADTT, and DHV are 11,100, 740, and 1,200, respectively.
- The superstructure needed to be replaced.
- Rehabilitation was not feasible.

Having made the decision to replace, not rehabilitate, VTrans considered three replacement alternatives:

- Alternative 1 – Construct a new bridge just south of the existing alignment.
- Alternative 2 – Construct a new bridge just north of existing alignment.
- Alternative 3 – Construct a new bridge on existing alignment

Alternatives 1 and 2 consisted of maintaining the existing bridge for traffic during construction of the new bridge south or north of the current location with roadway alignments modifications included. The new bridge would be built at the same grade as the existing bridge. Both alternatives were discarded because of potential environmental/cultural impacts including agricultural lands, wildlife, wetlands, floodplains, and archeological (if determined). Alternative 2 further required reverse curves to connect to existing roadway. The reverse curve would have required a speed reduction along US Route 2.

VTrans' consultant, Earth Tech, recommended Alternative 3 because the existing alignment was good, with less permanent impacts, and had the support of the public. VTrans accepted the recommendation and considered the following options to maintain traffic:

1. Close bridge and redirect traffic.
2. Phased construction.
3. Construct temporary bridge adjacent to the structure.

Option 1 required a detour of 8 miles (see Figure 5) through a small village and required intersection upgrades. Furthermore, a bridge on the detour route was structurally deficient. Concerned with the extended commute and traffic jams, the public was opposed to this option.

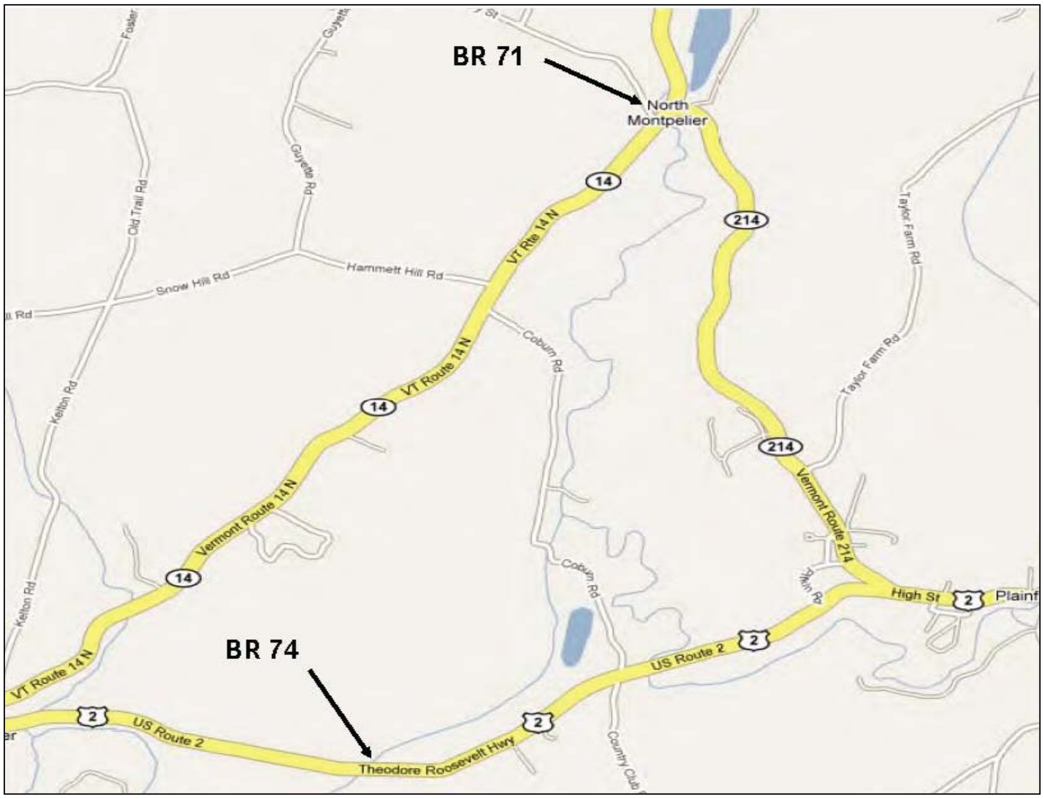


Figure 5. Detour route for option 1.

Option 2 required the bridge to be constructed in sections, with the left and right edges constructed first and then traffic shifted to newly constructed sections allowing the center to be completed (Figure 6 and Figure 7). The concerns with phased construction included a wider bridge than necessary and longer span for maintenance of traffic. Furthermore, the project would have required two construction seasons and would entail higher construction costs.

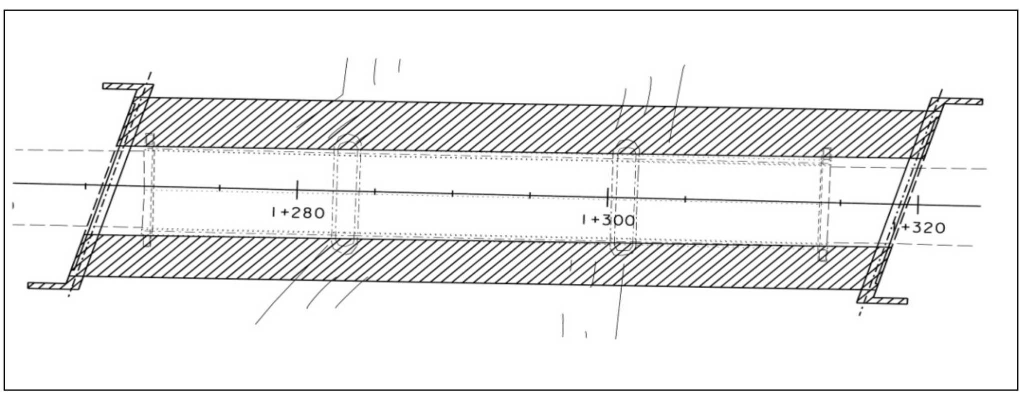


Figure 6. Phase I construction.

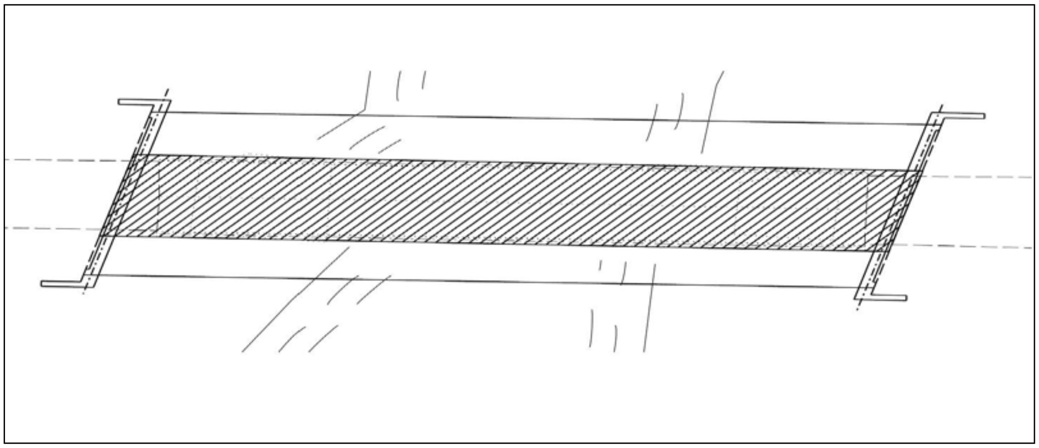


Figure 7. Phase II construction.

Option 3 was developed with a temporary bridge located to the south side of the structure. The simple span bridge would be 122 ft long. Concrete deck with a membrane and pavement, weathering steel girders and conventional abutments on piles would be used. The conventional superstructure is shown in Figures 8 and 9.

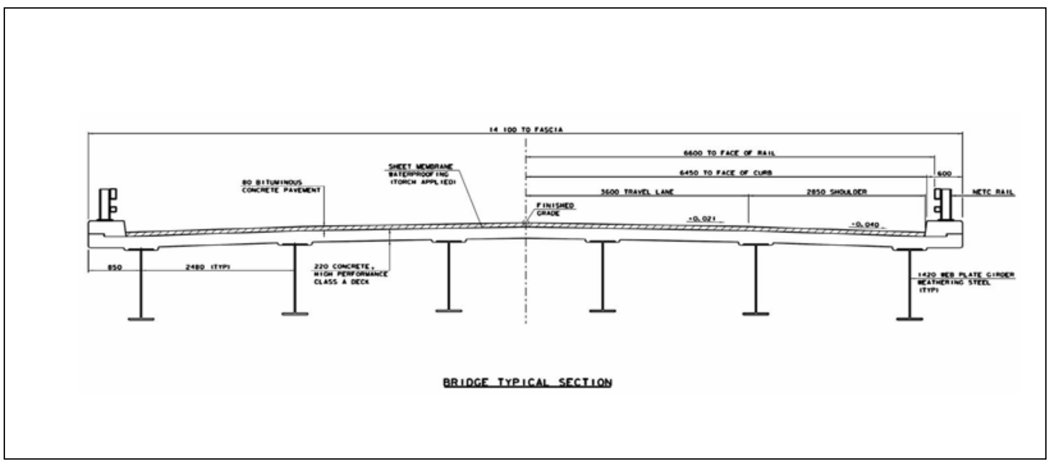


Figure 8. Temporary bridge with conventional structure, option 3.

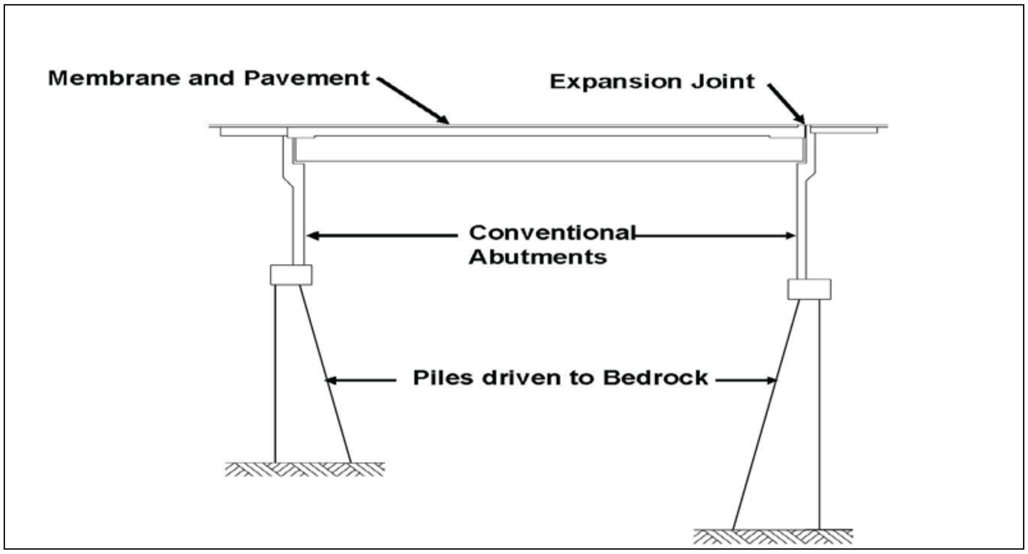


Figure 9. Bridge elevation, option 3.

A typical timeframe for the removal and replacement of this type and size bridge is about 6 months using a cast-in-place substructure with footings founded on bedrock.

At about the turn of the century, highway agencies across the nation started increasing emphasis on minimizing inconvenience to the traveling public caused by highway construction and maintenance operations. The slogan “Get In, Get Out, Stay Out” resonated with stakeholders in the highway industry. This concern for inconvenience prompted VTrans to take a fresh perspective on this project. The desired outcome was to have a bridge that could be constructed in less time than a traditional approach, would result in a durable product requiring minimal maintenance, and with reduced disruptions to the traveling public.

To achieve the goal of 100-year design life and minimal maintenance, the project team considered designing a single span integral abutment bridge. The superstructure would use weathering steel girders with a bare high performance concrete (HPC) deck reinforced with solid stainless steel, topped with a curbless, pedestal mounted rail. The result would be a bridge of simple design, with no membrane and pavement that can rut and pothole; no joints that can fall into disrepair and leak; no scuppers that can clog; no curbs that will retain salt-laden runoff and accelerate deck deterioration; no bearings that can corrode and freeze; and no beam paint system that can fail. Figures 10 through 14 show conditions that the project team attempted to avoid.

This approach is a departure from the norm for VTrans in many ways. Vermont traditionally has been a pavement and membrane State (Figure 15). The standard treatment is to use a torch welded membrane with a 2 ¾-in pavement overlay on bridge decks. Vermont has been re-evaluating the pavement and membrane policy and considering the use of “bare” decks for some of its bridges, as many neighboring States do for high-quality decks.

Figure 10. Failed membrane and pavement condition.

Figure 11. Failed deck joint condition.

Figure 12. Salt-laden runoff at curb.

Figure 13. Corroded bearing condition.

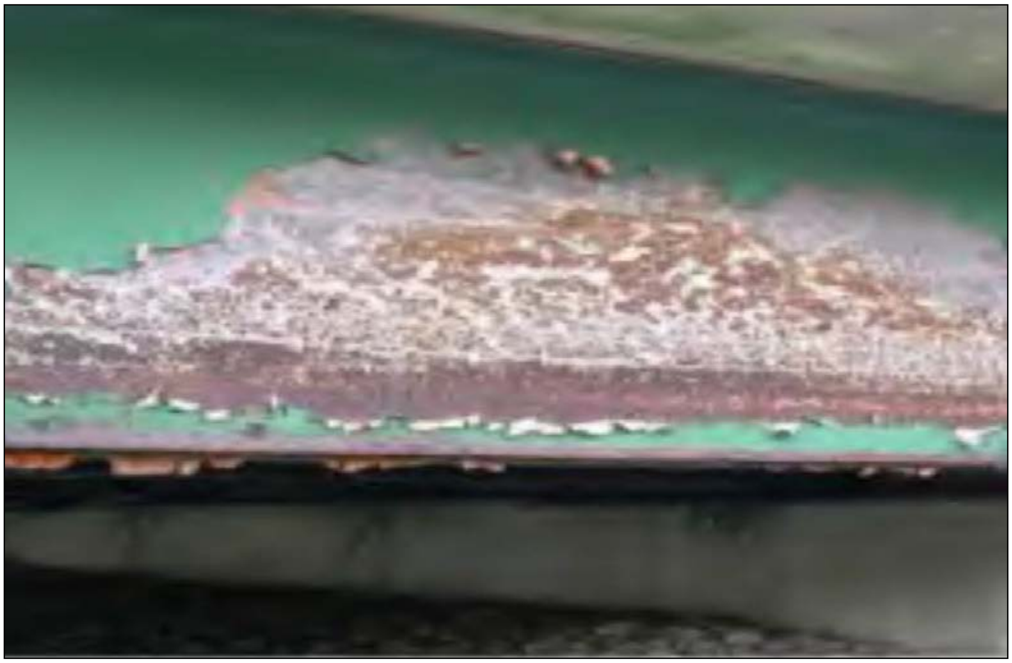


Figure 14. Failed paint system condition.

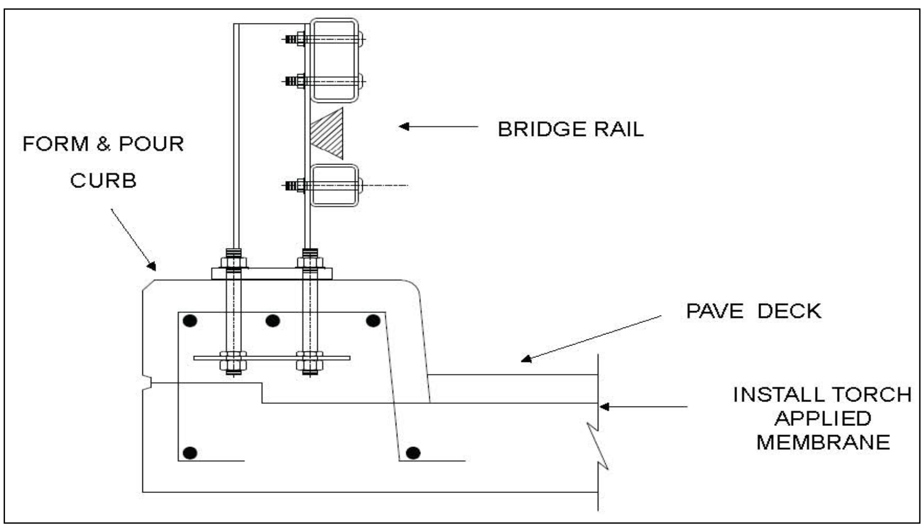


Figure 15. Conventional construction detail showing deck membrane and curb mounted rail system.

VTrans currently specifies epoxy-coated reinforcing steel for bridge decks. The agency hosted the FHWA seminar prior to this project on high performance reinforcing bars and was interested in trying improved reinforcing technologies for its bridge decks. They decided to use solid stainless steel rebars for deck reinforcement for the first time in the State.

Again, the norm for VTrans is to use the NETC two-rail curb mounted steel bridge rail. The use of curbs adds one more construction requirement and requires scuppers in the bridge deck. Instead, the project team decided to utilize the New York three-rail flush-mounted rail to simplify the construction and eliminate the need for the through-deck scuppers (Figure 16).

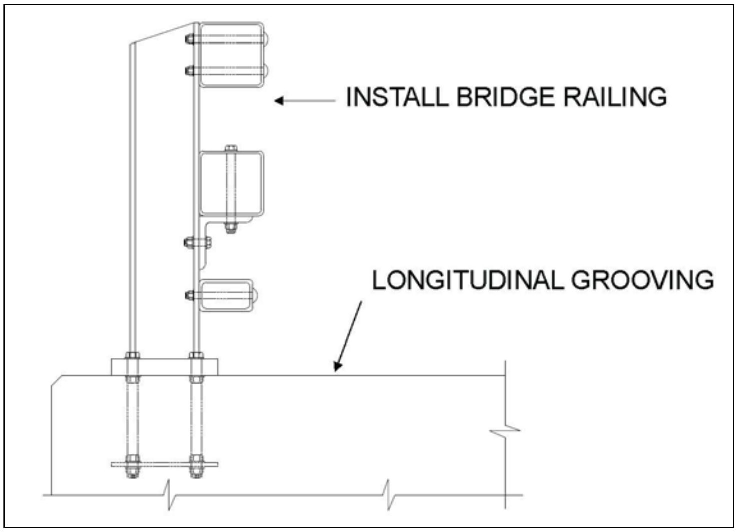


Figure 16. Construction detail of innovative bare deck design with flush-mounted rail.

The new structure also would use weathering steel plate girders and have an HPC deck. The deck and integral abutment stem would be reinforced using solid stainless steel. At each end of the bridge there would be at-grade approach slabs.

The innovative components of this bridge result in a simplified design with high performing materials that reduces the timeframe for construction and will result in fewer maintenance activities over the life of the structure.

The following subsections highlight the key features of this project that are either innovative to VTrans or have been implemented only recently.

Integral Abutments

Integral abutment bridges are designed without any expansion joints in the bridge deck. Bridges can be single span or multiple span continuous deck type structures with each abutment monolithically connected to the superstructure and supported by a single row of flexible piles. The primary difference between an integral abutment bridge and a conventional bridge is the manner in which movement is accommodated. A conventional bridge accommodates movement by means of sliding bearing surfaces. An integral abutment bridge accommodates movement by designing each abutment to move unrestricted as a result of longitudinal loading effects with less induced stress, thus permitting the use of lighter and smaller abutments. Accordingly, with the elimination of bearings and joints and with smaller abutments, these bridges require less time to build, cost less, and require less maintenance than equivalent bridges with expansion joints.

VTrans built its first integral abutment project about 10 years ago, and currently it is VTrans policy to consider integral abutment construction as a first option for all slab and slab-on-stringer bridges.

High Performance Concrete

The American Concrete Institute (ACI) defines HPC as, "concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely when using conventional constituents and normal mixing, placing and curing practices." Important characteristics of HPC include freeze-thaw resistance, alkali-silica reactivity, permeability, compressive strength, and resistance to early age shrinkage cracking. The project called for air content of 5.5 to 8.5 percent. Laboratory testing was conducted to optimize mix design, and 30 percent of the cementitious material was fly ash. Through the mix design process, the agency found that just fly ash can be used, no silica fume, to optimize the performance of the HPC on this project.

The minimum compressive strength for the concrete was 4,000 psi, and to prevent early age shrinkage cracking, cement was limited to 611 lb/yd^3 versus 660 lb/yd^3 for Class A concrete. The maximum water/cement ratio was 0.44. The concrete was to be wet cured immediately (within 10 minutes of finishing), and uninterrupted 10-day wet cure was specified. The special provision for HPC is shown in Appendix A.

Stainless Steel Reinforcement

The special provision for stainless steel reinforcement is shown in Appendix A. The contract required that the stainless steel meet the requirements of ASTM A955 M and its designated grade, either 420 or 520, and the requirements of ASTM A 276 UNS 31653 or UNS 32304, since both grades show in testing that a service life of 100 years can be achieved. The contractor opted to go with 32304 based on cost, and the laboratory tests met both strength and elongation criteria. The price of stainless steel was $3.64 per lb, versus epoxy coated steel that normally is priced at about $1.25 per lb. VTrans used the American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) guidance for empirical deck design to determine steel requirements and specified:

- #4 bar at 12 inches each direction (top).
- #4 bar at 8 inches each direction (bottom).

This resulted in a total weight of reinforcing steel of 23,000 lb.

Bridge Construction

There were five bidders on this project. The winning and low bid came from Winterset, Inc. at $2,369,907. This amount included $560,000 for the temporary two-way bridge, $95,000 for removal of the old structure, $178,000 for mobilization/demobilization, $60,000 for traffic control and $143,500 for the Superpave asphalt mix. Unit prices for unique special provision items are shown below:

- HPC $565.78/yd^3
- Stainless steel reinforcing $3.63/lb
- Bridge rail box beam $152.40/ft
- Guardrail approach, box beam $3,800 ea.
- Bridge instrumentation for abutment monitoring $72,000

The supplier/fabricator information for the stainless steel, guardrail, and HPC is provided in Appendix B.

The contractor's schedule shown in Appendix C estimated that the new bridge would be open to traffic on October 9, 2009.

Initially, the construction progressed on schedule. Figure 17 shows the construction of the temporary bridge. After the traffic was switched to the temporary bridge, work began on demolition of the old bridge (Figure 18). This was followed by pile driving and abutment construction. Instrumentation was installed in both abutments to monitor their movement as part of ongoing VTrans research to improve understanding of integral abutment behavior**.**

The next major step in the construction process was the placement of girders made of weathering steel (Figure 19), followed by forming deck, installation of studs, and tying of stainless steel deck reinforcement, which was scheduled the week of August 20 through 24, 2009.

Figure 17. Construction of two-way temporary bypass bridge.

Figure 18. Demolition of the existing bridge.

Figure 19. Placement of weathering steel girders.

It was at this juncture that the project team experienced its first significant unanticipated challenge. The stainless steel rebars that arrived to the site were not straight, with the deformations twisted around the bar. (See Figures 20 through 22.) The cause for the problem was identified as rebar steel being produced in large coils, which the fabricator then cut to desired lengths. The resident engineer rejected the material for straightness, or lack thereof, as the contractor was unable to place the bars within specified tolerance of ¼ inch on cover and 1 inch on spacing.

The stainless steel rebars that arrived at the site also showed signs of rust. Since stainless steel does not rust, the "rust" on the rebars was contamination caused by any or all of the following:

- Stainless steel rebars being bent on the wrong kind of equipment.
- Steel from the bending equipment.
- Contaminants in the environment.

Contract specifications required that in-place stainless steel be free from contamination. The contractor was allowed to use stainless steel wire brush to remove contaminants. The contamination removal criteria were as follows:

1. Any area of contamination that exceeds 4 inches in length.
2. Two or more areas of contamination greater than 1 inch in length along the length of the bar.
3. Frequent small occurrences of contamination along the full length of the bar.

Figure 20. Condition of stainless steel rebar upon arrival.

Figure 21. Close-up of stainless steel rebar condition.

Figure 22. Curved condition of stainless steel rebar.

The laboratory test results showed compliance with the strength and elongation requirements of the specifications.

A significant amount of reinforcement steel was returned to the fabricator for straightening. The returned steel was corrected and shipped to the site. It was again found to be unacceptable and sent back to the fabricator. The fabricator made significant improvement the second time. Figure 23 shows the condition of the bars prior to placement in the deck. The correction delayed the project by about 4 weeks.

Figure 23. Stainless steel reinforcing bars prior to placement.

The stainless steel reinforcement as placed in the deck is shown in Figures 24 and 25, and the anchor bolt detail is shown in Figure 26. The contractor had considerable difficulty in threading the stainless steel anchor bolts for the deck rail. VTrans has decided to specify galvanized anchor bolts in the future.

Deck pour was scheduled to occur on August 27, 2009. However, because of the delay with the stainless steel, it did not occur until September 25. During the deck pour, the exterior girders began to rotate, causing the screed rails to drop, which compromised the thickness of the deck in the center of the bridge. The compromised portion was removed, and the contractor's temporary lateral bracing was replaced by a permanent bracing that solved the problem. The deck was re-poured, and the bridge was opened to traffic on November 19, 2009—41 days behind schedule. Figures 27 shows traffic moving on the new, wider bridge. Figures 28 and 29 show the completed bridge.

Figure 24. View of deck reinforcement.

Figure 25. Close-up of deck reinforcement.

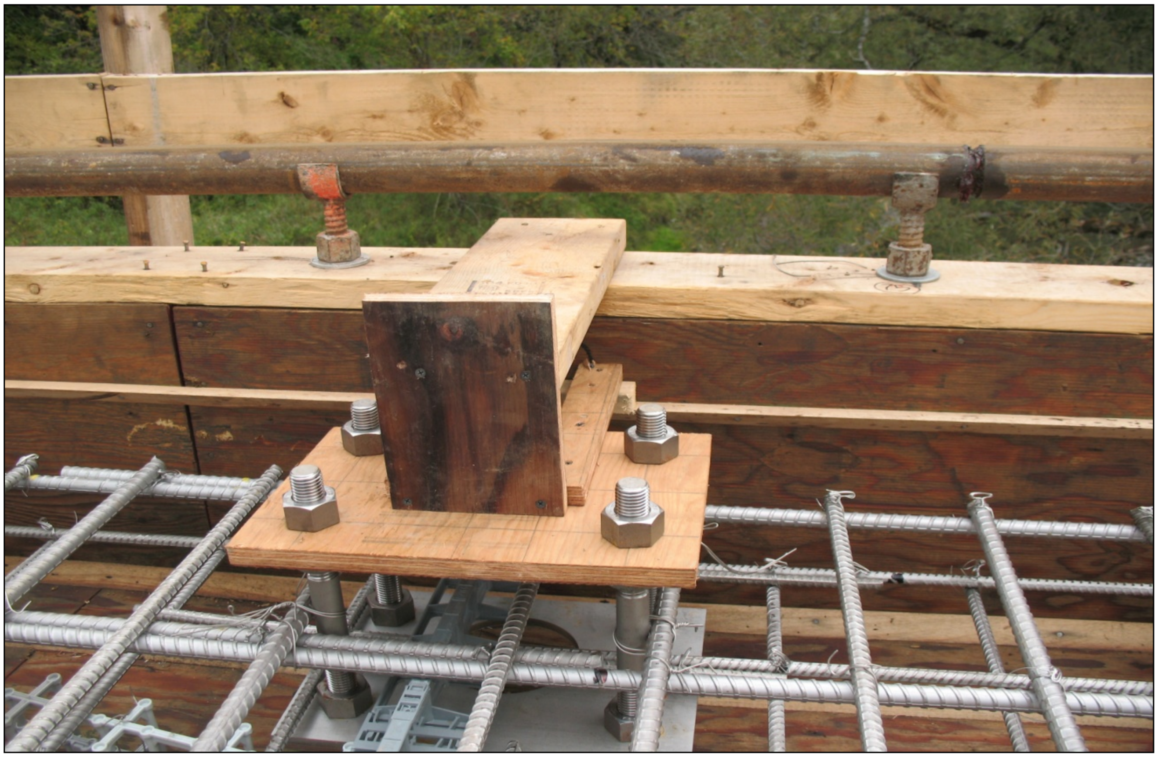


Figure 26. Anchor bolt assembly detail.

Figure 27. View of the new, wider bridge.

Figure 28. View of the completed bridge.

Figure 29. Roadside view of the completed bridge.

DATA ACQUISITION AND ANALYSIS

Data on safety, traffic flow, quality, and user satisfaction before, during, and after construction were collected to determine if this project met the HfL performance goals.

The primary objective of acquiring these types of data was 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:

- Achieve a safer work environment for the traveling public and workers.
- Reduce construction time and minimize traffic interruptions.
- Produce a high-quality project and gain user satisfaction.

This section discusses how the VTrans project met the HfL performance goals related to these areas.

SAFETY

There were no contractor injuries or incidents during construction. Reasons cited for this success include:

- Work being performed behind concrete barrier, away from the traveling public.
- Workers being well rested because contractor shift duration was 8 to 9 hours, 5 days a week.

Furthermore, with the replacement structure's width of 44 ft, which is about 24 ft more than the old structure, the travel environment should be safer and minimize the "near misses" and broken side view mirrors that adjacent property owners complained about.

CONSTRUCTION CONGESTION

Preconstruction Traffic Study

Attempting to mimic the typical driving speed of other vehicles along the various roadway segments, the floating vehicle methodology was used to collect travel times prior to construction. The goal of the traffic data collection was to determine the preconstruction trip time and queues through the project's influence area. This information was planned to be used as a benchmark to compare against similar data collected during construction.

Trips were made in each direction of travel between the first work zone warning sign (see Figure 30) and the "end construction" sign past the bridge. For the eastbound direction, the odometer was reset to 0.0 and the stopwatch was started at the intersection of VT 14 and US 2 (see Figure 31). At the first work zone warning sign approaching the bridge, the stopwatch time (to the nearest second) and the odometer reading (to the nearest $1/10^{th}$ mile) were recorded accordingly. The stopwatch and odometer readings were recorded again at the end construction sign on the other side of the bridge. The final stopwatch and odometer readings were recorded upon reaching the VT 214 and US 2 intersection. The process was repeated in the westbound direction beginning at the VT 214 and US 2 intersection and ending at the VT 14 and US 2 intersection. A minimum of five travel time runs were performed in each direction.

Figure 30. First work zone warning.

Figure 31. Intersection of VT 14 and US 2.

The data collection exercise was performed during the two peak traffic hours of noon and 4-5 PM. The first travel time data was recorded on Sunday (May 10, 2009) and was repeated on Monday (May 11, 2009).

Reducing the speed limit from 50 mph to 35 mph proportionally increased the trip time. However, based on the trip time study undertaken prior to the initiation of construction activities, traffic flowed freely and no noticeable back-ups were reported. As a result, queue lengths for vehicles approaching and traveling through the detour were nonexistent.

During Construction Traffic Study

Considering that there were no queues prior to construction, even with the reduced work zone speed limits and the fact that an on-site two-way temporary bridge was built in close proximity to the project (see Figure 17), no significant congestion related delays were experienced on this project during construction.

QUALITY

Sound intensity and smoothness test data were collected before and after construction. Comparing these results provides a measure of the quality of the finished bridge.

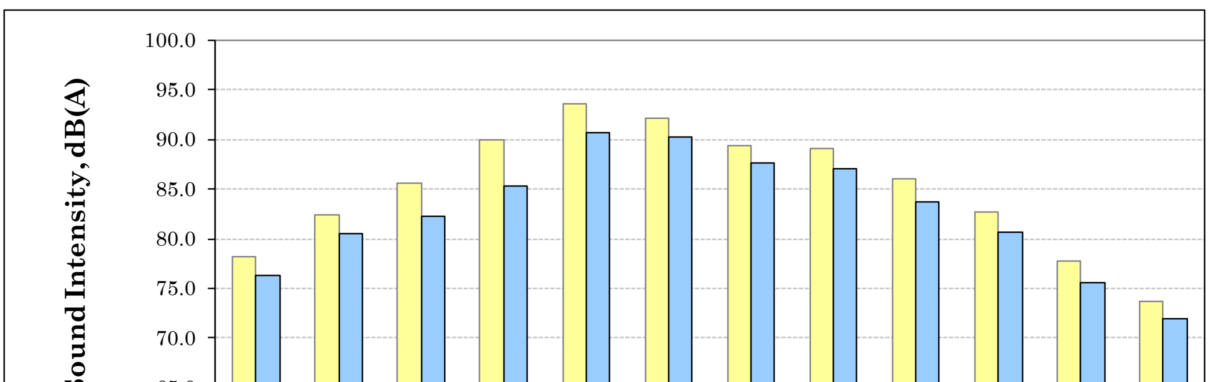
Sound Intensity Testing

OBSI test method was used to collect tire-pavement sound intensity (SI) measurements from the existing bridge to establish a baseline for comparison after construction was complete.

SI measurements were made using the currently accepted OBSI technique, AASHTO TP 76-10, which includes dual vertical SI and an ASTM recommended Standard Reference Test Tire (SRTT). Multiple runs were made at 35 mph in the right wheelpath. The SI probes simultaneously captured data from the leading and trailing tire-pavement contact areas. Figure 32 shows the dual probe instrumentation and the tread pattern of the SRTT.

Figure 32. OBSI dual probe system and the SRTT.

The average of the front and rear SI values was computed for the bridge to produce mean SI values. Raw data were normalized for the ambient air temperature and barometric pressure at the time of testing. The resulting mean SI levels were A-weighted to produce the noise-frequency spectra in one-third octave bands, as shown in Figure 33. The sound generated from the tire-pavement interaction was lower across the full range of frequencies.



	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000
Preconstruction	78.2	82.4	85.6	90.0	93.6	92.1	89.3	89.1	86.1	82.7	77.8	73.6
Postconstruction	76.3	80.5	82.3	85.3	90.7	90.3	87.7	87.1	83.7	80.6	75.6	71.9

Figure 33. Mean A-weighted SI frequency spectra.

Global SI levels were calculated using logarithmic addition of the one-third octave band frequencies across the spectra. The mean value before construction was 99.0 dB(A), and the value for the new bridge was 96.4 dB(A). While not meeting the HfL goal of 96.0 dB(A), the new bridge was noticeably quieter than the old bridge.

Smoothness Measurement

Smoothness data were collected in conjunction with OBSI testing utilizing a high-speed inertial profiler integrated with the OBSI test vehicle. Figure 34 is an image of the test vehicle showing the profiler positioned in-line with the right rear wheel. Multiple test runs were performed in each wheel path in each direction. The eastbound and westbound test runs were averaged to produce a single IRI value with units of in/mile.

Figure 34. High-speed inertial profiler mounted behind the test vehicle.

Figure 35 graphically presents the mean IRI values at 20-ft intervals for the old and new bridge and approach pavement. For reference, the bridge location is shaded in the figure. Overall, the increased smoothness of the new construction decreased the IRI values for the bridge and surrounding pavement. The mean IRI value for the bridge decreased from 126 in/mi to 78 in/mi. While not satisfying the HfL goal of 48 in/mi, this represents a noticeable improvement in smoothness.

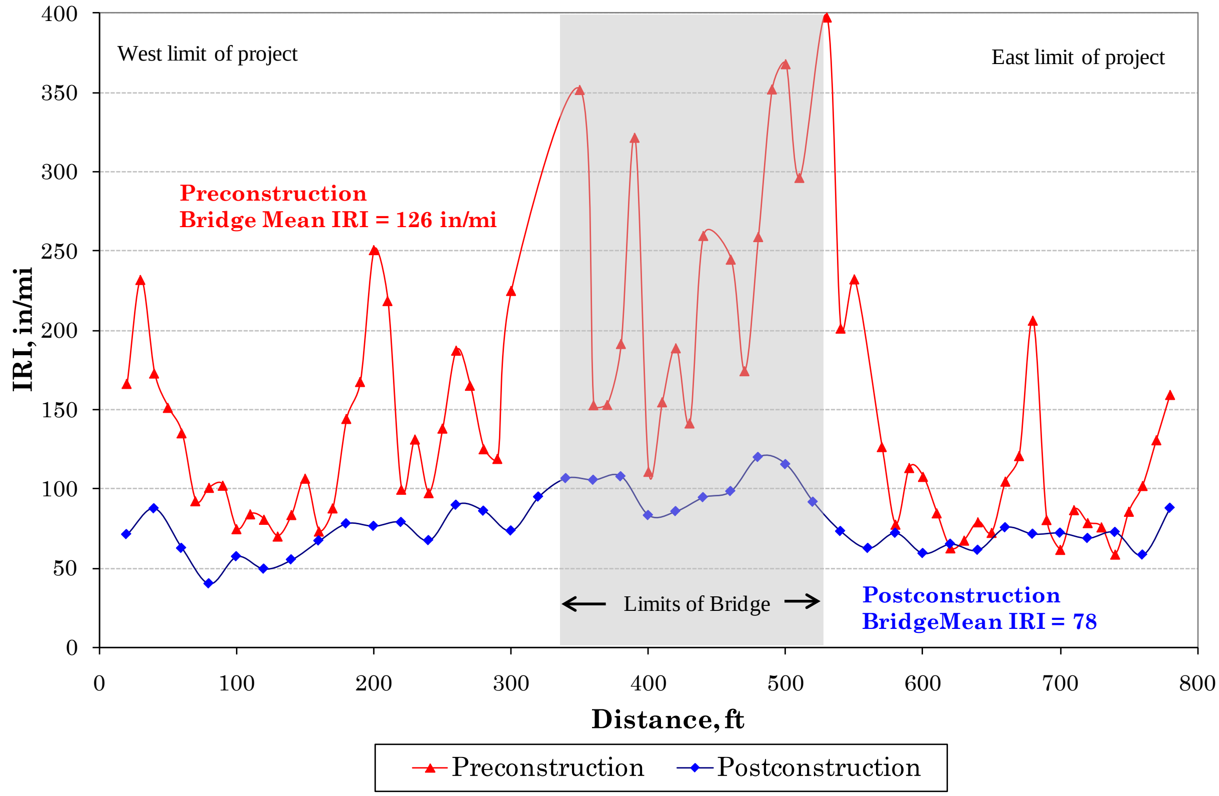


Figure 35. Mean IRI values.

User Satisfaction

VTrans conducted a postconstruction survey on user satisfaction at project completion. The agency distributed the survey to stopped traffic at the site when it was performing live load testing on the bridge as part of its research on integral abutments. The survey questions shown in Figure 36 were on prepaid postcards that were to be mailed by the respondents. Approximately 500 cards were handed out, and responses were received from 129 driving passenger vehicles and 6 from those driving heavy trucks. The results are summarized in Table 1.

The Vermont Agency of Transportation is seeking your input on the U.S Route 2 bridge project in East Montpelier (The Carpet Barn Bridge). Please assist us by answering the following questions and dropping this post card in the mail. **Postage is not necessary.**

What type of Vehicle do you drive?

Passenger Vehicle Heavy Truck

On a scale from 1-5 (5 being very often and 1 being never)
How often did you pass through the Construction site?

1 2 3 4 5

On a scale from 1-5 (5 being very satisfied and 1 being unsatisfied) please rate the project in the following areas

Traffic movement through the project during construction

1 2 3 4 5

Length of time the project was under construction

1 2 3 4 5

Overall satisfaction with the new bridge compared to the old bridge

1 2 3 4 5

What suggestions, comments, or questions do you have concerning the recently completed bridge work on US Route 2 in East Montpelier?

Figure 36. User survey form.

Table 1. User satisfaction survey results.

Question	Passenger vehicles	Trucks	Combined	Percent favorable response
1. Traffic movement through project during construction	4.4	3.7	4.4	83
2. Length of time the project was under construction	4.0	3.0	3.9	
3. Overall satisfaction with new bridge	4.9	4.0	4.8	96

In reviewing the data, it seems most users were satisfied with the movement of traffic through the construction site. The lower score from the truckers perhaps reflects the maneuvering the truckers needed to negotiate the detour curves. The scores from both groups were relatively lower for project construction time but still scored 83 percent favorable response. The delays attributed to stainless steel delivery and re-pouring of a portion of the deck, which extended the project duration, perhaps contributed to these ratings.

Both groups gave the highest score for overall satisfaction with the new bridge compared to the old bridge, with the combined score of 4.8 out of a possible 5.0, or 83 percent, perhaps because the new bridge is smoother and wider and offers a sense of safer travel. The response to the questions exceeded the HfL goal of 4-plus on a Likert scale of 1–7 (in other words, 57 percent or more participants showing favorable response).

TECHNOLOGY TRANSFER

Because the Vermont project demonstrated the applicability of several innovative concepts related to simplified bridge design and construction, the use of high-quality durable materials that minimize future maintenance, and meeting the HfL program's goals on safety, construction congestion, and quality, it was selected for a project demonstration showcase to provide technology transfer. A team consisting of representatives from VTrans, FHWA Vermont Division, FHWA Highways for LIFE, the University of Florida, and Applied Research Associates, Inc., planned, coordinated, and hosted the showcase.

The showcase was held on September 29, 2009, at VTrans' offices in Montpelier. Invitations were extended to VTrans representatives and their partners in municipalities, academia, and consultants/contractors. Representatives from neighboring northeastern States also were invited. Registration filled up quickly, and approximately 50 people participated.

The showcase consisted of a morning session of presentations at the VTrans headquarters, an afternoon visit to the construction site, and a return to the headquarters for a question and answer and wrap-up session. The showcase agenda is shown in Appendix D.

The showcase benefited greatly by having Messrs. David Dill, VTrans Secretary of Transportation, and Ernie Blais, Vermont FHWA Division Administrator, and Wayne Symonds, VTrans Structure Design Engineer, open the meeting with their support and enthusiastic encouragement. This was followed by a fairly detailed project overview presented by Ms. Kristin Higgins, Project Manager, and Mr. Jim LaCroix, Project Engineer. Resident Engineer Mr. Chris Jolly and Contractor Superintendent Mr. Gordy Eastman followed with construction commentary and contractor perspective on the innovative features of the project. Mr. Jolly also provided a job site safety briefing. Both design and construction perspectives generated considerable interest and participation by the attendees. A number of questions were asked on the innovative features of the project. Ms. Pam Thurber then presented the Bridge Inspection and Preservation Unit perspective on design. This unit will benefit immensely from this project, which is anticipated to require minimal maintenance. Mr. Lou Triandfilou, FHWA's High Performance Structural Materials Engineer, provided a national perspective on accelerated bridge construction.

The contractor stopped all construction activity during the site visit, enabling the visitors to walk around freely and look at the innovative features. At the time of the visit, the project was in the deck construction stage. Concrete had been poured on a portion of the deck. The attendees could see the condition of the solid stainless steel reinforcement in the deck. The contractor was very cooperative, and the construction workforce eagerly shared their experiences and answered questions from the showcase participants. After about 1.5 hours at the work site, the participants returned to the conference location for a question and answer and wrap-up session.

Proceedings of the Vermont showcase were both videotaped and photographed. The presentations are accessible from the Highways for LIFE website.

The Vermont project showcase was deemed a success. Participants had an opportunity to hear about and see first-hand the positive attributes of setting project stretch goals and meeting those goals with innovative elements and minimal construction delays. The VTrans project personnel were lauded for their efforts among their peers and contemporaries. This public praise and acknowledgement and success of the innovative approach undoubtedly will spur more innovation on future Vermont bridge projects.

ECONOMIC ANALYSIS

A key aspect of the HfL demonstration projects is to quantify, inasmuch as possible, the value of innovations deployed. This quantification entails a comparison of the benefits and costs associated with the innovative project delivery approach adopted on a given HfL project with those from a more traditional delivery approach (i.e., an approach which does not include the project's highlighted innovations) for a project of similar size and scope. The latter type of project is referred to herein as a *baseline* case and is an important component of the economic analysis.

The following paragraphs discuss the cost comparisons for the US Route 2 replacement bridge project. VTrans supplied most of the cost figures for the as-built project and the baseline case.

CONSTRUCTION TIME

VTrans conservatively estimated that the innovative approach saved 8 weeks of construction time, compared to the baseline case. The innovative approach called for a completion in 120 days. The baseline approach would have taken 176 days. Therefore, the net projected time savings was 56 days.

Observations during construction showed no queuing, even during peak hour travel, and traffic disruption during construction was limited to slower movement through the construction work zone caused by the speed reduction from 50 mph to 35 mph. With the construction work zone including signing being about 0.25 miles long, the delay per vehicle is calculated by dividing the work zone length by the difference in speed of 15 mph:

$$0.25 / 15 = 0.0167 \text{ hr/vehicle}$$

With ADT of 8,500 and savings in construction time of 15 days, the innovative approach's reduction in delay over the baseline case is computed to be:

$$8{,}500 \times 56 \times 0.0167 = 7{,}950 \text{ vehicle hours, approximately.}$$

As indicated earlier in the report, both innovative and conventional approaches called for the bridge to be built on existing alignment with a temporary bridge built just to the south side of the site. As such, the very minimal detour is the same in both instances.

CONSTRUCTION COSTS

Initial Construction Costs

The cost estimate for the baseline structure was $1,351,500, and the cost for the as-built structure was $918,700, resulting in savings in construction cost of $432,800. The significant amount of money saved is based on the hydraulic requirement to place spread footings in the conventional design 6 ft below the stream bed because of scour concerns. Computations for both options are shown in Appendix E.

Future Construction Costs

The project goals included achieving a 100-year design life and reducing the life cycle costs. VTrans anticipated the following demands for major maintenance activities during this period for the baseline option (conventional structure). Present worth of each activity is shown in parenthesis. Note that routine maintenance activities have not been included in the analysis, as they would be essentially the same for both baseline and as-built options:

- 25 years – replace membrane & pavement ($75,000).
- 50 years – replace deck and major repairs ($500,000).
- 75 years – replace membrane & pavement ($75,000).
- 100 years – Bridge replacement.

In contrast, future major maintenance needs for the as-built options are estimated as follows:

- 40 years – diamond grind top 0.5 inch of deck ($75,000).
- 75 years – possible membrane and pavement to help extend service life, otherwise diamond grind ($75,000).
- 100 years – Bridge replacement.

In summary, the present worth of future maintenance cost for the baseline option is estimated at $650,000 and that of the as-built option at $150,000, resulting in estimated saving of $500,000 for the as-built option.

USER COSTS

Three categories of user costs are generally used in an economic analysis. These include:

- Vehicle operational costs.
- Delay costs.
- Crash costs or safety related costs.

Considering that the work zone setups were identical for both the baseline and as-built cases, user costs were not considered to be significantly different. It can be argued that, since the as-built case could have been completed in a relatively quicker time period (56 days faster), the travel time delay costs due to 15 mph reduction in speed limit for this case would be lower. However, given the relatively small impact of the lower posted speed limit on delays, the short project length (approximately 0.25 miles), and relatively low traffic volumes that the roadway carries, it was determined that the savings in road user cost were not significant.

COST SUMMARY

All costs are tabulated below for the baseline and as-built options.

Item	Baseline	As- Built
Initial construction cost of bridge	$1,351,500	$918,700
Future maintenance costs	$ 650, 000	$150,000
TOTAL	**$2,001, 500**	**$1,068,700**
Cost Savings	**$932,800**	

Using the estimated total costs for constructing the bridge and the projected maintenance needs over the life span of the structure, it is clear that the innovative HfL project delivery approach will realize a cost savings of $932,800 over the life of the project when compared to the traditional approach (a net savings of 47 percent). The savings exceed the construction cost estimate of the as-built bridge portion of the project of $918,700.

APPENDIX A-SPECIAL PROVISIONS

SECTION 900 - SPECIAL PROVISION ITEMS

HIGH PERFORMANCE CONCRETE, NO SILICA FUME

33. DESCRIPTION. This work shall consist of furnishing and placing high performance portland cement concrete at the locations indicated in the Plans and as directed by the Engineer.

The work under this Section shall be performed in accordance with these provisions, the Plans, and Section 501 of the Standard Specifications.

34. CLASSIFICATION AND PROPORTIONING. Proportioning of High Performance Concrete, No Silica Fume shall meet the following requirements:

HPC Class	Req.*** Cem. Mat. (kg/m^3)	Maximum Water-Cem. Mat. Ratio	Max.* Slump (mm)	Air Content (%)	Coarse Aggregate Gradation Table	28-Day** Comp. Strength (MPa)	28-Day* Modulus of Rupture (MPa)
No Silica Fume	362	0.44	180	7.0 ± 1.5	704.02B	28	4.48

*A maximum slump of 200 mm is allowed after the addition of admixtures.
**The listed 28-day compressive strength or modulus of rupture will serve as the basis of designing or approving the concrete mix.
***See tables below for required cementitious materials.

Required Cementitious Materials

Cement (kg/m^3)		Fly Ash (kg/m^3)		Cementitious Materials (kg/m^3)
266	+	96	=	362

OR

Cement (kg/m^3)		GGBFS (kg/m^3)		Cementitious Materials (kg/m^3)
248	+	114	=	362

The Contractor will be responsible for providing a workable mix design.

35. CONCRETE FINISHING.

(a) Finishing Bridge Decks with No Asphalt Wearing Surface.

(1) Rail Support Requirements. Finishing machine rail supports shall be accurately set and of substantial construction so that the finished deck surface will conform to the profile and transverse sections shown in the Plans. Finishing machine rail supports shall be placed and adjusted to properly provide for the deflection of forms, falsework, and structural supporting members which will occur during the placement of the concrete. Finishing machine rail supports shall not be attached by welding to portions of the flanges. The finishing machine rail supports shall be spaced at a maximum of 600 mm (2 feet) on center and of sufficient design as to secure the rail to prevent it from falling off the support.

(2) Straightness Check. Prior to texturing, the finished concrete surface shall be examined by the Contractor and the Engineer using a straightedge. The straightedge shall be not less than 3 m (10 feet) long. It shall be furnished by the Contractor and maintained in good, usable condition at the placement site at all times. While the concrete is still plastic, surface depressions shall be filled with concrete of the same Class as the placement in progress. The added concrete shall be worked sufficiently into the underlying concrete to ensure that it creates a single monolithic layer. Surface irregularities greater than 3 mm (1/8 inch) in 3 m (10 feet) in either the longitudinal or the transverse direction shall be corrected in a manner acceptable to the Engineer. Thin mortar or laitance, which may have accumulated ahead of the finishing machine screed, shall be removed from the work site. These materials shall not be used to fill depressions. All costs for providing a straightedge to test the trueness of the concrete finishing will be considered incidental to Contract item 631.16.

(3) Turf Drag. After finishing, the surface shall be given a suitable texture with an artificial turf drag made of molded polyethylene with approximately 64,000 synthetic turf blades per square meter (6000 blades per square foot), each approximately 13 mm (1/2 inch) long.

The Contractor shall apply texture in a transverse direction by hand methods. Other directions may be allowed with the approval of the Engineer. All texturing shall be performed from a work bridge immediately following the finishing operations and prior to curing operations. A second work bridge will be required for curing purposes unless a method utilizing a single work bridge has been approved by the Engineer.

One pass of the turf drag over the finished area is desired. The drag shall leave a seamless strip between passes. Texture resulting from the drag shall stop within 300 mm (1 foot) of the face of rail. Any build up of concrete at the beginning or end of the pass shall be hand troweled to provide an even transition. An acceptable broom finish may be applied to small areas of deck surface where a turf drag cannot be operated.

The drag should produce a transverse, skid resistant micro-texture acceptable to the Engineer, but should not tear the surface. If the drag is not producing an acceptable micro-texture, the Contractor shall adjust the means and methods until an acceptable micro-texture is achieved.

The Contractor shall check the drag material before the deck pour and from time to time during finishing for tears, worn surface, or hardened concrete. The Contractor should clean or replace the drag as often as necessary to maintain a well-defined micro-texture.

The turf drag should not be applied when the surface is so wet or plastic that the ridges formed flow back into the valleys when the drag has passed, nor should dragging be delayed until the concrete is so hard that sharp ridges cannot be formed by the drag. Surface conditions may not be fully uniform, however, and dragging should be timed to maximize skid resistance.

If the 10 minute maximum, as specified in Subsection 501.17(c), for applying the wet cure cannot be met, then fogging of the area shall be performed. Fogging shall be performed in a manner that keeps the relative humidity above the evaporation rate of the concrete surface, but not so excessive that water begins to collect on the surface prior to texturing or other surface manipulating procedures.

(4) Hand Finishing. In areas which are inaccessible to finishing machines, use of approved manual vibratory-equipped power screeds with approved grade control method may be used, with approval of the Engineer. Straightness shall be checked as specified in subpart (a)(4) of this Section and to ensure a smooth ride and seamless transition to the finishing machine's finished area. If manual vibratory-equipped power screeds are used, then initial vibration of the concrete for consolidation in those areas shall be of the minimal duration possible to avoid over vibration and loss of air entraining of the surface concrete in these areas.

Hand finishing shall be allowed only in areas inaccessible to finishing machines or manually driven vibratory-equipped power screeds. Hand screeds or bullfloats shall be magnesium and 250 mm (10 inches), or more, in width. Care shall be taken not to overwork the concrete surface during any finishing operation. Straightness shall be checked in any hand finished area as specified in subpart (a)(4) of this Section and to ensure a smooth ride and seamless transition to the finishing machine's finished area.

36. CURING CONCRETE. No work will be allowed on the deck during the 10 day wet cure period.

37. METHOD OF MEASUREMENT. The quantity of Special Provision (High Performance Concrete, No Silica Fume) to be measured for payment will be the number of cubic meters (cubic yards) of concrete placed in the complete and accepted work, as determined by the prismoidal method using dimensions shown on the Plans or as directed by the Engineer, including the volume of precast concrete stay-in-place forms, but excluding the volume of steel or other stay-in-place forms and form filling materials. No deductions will be made for the volume of concrete displaced by steel reinforcement, structural steel, expansion joint material, scuppers, weep holes, conduits, tops of piles, scoring, chamfers or corners, inset panels of 38 mm (1½ inches) or less in depth, or any pipe less than 200 mm (8 inches) in diameter.

38. BASIS OF PAYMENT. The accepted quantity of Special Provision (High Performance Concrete, No Silica Fume) will be paid for at the Contract unit price per cubic meter (cubic yard). Payment will be full compensation for performing the work specified, including designing the mix, satisfactory finishing and curing, and for furnishing all forms, materials, including joint filler and bond breaker, labor, tools, admixtures, equipment, including automatic temperature recording units, trial batches, and incidentals necessary to complete the work.

The cost of heating materials and protecting the concrete against cold weather, and any additional cost for cement, will not be paid for separately but will be considered incidental to Special Provision (High Performance Concrete, No Silica Fume).

The cost of furnishing testing facilities and supplies at the batch plant and the setting of inserts, bench marks, and bridge plaques furnished by the Agency will not be paid for separately but will be considered incidental to Special Provision (High Performance Concrete, No Silica Fume).

Costs for all materials, labor, and incidentals for steel or other stay-in-place forms and form filling materials will not be paid for separately, but will be considered incidental to Special Provision (High Performance Concrete, No Silica Fume).
Payment will be made under:

Pay Item	Pay Unit
900.608 Special Provision (High Performance Concrete, No Silica Fume)	Cubic Meter

GUARDRAIL APPROACH SECTION, GALVANIZED 3 RAIL BOX BEAM

39. DESCRIPTION. This work shall consist of furnishing and erecting galvanized 3-rail box beam guardrail approach sections as shown in the Plans and as directed by the Engineer.

The work under this Section shall be performed in accordance with these provisions, the Plans, and Section 621 of the Standard Specifications.

40. MATERIALS. Materials shall meet the requirements specified in the Plans.

41. CONSTRUCTION REQUIREMENTS. Guardrail approach sections shall be provided and erected to the configuration shown in the Plans.

42. METHOD OF MEASUREMENT. The quantity of Special Provision (Guardrail Approach Section, Galvanized 3 Rail Box Beam) to be measured for payment will be the number of units installed in the complete and accepted work.

43. BASIS OF PAYMENT. The accepted quantity of Special Provision (Guardrail Approach Section, Galvanized 3 Rail Box Beam) will be paid for at the Contract unit price for each. Payment will be full compensation for furnishing, transporting, handling, and placing the material specified, and for furnishing all labor, tools, equipment, and incidentals necessary to complete the work.

Payment will be made under:

Pay Item		Pay Unit
900.620	Special Provision (Guardrail Approach Section, Galvanized 3 Rail Box Beam)	Each

STAINLESS STEEL REINFORCING

44. DESCRIPTION. This work shall consist of furnishing and placing stainless steel bar reinforcement.

The work under this Section shall be performed in accordance with these provisions, the Plans, and Section 507 of the Standard Specifications.

45. MATERIALS.

(a) Stainless Steel. Stainless steel shall meet the requirements of ASTM A955 M and its designated grade, either 420 or 520, and the requirements of ASTM A 276 UNS 31653 or UNS 32304.

(b) Tie Wires and Supports. Tie wire used to tie stainless steel reinforcing bars to stainless steel reinforcing bars, reinforcing steel bars, and shear studs shall be Type 316LN or Type 316L stainless steel wire, 1.2 mm or 1.6 mm (17 or 14 gauge) in diameter. Tie wire used to tie stainless steel reinforcing bars to coated reinforcing steel bars shall be coated wire.

Bar chairs for supporting stainless steel reinforcing bars shall be non-metallic. Concrete chairs shall not be used.

46. QUALITY CONTROL. A minimum of thirty (30) days prior to delivery to the project site, the manufacturer shall provide a quality control plan for review and approval by the Materials and Research Engineer. The plan shall clearly demonstrate the ability to manufacture, test, certify, maintain, and assure the identity of bars from manufacture to placement.

The receipt of the manufacturer's quality control plan will serve as notification to the Agency of the manufacturer's intention to supply reinforcing bars to an Agency project.

47. SAMPLING AND TESTING. Samples of bar reinforcement a minimum of 1.5 m (60 inches) long shall be submitted to the Materials and Research laboratory for testing as specified in the Plans.

A Type D Certification shall be furnished in accordance with Subsection 700.02.

48. PROTECTION OF MATERIAL. Stainless steel reinforcement shall be stored separately from other reinforcing steel at all times (including being separated during transport so that there is no direct contact) to avoid contamination. The reinforcement shall be stored clear of the ground on timbers or other suitable protective cribbing spaced to prevent sags in the bundles. When placed in the work, stainless steel reinforcement shall be clean of all scale or other foreign substances.

APPENDIX B-CONTRACTOR/SUPPLIER/FABRICATOR INFORMATION

PRIME CONTRACTOR

Winterset, Inc.
128 Winter Lane
Lyndonville, VT 05851
802-626-9330

STAINLESS STEEL

SUPPLIER

American Arminox, Inc.
1285 Avenue of the Americas
35th Floor
New York, NY 10019
212-554-4002

FABRICATOR

North American Stainless
6870 Highway 42 East
Ghent, KY 41045
502-347-6000

RAIL

SUPPLIER

F.R. Lafayette, Inc.
52 Kellogg Road
Essex Junction, VT 05452
802-878-5341

Fabricator

Elderlee, Inc.
Oaks Corners, NY 14518
315-789-6615

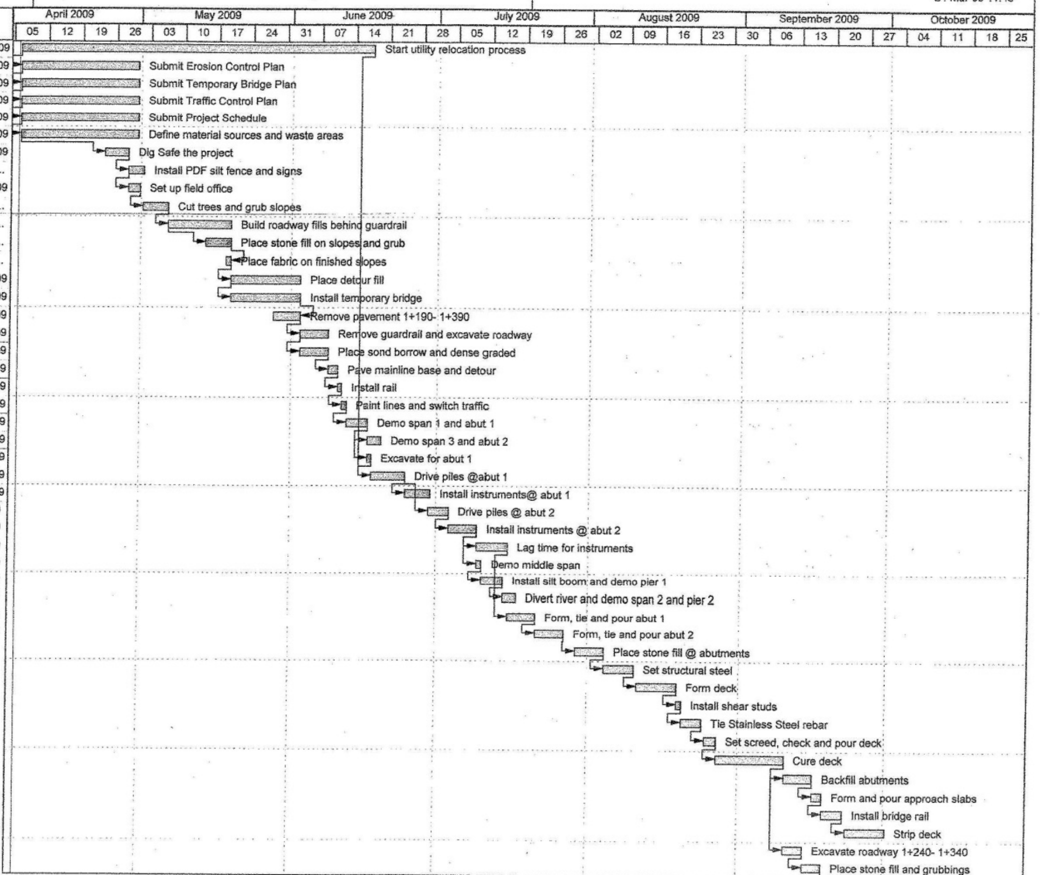
HPC SUPPLIER

Carroll Concrete Company
PO Box 1000
8 Reeds Mill Road
Newport, NH 03773-1000
1-800-622-4100

APPENDIX C-CONTRACTOR SCHEDULE

East Montpelier BRF 028-3 (36) — Classic Schedule Layout — 24-Mar-09 11:45

Activity ID	Activity Name	Original Duration	Remaining Duration	Start	Finish
A1000	Start utility relocation process	57	57	06-Apr-09	17-Jun-09
A1010	Submit Erosion Control Plan	20	20	06-Apr-09	30-Apr-09
A1020	Submit Temporary Bridge Plan	20	20	06-Apr-09	30-Apr-09
A1030	Submit Traffic Control Plan	20	20	06-Apr-09	30-Apr-09
A1040	Submit Project Schedule	20	20	06-Apr-09	30-Apr-09
A1050	Define material sources and waste ar...	20	20	06-Apr-09	30-Apr-09
A1060	Dig Safe the project	3	3	23-Apr-09	28-Apr-09
A1070	Install PDF silt fence and signs	4	4	28-Apr-09	01-May...
A1080	Set up field office	3	3	28-Apr-09	30-Apr-09
A1090	Cut trees and grub slopes	4	4	01-May-09	06-May...
A1100	Build roadway fills behind guardrail	10	10	06-May-09	19-May...
A1110	Place stone fill on slopes and grub	4	4	14-May-09	19-May...
A1120	Place fabric on finished slopes	1	1	18-May-09	19-May...
A1130	Place detour fill	10	10	19-May-09	02-Jun-09
A1140	Install temporary bridge	10	10	19-May-09	02-Jun-09
A1150	Remove pavement 1+190- 1+390	4	4	28-May-09	02-Jun-09
A1160	Remove guardrail and excavate road...	4	4	02-Jun-09	08-Jun-09
A1170	Place sond borrow and dense graded	4	4	02-Jun-09	08-Jun-09
A1180	Pave mainline base and detour	2	2	08-Jun-09	10-Jun-09
A1190	Install rail	1	1	10-Jun-09	11-Jun-09
A1200	Paint lines and switch traffic	1	1	11-Jun-09	12-Jun-09
A1210	Demo span 1 and abut 1	3	3	12-Jun-09	16-Jun-09
A1220	Demo span 3 and abut 2	3	3	16-Jun-09	19-Jun-09
A1230	Excavate for abut 1	1	1	16-Jun-09	17-Jun-09
A1240	Drive piles @abut 1	5	5	17-Jun-09	24-Jun-09
A1250	Install instruments@ abut 1	4	4	24-Jun-09	29-Jun-09
A1260	Drive piles @ abut 2	5	5	29-Jun-09	03-Jul-09
A1270	Install instruments @ abut 2	4	4	03-Jul-09	09-Jul-09
A1280	Lag time for instruments	5	5	09-Jul-09	15-Jul-09
A1290	Demo middle span	1	1	09-Jul-09	10-Jul-09
A1300	Install silt boom and demo pier 1	3	3	10-Jul-09	14-Jul-09
A1310	Divert river and demo span 2 and pier 2	3	3	14-Jul-09	17-Jul-09
A1320	Form, tie and pour abut 1	4	4	15-Jul-09	21-Jul-09
A1330	Form, tie and pour abut 2	4	4	21-Jul-09	27-Jul-09
A1340	Place stone fill @ abutments	4	4	29-Jul-09	04-Aug...
A1350	Set structural steel	5	5	04-Aug-09	10-Aug...
A1360	Form deck	7	7	11-Aug-09	19-Aug...
A1370	Install shear studs	1	1	19-Aug-09	20-Aug...
A1380	Tie Stainless Steel rebar	3	3	20-Aug-09	24-Aug...
A1390	Set screed, check and pour deck	3	3	25-Aug-09	27-Aug...
A1400	Cure deck	10	10	27-Aug-09	10-Sep...
A1410	Backfill abutments	4	4	10-Sep-09	16-Sep...
A1420	Form and pour approach slabs	2	2	16-Sep-09	18-Sep...
A1430	Install bridge rail	3	3	18-Sep-09	22-Sep...
A1440	Strip deck	7	7	23-Sep-09	01-Oct-09
A1450	Excavate roadway 1+240- 1+340	2	2	10-Sep-09	14-Sep...
A1460	Place stone fill and grubbings	4	4	14-Sep-09	18-Sep...



Actual Work — Critical Remaining Work — Summary
Remaining Work ◆ — ◆ Milestone

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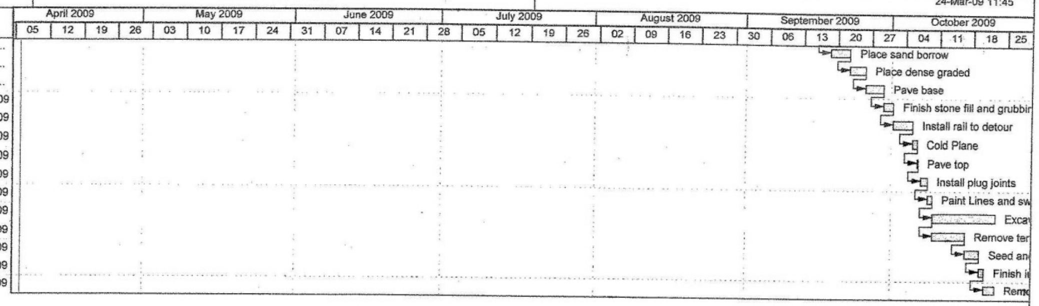
TASK filter: All Activities

East Montpelier BRF 028-3 (36) — Classic Schedule Layout — 24-Mar-09 11:45

Activity ID	Activity Name	Original Duration	Remaining Duration	Start	Finish
A1470	Place sand borrow	2	2	18-Sep-09	22-Sep...
A1480	Place dense graded	4	4	22-Sep-09	25-Sep...
A1490	Pave base	2	2	25-Sep-09	29-Sep...
A1500	Finish stone fill and grubbings & see...	2	2	29-Sep-09	01-Oct-09
A1510	Install rail to detour	2	2	01-Oct-09	05-Oct-09
A1520	Cold Plane	1	1	05-Oct-09	06-Oct-09
A1530	Pave top	1	1	06-Oct-09	06-Oct-09
A1540	Install plug joints	2	2	07-Oct-09	08-Oct-09
A1550	Paint Lines and switch traffic	1	1	08-Oct-09	09-Oct-09
A1560	Excavate detour fills	10	10	09-Oct-09	22-Oct-09
A1570	Remove temporary bridge	5	5	09-Oct-09	16-Oct-09
A1580	Seed and mulch detour footprint	1	1	16-Oct-09	19-Oct-09
A1590	Finish installing rail	1	1	19-Oct-09	20-Oct-09
A1600	Remove office site & seed area	3	3	20-Oct-09	22-Oct-09



Actual Work | Critical Remaining Work | Summary
Remaining Work ◆ | ◆ Milestone

Page 2 of 2

TASK filter: All Activities

APPENDIX D-PROJECT DEMONSTRATION SHOWCASE AND LIST OF PARTICIPANTS

September 29, 2009

VTrans & Highways for LIFE
US 2 - Accelerated Bridge Construction
Showcase

AGENDA

Tuesday, September 29, 2009

Meeting Moderator: Wayne Symonds, Structures Design Engineer - VTrans

8:30am	**Registration and Sign In**
9:00am – 9:15am	**Welcome and Introductions** Wayne Symonds, Structures Design Engineer – VTrans David Dill, Secretary of Transportation – VTrans
9:15am – 9:30am	**Highways for LIFE Overview** Ernie Blais, Division Administrator – FHWA, Vermont Division Office
9:30am – 10:15am	**Project Overview** Kristin Higgins, Project Manager – VTrans Jim Lacroix, Project Engineer – VTrans
10:15am – 10:30am	**Break**
10:30am – 10:45am	**Accelerated Bridge Construction – A National Perspective** Lou Triandafilou, High Performance Structural Materials Engineer – FHWA
10:45am – 11:15am	**Construction Photos/Commentary and Contractor Perspective on Contract Requirements and Construction** Gordy Eastman, Superintendent – Winterset Construction, Inc. Chris Jolly, Resident Engineer - VTrans
11:15am – 11:30am	**Bridge Inspection and Preservation Unit Perspective on Design** Pam Thurber, Bridge Management & Inspection Engineer – VTrans
11:30am – 11:45am	**Question and Answer**
11:45am – 12:45pm	**Lunch** *(on your own)*
12:45pm – 1:00pm	**Job Site Safety Briefing** Chris Jolly, Resident Engineer - VTrans
1:00pm – 2:30pm	**Travel to Project Site** Field View and Contractor/Resident Engineer Comments
2:30pm	**Return to Conference Room**
2:30pm – 3:00pm	**Summary and Question and Answer** All Speakers
3:00pm – 3:15pm	**Evaluations & Adjourn**

HIGHWAYS FOR LIFE
Accelerating Innovation for the American Driving Experience.

VTrans Working to Get You There
Vermont Agency of Transportation

APPENDIX E-COST ESTIMATES FOR BASELINE STRUCTURE (ALTERNATIVE A) AND AS-BUILT STRUCTURE (ALTERNATIVE B)

INITIAL COSTS

Alternative A - Estimated

Cofferdam and Excavation = $100,000
- 2 Cofferdams @ $35,000 Each
- Cofferdam and Structure Excavation @ $30,000

Granular Backfill For Structures = $50,000
- 1000 Cubic Meters @ $50/CM

High Performance Class B Concrete = $350,000
- 500 Cubic Meters @ $700/CM

Expansion Joint = $20,000
- 30 meters @ $667/CM

Piles and Equipment = $135,000
- Furnishing Equipment @ $111,000 Lump Sum
- Steel Piling 1200 Meters @ $20/M

Reinforcing Steel = $75,000
- 37,500 KG @ $2.00/KG

Bearings = $10,000
- 10 Each @ $1000 - Elastomeric Bearings

Structural Steel = $255,000
- 76200 KG @ $3.35/KG

Water Repellent = $5,000
- 500 Liters @ $10/L

Stone Fill = $47,000
- 1060 CM @ $45/CM

High Performance Class A Concrete = $141,000
- 190 Cubic Meters @ 900/CM

Epoxy Coated Reinforcing Steel = $98,000
- 39,200 KG @ $2.50/KG

Torch Applied Membrane = $12,500
- 500 SM @ $25/SM

High Performance Class A Concrete Curbs = $10,000
- 10 CY @ $1000/CY

NETC Bridge Rail = $26,500
- 76 Meters @ $350/M

Pavement = $16,500
- 110 Tons @ $150/T

Alternative A Total = $1,351,500

Alternative B - As Built (ACTUAL COSTS)

Structure Excavation = $7500

340 Cubic Meters @ $21.00/CM

Granular Backfill for Structures = $28,000

550 Cubic Meters @ $51.00/CM

High Performance Class A Concrete = $141,000

190 Cubic Meters @ 900/CM

High Performance Class B Concrete = $105000

150 Cubic Meters @ $700/CM

Expansion Joint = $12,300

30 Meters @ $410/M - Asphaltic Plug Joint at end of Approach Slabs

Piles and Equipment = $117,000

Furnishing Equipment @ $111,000 Lump Sum

Steel Piling 400 Meters @ $15.50/M

Reinforcing Steel = $22,800

11,400 KG @ $2.00/KG

Bearings = $7,900

10 Each @ $790 Each - Temporary Pads Cast into Concrete

Structural Steel = $255,000

76,200 KG @ $3.35/KG

Water Repellent = $2,800

270 Liters @ $10.25/L

Stone Fill = $47,000

1,060 CM @ $45/CM

Stainless Reinforcing Steel = $126,400

15,800 KG @ $8/KG

Longitudinal Deck Grooving = $8,500

500 Square Meters @ $17.50/SM

Bridge Rail = $37,500

76 Meters @ $500/M

Alternative B Total = $918,700