

# ASPIRE™

THE CONCRETE BRIDGE MAGAZINE

SPRING 2011

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## Don E. Wickstrom Bridge

*Kent, Washington*

**COLORADO RIVER BRIDGE**

*Moab, Utah*

**HAVEN AVENUE GRADE SEPARATION BRIDGE**

*Rancho Cucamonga, California*

**TRINITY RIVER BRIDGE**

*Between Houston and Beaumont, Texas*

**HARBOR DRIVE PEDESTRIAN BRIDGE**

*San Diego, California*

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### US 191 Colorado River Bridge Moab, Utah

This crossing of the Colorado River near Arches National Park in Moab, Utah was designed with **respect for the environment – preserving, blending and connecting with the beautiful landscape**. This sustainable bridge features a 438' main span, with only one pier in the river. Long sweeping spans cross the river valley with rock textures and colors that blend seamlessly with canyon walls to keep the focus on nature. Through a design charrette with the community, the bridge features were selected to be in harmony with the environment, giving the bridge the appearance of being born of the earth. The southbound bridge opened to traffic in February 2010, and construction of the northbound bridge was completed December of 2010.

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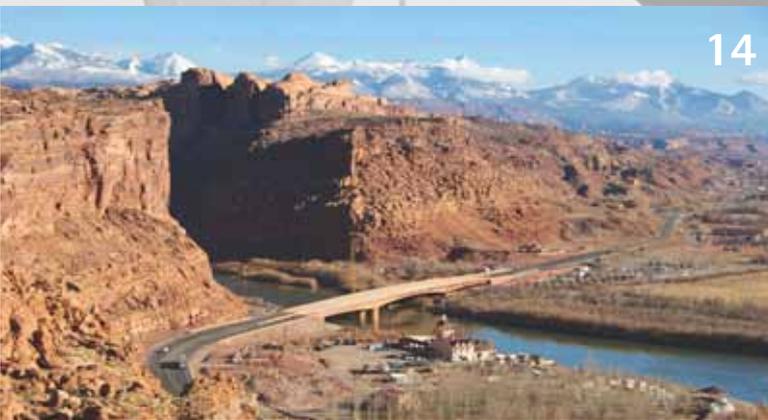


Photo: ©Figg Bridge Engineers.



Photo: City of Rancho Cucamonga.

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Photo: Tampa Hillsborough Expressway Authority.

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## The Many Applications of Concrete

Henry G. Russell, *Managing Technical Editor*

Photo: Ted Lacey Photography.

When we started *ASPIRE*™ more than 4 years ago, none of the staff realized how much we would discover about concrete bridges and their applications. We knew that we wanted to present solutions that used cast-in-place concrete; precast, prestressed concrete; and segmental construction. Within these broad categories, we have shown a host of options: arches, box beam bridges, bulb-tee beam bridges, cable-stayed bridges, I-beam bridges, spliced-girder bridges, stress ribbon bridges, and suspension bridges. Now, we even have new double-tee beam bridges (see page 46). We also set out with the goal of including transit and railway bridges, pedestrian bridges, and aircraft runway or taxiway bridges as well as highway bridges.

In addition, concrete is no longer plain vanilla concrete! Bridges can now be built with a variety of concretes:

- High-performance concrete for durability
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In every issue, we include a variety of topics to illustrate the available options. We also show how bridges are built, particularly when there are environmental, traffic, space, or time restrictions that prevent the traditional methods of construction from being used.

The articles in this issue continue to meet our goals of illustrating the many applications of concrete. On page 26, we feature a cast-in-place, horizontally curved pedestrian bridge. However, it is not as simple as that. The bridge is also a self-anchored suspension bridge supported by an inclined mast. The author explains how equilibrium of forces was maintained and geometric compatibility was achieved.

The Phoenix Sky Harbor International Airport is constructing a 5-mile transit system to connect the various airport facilities. This system crosses an active taxiway requiring a 340-ft main span using a cast-in-place, post-tensioned, box-girder bridge (page 34).

In the process of producing *ASPIRE*, we have also noticed the pride that communities take in their bridges. Such is the case of the grade-separation railway bridge in Rancho Cucamonga, Calif., where the new bridge provides a city landmark that complements the dramatic backdrop of the mountains. See page 18.

In this issue, we feature three highway bridges to show their diverse applications. The Trinity River Bridge in Texas, described on page 22, uses a combination of structural systems with precast, prestressed concrete beams for the approach spans and variable depth, cast-in-place, twin segmental box girders for the main spans. The Colorado River Bridge in Moab, Utah, (page 14) is also a cast-in-place, twin segmental box-girder bridge, which is designed to blend with the surrounding environment.

When it comes to quantities of concrete components, it is hard to compete with the new I-10 Twin Span Bridges over Lake Ponchartrain in Louisiana (see page 30). Four manufacturers were needed to produce the necessary components for this bridge. The bridge had to be constructed rapidly because the I-10 traffic was using the old bridge that had been patched together following Hurricane Katrina. And talking of rapid construction, read about the FHWA Every Day Counts Initiative on page 38.

None of these articles would be possible without the ingenuity, creativity, and innovation of the bridge community. To the authors of our articles, we offer a big "Thank you."

Don't forget, we are always looking for innovative applications. If you have a project that you would like to have considered, whether large or small, please contact us at [www.aspirebridge.org](http://www.aspirebridge.org) and select "Contact Us." We look forward to hearing from you.

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### Cover

Don E. Wickstrom Bridge in Kent, Washington

Photo: BergerABAM.

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Photo: Ted Lacey Photography.

## CONCRETE CALENDAR 2011/2012

For links to websites, email addresses, or telephone numbers for these events, go to [www.aspirebridge.org](http://www.aspirebridge.org) and select "EVENTS."

**April 18-19, 2011**  
**ASBI 2011 Grouting Certification Training**  
J.J. Pickle Research Campus  
The Commons Center  
Austin, Tex.

**April 26-27, 2011**  
**ASBI Construction Practices Seminar**  
Hyatt Harborside Hotel  
Boston, Mass.

**May 1-3, 2011**  
**PTI Technical Conference & Exhibition**  
The Westin Crown Center  
Kansas City, Mo.

**May 9-12, 2011**  
**World of Coal Ash**  
Marriott Tech Center  
Denver, Colo.

**May 15-19, 2011**  
**AASHTO Subcommittee on Bridges and Structures Annual Meeting**  
Marriott Norfolk Waterside  
Norfolk, Va.

**June 5-8, 2011**  
**International Bridge Conference**  
David L. Lawrence Convention Center  
Pittsburgh, Pa.

**August 9-12, 2011**  
**Ninth International Symposium on High Performance Concrete**  
Christchurch Convention Centre  
Christchurch, New Zealand

**September 25-28, 2011**  
**Western Bridge Engineers' Seminar (Abstract Proposals due April 22)**  
The Arizona Grand Resort  
Phoenix, Ariz.

**October 2-6, 2011**  
**7th World Congress on Joints, Bearings and Seismic Systems for Concrete Structures**  
Green Valley Ranch Resort  
Las Vegas, Nev.

**October 16-20, 2011**  
**ACI Fall Convention**  
Millennium Hotel & Duke Energy Center  
Cincinnati, Ohio

**October 22-25, 2011**  
**PCI Annual Convention and Exhibition and National Bridge Conference**  
Salt Lake City Marriott Downtown and Salt Palace Convention Center  
Salt Lake City, Utah

**November 7-8, 2011**  
**ASBI 23rd Annual Convention**  
Washington Marriott Wardman Park  
Washington, D.C.

**January 22-26, 2012**  
**91st Annual Meeting Transportation Research Board**  
Marriott Wardman Park, Omni Shoreham, and Hilton Washington  
Washington, D.C.

**March 18-22, 2012**  
**ACI Spring Convention**  
Hyatt Regency Dallas  
Dallas, Tex.

**July 8-12, 2012**  
**2012 AASHTO Subcommittee on Bridges and Structures Meeting**  
Texas

**September 29–October 2, 2012**  
**PCI Annual Convention and Exhibition and National Bridge Conference**  
Nashville, Tenn.

**October 21-25, 2012**  
**ACI Fall Convention**  
Sheraton Centre  
Toronto, Ontario, Canada



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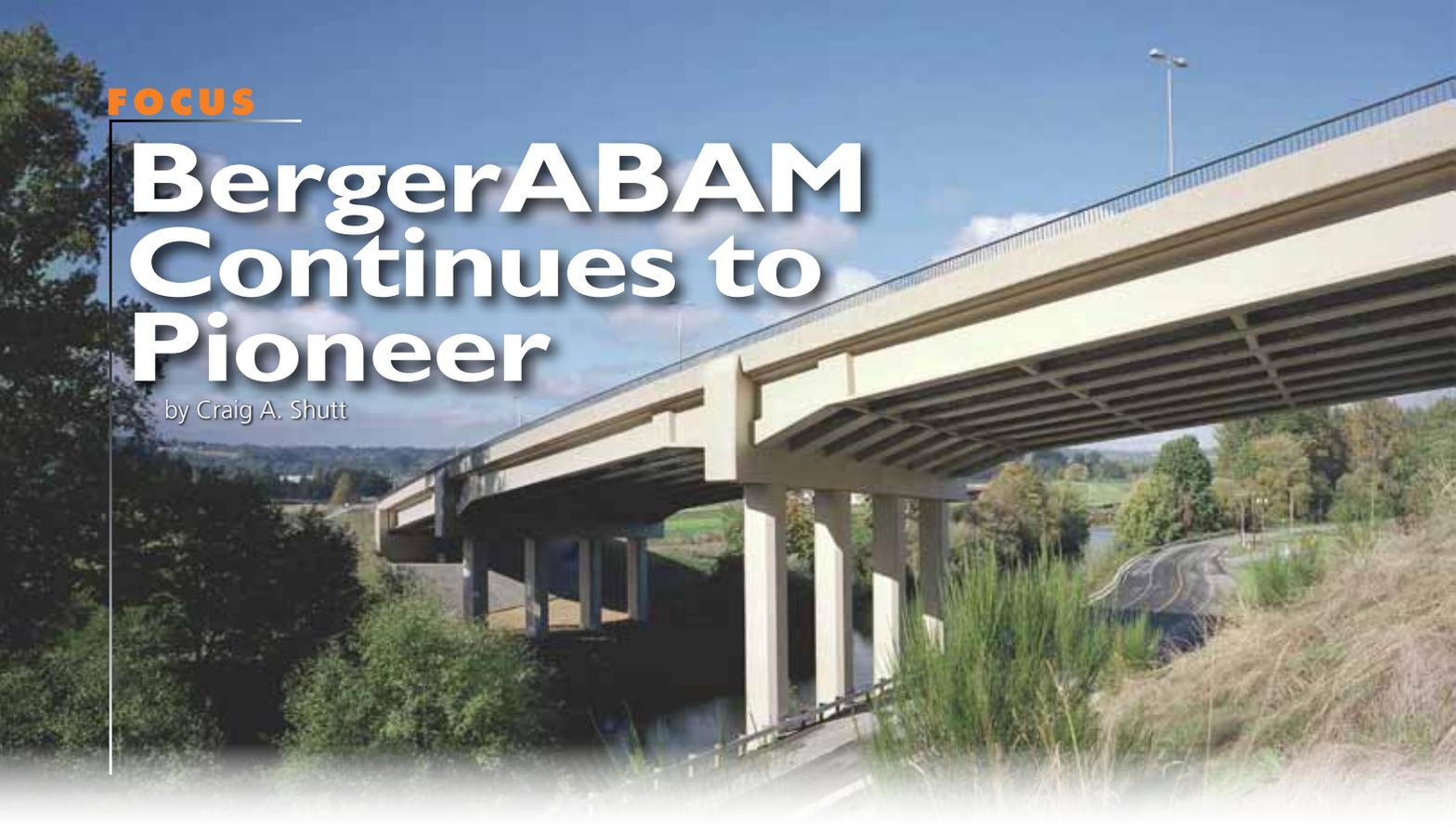


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# BergerABAM Continues to Pioneer

by Craig A. Shutt



A precast, prestressed concrete spliced girder design was used in the Don E. Wickstrom Bridge in Kent, Wash., to avoid any piers or falsework in the river. The girders feature 60-ft-long variable-depth haunched segments balanced on the piers. All photos: BergerABAM.

## One of the first firms involved with prestressed concrete looks to new innovations

In the 1950s, the founders of BergerABAM created a revolutionary instrumentation and testing procedure to validate the use of prestressed concrete, thereby ushering in a new era for bridge construction. Today, the firm remains a leader in the use of prestressed concrete for a variety of projects, including routine and first-of-its-kind applications for transportation, marine, and building structures. And, with its eye firmly set on the challenges facing the industry, it plans to continue to innovate with concrete in the future.

“Concrete is generally considered more durable than steel and requires less maintenance, especially in a marine environment,” says Bob Fernandes, vice president of BergerABAM’s Public Works

## ‘We have a design-for-construction mentality and we enjoy overcoming obstacles.’

& Transportation Department. “The use of prestressed concrete allows the use of longer spans when required.”

Although clients benefit from the firm’s technical expertise with concrete, they are also looking for other qualities when they hire the firm, he says. “Each client is different, but I suspect the qualities they appreciate most are the ones that our founders used to succeed: creativity and persistence. Our company was founded by individuals who were entrepreneurs and contractors. We have a design-for-construction mentality and we enjoy overcoming obstacles.”

Constructability is a critical ingredient for today’s projects, he notes. “The need goes beyond a bridge’s actual design to include a strong sensitivity to environmental concerns. Due to an increasingly complex regulatory environment, we are generally required to document the entire construction process in great detail in order to secure

permits for the project. Obviously, this needs to be done early in the process if the design is to be completed in an efficient manner.”

In some cases, the firm is required to engineer aspects of the construction process, which it previously left to the contractor, to ensure the client can follow through on commitments made to the regulatory agency issuing the permits.

“Following through and helping the contractor execute the design are also important,” adds Chuck Spry, senior project manager, with BergerABAM’s Public Works & Transportation Department. “Wherever possible, we try to be open to project improvements suggested by contractors that are consistent with the client’s goals for the project and the permits. In some cases, we have been able to get permits altered to implement a contractor’s ideas that benefit the project. As

## 'As projects become more complex . . . we need good relationships with the contractor.'

projects become more complex and have more requirements, we need good relationships with the contractor to ensure the design becomes reality."

Devising designs that meet all the owners' needs has been foremost since the firm's inception. BergerABAM's heritage dates to 1951. Concrete Engineering Co., which would become Concrete Technology Corp., was founded by brothers Art and Tom Anderson. Using his innovative instrumentation (strain gauge) and testing program, Art proved prestressed concrete was reliable to early skeptics on the Walnut Lane Bridge in Philadelphia. Built during 1949 and 1950, the bridge became famous for its first use of prestressed concrete in a structure built in the United States, leading to many more bridges using this innovative technique.

Art's work ultimately led to the founding of Anderson, Birkeland, Anderson and Mast, shortened to ABAM Engineers in 1966. It became an affiliate of The Louis Berger Group Inc. in the late 1980s, creating BergerABAM. "The firm essentially was founded due to the Walnut Lane Bridge, and bridges have been a major focus of our work ever since," says Bob Mast, senior principal and the last remaining namesake

The Elwha River Bridge in Clallam County, Wash., combines a cast-in-place segmental concrete bridge with a precast concrete pedestrian bridge hung beneath the structure. The three-span bridge separates vehicle traffic from pedestrians using the Olympic Discovery Trail.



partner. (For more on the company's history, see the sidebar.)

### Long Spans Reduce Impact

Long spans are becoming more popular to reduce environmental impact and to simplify complex geometries at interchanges, where ramps and junctions create traffic congestion. This has been aided by the Washington State Department of Transportation (WSDOT) devising its own precast concrete girder shapes, which it encourages designers to use.

Longer spans and more slender girders are heavier and more difficult to handle than shorter shallower girders. This challenge has required the industry to develop new engineering practices. Mast has added to that body of knowledge, having worked at BergerABAM for over 50 years, including serving as president from 1972 to 1986. Among his contributions has been intensive study to develop standards and procedures for handling long precast concrete beams to ensure their stability during transport and erection.

"The ways that long and heavy components are shipped have really changed, which has had an impact on what's possible for bridge designs,"

Mast says. "There is much more availability of specialized equipment to ensure that large, complex pieces can be handled easily. When I began, the absolute limit for transporting components on the highway was 60 tons. Now it's double that, and we're pushing 200-ft for long plant-made beams."

An example of the creative use of precast concrete to construct longer spans is the Don E. Wickstrom Bridge, a precast concrete spliced-girder design, created for the City of Kent, Wash. A key reason for selecting the precast concrete option was that the city did not want any piers, or even falsework, to impact the Green River. The site also did not have good access.

The design allowed the delivery and erection of precast concrete in reasonable sizes so they could be site-assembled into the final structure. The bridge also required a curving alignment on a 9% grade, adding challenges. The three-span bridge includes a 183-ft-long main span using 7-ft-deep WSDOT super girders.

The firm also uses cast-in-place concrete to build slender and longer spans. A creative example is the State Route 509 (SR 509) Bridge that spans I-705 and the



On the State Route 509 interchange that spans I-705 and the BNSF Railway track in Tacoma, Wash., BergerABAM created a curving, elevated single point urban interchange, the first in Washington state and one of the first in the country. The structure features cast-in-place, post-tensioned concrete box girders with variable-depth webs.



BergerABAM value-engineered the design for a new bridge spanning SR 520 in Redmond, Wash., to connect a new Microsoft campus with the original one. Although the city envisioned a steel-plate girder bridge, BergerABAM used precast, prestressed concrete girders, 83 in. deep with an 8-in.-thick, cast-in-place concrete deck. The large, flat surfaces provided landscaping and trail amenities to enhance aesthetics.

BNSF Railway mainline tracks in Tacoma, Wash. The bridge supports an elevated single-point urban interchange (SPUI), the first elevated SPUI designed in the state of Washington and one of the first in the country. The superstructure is a cast-in-place, post-tensioned concrete box girder with superelevation, variable-depth webs, and complex geometry. It shows the material's ability to be formed into almost any shape.

The SR 509 Bridge created a combination of needs for long spans to clear railroad tracks, vertical clearances over the railroad, and freeway restricted design options, Spry says. Cast-in-place concrete girders with curved exterior webs were used, with the overall bridge measuring 340 ft wide and 320 ft long with scalloped cutouts. "We had to completely rethink how we prepare design drawings in order to communicate the complex reinforcement requirements to the contractor on this project," he explains. "In retrospect, this was really an early example of using computers to create three-dimensional models of the structure in order to build it."

### Speed Becomes a Focus

In all types of projects, the designers are seeing more emphasis on speed of

construction to minimize user costs and traffic congestion. The firm's focus on constructability aids this process.

BergerABAM is taking that focus further through a grant from the Federal Highway Administration's Highways for LIFE Technology Partnerships Program. The grant is being used to develop a precast pier system for accelerated bridge construction (ABC) in high-seismic areas. Dr. Lee Marsh, seismic specialist with BergerABAM, is managing the project, with a team comprising WSDOT, the University of Washington, Concrete Technology Corp., and TriState Construction. A demonstration project for the pier system will be constructed for WSDOT in 2011.

Marsh is also leading a team that is developing a synthesis of practice for the National Cooperative Highway Research Program in Washington, D.C. The synthesis will summarize the innovative techniques for applying ABC concepts in moderate to high-seismic areas and will recommend the next steps the bridge industry should take to make ABC a reality in these areas.

The firm recently completed a notable project in Redmond, Wash., in which

## The ways that long and heavy components are shipped have really changed.

additional attention was paid to accelerating construction while creating a dramatic design. BergerABAM devised a unique design for a roadway that crossed SR 520 at a skew of 70 degrees. Offset spans allowed the structural framing to be skewed at 30 degrees and provided additional surface area for landscaping and park-like amenities. The resulting design was a cost-effective solution that ideally suited the goal of the project, which was to connect the Microsoft campuses on both sides of SR 520.

To speed construction, precast concrete columns were used, minimizing construction time for an intermediate pier in the medians. "High-seismic forces require close attention to the connections," says Spry. Meeting those requirements, while also incorporating ABC concepts, necessitates the proper balance to ensure all needs are met.

The Tacoma Spur, designed by BergerABAM for the Washington State Department of Transportation, involved more than 14,500 lineal ft of elevated post-tensioned concrete box girder freeway bridges and a complex interchange connecting the downtown business district with I-5 in Tacoma, Wash. The design included 2200 linear ft of retaining wall on a difficult sloping site.



## Innovations Continue

The firm continues to look to innovative approaches, including combining materials and girder types to create the most effective designs. "We're combining post-tensioned concrete box girders on end spans and precast, prestressed concrete girders over waterways more often to meet individual project needs," says Fernandes. Recently, designers combined 210-ft-long, post-tensioned concrete box girders over a railroad site with precast, prestressed concrete girders for the approaches.

In the case of the Elwha River Bridge in Clallam County, Wash., the firm combined precast concrete and cast-in-place concrete to achieve multiple user goals. The bridge features cast-in-place segmental concrete spans that support a precast concrete pedestrian bridge hung beneath the main structure.

The bridge was built with two end spans of cast-in-place concrete formed on falsework while two center, cantilevered sections were placed with a form traveler. For the pedestrian bridge underneath, which connects to the Olympic Discovery Trail, precast concrete panels were suspended from the main superstructure, while precast concrete deck bulb-tee girders were used for

BergerABAM completed a type, size, and location study and prepared plans, specifications, and cost estimates for the replacement of two bridges and approach roadway along Valley Avenue in Tacoma, Wash. The new 662-ft-long, four-span, Valley Avenue Bridge design includes a 215-ft-long, cast-in-place, post-tensioned concrete box girder main span that cantilevers 30 ft beyond piers to support the ends of precast, prestressed concrete girder approach spans.



the section that runs perpendicular to the main structure. (For more on this project, see the Spring 2010 issue of *ASPIRE*.™)

"We're proud of the way we're combining materials to maximize their effectiveness and eliminate expansion joints," says Fernandes. "We primarily use precast, prestressed concrete girders and post-tensioned concrete box girders, but there are many ways to combine those to get the most out of them."

Innovative designs will continue to be required, Spry notes, but BergerABAM's designers are up to the challenges. "There are a lot of people here who have spent all of their careers with the company, even though they had a lot of other options. That's one reason we have succeeded. Each generation has passed down its knowledge and created a strong working environment that gives us continuity and encourages us to innovate."

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**

## Prestressed Concrete Inspires BergerABAM

Arthur Anderson learned about the potential of prestressed concrete while providing instrumentation for the 150-ft-long, full-scale test beam used for the Walnut Lane Bridge in Philadelphia, Pa., in 1949. That insight eventually led to the founding of ABAM.

Seeing opportunity, Anderson joined with his brother Tom, also a contractor, to form Concrete Engineering Co. That company later became Concrete Technology Corp., a precast concrete manufacturer that remains an industry leader. The brothers, both with advanced engineering degrees, discovered they were conflicted out of bidding on engineering projects, so they created a sister company called Anderson & Anderson Consulting Engineers to design prestressed concrete projects.

The firm thrived by creating small, prestressed concrete bridges for logging companies that originally constructed only short-term timber bridges. "It's always more difficult to introduce new ideas to large groups, so the smaller the unit, the easier new ideas will be accepted," says Bob Mast, senior principal, about starting out on small projects. From there, the firm developed strong relationships with a number of city and county officials, who took advantage of the company's turnkey capabilities and innovative approaches.

Hal Birkeland joined the firm in 1957 as a partner, and Mast joined in 1959 as a junior engineer, becoming a partner in 1963. They became Anderson, Birkeland, Anderson and Mast, creating ABAM Engineers. A downturn in two key markets—offshore and transit—during the late 1980s led to the affiliation with The Louis Berger Group Inc., which owns 51% of the firm's stock, with the rest owned by BergerABAM key employees.

Today, BergerABAM operates six offices (Federal Way, Seattle, and Vancouver, Wash.; Portland, Ore.; Las Vegas, Nev.; and Houston, Tex.) with over 200 employees. In addition to its transportation (roadway, bridge, and transit) department, it also operates waterfront and marine, offshore and energy, building, planning, and natural resources, construction administration, and underwater services sectors. Revenues are approximately \$37.4 million.

# Financially Sustainable Individual Mobility

EQUATING BENEFITS AND COSTS VIA PRICING SYSTEMS



by Kenneth C. Saindon,  
PBS&J, an Atkins company

You have to love the irony—transportation is at a crossroads! Why? Because aggregate demand for individual mobility has rendered the traditional funding mechanism for surface transportation, the federal gas tax, obsolete. *Unsustainable* best describes this funding mechanism, in its current form, to meet current and future mobility demands. Individual mobility is the freedom of where to go, when to go, and how to go; the challenge to the transportation industry is how best to meet the demand for individual mobility in a *financially sustainable* manner.

## “Free” Mobility

General highway mobility and the congestion experienced in many areas represent a classic case of economics related to “free” resources. The perception to drivers that driving on highways is “free” causes traffic congestion, with highway capacity being the resource in short supply. It is not difficult to see why highway mobility demand is growing. The individual freedom offered by traditional highway mobility is unmatched in terms of unrestricted arrival/departure times and destinations, scalability to group size, all-weather operation, protection of users from the elements, and accommodation of personal belongings (e.g., groceries or recreational equipment). From this reality, demand management strategies that seek to equate supply and demand via *pricing systems* represent the best practice for accommodating individual mobility in a financially sustainable manner. Although an increase in the federal gas tax would generate more revenue, it does not permit the establishment of equilibrium between supply and demand that would naturally develop through the use of a pricing system.

Selmon Expressway with Tampa, Fla., skyline. Photo: Tampa Hillsborough Expressway Authority.

## Cost Versus Benefit

Sustainability in transportation has thus far focused almost exclusively on the cost side of the mobility equation. Increased effort has been spent recently on discernment of incremental “impacts” to the environment. These are used in part as a means to justify everything from subsidizing transit with federal gas tax revenues, to growth boundaries, and to transit-oriented development (including high-density housing). Nevertheless, the only sane definition of sustainability related to the cost side of the mobility equation is adopting *lowest life-cycle costing and asset management* methodologies.

What about the benefit side of the mobility equation? Is there a way to quantify the benefits of individual mobility? Quantification of the mobility

benefit via *pricing systems* would enable appropriate decision making regarding future expenditures, such as how much capacity should be added and what mode or modes should be advanced. Many fine examples of financially sustainable transportation incorporating pricing systems support the hypothesis that users value their individual mobility highly. So what does *financially sustainable individual mobility* look like?

## Selmon Expressway

Perhaps the best example of financially sustainable transportation that responds to individual mobility demand is the Tampa Hillsborough Expressway Authority (THEA) Selmon Expressway in Tampa, Fla. The Selmon Expressway is an important east-west link near downtown Tampa funded entirely with



user fees since its inception in 1976. Elevated reversible express lanes (REL) were added to the median in 2005, ushering in the use of electronic toll collection for the REL and conversion of the local lanes to electronic tolling in 2010. The Selmon Expressway has met projected traffic and revenue data and currently generates revenues in excess of annual operation and maintenance (O&M) expenses, with excesses reinvested in other transportation projects within THEA's jurisdiction. The REL currently operates at free flow conditions. Variable-price tolling (congestion pricing) has been discussed for the REL should the need arise in the future to maintain free-flow conditions. The successful financial performance of the Selmon Expressway is strong evidence of the effectiveness of pricing systems. By adopting tolling from the beginning, the Selmon Expressway has been able to respond to user demand via a pricing system that provides a sustainable revenue stream.

### Other Opportunities

Are there other opportunities to implement financially sustainable individual mobility? You bet! Never before has there been a more ideal opportunity to embrace similar financially sustainable mobility than the I-70 Mountain Corridor in central Colorado. Peak weekend travel demand in this corridor, between metro Denver and Glenwood Springs, is primarily comprised of recreational travel with significant unmet travel demand currently and in the future. Weekend recreational travel demand is typically double that of weekday demand for all other purposes combined (i.e., excluding recreation). The addition of reversible, variable-price high occupancy/toll (HOT) lanes to supplement the existing "free" general purpose lanes is an ideal solution to pay for the construction of the HOT lanes (likely elevated in certain segments) and assure a steady revenue stream for ongoing O&M expenses in the corridor. A transit alternative has been proposed for this corridor despite the fact that such an alternative, even heavily subsidized by highway users, will not benefit individual mobility in this corridor given the recreational nature of the travel demand.

### Summary

The time has come for the transportation industry to reprioritize public perception of individual mobility, particularly with respect to the often overlooked benefit. Individual mobility is not a luxury, it is a necessity. In the modern exchange economy, individual mobility is on par with energy in terms of importance to the modern fabric of life. Demand for individual mobility continues to



Weekend individual mobility demand in the I-70 Mountain Corridor; westbound looking east near El Rancho, Colo., January 15, 2011. Photo: Kenneth C. Saindon.



Concept rendering of elevated HOT lane facility in I-70 Colorado Mountain Corridor. Image: ©Kenneth C. Saindon.

grow, and the transportation industry needs to respond to this demand by facilitating individual mobility because the individual is the ultimate client we serve. Institution of pricing systems to attain financial sustainability is the industry's best path forward to achieving prominence in the modern exchange economy. Mode choice and the split of future expenditures across modes should be determined via pricing systems to ensure financial sustainability. Elimination of mode subsidies is implicit in such pricing systems.

A financially sustainable model for transportation, applicable to *all* modes, would include the following:

- Pricing systems
- Maximizing individual mobility
- Minimizing cost through life-cycle costing and asset management methodologies
- Clean accounting, whereby each mode must pay for itself

**Reference:** *Economics in One Lesson*, Henry Hazlitt, 1946; reproduced by Ludwig von Mises Institute by arrangement with Three Rivers Press, 2008.

**Acknowledgement:** The author wishes to thank Sue Chrzan, communications manager of the Tampa Hillsborough Expressway Authority, for information and photographs of the Selmon Expressway. Chrzan may be reached at (813) 272-6740 or through the authority's website at [www.tampa-xway.com](http://www.tampa-xway.com).

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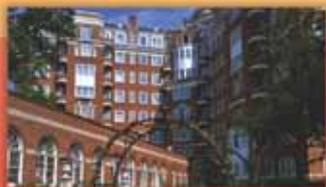
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## PROJECT

# In Harmony with Nature

by Fred Doehring, Utah Department of  
Transportation and Stephen E. Fultz,  
Figg Bridge Engineers

Construction was completed in December 2010, on the U.S. 191 Colorado River Bridge in Moab, Utah, the state's first concrete segmental bridge. The bridge's sustainable design kept the focus on the natural wonder of the environment. All photos: ©Figg Bridge Engineers.

## Utah's first segmental bridge constructed from above to minimize impact on scenic national park

The new U.S. 191 Bridge over the Colorado River in Moab, Utah, blends with the spectacular Canyonlands region and offers a number of features to ensure that the landscape remained pristine during and after construction. The state's first segmental concrete bridge was constructed in a way that allowed continual recreational use of the river and surrounding area during construction. Long spans ensured a

minimal bridge footprint, while a unique public involvement process provided a context-sensitive design representative of the community's vision.

The pristine environment surrounding Moab was acknowledged in the solution by the Utah Department of Transportation (UDOT) and Figg Bridge Engineers. The twin, 1022-ft-long bridges consist of cast-in-place, post-tensioned concrete segmental structures built from above using the balanced cantilever method of construction to protect the environment. Piers and abutments were staggered 38 ft to align the substructure with the river-flow direction, which is skewed to the roadway alignment. The bridges are 39 ft 10 in. wide including two 12-ft-wide lanes, a 7-ft-wide outside shoulder and a 6-ft-wide inside shoulder. Pedestrians, mountain bikers, and casual riders are separated from the highway traffic

by using a new pedestrian bridge upstream.

### Unique Site Characteristics

The bridge is in one of the most high-profile locations in the region, drawing more than 1.5 million visitors a year to its picturesque landscapes. It provides a gateway to Arches National Park, Canyonlands National Park, Dead Horse Point State Park, and the Sand Flats Recreation Area.

Designated wetlands along the south bank required careful consideration. In addition, water levels in the river can vary greatly, historically causing flooding of the Moab Valley. Flows in excess of 100,000 ft<sup>3</sup>/sec have been recorded at the bridge site. The design had to accommodate seasonal variations in water-surface elevation of more than 15 ft. A site-specific hydraulic analysis completed for the project ensures that the new bridge

## profile

### COLORADO RIVER BRIDGE / MOAB, UTAH

**ENGINEER:** Figg Bridge Engineers, Denver, Colo.

**CONSTRUCTION ENGINEERING INSPECTION:** Figg Bridge Engineers, Denver, Colo.

**CONSTRUCTION ENGINEER:** Summit Engineering Group Inc., Littleton, Colo.

**ROADWAY ENGINEERS:** Lochner, Salt Lake City, Utah

**SURVEY, ROW, AND GEOTECHNICAL ENGINEERING:** RB&G Engineering, Provo, Utah

**PRIME CONTRACTOR:** Wadsworth Brothers Construction, Draper, Utah

**CONCRETE SUPPLIER:** Legrand Johnson, Moab, Utah

**POST-TENSIONING CONTRACTOR:** DYWIDAG-Systems International USA Inc., Bolingbrook, Ill.

will survive the predicted 500-year event. The river also is home to several endangered fish species. Construction activities that disturb the river cannot be conducted during the fish-spawning season of May through August.

### Segmental Solution

To meet these challenges, a three-span, segmental bridge was selected using cast-in-place, single cell, concrete trapezoidal box girders. The spans consist of two 292-ft-long end spans and a 438-ft-long main span. The superstructure depth varies from 19 ft 2½ in. to 9 ft 2½ in. The deck varies in thickness from 11½ in. at the center and wing tips to 1 ft 8½ in. over the webs. The deck thickness includes a 2½ in. integral wearing surface. Webs are typically 1 ft 2 in. thick, and the bottom slab varies in thickness from 9 in. at midspan and near the abutments to 3 ft 0 in. at the piers.

The design creates open space beneath the bridge and minimizes its footprint. Only one pier of each structure is located in the river, strategically placed to maintain the navigational channel. The other pier is located well outside the channel and adjacent wetlands, which streamlined the permitting process. Long side spans allow enhanced and new trails beneath the bridge at each end.

Building from above using balanced cantilevers, construction began with 45-ft-long sections of the superstructure atop each pier. These “pier tables” serve as launching points for form travelers

Balanced cantilever construction extended out from both sides of the single river pier to create long, arching spans of 438 ft over the water that protected the environment below.

that advance horizontally away from each pier to construct segments of the bridge. Casting in an alternating fashion, first on one side of the pier and then on the other, ensured that pier-construction loads remained balanced.

The segmental concrete design eliminated the need for large ground-based equipment, which would have been difficult to place. The river conditions are often less than 5 ft deep in winter and more than 20 ft deep in summer. This would have made construction of other bridge types difficult. UDOT also benefited from the sustainable, low-maintenance nature of this bridge type, which features bi-directional post-tensioning.

### Substructures and Materials

The southbound bridge was constructed adjacent to the existing bridge, which continued in operation during this initial phase. The work began with 7-ft diameter, 150-ft-long drilled shafts for the land pier (Pier 3) using polymer slurry. The 7-ft-diameter, 100-ft-long shafts for Pier 2 in the river were installed after completion of a cofferdam and used oscillator casings.

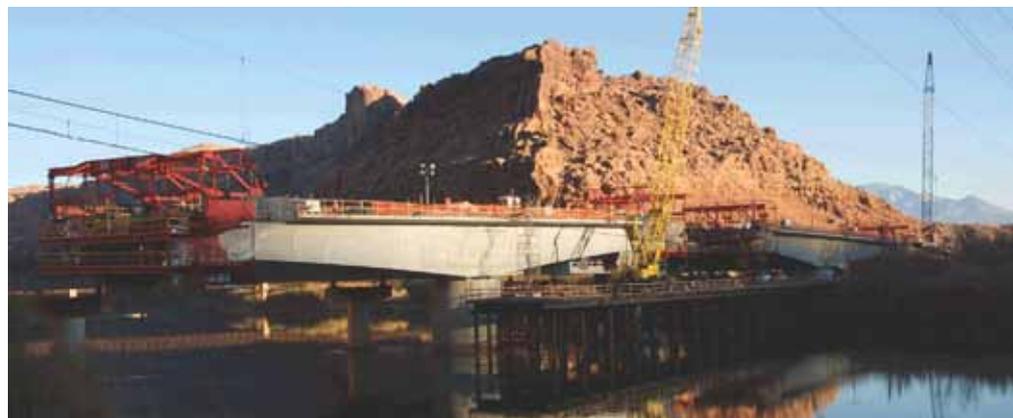
Footings at the piers are 30 ft square and 8 ft thick. A mass concrete plan

### Features ensured that the landscape remained pristine during and after construction.

ensured controlled thermal stresses arising from the heat of hydration. A 4000 psi compressive strength concrete with Type II cement mixture and 30% Class F fly ash was specified for piers and foundations. Concretes were tested for chloride permeability to make sure they fell within the “low” range for long-term durability.

Cylindrical columns 24 ft in diameter were selected for aesthetics and to facilitate a four-bearing configuration, eliminating the need for temporary works during cantilever construction. The circular profile also enhanced pier-shape characteristics against the river flow. Piers were cast hollow and filled with concrete flow-fill, eliminating mass concrete concerns. Pier 2 on the south bank is 13 ft tall, while Pier 3 in the river is 33 ft tall.

The construction of a temporary causeway and work trestle over the floodplain and river was completed as the foundation work progressed. It had to be accomplished before the May-to-August restriction on work in the river began due to fish habitat concerns.



TWIN, 1022-FT-LONG, THREE-SPAN SEGMENTAL CAST-IN-PLACE CONCRETE BOX-GIRDER BRIDGES / UTAH DEPARTMENT OF TRANSPORTATION, OWNER

**REINFORCING STEEL:** Masco Inc., Centerville, Utah

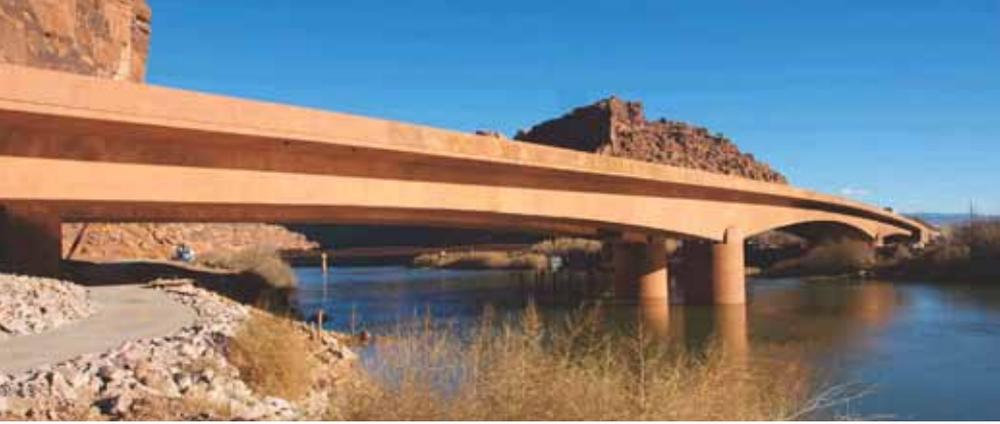
**EPOXY-COATED REINFORCING STEEL:** Western Coating, Ogden, Utah

**FORM TRAVELERS:** NRS-USA, Aventura, Fla.

**BRIDGE DESCRIPTION:** Twin, three-span, cast-in-place concrete segmental box-girder bridges with end spans of 292 ft and a center span of 438 ft, built with form travelers to minimize impact on the environment

**BRIDGE CONSTRUCTION COST:** \$25.9 million

**AWARDS:** Roads & Bridges *Top Ten*, 2010



Only one pier of the 1022-ft-long structure is located in the river, strategically placed to maintain the navigational channel preferred by recreational users. The other pier is located well outside the channel and adjacent wetlands.

## Superstructure

A minimum concrete compressive strength of 6000 psi was required by the design with high-performance concrete specified to ensure long-term durability. The concrete contained 30% Class F fly ash and was pumped from the shore area and from the work trestle as needed. The segments were 16 ft 6 in. long. Concrete was cured in all weather conditions using curing compound, heating, and insulating blankets. High early strength concrete was critical to the contractor's production schedule, with stressing and traveler-launching strengths achieved in less than 36 hours.

Once the southbound bridge was constructed, the original structure was demolished and the northbound bridge was built in its location, following the same procedure. The form traveler and forms were used for the 6-ft closure segments joining the cantilevers together over the river. End sections of the bridge were cast on falsework at each abutment.

The closure segment in Span 1, on the south side, was completed first, followed by the Span 3 segment on the north side. Finally, the main-span closure was completed in Span 2. Once closures were cast, the continuity tendons were post-tensioned.

## Post-Tensioning

Longitudinal top-slab cantilever post-tensioning tendons were embedded in the deck and anchored on each segment face. Fifty 12 x 0.6-in.-diameter strand tendons were used in each cantilever, with 25 over each girder web. Six 27 x 0.6-in.-diameter strand external continuity tendons were used in the box girder, three per web, in each span. Bottom slab continuity tendons consisted of 12 x 0.6-in.-diameter strands embedded in the bottom slab with 6 tendons used in the end spans and 14 tendons used in the main

span. Transverse tendons in the deck comprised 4 x 0.6-in.-diameter strands spaced typically at 3 ft 3 $\frac{3}{8}$  in. centers.

## Cost-Effective Design

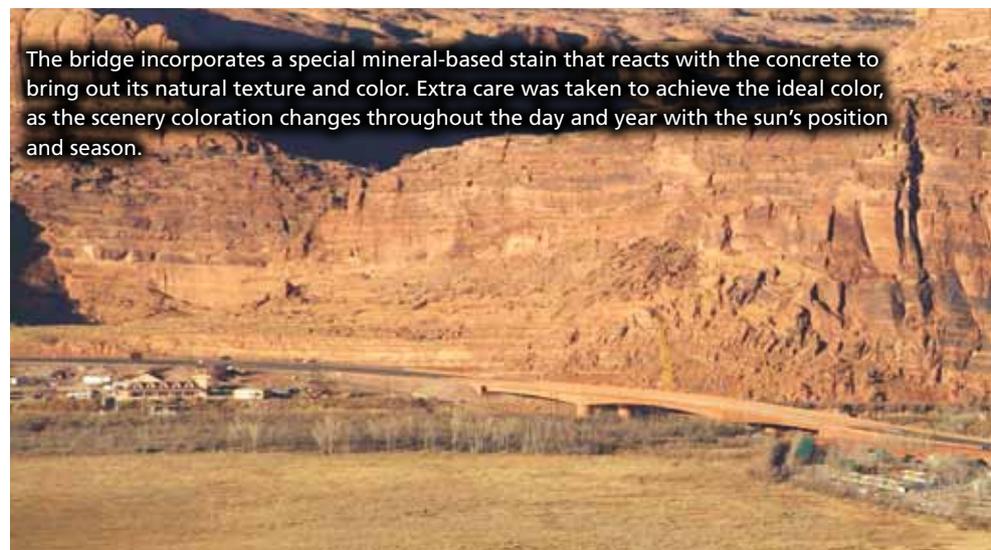
A cost-plus-time format determined the winning bidder in accordance with UDOT's statewide focus on accelerated bridge construction. The low bid saved UDOT \$3.1 million compared to the engineer's estimate. The bid schedule of 659 days was met with 18 days to spare,

completing work in early December 2010. That was accomplished despite construction taking place during the coldest Moab winter in more than 40 years, with consistent below-zero temperatures.

## Bridge Blends In

The bridge's aesthetic goals were designed to blend the structure with the scenery as much as possible rather than allow it to serve as a focal point. To achieve this, a special mineral-based

Long, sweeping spans, stone textures on the piers, smooth barrier details, and bridge colors were selected by the Moab community during special feedback sessions early in the design process.



The bridge incorporates a special mineral-based stain that reacts with the concrete to bring out its natural texture and color. Extra care was taken to achieve the ideal color, as the scenery coloration changes throughout the day and year with the sun's position and season.

stain that reacts with concrete was used to bring out the natural texture and color of the concrete. Extra care was taken to achieve the ideal color, as the scenery coloration changes throughout the day and year with the sun's position and season. Formliners also were used to create a rock texture on the mechanically-stabilized earth wall panels and piers matching the texture of nearby canyon wall relief, providing a natural rock appearance for river and trail users.

Long concrete spans, efficiently combined with post-tensioned segmental technology, resulted in a delicate footprint, and building from above protected the cherished environment during construction. Balanced cantilever construction allowed for continual recreation on the river, which was important to this region of outdoor enthusiasts. The cast-in-place segmental post-tensioned concrete box girders will offer long service life, resulting in low life-cycle cost for the citizens of Utah.

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*Fred Doehring is deputy bridge design engineer for the Utah Department of Transportation in Salt Lake City, Utah, and Stephen E. Fultz is assistant regional director with Figg Bridge Engineers in Denver, Colo.*

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**



## Visual Sensitivity

A guiding theme of "A Bridge in Harmony with Nature" shaped the context-sensitive design. A stakeholder group representing the community guided the design to ensure realization of the community's vision. Stakeholders included in the discussions included city and county leaders, property owners, businesses, the Lions Club, the Bureau of Land Management, the National Park Service (including Arches), and the Moab Trails Alliance.

The arching shape of the variable-depth superstructure reflects the spirit of nearby Landscape Arch, a prominent feature in Arches National Park. Bridge piers were located to avoid the trail network, and overhead construction allowed trail use and many recreational events to continue during construction.



### AESTHETICS COMMENTARY by Frederick Gottemoeller

Low and close to the Colorado River, surrounded by stunning high desert buttes and rock formations, this bridge occupies a very small part of the total visual field. Its designers were wise to design it so that it seems to be an integral part of the topography. Its most obvious feature, its color, captures the color of the surrounding rocks perfectly.

But, there's more. The girder is very well proportioned. The significant difference in girder depth between haunch and midspan, and end spans makes visible the concentration of forces over the piers. The clear desert sunlight causes the overhang to cast a deep shadow across the top of the girder that makes the midspan and end spans seem even thinner. The piers are too short to make a visual statement on their own, so the designer has not made the attempt. Instead, the piers have been designed as simple cylinders. They are notched at their tops and seem to cradle the haunches. As a result, they act as visual foils for the girder. Their visual mass contrasts with the relative thinness of the girder, reinforcing its delicate appearance.

Because the bridge is so low to the water, the view of the bridge interacts with its own reflection, which reinforces initial impressions. Altogether the bridge seems delicate, almost liquid, a fitting contrast to the robust formations in the background.

Bridges don't always have to be foreground elements. Sometimes it is best when they just blend in, become a part of a beautiful scene that was strong before they got there, and is strong still.



Snow covers the mountain landscape in Moab, showcasing the elegant, graceful curves of Utah's longest concrete bridge span.

# RANCHO CUCAMONGA'S HAVEN AVENUE GRADE SEPARATION BRIDGE

by Miguel A. Carbuccia and Sam S. Xie, PBS&J, an Atkins company

## A world-class design utilizing precast concrete turns an underpass bridge into a city attraction

The award-winning Haven Avenue Grade Separation Bridge has become a stunning new landmark in Rancho Cucamonga, Calif. Built with precast concrete, the colorful and innovative bridge has remedied multiple problems, including massive traffic congestion. By using architecturally enhanced prefabricated concrete elements, in the hands of a highly effective team, the project was completed ahead of schedule and under budget. This project puts to rest the notion that bridge underpasses have to be utilitarian to meet schedule and budgetary constraints.

Rancho Cucamonga lies at the base of the picturesque San Gabriel Mountains and is located roughly 39 miles east of Los Angeles. The city's population has grown by about 35% in the last decade due in large part to two east-west highways—I-10 and State Route 210—that traverse the city. These highways are connected perpendicularly by Haven Avenue, a six-lane divided arterial that leads to Rancho Cucamonga's city center.

Increasing traffic and demand for transportation services have also grown along with the city's population. The Metrolink commuter train and Burlington

Northern Santa Fe (BNSF) tracks intersected Haven Avenue at grade near the freeway interchanges. In recent years, rail service has increased to roughly 40 trains per day, which resulted in long traffic delays for the nearly 20,000 daily motorists traveling north and south on Haven Avenue. Before the bridge was built, vehicular traffic idled roughly 64 minutes daily, while emitting about 2.5 tons of carbon dioxide into the atmosphere.

The solution was to separate vehicle and train traffic by lowering the Haven Avenue roadbed by 28 ft and building



The Haven Avenue Grade Separation Bridge stands as a dramatic addition to the City of Rancho Cucamonga, Calif.  
Photo: City of Rancho Cucamonga.

## profile

### HAVEN AVENUE GRADE SEPARATION BRIDGE / RANCHO CUCAMONGA, CALIFORNIA

**BRIDGE DESIGN ENGINEER:** PBS&J, an Atkins company, Orange, Calif.

**ROADWAY DESIGN AND GENERAL ENGINEERING SERVICES:** URS Corporation, Santa Ana, Calif.

**PRIME CONTRACTOR:** KEC Engineering, Covina, Calif.

**BEAM PRECASTER:** Pomeroy Corporation, Perris, Calif., a PCI-certified producer

**PILASTER, BALUSTRADE, AND MEDALLION PRECASTER:** QuickCrete, Norco, Calif.

**CAST-IN-PLACE CONCRETE SUPPLIER:** Chaparral Concrete Company, Glendora, Calif.

**POST-TENSIONING CONTRACTOR:** DYWIDAG-Systems International USA Inc., Long Beach, Calif.



The tops of the piers, which supported the beams, were flared to match the arch shape. Seats on the noses of the piers will receive the precast concrete pilasters. Photo: PBS&J, an Atkins company.

an underpass bridge to support the two train tracks. Instead of a typical bridge underpass, the city and its residents wanted a monumental gateway to the town center.

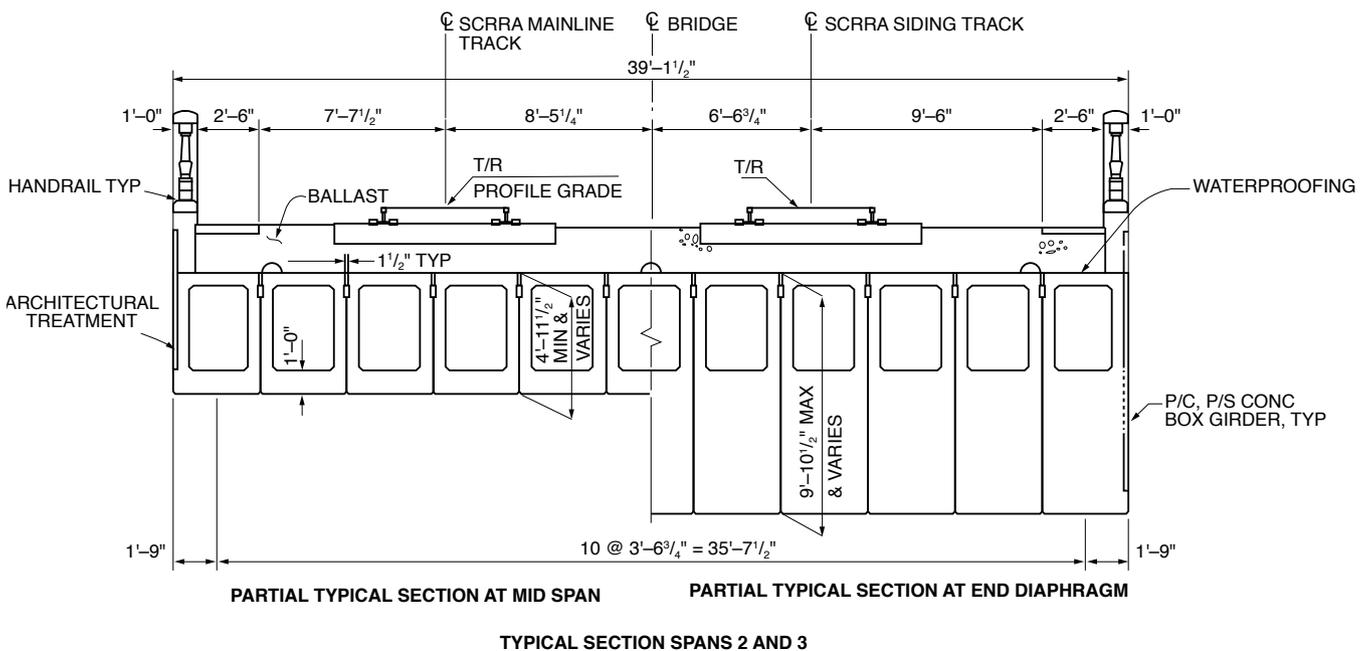
The Haven Avenue underpass bridge was planned to be built less than a mile away from Rancho Cucamonga's new city hall along a corridor that is emerging as a retail and commercial hub. The aesthetic treatment of the bridge was extremely important, though the

city had a relatively low budget of \$28 million for the entire bridge and roadway separation project. Furthermore, in order to minimize traffic disruption, the bridge needed to be built quickly.

### A Landmark Design with Precast Concrete

The innovative design for the Haven Avenue Bridge preserved the vertical railroad alignment, and won approval from the city, the Southern California Regional Rail Authority, and the

California Public Utilities Commission. To speed bridge construction and reduce costs, the design called for use of precast colored concrete arched girders to span arched piers. Precast bridge pilasters were used because of the limited space between the bridge structure and shoring that was necessary to support the adjacent bypass railroad tracks (called shoofly tracks). The precast method also cut construction time by allowing the completion of concurrent construction of the bridge and road project.



Typical section of the Haven Avenue Grade Separation Bridge in one of the main spans. Drawing: PBS&J, an Atkins company.

### FOUR-SPAN, 172-FT-LONG URBAN RAILROAD BRIDGE WITH ARCHED PRECAST, PRESTRESSED CONCRETE BOX BEAMS / CITY OF RANCHO CUCAMONGA, CALIFORNIA, OWNER

**BRIDGE DESCRIPTION:** A 172-ft-long bridge with four spans of 33.25, 53, 53, and 33.25 ft, 39 ft 1 1/2 in. wide comprising 44 arched precast, post-tensioned concrete abutted box girders, which are simply supported on cast-in-place concrete bents and abutments. The bridge also used precast concrete pilasters at the piers and abutments and a precast concrete balustrade railing.

**BRIDGE CONSTRUCTION COST:** \$4.7 million (\$650/ft<sup>2</sup>)

**AWARDS:** 2009-2010 ASCE Riverside/San Bernardino Chapter, Project of the Year; 2010 ASCE Los Angeles Chapter, "Outstanding Government Civil Engineering Project, Honorable Mention; 2010 PCI Bridge Design Award, Best Non-Highway Bridge; 2010 ACI, Outstanding Achievement in Excellence in Concrete Construction; 2011 ASCE, California Engineering Excellence Merit Award



Fascia beams with vertical face projections are 2.45 ft deeper providing confinement for the roadbed ballast and a base for the balustrade railings. Photo: PBS&J, an Atkins company.



Placement of balustrade railings on beam face projections and architectural precast concrete pilasters on the edges of bents 2, 3, and 4. Photo: City of Rancho Cucamonga.

### **Prefabrication Supports Schedule**

Girders, pilasters, and balustrade railings were prefabricated off site utilizing reusable forms to avoid the need for handling intricate forming details in the field. Prefabricating these units also accelerated construction, which further reduced costs.

### **Precast, Post-tensioned Concrete Arched Girders**

The four-span, 172-ft-long bridge is 39 ft 1½ in. wide with 44 arched precast concrete box girders; 11 in each span. These are simply supported at the pier supports and the abutments and are placed edge to edge, allowing a ¾-in.-wide joint. The span lengths were 53 ft in the center spans over the roadway and 33 ft in the approach spans over the sidewalks. The design utilized large girder units with depths of 9.88 ft and 12.33 ft and weighing up to 70 tons. The girders were designed to be cast on their sides and post-tensioned after removal from the forms and being set upright. In order to achieve a uniform appearance, the girders were cast so the exposed face was down-in-form to achieve a more

The City of Rancho Cucamonga has a bold new landmark—a precast concrete bridge that complements the San Gabriel Mountain range while welcoming visitors to the town center. Photo: City of Rancho Cucamonga.

uniform distribution of aggregate along that face. The design compressive strength of the girder concrete was 6000 psi. Since the width of the units was approximately 3.5 ft, casting sideways had the further benefit of reducing formwork costs. The use of precast elements accelerated the construction schedule. All girders were erected in just 4 days.

### **Piers and Pilasters**

Flared cast-in-place concrete piers consisting of arched concrete units supporting pilasters provide contrast and enhance the concrete arched girders. In section, each pier and abutment flares to match the arch of the supported girder. The piers are rounded at each end supporting a total of 10 decorative pilasters. The pilasters were precast and installed on supports on the piers. By doing so, the contractor was able to eliminate intricate forming at each pier and accelerate the construction schedule. The pilasters surrounding the main spans were 19 ft tall, 9 ft wide, and 4.5 ft deep.

### **Balustrade Railings and Medallions**

More than 1100 individual precast concrete pieces were required for the railings. Four custom logo medallions were produced and attached at the crowns of the arches.

### **Utilities and Traffic Issues**

Utilities were a problem and caused more than minor delays. Haven Avenue is a utility corridor that includes buried wet and dry utilities, in addition to overhead

power and communication lines. During project construction, utility line relocation caused a 5-month delay in the construction schedule. Aggressive rescheduling was required to keep the bridge and roadway project on track.

Throughout construction of the bridge, rail traffic continued on schedule without disruption. Two lanes of vehicle traffic in each direction remained open on Haven Avenue during peak travel times, using a temporary bypass parallel and adjacent to the west side of Haven Avenue. The avenue was closed to traffic on only two limited occasions when an alternate traffic detour was constructed and later removed.

### **Low Price, Inestimable Value**

The Haven Avenue underpass bridge was completed in only 13 months—ahead of schedule—between November 2008 and December 2009. According to the Southern California Regional Rail Authority, this was the fastest grade separation construction of this scale to be completed in the region. Even better, the architecturally significant project cost \$2 million less than the engineer’s estimate of \$16 million (excluding right-of-way and engineering costs).

The innovative bridge has remedied multiple problems. The traffic bottleneck at grade has been removed, resulting in smoother flowing traffic and improved motorist safety. Fuel emissions from idling vehicles has been greatly reduced, which contributes to better air quality and a healthier environment. New



sidewalks have increased mobility for pedestrians and bicyclists.

The bridge's ornamental railing, bold color, massive columns, and curvilinear form has given Rancho Cucamonga an impressive city landmark that compliments the dramatic backdrop provided by the mountain range. Having an architecturally significant entry monument to Rancho Cucamonga is helping to improve the livability of the community, attract new businesses, and enhance property values—all of which contribute to improving the lives of local residents.

*Miguel A. Carbuccia and Sam S. Xie are transportation project managers with PBS&J, an Atkins company, in Orange, Calif.*

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©Photo courtesy of FIGG, photographer Tim Davis.

# DESIGN AND CONSTRUCTION OF THE I-10 TRINITY RIVER BRIDGE

by Michael D. Hyzak, David P. Hohmann, David Collins, and Brian Merrill, Texas Department of Transportation



By February 2011, traffic was using the westbound bridge. The total project was 75% complete. All photos and drawings: Texas Department of Transportation.

## A combination of concrete solutions

The Trinity River Bridge carries heavily traveled I-10 over the Trinity River between Houston and Beaumont. The existing bridge built in the 1950s consisted of twin structures with a combined roadway width of 52 ft for two lanes in each direction. The existing bridge also had steep 4% grades to provide for 73 ft of navigation clearance. The main span consisted of fracture-critical steel through-girder systems. The existing bridge represented a choke point for the current traffic volume of 47,000 vehicles/day. The roadway to the west had already been widened to three or more lanes in each direction, and similar work is being done to the east. For these reasons, the project will provide welcome relief to a vital route.

### Design Solution

An original concept was conceived using twin continuous steel plate girders

with piers in the water for the main river crossing and precast, prestressed concrete I-beams on the approaches. On the river crossing, this would have necessitated a significant amount of river access for construction. In addition, construction and maintenance of the pier fender systems would be required. With a river opening of 400 ft and environmental and navigational reasons to span the entire waterway, the most viable option became a segmental box girder bridge built using the balanced cantilever method. To minimize project costs, the approach spans remained precast, prestressed concrete I-beams. With the resulting reduced length of segmental spans, a cast-in-place segmental box girder cast with form travelers was the preferred structure type.

The project was let to contract in 2006. In February 2011, the project was approximately 75% complete. The new Trinity River Bridge has twin structures 3636 ft long with approach spans of 72-in.-deep precast, prestressed concrete I-beams supported on

reinforced concrete bents using 18-in.-square, precast, prestressed concrete piles. Twin 990-ft-long segmental box girder units carry traffic over the navigable Trinity River with 50 ft of vertical clearance. Each cast-in-place concrete box girder unit consists of a 450-ft-long main span flanked by two 270-ft-long end spans. The girder depth varies between 25 ft at the piers to 10.5 ft at midspan. This span arrangement with a back span-to-main span length ratio of 0.60 required a nominal amount of shored construction at each end. This was required to avoid conflict with existing multi-pile footing foundations from the existing structure.

The twin cell box girder structures are 62 ft wide at the top slab level. The 60 ft roadway width provides space for four lanes plus shoulders for each of the twin structures, for a total of eight lanes of capacity. The project phasing dictated the complete construction of the westbound bridge. Then, all traffic was rerouted onto the new structure to permit removal of the existing bridge

## profile

**TRINITY RIVER BRIDGE/ BETWEEN HOUSTON AND BEAUMONT, TEXAS**

**BRIDGE DESIGN ENGINEER:** Texas Department of Transportation, Bridge Division, Austin, Tex.

**SEGMENTAL CONSTRUCTION ENGINEER:** Summit Engineering Group, Littleton, Colo.

**PRIME CONTRACTOR:** Williams Brothers, Houston Tex.

**PRECASTER:** Valley Prestress Products Inc., Eagle Lake, Tex.

**POST-TENSIONING CONTRACTOR:** Williams Brothers, Houston, Tex.

**POST-TENSIONING HARDWARE AND SERVICES:** VSL, Grand Prairie, Tex.

## There were environmental and navigational reasons to span the entire 400-ft-wide waterway.

and construction of the eastbound bridge on the footprint of the former bridge.

The bridge features twin wall piers 42 ft tall spaced 20 ft 0 in. out-to-out in the longitudinal direction. Inclined pier table "A-frame" diaphragms 2 ft 9 in. thick, provide a requisite load path to the top of the piers during the balanced cantilever construction. The piers have sufficient longitudinal flexibility to reduce stresses from substructure restraint.

### Post-Tensioning Provisions

The primary longitudinal post-tensioning includes both cantilever and continuity tendons. To simplify construction, balanced cantilever segmental bridges in Texas typically have each set of cantilever tendons anchored within the top slab at the stiff web to flange junction. Having the cantilever tendon anchorages at this location at the bulkhead face simplifies the traveler formwork in each typical segment. For each segment that is constructed, a single cantilever tendon containing thirteen 0.6-in.-diameter strands in each web is stressed with the live end at the bulkhead face of the segment previously cast and the dead end at the free end of the last segment in the opposite cantilever. As such, each segment has two anchorages in each web-to-flange joint. The end result is a series of cantilever tendons that increase in number as the construction progresses with the maximum number of tendons occurring at the pier table and decreasing in each segment moving away from the pier.



Nearing closure of the 450-ft-long main span of the eastbound bridge. The girder is 10.5 ft deep at midspan.

## Sustainability

In Texas, alkali-silica reaction (ASR) is a very real problem that threatens the service life of concrete structures. Nearly 90% of the fine aggregate sources and over 60% of the coarse aggregate sources have the potential to develop ASR. To combat this problem, TxDOT uses prescriptive specifications, based on over \$8M in research, to mitigate ASR. These specifications go hand-in-hand with the specifications used for high-performance concrete (HPC), which provides low-permeability concrete. The result is very high-quality concrete in all structural elements to ensure long-term performance.

The prescriptive approach provides mix design options for contractors without the need for additional material testing. TxDOT's ASR mitigation options include the following:

- various supplementary cementitious materials (fly ash, silica fume, or ground-granulated blast-furnace slag)
- lithium nitrate admixture
- cement-only mixes with a limit on the total alkali content
- custom mix designs based on aggregate test results

In addition to the ASR mitigation requirements, TxDOT also has the following special requirements for mass concrete used for the footings and twin-wall piers:

- a maximum concrete temperature at time of placement of 75 °F
- a maximum temperature differential between the central core and the exposed surface of 35 °F during the heat dissipation period
- a maximum core temperature of 160 °F during the heat dissipation period

The contractor supplied several different concrete mixes for this project. The two main concrete mixes used for the segmental superstructure and the main pier substructure had a Class F fly ash content of 25% and 30%, respectively, of the total cementitious materials content to comply with TxDOT's ASR mitigation requirements. Both mixes produced concrete compressive strengths greater than 9000 psi during trial batch evaluations. The additional strength was not required by the design but was desired to keep the casting and stressing operations on schedule. These strengths were obtained with only 464 lb/yc<sup>3</sup> of cement and 155 lb/yc<sup>3</sup> of fly ash and a water-cementitious materials ratio of 0.40.

TWIN BRIDGES USING BOTH CAST-IN-PLACE CONCRETE BALANCED CANTILEVER SEGMENTAL MAIN SPANS AND PRECAST, PRESTRESSED CONCRETE BEAM APPROACH SPANS / TEXAS DEPARTMENT OF TRANSPORTATION, OWNER

**CONCRETE SUPPLIER:** ANT Enterprises, Baytown, Tex.

**FORM TRAVELERS:** Mexpresa, Mexico City, Mexico

**BRIDGE DESCRIPTION:** Twin bridges, 3636 ft long, 62 ft wide with a 990-ft-long, three-span, cast-in-place concrete segmental, variable-depth box girder unit (270, 450, and 270 ft span lengths) and 2646 ft of precast, prestressed concrete I-beam approach spans with AASHTO Type VI beams, up to 150 ft long, and 18-in.-square precast, prestressed concrete piles

**BRIDGE CONSTRUCTION COST:** \$67 million total project cost, \$37.5 million for bridges (\$164/ft<sup>2</sup> for segmental units and \$53/ft<sup>2</sup> for I-beam approaches)



## This is one of the first TxDOT segmental bridges to incorporate an integral wearing surface.

The westbound bridge was completed first followed by demolition of the existing bridge and construction of the eastbound bridge in its footprint.

by four 0.6-in.-diameter strand tendons in flat ducts, used in conjunction with nonprestressed reinforcement for the cantilever and interior spans of the bridge deck. Three webs, 20 in. thick with nonprestressed reinforcement provide requisite shear capacity without the need for additional web post-tensioning to limit principal tensile stresses.

### Integral Wearing Surface

The Trinity River Bridge is one of the first TxDOT segmental bridges to incorporate an integral wearing surface. The bridges are constructed with 3-in.-thick clear cover to the top mat of reinforcing steel in the deck, providing a maximum of 1 in. available for grinding to obtain the final surface profile and grading. The segmental superstructure called for a concrete design compressive strength of 6000 psi at 28 days.

### Approach Spans

Approach spans on the bridge utilize conventional precast, prestressed concrete AASHTO Type VI beams with spans that range from 116 ft to 150 ft. Span lengths were dictated by the locations of existing substructure piles and footings combined with the desire to maximize span lengths and minimize footprint in the environmentally sensitive wetlands.

### Conclusion

The new Trinity River Bridge on I-10 between Houston and Beaumont provides a significant increase in traffic capacity for this vital east-west route in Texas. The selection of twin, balanced cantilever segmental bridges also provides a solution that completely spans the 400-ft-wide commercial waterway while maintaining navigational clearances. When compared to alternative structure types, segmental construction provides better long-term durability in the

Forming of a pier segment showing cantilever tendon ducts and transverse deck tendon ducts.

aggressive environment found in the coastal regions of Texas. Long-term maintenance of the bridges is also enhanced through the elimination of labor intensive inspections required with certain other structure types. Economical precast, prestressed I-beam approach spans help limit the overall length of the more costly segmental portion of the bridge thus reducing the overall cost. This also provides the economic advantage of proven long-term durability of precast, prestressed concrete.

*Michael D. Hyzak is transportation engineer, David P. Hohmann is the Bridge Division director, Brian Merrill is the Construction and Maintenance Branch manager, all with the Texas Department of Transportation in Austin, Tex., and David Collins is assistant area engineer with the Texas Department of Transportation in Beaumont, Tex.*

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**

A nominal amount of shoring was required for the ends of the 270-ft-long end spans as they approached the transition to the I-beam approach spans.



The continuity tendons resist the relatively smaller positive moments from subsequent dead loads (and eventual live loads and long-term effects) once full continuity in the structure is achieved. The continuity tendons are anchored in blisters that rise out of the bottom slab at the stiff web-to-bottom flange junction. The Trinity River Bridge used 18 tendons each consisting of eleven 0.6-in.-diameter strands for the back spans and 30 tendons with the same configuration for the main span tendons.

The Texas Department of Transportation (TxDOT) specifies the use of plastic polypropylene ducts for internal post-tensioning. Compared to corrugated galvanized steel ducts, the plastic ducts are noncorrosive, provide better encapsulation of the grouted bonded tendons, and exhibit lower friction losses. The plastic ducts being used on the Trinity River Bridge require larger bending radii because of the stiffness of the ducts as compared to metal ducts and to avoid excessive abrasion when stressing the tendons.

Transverse post-tensioning is provided





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# The Harbor Drive Pedestrian Bridge

by Joe Tognoli and Dan Fitzwilliam,  
T. Y. Lin International



## An Iconic Bridge for One of America's Finest Cities

For an engineer, a pedestrian bridge is like a child's blank canvas, allowing nearly unlimited creativity in structural form. There simply are not the restrictions with geometry, structural systems, and details that constrain the engineer on a conventional vehicular bridge design. Winding ramps and stairs, inclined members, challenging cable geometry; are all possible on a pedestrian bridge.

With far more freedom than with a vehicular bridge, the pedestrian bridge allows for greater expression. There are less geometric constraints. Cars just don't like highly curved superstructures, but people do. In addition, the practical monetary constraints on a vehicular bridge can be greatly reduced on a pedestrian bridge. Their smaller scale makes them inherently less costly, even though their unit cost is much higher. Therefore, a community may be able to spend several million dollars more for a unique pedestrian bridge, while this same amount spent on a vehicular

The bridge carries pedestrians over a series of railroad lines including heavy freight, passenger rail, and trolley lines. It also allows pedestrians to cross over a busy downtown street and connects directly with a multi-level parking structure. Photo: Paul Savage. All other photos and drawings: T.Y. Lin International.

bridge would certainly enhance it, but may not be enough to allow for an iconic structure. Fine detail can be incorporated into the design and appreciated by pedestrians, whereas, on a vehicular bridge, a motorist traveling at highway speed cannot possibly see or appreciate such detail. With these freedoms, and the beautiful San Diego, Calif., downtown landscape as the canvas, we were able to create a dynamic, dramatic, and iconic structure.

The City of San Diego downtown area is situated on the San Diego Bay. For many years, it has been the goal of the city to complete a pedestrian and bicycle link between the historic Balboa Park and the picturesque San Diego Bay, dubbed the Park-to-Bay Link. The last section of the Link was blocked by local trolley tracks, several sets of freight train tracks, and a busy downtown thoroughfare. In 2004, the city commissioned the Centre City Development Corporation (CCDC), the city's redevelopment agency, to design and build a bridge to complete

the approximately 2-mile-long Park-to-Bay Link. The site chosen for the final bridge link is adjacent to the recently constructed Petco Park, home of Major League Baseball's San Diego Padres and the San Diego Convention Center on the San Diego Bay, covering over 1 million ft<sup>2</sup>.

### High-Profile Solution

CCDC recognized that the high-profile project location needed a landmark structure to act as the gateway to the city and as an icon of the revitalized downtown area of San Diego. They hired the design team to develop a concept and plans for the bridge and surrounding plazas. Although many alternatives were considered for the site, the final bridge type selection was a self-anchored suspension bridge with an inclined pylon.

The horizontally-curved superstructure of the 355-ft-long main span is a 3-ft-deep, single-cell, hollow, box girder section. The full 19-ft 7-in.-section width includes a 9-ft 1-in.-wide

## profile

### HARBOR DRIVE PEDESTRIAN BRIDGE/ SAN DIEGO, CALIFORNIA

**CLIENT:** Centre City Development Corporation, San Diego, Calif.

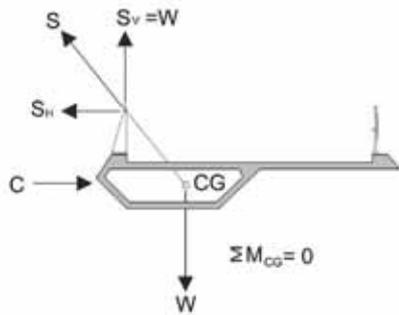
**BRIDGE DESIGN ENGINEER:** T. Y. Lin International, San Diego, Calif.

**ARCHITECT:** Safdie Rabines Architects, San Diego, Calif.

**CONCEPT COLLABORATION AND INDEPENDENT CHECK:** Strasky and Anatech, San Diego, Calif.

**PRIME CONTRACTOR:** Reyes Corporation, National City, Calif.

**CONCRETE SUPPLIER:** Hanson, San Diego, Calif.



Ideally, the line of action of the suspenders should pass through the center of gravity of the section to achieve equilibrium for dead loads.

cantilevered slab extending out on one side from the thin-walled closed box portion of the deck. The asymmetric section shifts the centroid of the shape as close as possible toward the edge of the deck that is supported by the single row of inclined suspension hangers. The typical thickness for the deck slab, webs, and soffit of the box is 5½ in. Transverse deck ribs and internal diaphragms spaced at 10 ft on center combine with the 8000 psi compressive strength concrete to add stiffness to the structure.

The pylon is 130 ft tall and inclined at a 30-degree angle from vertical. It leans over the deck to support the

suspension cables. Thirty-four individual suspenders are attached to the main cable to support the deck from the top of the railing at only one edge of the superstructure. The pylon cross-section has a tear drop shape that is a constant 5 ft 10 in. wide transverse to the bending direction for the full height of the pylon. The length of the shape in the primary bending direction tapers from 14 ft 0¾ in. at the base to 5 ft 2½ in. at the top. The pylon is constructed using 6000 psi compressive strength concrete and was internally post-tensioned with 128 0.6-in.-diameter prestressing strands. These were stressed from anchors in the footing at four stages during construction.

### Main Cable Trajectory

For most bridges, the structural system is relatively straightforward. In this case, the mechanics of the self-anchored suspension system presented the first challenge. In conventional suspension bridges, the main cable element is typically draped between two main pylons. The tension in the main cable, caused by the weight of the suspended bridge deck, is resisted by massive cable anchorages in the ground. In a self-anchored suspension bridge, the tension in the main cable is resisted by longitudinal compression in the superstructure. Consequently, the complete superstructure has to be in place before any part of it can be suspended from the main cable.

For this bridge, the main cable



The 130-ft-tall concrete pylon is inclined at 30 degrees from vertical and reaches over the deck to produce a lateral curve in the main cable necessary to provide equilibrium to the structure.

configuration is further complicated by the bridge deck not being linear. It has a vertical kink at the ends of the bridge due to the approach span stairs. The solution was to continue the main cables all the way to the base of the stairs and anchor them in the abutments at the bottom of each set of stairs. In order to handle the angle change from the deck to the stairs, the cable passes through a steel deviator device placed at the top of each stair span and embedded in the concrete bent cap at these locations. This solution means that some of the tension in the main cables is resisted by the abutment foundation, but the majority of the force from the main cable is still resisted by the much stiffer stair and superstructure section.



The Harbor Drive Pedestrian Bridge is a self-anchored suspension bridge with a 355-ft-long concrete main span situated in downtown San Diego adjacent to Petco Park, home of the San Diego Padres.

## SELF-ANCHORED, CAST-IN-PLACE CONCRETE BOX GIRDER SUSPENSION PEDESTRIAN BRIDGE WITH CAST-IN-PLACE CONCRETE INCLINED PYLON / CITY OF SAN DIEGO, OWNER

**POST-TENSIONING CONTRACTOR:** Dywidag-Systems International USA Inc., Bolingbrook, Ill.

**STEEL FABRICATOR:** AMECO, Cleveland, Ohio

**CABLES:** Pfeifer, Memmingen, Germany

**BRIDGE DESCRIPTION:** Self-anchored suspension bridge with 355-ft-long main span comprising a cast-in-place concrete single-cell box girder superstructure with 16-ft-wide walkway and cast-in-place concrete pylon, 130 ft tall inclined at 30 degrees from vertical

**BRIDGE CONSTRUCTION COST:** Bridge cost \$15 million (\$1760/ ft<sup>2</sup>); Project cost \$21 million (includes dual glass elevators and plazas)

## Asymmetric Equilibrium

Supporting the bridge deck with cables attached to only one side of the deck was an extremely challenging design feature. Looking at a typical section of the bridge, the unbalanced nature of the deck becomes very apparent. It seems as if the weight of the deck wants to roll the section about the suspender support. The torsion generated by the unbalanced support location must be compensated in some way. The best solution would be to get the line of action of the suspender supporting force to pass through the center of gravity of the bridge section. An unsymmetrical cross-section was developed to try to move the center of gravity of the section as far toward the suspenders as possible. Unfortunately, the center of gravity could not be shifted far enough toward the suspenders to achieve a balanced design. The support point was then moved to the top of the railing in an effort to shift the line of action farther toward the center of gravity of the section and thereby achieve a balance between the dead load of the bridge and the suspender force.

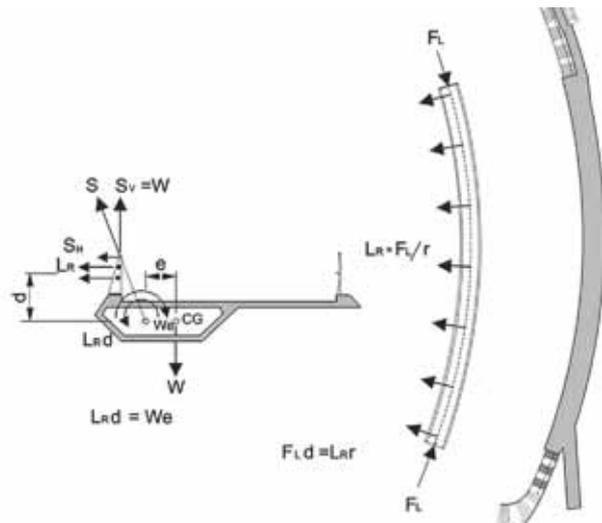
It turns out, it wasn't quite that simple. The dead load torsional force was still greater than the resisting horizontal component of the suspenders; the bridge wasn't balanced for torsional dead loads. In order to achieve equilibrium, an additional horizontal resisting force was needed. To provide this necessary horizontal balancing force, an additional longitudinal post-tensioned cable was added along the top of the railing post. Due to the curve of the bridge in plan, this created an additional radial inward force at the top of the railing to provide the balancing torsion needed.

## Main Cable and Hangers

The main cable is 36 strands of 0.6-in.-diameter waxed and sheathed strands inside a grouted stainless steel guide pipe. The cables from each side of the main span are anchored at the top of the pylon. The bundle of 36 individual strands was laid out adjacent to the bridge and taped together in a compact bundle. The entire bundle was pulled through the stainless steel guide pipe which was suspended in position using a temporary support wire. The hangers were cut to a predetermined length. They were attached to the main cable guide pipe while the pipe was in a slack position. After all the hangers were attached, the main cable was stressed, which removed the slack and put the final load in the hangers and lifting the bridge off the falsework. The pipe was then grouted.

## It's in the Details

For a pedestrian bridge, the user is much closer to the details of the bridge and is travelling at walking speeds. The details of the connections and hardware on the bridge take on a much more important role in these types of bridges. The guide pipe eliminates the need for cable bands and provides a smooth line along the length of the main cable without any discontinuities. The suspenders are in turn attached to gusset plates on the pipe rather than directly fastened to the main cable via a cable band, also providing a smooth, clean look and further adding to the pedestrian experience.



An additional longitudinal tendon was stressed at the top of the railing. Coupled with the curvature of the bridge, this tendon creates an inward radial force to provide the restoring torsion needed for equilibrium.

## Conclusion

The Harbor Drive Pedestrian Bridge completes the final piece of the City of San Diego's Park-to-Bay Link, and provides the city with a structural icon for the community. The new self-anchored suspension bridge, with its 130-ft-tall pylon inclined over the horizontally curved bridge deck, and suspenders only attached to one side of the bridge deck, truly is a bridge fitting for one of America's Finest Cities.

*Joe Tognoli is vice president and principal bridge engineer and Dan Fitzwilliam is senior bridge engineer, both with T. Y. Lin International in San Diego, Calif.*

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**



The stainless steel cable stays attached to only one edge of the concrete deck provide a sense of openness and create a dramatic cantilever effect.

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# REPLACEMENT OF THE I-10 Twin Span Bridges over Lake Pontchartrain

by Artur W. D'Andrea, Louisiana Department of Transportation and Development

The damage that Hurricane Katrina caused to the I-10 Twin Spans over Lake Pontchartrain created a need for both temporary repairs and a permanent replacement. The size and nature of the project, the schedule, and the project's location, demanded a very efficient solution for the replacement bridge.

The I-10 Twin Spans cross Lake Pontchartrain between Slidell and New Orleans, La. This crossing is approximately 5.5 miles long resulting in a project with a total bridge length of 11 miles. This corridor is important both nationally and locally. It connects the city of New Orleans, New Orleans' ports, and the petro-chemical industry along the Mississippi River. The main navigational channel provides 73 ft of vertical clearance and 200 ft of horizontal clearance and serves both commercial and personal boat traffic. The new bridges provide three lanes in each direction and serve as one of the main evacuation routes for New Orleans.

The concerns by the owner and public for expedient construction had to be tempered with the realities of the emergency recovery budget. This \$753 million project, entirely funded by the Federal Highway Administration, was constructed by two separate contracting teams. Project budget and schedule had to take into account traffic maintenance, building within the state's rights-of-way, and the limitations of undertaking a construction of this magnitude in a post-Katrina environment. The project is currently over 97% complete and the new bridges should be delivered ahead of schedule.

## Design Goals

The goals for these replacement structures included better storm protection, safe accommodation of six traffic lanes, enhanced barge collision resistance, and utilization of well-known materials and techniques to provide for low maintenance and a long service

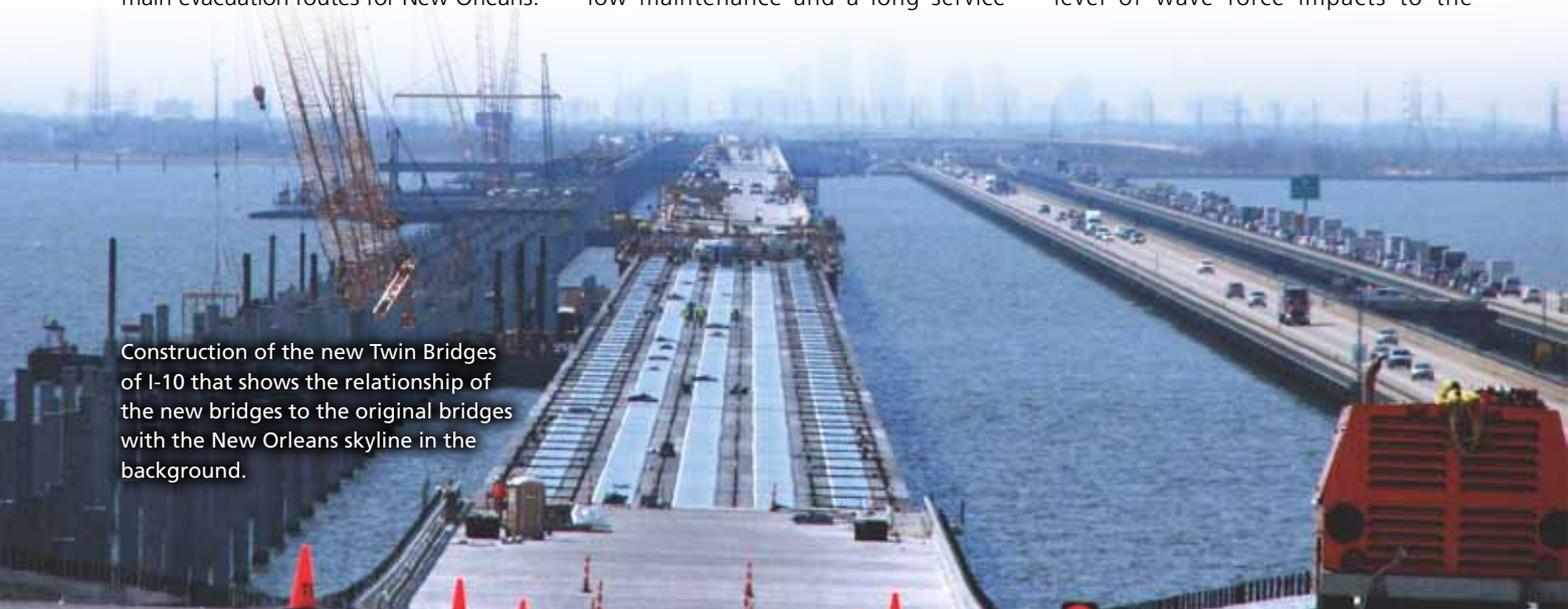
life. Seven requirements became the blueprint for the project planning.

1. Meet I-10 traffic demands
2. Design a structure that can both resist storm surge and barge impact
3. Provide a 100-year service life
4. Provide for rapid service
5. Minimize environmental impact during construction and operation
6. Avoid interference with existing traffic patterns
7. Work within existing rights-of-way

The twin, 5.5-mile-long structures were divided into three parts depending on the structure type.

Part 1 consisted of building the horizontal and vertical transitions and ramps with flaring widths. Approximately a ½ mile of structure needed to be designed to resist storm surge.

Part 2 consisted of constant width and level-grade spans set above the level of wave force impacts to the



Construction of the new Twin Bridges of I-10 that shows the relationship of the new bridges to the original bridges with the New Orleans skyline in the background.

## profile

### I-10 TWIN SPAN BRIDGES OVER LAKE PONCHARTRAIN/ BETWEEN NEW ORLEANS AND SLIDELL, LOUISIANA

**BRIDGE DESIGN ENGINEER:** Louisiana Department of Transportation and Development (LaDOTD), Baton Rouge, La.

**CONSTRUCTION ENGINEERING AND INSPECTION:** Volkert Inc. and LaDOTD, Baton Rouge, La.

**GENERAL CONTRACTOR, PARTS 1 AND 2:** Boh Bros. Construction Company LLC, New Orleans, La.

**GENERAL CONTRACTOR, PART 3:** Traylor, Kiewit, Massman JV, Slidell, La.



superstructure. These spans were designed to minimize the number of bents used and minimize impacts to boat traffic on the lake.

Part 3 consisted of twin, 1-mile sections over the navigational channel. These portions of the twin bridges were designed to resist large barge impacts, provide higher navigational clearance, and resist wave loads on the substructure elements. These sections have a significant number of above-water footings. Parts 1 and 2 were in a single contract and Part 3 in a second contract. Both contracts were conventional design-bid-build.

### Prefabrication

In consideration of their location, size, and functional requirements, the bridges were designed to take advantage of prefabrication as the primary construction method.

The precast bridge elements include:

- 36-in.-square hollow precast, prestressed concrete piles
- 4 ft by 5.5 ft by 59.25-ft-long precast concrete bent caps
- 135-ft long, 78-in.-deep Florida Bulb-tee girders
- stay-in-place precast concrete box forms for the footings on the piles

The majority of the spans were built with Florida Bulb-tee girders supported by pile bents. The higher elevation sections of the bridges near the main channel crossing contain column bent structures supported on two main pile footings. The main navigational channel spans used steel plate girders.

Typical moment connections were made between piles and footings by placing 6-ft-long reinforced plugs in the ends of the piles.

### Piles

The geological structure of the Louisiana coastal region favors large precast, prestressed concrete displacement piles. They are capable of developing large axial capacity with side friction, pile setup, and sometimes point bearing. This project utilizes 36-in.-square hollow piles containing twenty-eight 0.6-in.-diameter strands. This pile shape and strand configuration are capable of developing large moment capacity. It also enables fabrication and transportation in long lengths that varied between 100 ft and 180 ft. More than 433,000 linear ft of piles were used on the project.

### Pile-to-Cap and Pile-to-Footing Moment Connection

Depending on specific design requirements, the 36-in., precast concrete pile hollow core was reinforced by placing a 6-ft-long cast-in-place concrete moment plug in the top end.

**The project has a total bridge length of 11 miles.**

In other situations, the solid plug was extended to 30 ft in length. Piles are expected to resist moments and in some cases significant uplift loads.

### Precast Concrete Caps

Whenever they could, the Contract 1 contractor elected to use a precast concrete pile cap alternate offered in the original design. Working with the precast manufacturer, Gulf Coast Pre-Stress Inc., and the owner, the original design was modified to accommodate vertical and batter piles, as well as the moment connection of the cap and restraining walls. The precast cap weighed about 80 tons and contained conventional nonprestressed reinforcement. These caps were used for the majority of the spans where span length, bridge width, and pile configurations were the same. Over 20,000 yd<sup>3</sup> of concrete were used in the 496 pile caps.



Precast concrete elements being readied for use as a stay-in-place footing form.

## TWIN, 5.5-MILE-LONG PRECAST, PRESTRESSED CONCRETE TRESTLES / LOUISIANA DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT, OWNER

**PRECASTERS:** Gulf Coast Pre-Stress Inc., Pass Christian, Miss., a PCI-certified producer, Prestress Services Industries LLC, Memphis Tenn., a PCI-certified producer, Boykin Brothers Inc., Baton Rouge, La., a PCI-certified producer, and Traylor, Kiewit, Massman JV, Slidell, La.

**BRIDGE DESCRIPTION:** Parallel bridges that incorporate high-performance concrete in all of their components and include precast, prestressed concrete piles, AASHTO I-beams, Florida Bulb-tee beams, precast concrete pile caps, and precast concrete footing forms

**BRIDGE CONSTRUCTION COST:** \$753 million

## The design provides a 100-year service life.

### Permanent Precast Footing Form

The typical footing dimension was 44 ft by 44 ft by 7 ft thick on 24 piles. The footings were set above the low water elevation to facilitate construction. The plans allowed the use of stay-in-place precast concrete segments for formwork to support all footing construction and accommodate all pile arrangements. The footing forms were fabricated by the contractor.

### Superstructure Girders

Contracts for the bridges specified AASHTO Type III precast, prestressed concrete girders in the vertical transition portion of the bridges (Part 1). Type III girders are very economical and versatile in the 70-ft-span range in conditions where grade flares and ramps exist. In locations below the design wave elevation, the girders were anchored to resist uplift. Approximately 29,500 linear ft of Type III girders were used.

On Parts 2 and 3 of the bridge, Florida Bulb-tee 78-in.-deep girders were used in the majority of situations. The shape is very efficient in the 130-ft-span range. This shape permits the use of wide girder spacing and significantly larger prestressing forces. Site conditions facilitated the use of large barges to transport the bulb-tee girders eliminating any land transportation

issues associated with long precast members. Some 317,500 linear ft of 78-in.-deep bulb tees were used. Specified concrete compressive strength for the girders was 8500 psi.

All girders were required to age a minimum of 90 days prior to making the span continuous through the cast-in-place concrete deck. The maximum distance between expansion joints is 810 ft.

### Concrete Decks

Cast-in-place concrete on stay-in-place metal forms was required by the owner. Spans were made continuous thus minimizing expansion joints. In order to control shrinkage, closure placements were not made until after a predetermined waiting period. The decks encompassed 3,770,000 ft<sup>2</sup> and required 130,000 yd<sup>3</sup> of concrete.

### Demolition of the Original Bridges

The original bridges were retired in April 2010, and two additional contracts let to demolish them. These contracts involved removing two 5.4-mile-long bridges using an environmentally sensitive process. The material will be used to create shoreline protection, create fishing reefs, and provide fishing piers in the region. These efforts were partially funded by various entities tasked with protecting and enhancing the environment.

### Acknowledgements

Disasters often bring out the best in people. Many from the private sector, agencies, and organizations worldwide lent assistance. Louisiana thanks everyone who helped so willingly.

---

*Artur W. D'Andrea is bridge engineer administrator with the Louisiana Department of Transportation and Development in Baton Rouge, La.*



The typical spans included 135-ft-long, 78-in.-deep Florida Bulb-tee beams set on precast pile caps on 36-in.-square, hollow, precast, prestressed concrete piles.

**For additional photographs or information on this or other projects, visit [www.aspirebridge.org](http://www.aspirebridge.org) and open Current Issue.**

### Sustainability

Sustainability was a focus throughout this project in several ways:

- maximize the use of precast elements
- minimize the construction footprint near and around the bridge site
- design for 100-year service life
- restore service to the original twin spans while constructing the new bridges
- recycle bridge material for shoreline protection and aquatic life habitat

### Long-Term Durability

Increased concrete cover and controlled permeability of the concrete mixes will extend the design life of the components for the bridges. The extensive use of high-performance concrete was a key element specified to ensure a 100-year design life for this project situated in brackish water. Design concrete compressive strengths ranged from 4500 psi to 8500 psi and the permeability threshold was set at a maximum of 1000 coulombs at 28 days. Other mix improvements included the use of Class F fly ash or ground-granulated blast-furnace slag for portland cement. A minimum of 5% silica fume was also required. Detailed curing criteria were established such as match-curing of test cylinders to establish the strength of precast elements at transfer of the prestressing force. In addition, temperature ranges were monitored for all mass concrete used throughout the project.



Precast concrete pile caps were used on the 36-in.-square piles in 496 bents.



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# New! Coming Soon!

## The Third Edition of the *PCI Bridge Design Manual*

The third edition of the popular *PCI Bridge Design Manual* will be published soon. Prepublication sales will be starting—watch for announcements.

The manual is being updated to conform to the fifth edition of the *AASHTO LRFD Bridge Design Specifications* including the 2010 Interim Revisions. There are 11 new design examples that provide solutions using various precast, prestressed concrete bridge beams and products. The examples illustrate all of the various new alternative code provisions, including prestress losses, shear design, and transformed sections.

The new manual is a must-have for all design and load-rating engineers, owner agencies, contractors, specifiers, precasters, and suppliers.

A substantial discount will be available for registered holders of the second edition. Webinars will be available to help orient owners of the third edition.



# Phoenix Sky Harbor TRANSIT GUIDEWAY BRIDGE

by David A. Burrows, Gannett Fleming

## The evolution of the PHX Sky Train's crossing of Taxiway "Romeo"

At one of the 10 busiest airports in the United States, cast-in-place, post-tensioned concrete was used to provide superior value, meet an aggressive construction schedule, squeeze into a tight construction corridor, and accomplish the world's first transit crossing of an active aircraft taxiway.

The Phoenix Sky Harbor International Airport is constructing the PHX Sky Train™, a 5-mile-long automated transit system that will run through and connect key existing and future airport facilities with strategically located stations at terminals, parking areas, ground transportation centers, Metro Light Rail, and the Rental Car Center. The development of this system requires several very unique design features. The lead designers and the Aviation Department developed a predominantly elevated train alignment that offered the most economical facilities and the best level of service for station connections to airport facilities.

The construction of the PHX Sky Train will be implemented in two stages to spread the overall capital costs. Stage 1 is currently under construction with a planned opening in early 2013. Stage 2 is still in conceptual design development and is scheduled for opening in 2020. Stage 1 consists of three stations and 12,000 linear ft of guideway, of which 9000 ft will be elevated. One of the



Taxiway "R" looking north showing removal of end span falsework. Photo Rights: Hensel Phelps Construction Co.; Photo Credit: Visions in Photography.

biggest challenges to Stage 1 was the crossing of Taxiway Romeo (Taxiway "R"), the first time in the world that a transit system would cross over an active taxiway. In fact, the taxiway itself crosses over Sky Harbor Boulevard, thereby putting planes, trains, and automobiles all within close proximity.

### Design Constraints

The main span of the bridge is 340 ft long and 75 ft above the taxiway in order to provide the clearance required for Group V Aircraft. Additionally, to stay below the ceiling established by the Federal Aviation Administration for safe aircraft operations, the height of the bridge was limited. Thus, a narrow vertical band approximately 40 ft deep remained within which the bridge could be built. Equally daunting to the geometric constraints was the task of constructing the bridge above an active taxiway, which could only be shut down for a short period of 2 months.

In 2007, a selection process was begun to determine the structure type that

would best meet project objectives, while minimizing impacts to airport operations, facilities, and security and meeting or exceeding established design criteria. Because of advantages in constructability, maintenance, serviceability, inspection, and total life-cycle cost, a precast concrete segmental box girder was recommended. Evident from a drive on metro-Phoenix's freeway system, concrete box girders are a popular choice. They require little maintenance and only routine inspection and thus have a reduced life-cycle cost. Aesthetically, the box girder was the most streamlined and least obtrusive choice, fitting nicely with surrounding concrete structures and adjacent guideway.

### Cast-in-Place Box Girder Selected

After preliminary design of the precast concrete segmental box girder was completed, the contract for construction manager at risk was awarded. Then began an investigation into reducing the projected \$10.5 million construction

## profile

**TAXIWAY "R" BRIDGE/ PHOENIX SKY HARBOR INTERNATIONAL AIRPORT, PHOENIX, ARIZONA**

**BRIDGE DESIGN ENGINEER:** Gannett Fleming, Phoenix, Ariz.

**CONSTRUCTION MANAGER AT RISK:** Hensel Phelps Construction Company, Phoenix, Ariz.

**SUBCONTRACTOR, PIERS AND SUPERSTRUCTURE:** Austin Bridge & Road, Phoenix, Ariz.

**SUBCONTRACTOR, DRILLED SHAFTS:** Case Foundation Company, Tempe, Ariz.

**CONCRETE SUPPLIER:** CEMEX, Phoenix, Ariz.

## The world's first transit crossing of an active aircraft taxiway.

cost. The initial restriction to a taxiway shutdown period longer than 2 months was extended to 6 months based on the Aviation Department's ability to divert traffic to two parallel taxiways crossing Sky Harbor Boulevard. The shutdown timing was an additional factor to be managed. Due to seasonal traffic volumes, closure had to occur between Spring Break and Thanksgiving. If this window was missed, it would delay the construction of the bridge thus delaying the entire project.

Once the longer closure time appeared possible, several other advantages for a cast-in-place concrete option became apparent: the cost and difficulty of transporting precast segments would be eliminated, or a large staging area near the taxiway to cast segments on-site would not be needed, end spans could be constructed without cast-in-place closure placements, and significantly more experience within the local construction community building cast-in-place concrete box girders would result in more competitive bids. All of these issues led to the decision by the city to adopt cast-in-place concrete in lieu of precast concrete segmental construction.

Construction contracts were awarded in September 2009. With the demand for construction impacted by the recession, the contractor had access to an abundant supply of falsework material and proposed supporting all three spans simultaneously until post-tensioning was complete.

### Bridge Details

With the design adjusted to take advantage of the simultaneous falsework configuration, the following dimensions and reinforcement resulted:

- Three-span continuous cast-in-place concrete box-girder bridge with 200-ft-long end spans and a 340-ft main span
- A deck width of 27 ft to accommodate dual train tracks
- A trapezoidal three-cell box-girder section with depth varying from 8 ft 9 in. to 17 ft 6 in.
- Box girder cross section with an 8-in.-thick top slab; 12-in.-thick webs; and a bottom slab that varies from 12 in. to 24 in. thick
- Specified concrete compressive strengths of 6000 psi and 4000 psi for the superstructure and the



The erection of falsework for the center span showing the proximity of Sky Harbor Boulevard crossing under Taxiway "R." Photo: Gannett Fleming Inc.

- substructure, respectively
- Post-tensioning consisting of four tendons in each of the four webs. Each tendon contains twenty-seven 0.6-in.-diameter strands
- 5900 yd<sup>3</sup> of concrete and 1.2 million lb of uncoated, nonprestressed reinforcement



Taxiway "R" looking west showing deck and curb east of bridge complete. Photo Rights: Hensel Phelps Construction Co.; Photo Credit: Visions in Photography.

THREE-SPAN, CAST-IN-PLACE CONCRETE, POST-TENSIONED BOX GIRDER TRANSIT BRIDGE / CITY OF PHOENIX, ARIZONA, OWNER

**POST-TENSIONING CONTRACTOR:** DYWIDAG-Systems International USA Inc., Long Beach, Calif.

**BRIDGE DESCRIPTION:** Three span, 740-ft-long (200-ft end spans, 340-ft main span) cast-in-place concrete, post-tensioned box-girder transit bridge, 75 ft above an airport active taxiway

**STRUCTURAL COMPONENTS:** Three-cell box girder, 27-ft 0-in.-wide deck with depth varying from 8 ft 9 in. to 17 ft 6 in., 13-ft-diameter integral main piers and 8-ft-diameter end piers founded on 8-ft-diameter drilled shafts

**BRIDGE CONSTRUCTION COST:** \$6.7 million (\$335/ft<sup>2</sup>)

Below: Taxiway "R" looking north, showing shoring under 340-ft-long main span and floor and webs complete. Photo Rights: Hensel Phelps Construction Co.; Photo Credit: Visions in Photography.



While the taxiway remained open, construction began with pier foundations. The foundations included a group of four 8-ft-diameter drilled shafts 90 ft deep with a 10-ft-thick cap for the main piers and one 8-ft-diameter drilled shaft 75 ft deep for each end pier. Pier construction included 8-ft-diameter end piers first, followed by 13-ft-diameter main piers. The main piers required a limitation on the size of aircraft accessing the taxiway during their construction. Falsework towers and formwork for the end spans took approximately 2 months to build. Once the floor and webs of the girders for the end spans were constructed, the taxiway was shut down in April 2010 to begin the construction of the main span. A milestone was celebrated at

the construction site when the floor and webs of the bridge were completed on July 2, 2010. The deck was placed continuously over all three spans, and post-tensioning of the bridge occurred in early September 2010.

### Taxiway Reopening

A celebration to mark the re-opening of the taxiway was held by the city on Oct. 10, 2010, with members of the city's Aviation Department, designers, contractors and media watching as the first two planes taxied under the new bridge. Although the bridge itself is complete, the running surface and propulsion systems for the train have yet to be installed. Installation of these systems will occur through 2011, with rigorous testing of the train



Above: Taxiway "R" re-opening event on October 10, 2010, with a Southwest Airlines 737, the first plane to taxi under the completed bridge. Photo: City of Phoenix Aviation Department.

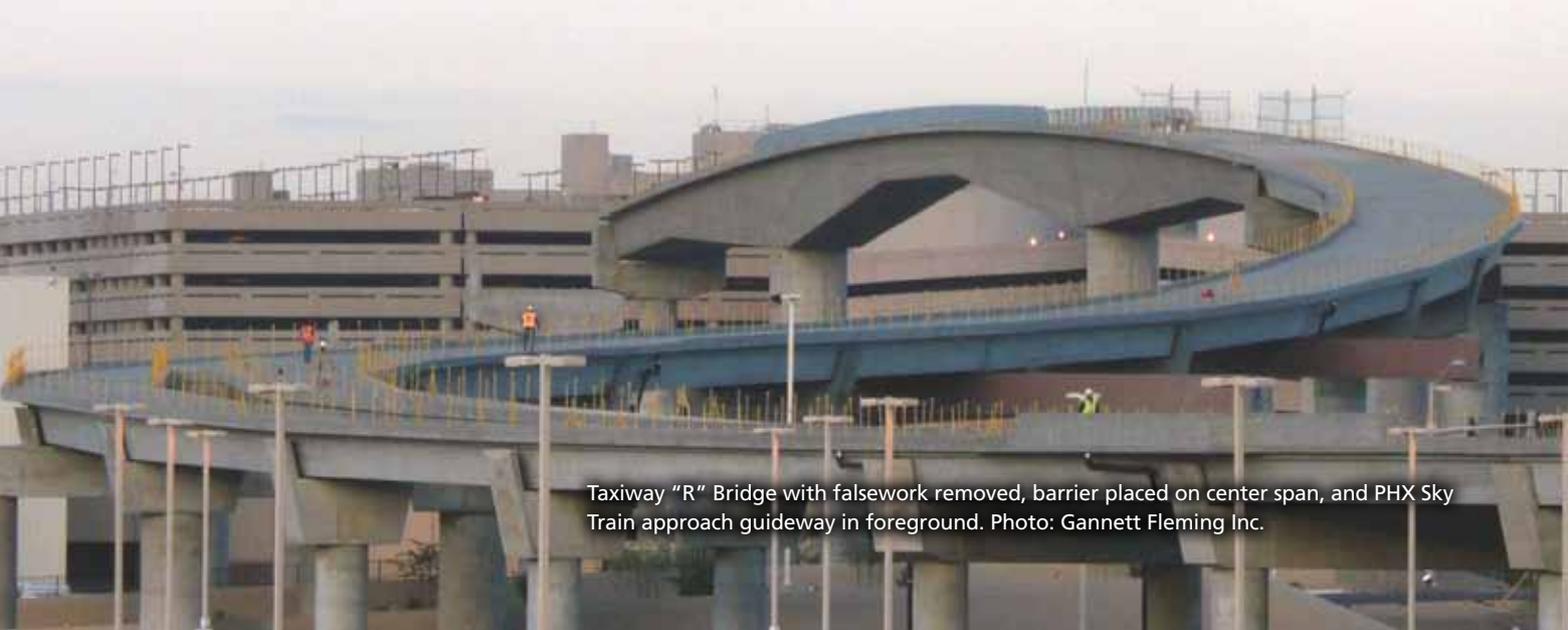
system occurring in 2012 and opening of the first stage of the Sky Train to the public slated for early 2013. Final accounting indicates a total bridge cost of approximately \$6.7 million, an impressive 36% savings from the preliminary estimate.

Thanks to the successful use of post-tensioned concrete, future passengers that cross over the taxiway will enjoy expansive views of Sky Harbor International Airport, the city, and surrounding desert landscape, as well as the experience of riding a train over planes and crossing above automobiles.

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*David A. Burrows is structural engineer with Gannett Fleming in Phoenix, Ariz.*

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Taxiway "R" Bridge with falsework removed, barrier placed on center span, and PHX Sky Train approach guideway in foreground. Photo: Gannett Fleming Inc.



  
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# EVERY DAY COUNTS: The FHWA Technology Deployment Initiative

Accelerating Bridge Construction



by Claude Napier, Lou Triandafilou, and  
M. Myint Lwin, Federal Highway Administration

**T**he Federal Highway Administration’s (FHWA) Every Day Counts (EDC) initiative is designed to shorten project delivery, accelerate innovative technology deployment, and “go greener.” The focus of this article is on accelerated bridge construction (ABC) using prefabricated bridge elements and systems (PBES) in support of the initiative. In the next issue of *ASPIRE*<sup>™</sup>, we will share the lessons learned from the regional EDC Innovation Summits, and case studies of states that are implementing concrete PBES in the EDC Initiative.

## Everyone Counts

Essential to the success of the initiative is the engagement of our leadership, our workforce, our partners, and our stakeholders. Everyone plays an important role in EDC. A collaborative process engaging representatives from FHWA, state DOTs, local agencies, industry, academia, and other stakeholders was used to identify and select technologies for the initiative. The five technologies selected for the initial phase of deployment are: warm-mix asphalt, adaptive signal control technology, highway safety edge, geosynthetic reinforced soil, and PBES. Deployment teams were then formed

for developing implementation, marketing, and training roadmaps for each of these technologies.

## Training

The deployment team for PBES developed eight modules for training FHWA field personnel in preparation for a national rollout of EDC. Training topics included defining and exploring PBES, understanding details and methods of ABC, and guidelines for communicating these issues effectively. The training phase is very important as the states begin to implement EDC this year.

## EDC Innovation Summits

FHWA partnered with the American Association of State Highway and Transportation Officials (AASHTO) to host 10 regional EDC Innovation Summits that were strategically located throughout the United States. These 1½-day summits were supported by a wide range of partners and stakeholders, including the Association of General Contractors of America, the American Road and Transportation Builders Association, the National Association of County Engineers, the American Public Works Association, the Local and Tribal Technical Assistance Programs, the American Council of

Engineering Companies, and various state and federal resource agencies. The purpose of the summits was to roll out a proposed model that could be used by the states to implement the EDC initiative and to initiate discussions that would lead to the development of action plans by the states.

An EDC initiative forum has been created on the FHWA website to serve as a market place of ideas and opinions from people in the transportation community. Several prominent executives of the partner and supporting organizations shared their opinions in the forum. The internet address of the EDC Forum is: [http://www.fhwa.dot.gov/everydaycounts/forum/whyninnov\\_nadeau.cfm](http://www.fhwa.dot.gov/everydaycounts/forum/whyninnov_nadeau.cfm).

## Prefabricated Bridge Elements and Systems

For the EDC initiative, PBES is defined as bridge structural elements and systems that are built off the bridge alignment to accelerate on-site construction time relative to conventional practice. Conventional practice is described as nonadjacent girders that have a cast-in-place concrete deck and a cast-in-place concrete substructure.

With PBES, many time-consuming

*During a 1-night closure of I-15 near American Fork, Utah, an entire span was moved 1200 ft from a fabrication staging area to its final position on the abutment and bent. In total, four spans were moved on self-propelled modular transporters with 1-day highway closures each. The longest span was 191 ft 9½ in. (For more information about the Pioneer Crossing Interchange, see the Winter 2011 issue of ASPIRE, p. 16.) Photos: FHWA.*



construction tasks no longer need to be accomplished sequentially in the work zone. Instead, PBES are constructed concurrently off site or off alignment, and brought to the project location ready to install. Time of construction can often be reduced from months to just days. Because PBES are usually fabricated under controlled environmental conditions, weather has a smaller impact on the quality, safety, and duration of the project. Through the use of standardized bridge elements, PBES offers cost savings in both small and large projects.

The use of rapid on-site installation for PBES can reduce the environmental impact of projects in environmentally sensitive areas. Prefabricated bridge construction can help minimize traffic delays and community disruptions by reducing on-site construction time and improving quality, traffic control, and safety of workers and the traveling public. Using PBES means that time-consuming formwork construction, concrete placement and curing, and other tasks associated with fabrication can be done off site in a controlled environment without affecting traffic.

## The Role of Concrete in EDC

Many of today's bridge construction and replacement projects take place in areas of heavy traffic, where detours and bridge closures severely impact the flow of people and goods on transportation corridors. One of the most common ways to accelerate bridge construction is prefabrication. Frequently, PBES are constructed with concrete: conventionally reinforced, pretensioned, or post-tensioned (or a combination of these), for superstructures as well as substructure members.

Contractors can avoid harsh weather conditions through prefabrication in protected environments; thereby improving the quality of the finished concrete products. In line with these methods, the implementation of PBES to accelerate bridge projects is tailor-made to continue the national implementation of high-performance concrete that state DOTs have been aggressively pursuing.

Depending on the size and scope of the project, unique placement techniques can be deployed to accelerate bridge projects. These include self-propelled modular transporters, longitudinal launching, and transverse sliding or skidding into place for long-span structures. For shorter span structures that make up the majority of the national bridge inventory, conventional equipment will often prove to be most effective.

## Closing Remarks

FHWA's EDC initiative emphasizes an improved driving experience for the American public, through rapid deployment of several



*Route 103 over the York River in Maine employs the Northeast Extreme Tee (NEXT) Beam, developed by the Northeast Chapter of PCI to accommodate accelerated construction of bridges in the region. (Additional information on the NEXT beam and York River Bridge can be found on page 46 in this issue.) Photo: Dailey Precast LLC.*

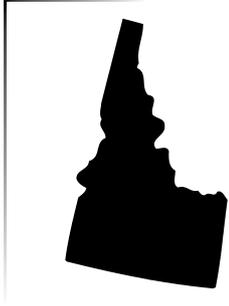
proven technologies and solutions to speed up project delivery with minimal disruption to traffic. PBES will continue to demonstrate that bridges can be built better, faster, and more safely.

To learn more about the FHWA's EDC initiative, please contact any of the FHWA Division Offices using <http://www.fhwa.dot.gov/field.html>.

*Claude Napier is senior structural engineer with the FHWA Resource Center Structures Technical Service Team in Richmond, Va.; Lou Triandafilou is team leader, Bridge and Foundation Engineering with the FHWA Turner-Fairbank Highway Research Center in McLean, Va., and M. Myint Luwin is director, Office of Bridge Technology at the FHWA in Washington, D.C.*



*Two spans for the Pioneer Crossing Interchange project in Utah are seen in the fabrication staging area before their move on self-propelled modular transporters to one of two bridges over I-15. Photo: Kiewit/Clyde, a joint venture.*



# SPANNING THE PAST AND FUTURE

IDAHO LOOKS TO PRESERVE EXISTING BRIDGES WHILE EXPANDING CAPABILITIES FOR NEW STRUCTURES

by Matthew Farrar, Idaho Transportation Department

**A**long with many other states, Idaho faces challenges in managing its bridge assets by cost effectively extending their service life or replacing them. For bridges with spans of less than 130 ft, the need for economical, durable, and quickly constructed bridges usually makes prestressed concrete the first choice. Innovative options, especially with accelerated bridge construction (ABC) techniques, also have proven to work well with precast concrete.

Precast, prestressed concrete bridges have become Idaho Transportation Department's (ITD) first choice for a variety of reasons, particularly because they usually provide the lowest first-cost solution. But they also offer low, long-term maintenance costs due to their high durability. They provide flexibility, offering many cross sections to choose from and providing a range of ways they can be used.

Precast concrete bridge components are readily available in the state, and several fabricators regularly supply products. In some cases, for bridges with spans under 30 ft, ITD uses cast-in-place or precast concrete box culverts or three-sided structures.

Generally, the ITD undertakes 50 to 60 bridge projects each year, but they vary widely in their scope. Only about 10 of those projects

are complete replacements for existing structures. The rest are rehabilitations, widening, and upgrades of all types. Keeping the existing bridges accessible and functional is a key part of the work.

## Rainbow Bridge Restored

An example of rehabilitation work is the State Highway 55 Bridge over the north fork of the Payette River. This structure, known as the Rainbow Bridge, is a 411-ft-long, open-spandrel, cast-in-place concrete arch bridge. Built in 1936, it is now on the National Register of Historic Places and has become well recognized in the state. It's definitely considered a keeper, and great efforts have been taken to preserve its structural integrity. In 2007, it was completely rehabilitated. Techniques included chloride extraction and the installation of materials to mitigate corrosion in the future.

A few components were replaced during the work, such as the end portion of some stringers. Also, the existing railing had deteriorated, so it was demolished and a precast concrete railing replaced it. As this design had to perfectly replicate the original, it was fabricated in a precast concrete plant and shipped in segments to the site to provide better control over its character and quality. All of the work was done in stages, to allow vehicle access to the bridge



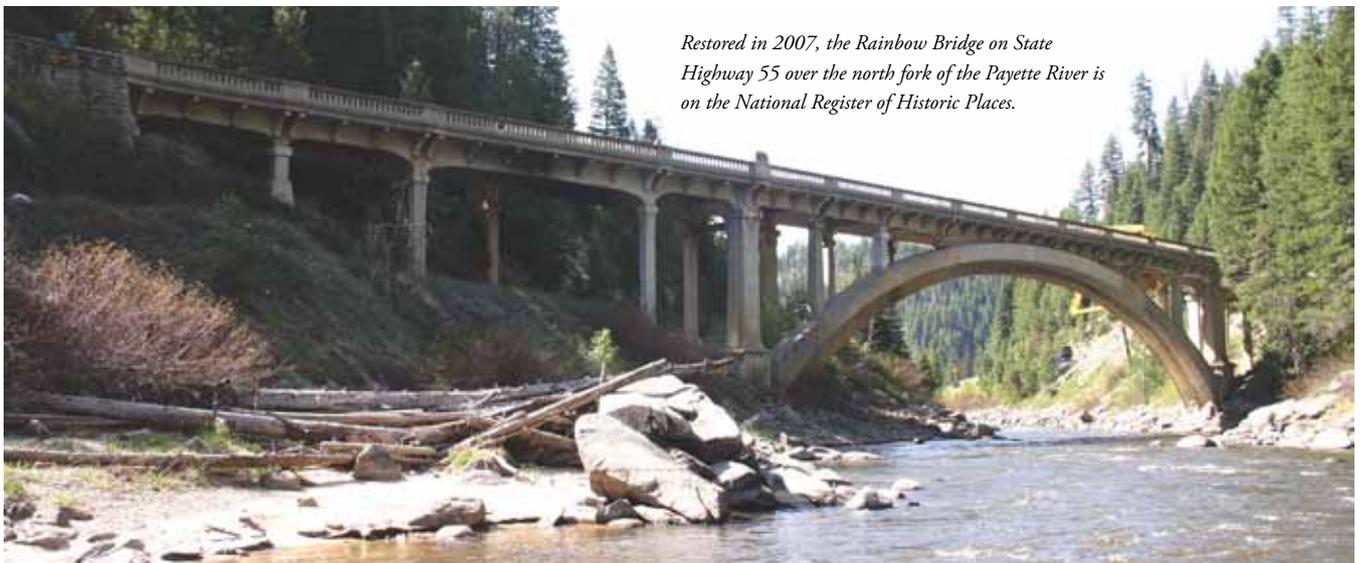
*The I-84 Ten Mile Interchange in Meridian, Idaho, features a 189-ft single-span, cast-in-place concrete box girder. A single-point urban interchange (SPUI), the post-tensioned design provided cost effectiveness and constructability at the complex site.*

throughout the construction. The local office of CH2M-Hill assisted ITD with the restoration project.

## Snake River Bridge Completed

At the other end of the spectrum on bridge construction is the new U.S. 95 Spur over Snake River near Weiser, Idaho, which was completed in 2010. The \$10-million project replaced a bridge originally built in 1950, providing wider lanes (a total of 46 ft 4 in. versus 30 ft 6 in.) and capable of carrying greater traffic volumes.

The 876-ft-long bridge features six spans of precast, prestressed concrete girders comprising 144 ft-long, 84-in.-deep, modified bulb-tee



*Restored in 2007, the Rainbow Bridge on State Highway 55 over the north fork of the Payette River is on the National Register of Historic Places.*



*The U.S. 95 Spur Bridge over the Snake River features six spans of precast, prestressed concrete modified bulb-tee girders 144 ft long and 84 in. deep.*

girders. The 144-ft girders are the longest yet to be used in Idaho, and they were selected while working closely with city officials to replicate the look of the original bridge. A cast-in-place concrete railing was provided, along with vintage light standards to create the proper tone.

As the 144-ft-long girders indicate, ITD has been pushing to achieve longer spans with precast concrete girders. They eliminate the need for piers in the water, which has become a much larger concern. Handling and transporting such long spans can create its own challenges, however, so a balance must be maintained between effective span lengths and efficient handling methods.

Another complex bridge to be completed this year is the I-84 Ten Mile Interchange in Meridian, Idaho. The project was singled out by the ITD and the Community Planning Association of Southwest Idaho as the highest priority for a new interchange in the 2001 I-84 Corridor Study and it is finally nearing completion. The project will result in a new interchange and improvements to the surrounding roadways.

The 189-ft-long, single-span bridge consists of post-tensioned, cast-in-place concrete box girders designed as a single-point urban interchange (SPUI). The post-tensioned design was chosen for its cost effectiveness and constructability at this complex site. The concrete boxes were necessary to provide the span length needed to complete the SPUI geometry and to ensure the design was aesthetically pleasing. HDR Engineering assisted ITD with this project.

*Idaho uses consulting engineers for complex projects.*

*HNTB designed the I-90 Bridge over Bennett Bay, known as the Veterans Memorial Centennial Bridge.*

*The bridge is the only cast-in-place, post-tensioned segmental concrete box-girder bridge on the state highway system. All photos: Idaho Transportation Department.*

## Segmental Design Used

When long-span bridges are necessary, ITD found that concrete segmental construction is cost effective. One of the largest of those projects is the Veterans Memorial Centennial Bridge over Bennett Bay and Sunnyside Road near Coeur d'Alene, Idaho. It was completed in 1991.

The \$20-million project produced a 1730-ft-long cast-in-place, post-tensioned segmental concrete box-girder bridge. The four-span bridge features end spans of 345 ft and two interior spans of 520 ft. The design, by HNTB, was the most economical approach for this unique situation, but it remains the only segmental cast-in-place concrete bridge on the state highway system.

As several of these projects indicate, ITD works with outside designers on complex bridges. However, the majority of the bridges are designed in house. Another significant state bridge designed in conjunction with an outside designer was the Bryden Canyon Road Bridge over the Snake River in Lewiston, Idaho.

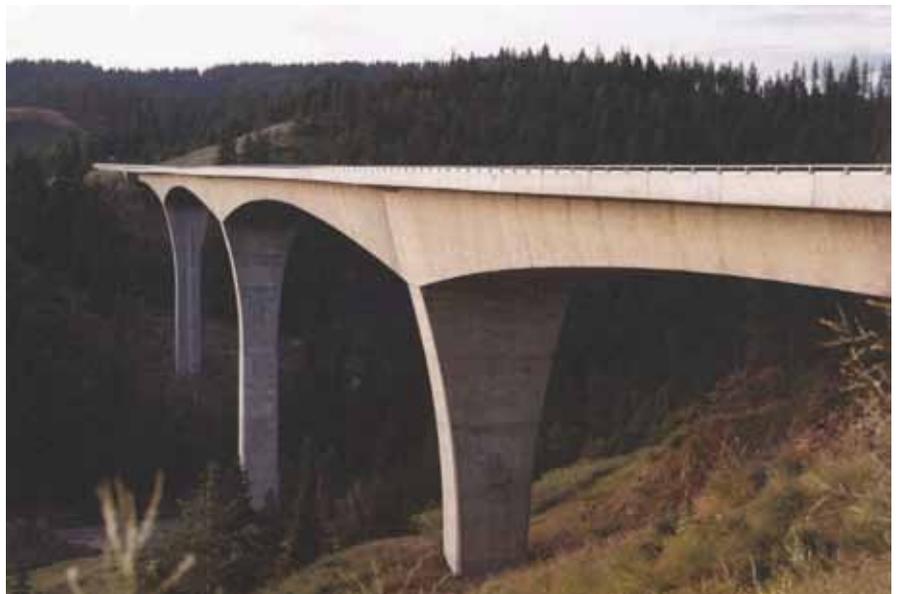
Designed by T.Y. Lin International in San

Francisco, Calif., and completed in 1981, the 1750-ft-long bridge is located on a local road and spans between Idaho and Washington. The structure consists of cast-in-place, post-tensioned segmental concrete box girders. The long-span design was used to span the backwaters of a dam that was being raised.

## Longevity Is Key Concern

With all of the state's projects, durability and longevity have become key focus concerns. A primary goal is to ensure that bridges last longer and require less maintenance so the state is better able to manage its assets. To extend service life, all cast-in-place, post-tensioned concrete bridges today are designed for zero tension. Fly ash and other additives are used to add durability and reduce the cement content.

ITD also has experimented with Type K cement, a hydraulic cement for use in shrinkage-compensating concrete. It helps mitigate cracking caused by drying shrinkage. Monofilament fibers also have been used in



some cases to stitch together micro-cracks that might arise.

Concrete with monofilament fibers was used for the Wye Interchange on I-184 in Boise, Idaho, in 2000. When originally constructed in 1969, the interchange could easily carry 33,000 vehicles per day. By 1998, the average daily traffic had reached 92,000 vehicles. The redesign allows it to carry about 120,000 vehicles per day, the anticipated traffic level in 2020. The project was constructed in two stages at a total cost of about \$80 million. Throughout the construction, two lanes of traffic remained open in all directions—the same level of service available before construction began.

The 817-ft-long bridge features cast-in-place, single-cell concrete box girders that were post-tensioned both transversely and longitudinally. The bridge consists of four spans, with 187-ft end spans and two interior 222-ft spans. The structure is 58 ft wide with just a single-cell box. This approach, which is more common in California, helped meet a multitude of challenges resulting from the curvature of the roadway.

### ABC Concepts Used

ITD has also been examining a variety of ABC methods. One of the approaches that has proven effective is precast concrete columns and pier caps. This technique allows the components to be fabricated as other work progresses, speeding up installation when the site is ready.

This approach was used on three interchanges or overpasses in the past 2 years, on Black Cat Road, Robinson Road, and the Vista Interchange over I-84 in Boise. The two overpasses feature precast, prestressed concrete girders, precast concrete columns, and precast pier caps. The Vista Interchange uses precast, prestressed concrete girders with precast concrete pier caps but cast-in-place concrete columns, because the construction staging did not benefit from accelerating the column construction. The local offices of HDR Engineering, Forsgren Engineers,



*On the Wye Interchange on I-184 in Boise, the 817-ft-long, fly-over bridge features cast-in-place, single-cell concrete box girders that were post-tensioned both transversely and longitudinally.*

and Stanley Engineers assisted on these projects.

Mixing the two types of components and targeting those elements where accelerated construction can be most effective offers significant benefits for future designs. Where appropriate, ITD intends to continue to use these concepts, while tweaking them to gain maximum effectiveness. The experience represented a fairly innovative approach and showed us how we can utilize ABC techniques.

Another project using all precast concrete components is on the drawing boards. The State Highway 200 Bridge over Trestle Creek, to be constructed in 2013, consists of a 105-ft-long, simple-span structure using entirely precast concrete elements, including deck bulb-tee beams and precast concrete abutments. The road is not heavily trafficked, but it provides an opportunity to test ABC principles in practice. If this project proves successful by significantly

cutting construction time, the concepts will be expanded.

These projects show the wide range of designs and construction methods being used by ITD. The state tracks its bridge conditions closely, although funding to accomplish all that should be done creates a great challenge. Fortunately, the state is focusing more attention on bridges today as it realizes the great value in providing effective asset management to make best use of taxpayer dollars. No doubt, with past history as a guide for future projects, many of those bridges will feature innovative concrete methods.

---

*Matthew Farrar is the state bridge engineer with the Idaho Transportation Department in Boise, Idaho.*

**For more information on Idaho's bridges, visit [www.dot.state.idaho.gov](http://www.dot.state.idaho.gov).**



*Precast concrete bent caps and columns were used on the Robinson Road over I-84 Bridge, one of several recent projects to incorporate accelerated bridge construction (ABC) techniques.*

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# small town BIG PLANS

by Bill Finger and Dan Werner,  
Town of Middlebury, Vt.

MIDDLEBURY TOWN OFFICIALS JOIN WITH COLLEGE  
TO FUND AND BUILD \$16-MILLION, 480-FT-LONG BRIDGE

Until 2010, the Town of Middlebury, Vt., had only one narrow, late-1800s-era, stone-arch bridge across Otter Creek to connect the two sides of the town. The town had understood the necessity for another bridge since the 1950s, especially with the bridge deteriorating, but no funds were available. After years of planning, the town decided to build the bridge without state or federal financial assistance. The new Cross Street Bridge, which opened in October 2010, shows what can be accomplished with innovative local partnerships.

It created a true challenge to design and construct the \$16-million project, which features a 480-ft-long, three-span, precast, prestressed concrete bridge with a 240-ft-long center span, especially with no outside funding sources. But it was imperative that it be accomplished. The town's emergency services were located on one side of the creek, while the hospital and college were on the other side, creating potential for significant problems. Any closure of the stone arch bridge required a minimum additional 20-mile trip for emergency vehicles.

A bridge committee comprising town officials, staff, and citizens was formed to steer the project. Initial evaluations considered several alternatives: steel, cast-in-place concrete, precast concrete, cable-stayed, and other options. The cost estimate was significant: \$9 million for the bridge and another \$7 million for approaches including a roundabout intersection. But

Vermont officials said that state and federal aid for the project was at least 15 years away!

To secure the needed funds, the bridge committee met with officials of Middlebury College, who agreed a new bridge was essential. The college pledged \$600,000 per year for 30 years to pay for the bridge construction, while the town adopted a Local Option Tax that included a 1% sales tax and a 1% tax on hotel rooms and restaurant meals to pay the rest. These funds will be used to amortize a 30-year, \$16-million bond.

## Design-Build Process Used

A design-build process, the first in the state, reduced overall design and construction costs. The team comprised town staff, local precast manufacturer J.P. Carrara & Sons, engineering firm VHB-Vanasse Hangen Brustlin Inc. in North Ferrisburgh, Vt., and general contractor Kubricky Construction Corp. in Glen Falls, N.Y.

The team confirmed the project's financial feasibility. The initial plan called for four equal spans with one pier in the middle of Otter Creek, but environmental regulators objected. Arguing the issue would add months or years to the schedule, so the three-span option was adopted.

The design-build format created such close communication among town officials, designers, contractors, and concrete fabricators, that it is estimated approximately 30 to 40% in cost was saved over more traditional methods.

Taking on this project was daunting. The work had to be completed in a small New England town's busy downtown district. The community strongly supported the project but dreaded the anticipated traffic delays and disruptions during the busy summer tourist season. However, many residents commented that it was the smoothest project they had ever seen. Business in fact increased for some stores, and few complaints were received.

Since the bridge opened in October 2010, it's been like uncorking a bottle. The new structure redistributed traffic, so there are virtually no traffic tie ups. The project's example of local cooperation and innovation can serve as an inspiration for other towns to consider projects they otherwise deem impossible.

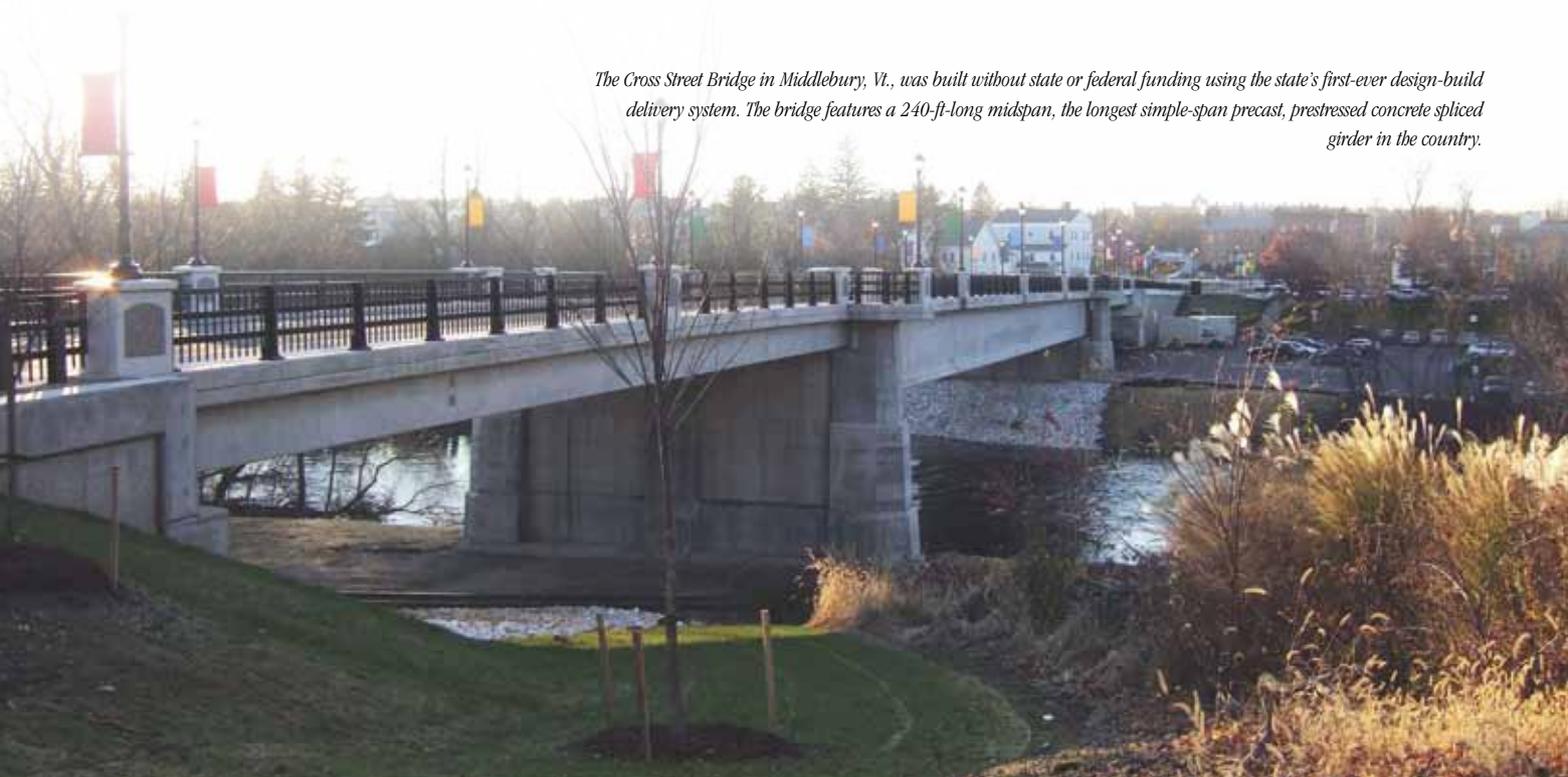
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*Bill Finger is town manager and Dan Werner is director of operations for the Town of Middlebury, Vt.*

## EDITOR'S NOTE

*For more on this project, see the Winter 2011 issue of ASPIRE,™ page 32.*

*The Cross Street Bridge in Middlebury, Vt., was built without state or federal funding using the state's first-ever design-build delivery system. The bridge features a 240-ft-long midspan, the longest simple-span precast, prestressed concrete spliced girder in the country.*



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## CREATIVE CONCRETE CONSTRUCTION

by Steven Hodgdon,  
Vanasse Hangen Brustlin Inc. (VHB)

# The First Northeast Extreme Tee (NEXT) BEAM BRIDGE

The first Northeast Extreme Tee (NEXT) Beam bridge, located in York, Maine, opened to traffic in November 2010. The bridge, which replaces a deteriorated, 17-span steel girder bridge constructed in 1957, is located on Route 103 and crosses the York River near the Atlantic Ocean. The continuous bridge consists of two 55-ft-long end spans and five 80-ft-long interior spans. Each span uses four 36-in.-deep NEXT beams, 9 ft 4½ in. wide that are butted together edge-to-edge. The top flange is 4 in. thick and provides the form for the 38-ft 2-in.-wide, 7-in.-thick cast-in-place composite concrete deck. The bridge is supported by steel pipe pile pier bents and integral abutments.

The NEXT Beams were fabricated by Dailey Precast of Shaftsbury, Vt., and the bridge was constructed by CPM Constructors of Freeport, Maine. The NEXT Beam is similar to a standard double-tee beam except the stems are wider (15 in. at the top tapering to 13 in. at the bottom for this project) to accommodate bridge design loads. This beam cross section was developed by the Northeast Chapter of PCI ([www.pcine.org](http://www.pcine.org)) as an alternative to adjacent box beams in the 45-ft- to 90-ft-span range to accommodate accelerated construction of bridges. The beam depths may be varied from 24 in. to 36 in. and the top flange width may be varied from 8 ft to 12 ft to meet specific span and width requirements. Sections are available that include a full-depth deck for ride-direct or noncomposite applications.

Sustainability was an important element in the design of the bridge. Several features enhance durability, longevity, and minimize future maintenance. The steel pipe piles are coated with a fusion-bonded epoxy coating and equipped with cathodic protection elements. The steel pipe piles are also designed for up to 50% future section loss and the inner core is filled with reinforced concrete. There are no joints or bridge drains. The deck is constructed with epoxy-coated reinforcing steel and is covered with a high-performance waterproofing membrane and 3-in.-thick bituminous wearing surface. Self-consolidating

concrete for the NEXT beams included calcium nitrite to inhibit corrosion. In addition, the navigational lighting on the bridge uses solar power.

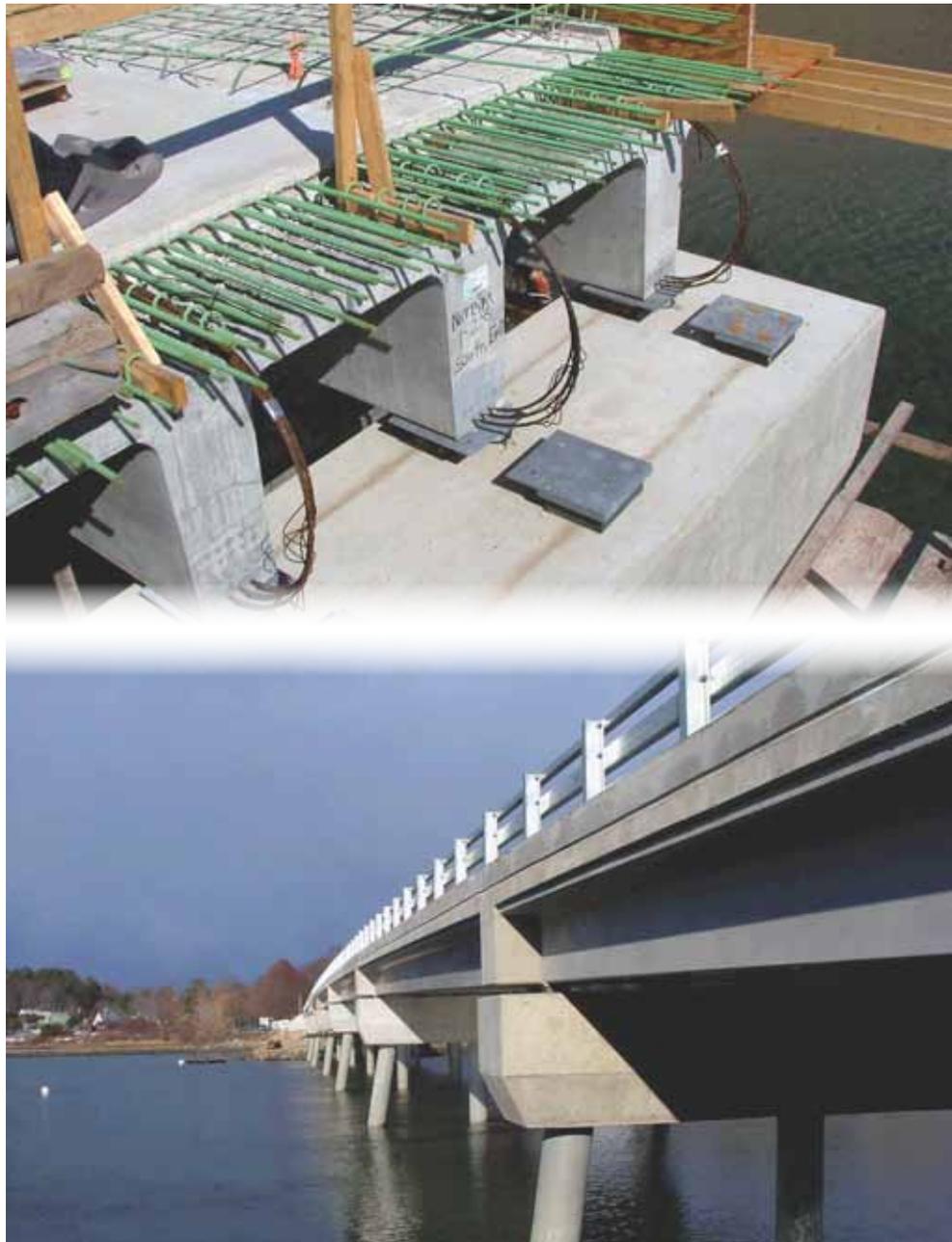
*Steven Hodgdon is project manager with Vanasse Hangen Brustlin Inc. (VHB) in Bedford, N.H.*

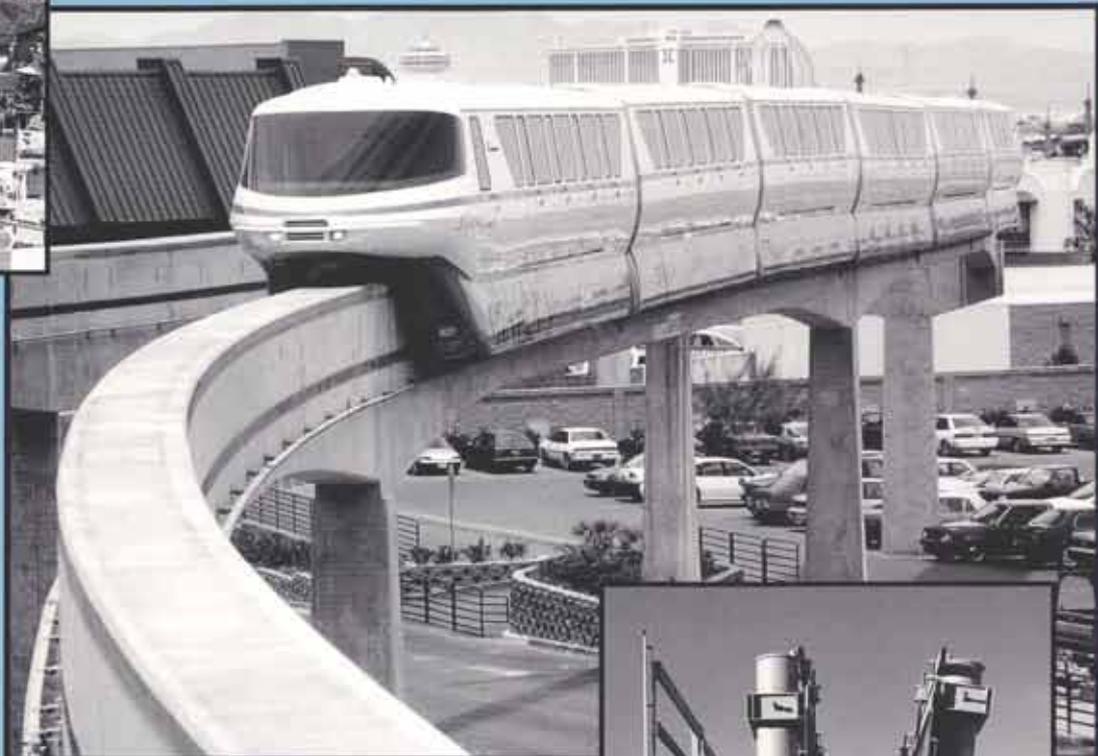
*Epoxy-coated reinforcement extending from the cast-in-place concrete deck provided for the negative moment over the piers.*



*Beams were erected with a crane from jack-up barge on the York River.*

*Beams were made continuous over the piers and integral with the abutments. All photos: VHB.*

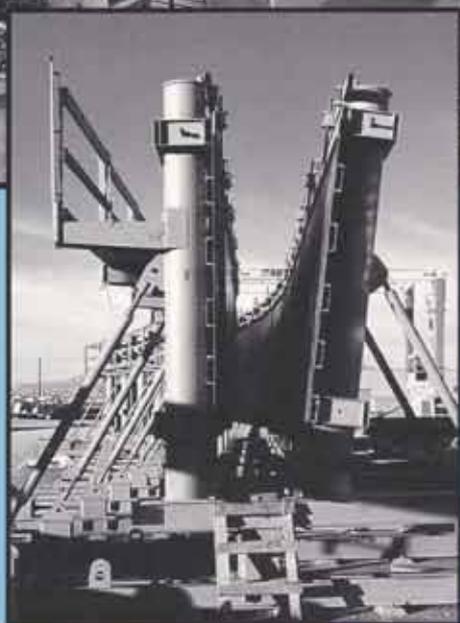




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# Longitudinal Cracks in the Webs of Precast, Prestressed Concrete Girders: To Repair or not to Repair?

by Steve Seguirant,  
Concrete Technology Corporation

With the increased use of higher strength concretes, deeper girders, and larger amounts of prestressing, longitudinal cracks in the webs of precast, prestressed concrete bridge girders have become more prevalent during the last two decades. These cracks generally appear at the ends of girders following transfer of the prestressing force. Sometimes they become more noticeable when the girders are lifted from the casting bed. Nonprestressed transverse reinforcement is provided at the ends of the girders to control the width of these cracks.

In practice, there has been no consistent understanding of the impact of end-zone cracking on the strength and durability of the girders. Thus, the assessments made by bridge owners vary from doing nothing to total rejection of the girders. Other reactions include debonding of strands at the girder ends, limiting prestressing levels, reducing the allowable concrete compressive stress at the time of transfer, injecting epoxy into the cracks, and coating the girder ends with sealants. There has been no consensus among owners on the level of tolerance allotted to these longitudinal cracks.

With this in mind, National Cooperative Highway Research Project 18-14 was initiated to establish a user's manual for the acceptance, repair, or rejection of precast, prestressed concrete girders with longitudinal web cracks. The research involved the following activities:

- Structural investigation and full-scale testing of girder specimens to study the effect of end zone cracking and transverse

reinforcement details on shear and flexural strengths.

- Epoxy injection to investigate its ability to restore the tensile capacity of cracked concrete.
- Durability testing to investigate what repair methods and materials should be used if repair is deemed necessary.
- Field inspection of bridges to check if the in-service condition of end zone cracking changes with time.

Based on the research, the following proposed crack width limits were developed:

- Cracks narrower than 0.012 in. may be left unrepaired.
- Cracks ranging in width from 0.012 in. to 0.025 in. should be repaired by filling the cracks with approved specialty cementitious materials, and coating the end 4 ft of the girder web side faces with an approved sealant.
- Cracks ranging in width from 0.025 in. to 0.05 in. should be filled by epoxy injection and the end 4 ft of the girder web coated with a sealant.
- For girder webs exhibiting cracks wider than 0.05 in., the research team recommends that the girders be rejected unless shown by detailed analysis that structural capacity and long-term durability are sufficient.

Although the report does not address the timing of repairs, state practices vary from repairing before shipment to repairing after girder erection

and the deck has been cast. In the latter case, the crack widths are likely to be less as a result of prestress losses and the application of dead load. Consequently, a less intrusive and less expensive repair procedure may be appropriate.

Perhaps more importantly, the research suggests that transverse reinforcement details have been shown by experience to control end-zone cracking so that repair is not needed. More details about this reinforcement and the repair materials used in the research are given in the full report along with recommendations about repair procedures.

---

*Steve Seguirant of Concrete Technology Corporation, Federal Way, Wash., served as a consultant on the project.*

### EDITOR'S NOTE

This article is based on NCHRP Report No. 654 titled *Evaluation and Repair Procedures for Precast/Prestressed Concrete Girders with Longitudinal Cracking in the Web*, which is available at [www.trb.org/Publications/Blurbs/163575.aspx](http://www.trb.org/Publications/Blurbs/163575.aspx).

*Cracks ranging in width from 0.025 in. to 0.05 in. should be filled by epoxy injection. Photos: Mobsen Shabawy, SDDEngineering Consultants Inc., Tallahassee, Fla.*



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## SFA Silica Fume Association

The Silica Fume Association (SFA), a not-for-profit corporation based in Delaware, with offices in Virginia and Ohio, was formed in 1998 to assist the producers of silica fume in promoting its usage in concrete. Silica fume, a by-product of silicon and ferro-silicon metal production, is a highly-reactive pozzolan and a key ingredient in high performance concrete, dramatically increasing the service-life of structures.

The SFA advances the use of silica fume in the nation's concrete infrastructure and works to increase the awareness and understanding of silica fume concrete in the private civil engineering sector, among state transportation officials and in the academic community. The SFA's goals are two-fold: to provide a legacy of durable concrete structures and to decrease silica fume volume in the national waste stream.

Some of the recent projects completed by the SFA, under a cooperative agreement with the Federal Highway Administration (FHWA), include:

- The publication of a *Silica Fume User's Manual*—the manual is a comprehensive guide for specifiers, ready mixed and precast concrete producers, and contractors that describes the best practice for the successful use of silica fume in the production of high performance concrete (HPC).
- The introduction of a Standard Reference Material (SRM)<sup>®</sup> 2696 Silica Fume for checking the accuracy of existing laboratory practices and to provide a tool for instrument calibration. This SRM is available from the National Institute of Standards and Technology (NIST).

A much anticipated research program nearing completion by the SFA is the testing of in-place silica fume concrete under service conditions. At the conclusion of this research the results will demonstrate the benefit of silica fume concrete's unparalleled long-term performance. For more information about SFA, visit [www.silicafume.org](http://www.silicafume.org).

# CONCRETE CONNECTIONS

Concrete Connections is an annotated list of websites where information is available about concrete bridges. Fast links to the websites are provided at [www.aspirebridge.org](http://www.aspirebridge.org).

## IN THIS ISSUE

### [www.twinspanbridge.com](http://www.twinspanbridge.com)

This website features the latest news on the replacement of the I-10 Twin Span Bridges over Lake Ponchartrain featured on page 30.

### [www.fhwa.dot.gov/everydaycounts/](http://www.fhwa.dot.gov/everydaycounts/)

This Federal Highway Administration website provides more information about the Every Day Counts initiative described in the FHWA article on page 38. A link is provided to a brochure about Prefabricated Bridge Elements and Systems.

### [www.pcine.org](http://www.pcine.org)

Visit this PCI Northeast website for more information about the NEXT beams described on page 46. Click on Resources/Bridge Resources and then Northeast Extreme Tee (NEXT) Beam for the NEXT standards or click on York River Bridge in top right corner for information about the project.

### [www.trb.org/Publications/Blurbs/163575.aspx](http://www.trb.org/Publications/Blurbs/163575.aspx)

NCHRP Report No. 654 titled *Evaluation and Repair Procedures for Precast/Prestressed Concrete Girders with Longitudinal Cracking in the Web* discussed in the Safety and Serviceability article on page 48 is available at this Transportation Research Board website.

### [www.wsdot.gov/Research/Reports/400/417.1.htm](http://www.wsdot.gov/Research/Reports/400/417.1.htm)

The Washington State Department of Transportation report titled "Noncontact Lap Splices in Bridge Column Shaft Connections" mentioned in the AASHTO LRFD article on page 52 is available at this website.

## Environmental

### <http://environment.transportation.org/>

The Center for Environmental Excellence by AASHTO's Technical Assistance Program offers a team of experts to assist transportation and environmental agency officials in improving environmental performance and program delivery. *The Practitioner's Handbooks* provide practical advice on a range of environmental issues that arise during the planning, development, and operation of transportation projects.

### [www.environment.transportation.org/teri\\_database](http://www.environment.transportation.org/teri_database)

This website contains the Transportation and Environmental Research Ideas (TERI) database. TERI is the AASHTO Standing Committee on Environment's central storehouse for tracking and sharing new transportation and environmental research ideas. Suggestions for new ideas are welcome from practitioners across the transportation and environmental community.

## Sustainability

### **NEW** <http://sustainablehighways.org>

The Federal Highway Administration has launched a new Internet-based resource designed to help state and local transportation agencies incorporate sustainability best practices into highway and other roadway projects. The Sustainable Highways Self-Evaluation Tool, currently available in beta form, is a collection of best practices that agencies can use to self-evaluate the performance of their projects and programs to determine a sustainability score in three categories: system planning, project development, and operations and maintenance.

## Bridge Technology

### [www.aspirebridge.org](http://www.aspirebridge.org)

Previous issues of *ASPIRE*<sup>TM</sup> are available as pdf files and may be downloaded as a full issue or individual articles. Information is available about subscriptions, advertising, and sponsors. You may also complete a reader survey to provide us with your impressions about *ASPIRE*. It takes less than 5 minutes to complete.

### [www.nationalconcretebridge.org](http://www.nationalconcretebridge.org)

The National Concrete Bridge Council (NCBC) website provides information to promote quality in concrete bridge construction as well as links to the publications of its members.

### [www.hpcbridgeviews.org](http://www.hpcbridgeviews.org)

This website contains 65 issues of *HPC Bridge Views*, an electronic newsletter published jointly by the FHWA and the NCBC to provide relevant, reliable information on all aspects of high-performance concrete in bridges. Sign up at this website for a free subscription.

### **NEW** <http://fhwa.adobeconnect.com/n134083201011>

If you missed the NHI Innovations and Highways for LIFE webinar on Ultra-High-Performance Concrete, it is now available for viewing on this website.

### [www.wsdot.wa.gov/eesc/bridge/ABC/](http://www.wsdot.wa.gov/eesc/bridge/ABC/)

Visit this Washington State DOT website to learn more about the state's accelerated bridge program and available resources.

### <http://international.fhwa.dot.gov/pubs/pl10014/pl10014.pdf>

The U.S. Federal Highway Administration's Office of International Programs has released a report titled *Assuring Bridge Safety and Serviceability in Europe*. The report describes a scanning study of Europe that focused on identifying best practices and processes designed to help assure bridge safety and serviceability. The scan team gathered information on safety and serviceability practices and technologies related to design, construction, and operations of bridges. A summary of the study was provided in *ASPIRE* Winter 2010, page 50.

### [www.tsp2.org/bridge](http://www.tsp2.org/bridge)

This website was developed to provide highway agencies and bridge preservation practitioners with on-line resources about bridge preservation, maintenance, and inspection.

## Bridge Research

### [www.trb.org/CRP/NCHRP/NCHRPprojects.asp](http://www.trb.org/CRP/NCHRP/NCHRPprojects.asp)

This website provides a list of all National Cooperative Highway Research Program (NCHRP) projects since 1989 and their current status. Research Field 12—Bridges generally lists projects related to bridges although projects related to concrete materials performance may be listed in Research Field 18—Concrete Materials.

### [www.utexas.edu/research/ctr/pdf\\_reports/0\\_5706\\_1.pdf](http://www.utexas.edu/research/ctr/pdf_reports/0_5706_1.pdf)

The Center for Transportation Research of the University of Texas at Austin has released a research report titled *Impact of Overhang Construction on Girder Design*. The research included field monitoring, laboratory testing, and parametric analyses. The report includes recommendations for prestressed concrete girder systems.



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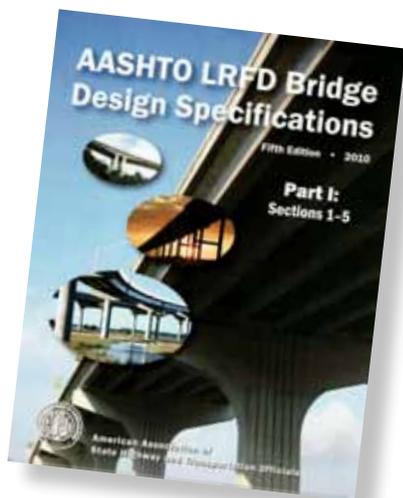


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# 2011 Interim Revisions Related to Concrete Structures



by Dr. Dennis R. Mertz



**Agenda Item 23** deleted provisions and commentary from Article 5.12.2 relative to aggregates that are known to be excessively alkali-silica reactive (ASR). These provisions and the commentary related to the testing of aggregates for ASR were deemed more appropriate for the *AASHTO LRFD Bridge Construction Specifications*. Appropriate reference was made to the Construction Specifications.

As a companion to Agenda Item 23, **Agenda Item 31** was approved in conjunction with SCOBs Technical Committee T-4, Construction. Through this agenda item, the provisions deleted from the *LRFD Bridge Design Specifications* in Agenda Item 23 were revised, updated, and inserted into the *LRFD Bridge Construction Specifications*.

These and the complete set of 2011 Interim Revisions to the *AASHTO LRFD Bridge Design Specifications* will be published in 2011 by AASHTO.

## EDITOR'S NOTE

*If you would like to have a specific provision of the AASHTO LRFD Bridge Design Specifications explained in this series of articles, please contact us at [www.aspirebridge.org](http://www.aspirebridge.org).*

The Fifth Edition of the *AASHTO LRFD Bridge Design Specifications* was published in 2010. It was subsequently revised when the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Bridges and Structures (SCOBs) considered and adopted changes at their annual meeting in Sacramento, Calif., in May of 2010. Technical Committee T-10, Concrete Design, developed Agenda Items 22, 23, and 31 over the past several years and moved them to the full subcommittee ballot during this meeting. These revisions are described in this article.

**Agenda Item 22** adds provisions to Article 5.11.5.2.1 for lap splices of reinforcement. Based on research published in the Washington State Department of Transportation (WSDOT) Transportation Center (TRAC) Report WA-RD 417.1, titled "Noncontact Lap Splices in Bridge Column-Shaft Connections," an equation was added to limit the spacing of transverse reinforcement in the splice zone of such shafts. The provisions are for columns with longitudinal reinforcement that anchors into oversized drilled shafts, where the bars are spliced by noncontact lap splices, and the longitudinal column and shaft reinforcement are spaced farther apart transversely than one-fifth the required lap splice length or 6 in.

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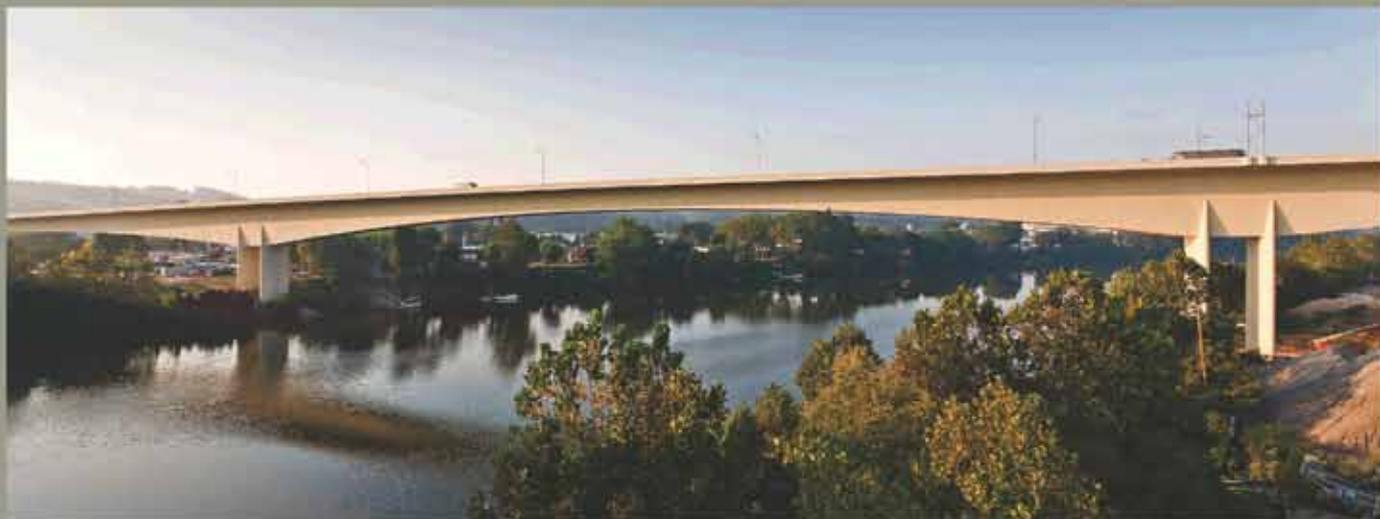
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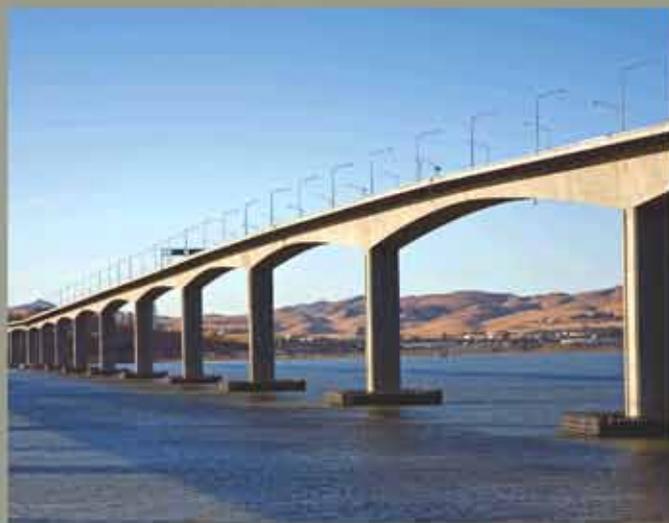
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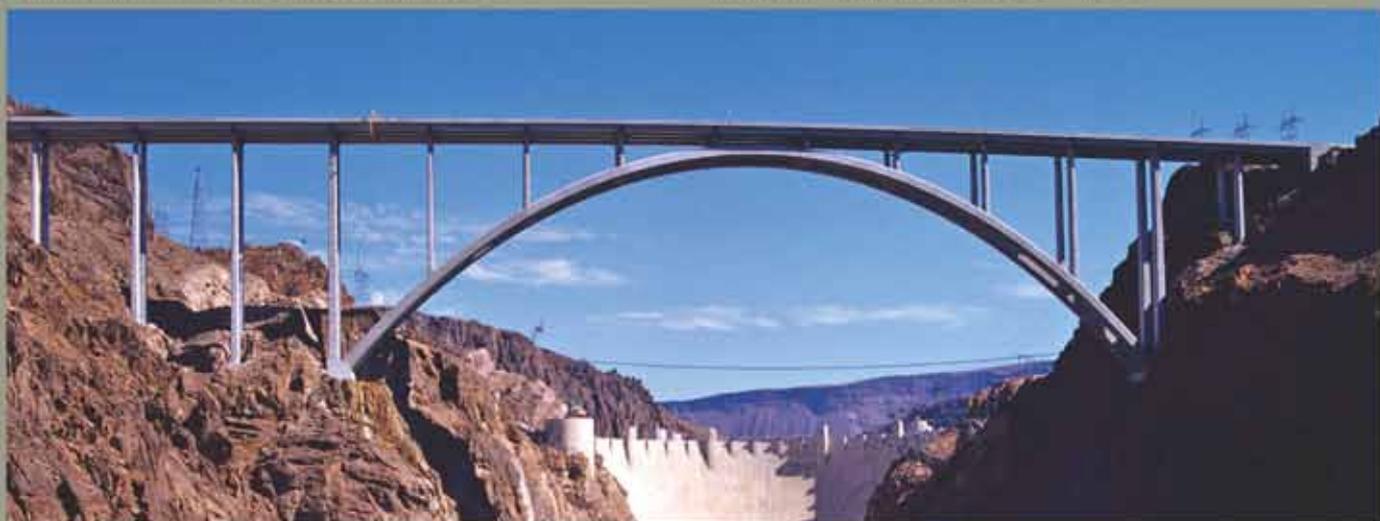
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San Francisco-Oakland Bay Bridge, Oakland, CA



New Benicia-Martinez Bridge, Benicia, CA



Hoover Dam Bypass/Mike O'Callaghan-Pot Tillman Memorial Bridge, Clark County, NV and Mohave County, AZ

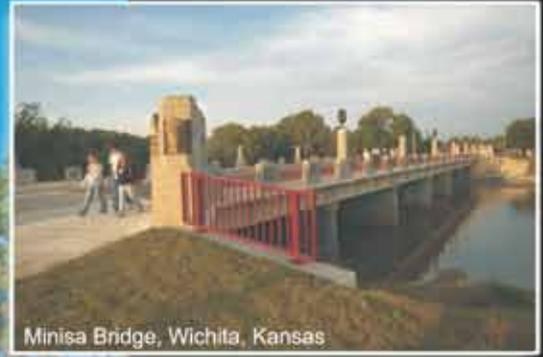
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