

ASPIRE™

THE CONCRETE BRIDGE MAGAZINE

Summer 2010

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Indian River Inlet Bridge

Sussex County, Delaware

BELLEAIR BEACH CAUSEWAY

Pinellas County, Florida

KEALAKAH STREAM BRIDGE

North Hilo, Hawaii

ROUTE 36 HIGHLANDS BRIDGE

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I-76 Allegheny River Bridge, Pittsburgh, Pennsylvania

The I-76 Allegheny River Bridge near Pittsburgh features Pennsylvania's longest concrete segmental span. The twin 2,350' long environment friendly bridges feature long spans of 285', 380', 380', 444', 532', and 329' built using balanced cantilever construction over the river, rail tracks and local roads. Curved piers and stone texturing are in harmony with the landscape. The final segment was placed in May 2010 and completion of the project is scheduled for later this year.

Owner: Pennsylvania Turnpike Commission
Designer: FIGG
Contractor: Walsh Construction Company

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4th Street Bridge, Pueblo, Colorado

The 4th Street Bridge in Pueblo features Colorado's longest highway span at 378'. The sustainable bridge crosses 28 sets of heavy rail tracks in the Pueblo Rail Yard and the Arkansas River using balanced cantilever construction. Aesthetics selected by the community blend contemporary lines with the natural environment and elements of Pueblo heritage. The first of the twin 1,137' long bridges opened to traffic in April 2010, and completion of the project is expected in Spring 2011.

Owner: Colorado Department of Transportation
Designer: FIGG
Contractor: Flatiron

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Social, Economic, and Ecological Benefits of Sustainable Concrete Bridges



8

Photo: Danya-Cebus Ltd.



12

Photo: CH2M Hill.



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Photo: T.Y. Lin International.

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Photo: Skanska USA Civil Southeast Inc.

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Concrete Bridge Preservation

John S. Dick, *Executive Editor*

Photo: Ted Lacey Photography.

In this issue of *ASPIRE*[™], we introduce a new feature devoted to the preservation of concrete bridges. It begins on page 44.

ASPIRE features innovative design and construction projects that largely define the state of the art. In the area of preservation, we are seeing new methods, materials, and tools that are extending the useful lives of concrete bridges significantly. We will be highlighting examples, written by the practitioners, to help our readers become aware of the art and science of concrete bridge preservation.

The topic has many facets. Preservation begins in design with the selection of high-performance materials, the use of details that are durable and readily constructable, and the requirements for certified personnel, companies, and processes. These all lead to the creation of bridges considered sustainable and destined to outperform and outlive even optimistic expectations. Examples of how longevity is designed into projects can be found in most every featured project in *ASPIRE*. Highlighting sustainability continues to be our key objective.

The preservation of existing bridges extends to preventative maintenance, repair, and rehabilitation. In this issue, beginning on page 44, Paul Krauss, John Lawler, and Kimberly Steiner report on the results of a study conducted for the National Cooperative Highway Research Program to develop a methodology for selecting bridge deck treatments for different bridge deck conditions and deck materials. On page 47, Larry Olson and Yajai Tinkey report on new technology to assess the condition of concrete such as in decks and the detection of voids in post-tensioning ducts. They report on equipment now available to remotely measure the deflection of a structure during load tests.

The Louisiana Department of Transportation and Development (LADOTD) believes that an aggressive

and strong preventive maintenance program is needed to slow the deterioration of its bridges. And so, in 2006, LADOTD initiated the Bridge Preventive Maintenance Program to help extend bridge service lives. On page 46, Danny Tullier, program manager, explains the nature of the program and provides some examples.

In our county feature (see page 55), Thomas Menke and Peter Yauch of Pinellas County, Fla., describe the use of concrete for their bridges and introduce the Bridge/Asset Management and Preventative Maintenance programs designed to preserve their structures.

Craig Finley, in our FOCUS feature on FINLEY Engineering Group, beginning on page 8, concurs that, "...preservation work...is an exacting area that has a lot of potential, because there are new materials being used that will last much longer." One of those new materials is ultra-high-performance concrete (UHPC) that may end concrete maintenance as we know it today. Ultra-strong and ultra-durable, UHPC is being researched and tested by the Federal Highway Administration. The article on that work by Myint Lwin and Ben Graybeal begins on page 50.

The articles about concrete bridge preservation and those describing the interesting projects being built throughout the country, are but a glimpse of the innovative ways concrete is being used to sustain the nation's infrastructure. We endeavor to continue to bring you the best and most innovative projects in every issue of *ASPIRE*! We hope you enjoy and benefit from their presentation. Be sure to tell us about your projects. It's easy to drop us a line from www.aspirebridge.org. You can also help by completing a brief survey there that will give us guidance about *ASPIRE*. All previous issues of *ASPIRE* can be viewed or downloaded from the website.

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Cover

Indian River Inlet Bridge, Sussex County, Delaware

Photo: Skanska USA Civil Southeast Inc.



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PHOTO OF ROUTE 70 OVER MANASQUAN RIVER IN NEW JERSEY (PHOTO COURTESY ARORA ASSOCIATES).

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READER RESPONSE



Editor,

I have been very impressed with the quality of the content in your magazine and the variety of the projects featured. Keep up the good work.

Greg Redmond
AVAR Construction Systems
Fremont, Calif.

Editor,

I saw the Oregon article (Concrete Bridges in Oregon, Spring 2010, pages 48-50) and it turned out well. Thanks very much for the opportunity to write it.

Ray Bottenberg
Oregon Department of Transportation Bridge
Preservation
Salem, Ore.

Editor,

The article, SH58 Ramp A Flyover Bridge (ASPIRE™ Spring 2010, pages. 28-31) contains an error in the project profile. DSI executed the longitudinal post-tensioning, not VSL. The post-tensioning was both at the Encon Bridge fabrication yard for the girders as well as on site for the spliced frames. Other than that, thank you for the credits in this issue.

Ron Giesel
DYWIDAG-Systems International USA Inc.
Long Beach, Calif.

[Editor's Reply]

Mr. Giesel...

We apologize for the error. This information was checked with a usually reliable source. Turns out, DSI was involved in four of the six articles in that issue.

Editor,

Thanks for the additional copies of the Spring 2010 issue of ASPIRE. It was a real pleasure working with your staff on the Eluba Bridge article (Batling the Terrain, pages 24-26). ASPIRE continues to be a great resource for both newcomers and the more experienced members of the community. I appreciate the well-rounded approach that covers different construction methods and latest updates on technical issues. I found out about your magazine about a year ago and immediately downloaded all the past issues. Any plans for a switch to a monthly publication rather than quarterly? I'd like to see more of the same, but more often!

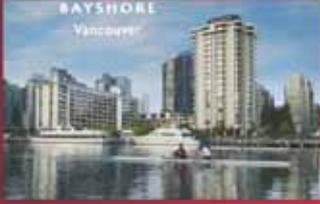
Scott Nelson
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Sumner, Wash.

EDITOR'S NOTE

Additional copies of *ASPIRE* may be purchased for a nominal price by writing to the Editor through "Contact Us" at the *ASPIRE* website, www.aspirebridge.org. A free subscription can be arranged there using the "Subscribe" tab.

The advertisement for PBS&J's 50th anniversary is a vertical rectangular graphic. At the top, it lists 'Engineering | Construction | Environmental | Architecture'. Below this is the PBS&J logo, which includes the letters 'PBS&J' in a stylized font and a circular emblem with '50th ANNIVERSARY' around it. To the right of the logo, the text reads 'SERVING TODAY'S NEEDS, SHAPING TOMORROW'S WORLD' in large, bold, white letters, with 'improving life for generations™' in a smaller, cursive font below it. The bottom half of the ad features two images: on the left, a photograph of a bridge over a river; on the right, an aerial photograph of a complex highway interchange. At the very bottom, it says 'Offices throughout the US • pbsj.com • 800.477.7275'.

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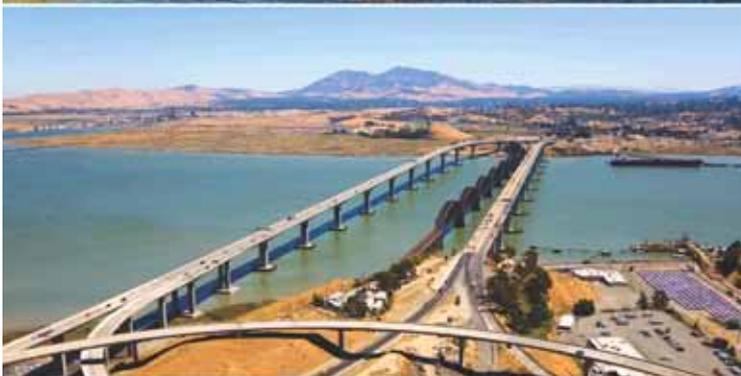
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M. Myint Lwin is director of the FHWA Office of Bridge Technology in Washington, D.C. He is responsible for the National Highway Bridge Program direction, policy, and guidance, including bridge technology development, deployment and education, and the National Bridge Inventory and Inspection Standards.



Dr. Benjamin A. Graybeal is a research structural engineer at the Federal Highway Administration's Turner-Fairbank Highway Research Center in McLean, Va., where he manages the FHWA UHPC research program.



Joseph Showers is the chief bridge engineer at CH2M HILL and has more than 28 years of experience designing bridges throughout North America. He received his masters degree in civil engineering and a masters degree in architecture from Virginia Polytechnic Institute.



Jeralee L. Anderson is pursuing her doctorate at the University of Washington with a research focus in sustainability applications. Previously, she worked in California in a variety of structural, geotechnical, and construction engineering positions



Frederick Gottmoeller is an engineer and architect, who specializes in the aesthetic aspects of bridges and highways. He is the author of *Bridgescape*, a reference book on aesthetics and was deputy administrator of the Maryland State Highway Administration.

MANAGING TECHNICAL EDITOR



Dr. Henry G. Russell is an engineering consultant, who has been involved with the applications of concrete in bridges for over 35 years and has published many papers on the applications of high-performance concrete.

Photo: Ted Lacey
Photography.

CONCRETE CALENDAR 2010/2011

For links to websites, email addresses, or telephone numbers for these events, go to www.aspirebridge.org.

July 11-15, 2010

Fifth International Conference on Bridge Maintenance, Safety and Management

International Association for Bridge Maintenance and Safety (IABMAS)
Loews Philadelphia Hotel, Philadelphia, Pa.

August 5-6, 2010

2010 Bridge Professors Seminar
Portland Cement Association, Skokie, Ill.
Basile Rabbat, PCA

August 16-20, 2010

NDE/NDT for Highways and Bridges: Structural Materials Technology 2010
LaGuardia Airport Marriott, New York, N.Y.

September 7-10, 2010

PCI Quality Control & Assurance Schools, Levels I, II & III
Chicago O'Hare Four Points Sheraton, Schiller Park, Ill.

September 23-26, 2010

PCI Committee Days and Membership Conference
Westin Michigan Avenue, Chicago, Ill.

October 11-12, 2010

2010 ASBI 22nd Annual Convention
The Westin Bayshore, Vancouver, British Columbia, Canada

October 24-28, 2010

ACI Fall Convention
The Westin Convention Center, Pittsburgh, Pa.

December 1-3, 2010

TRB-FHWA 7th International Bridge Engineering Conference Improving Reliability and Safety
Grand Hyatt, San Antonio, Tex.

January 23-27, 2011

90th Annual Transportation Research Board Annual Meeting
Marriott Wardman Park, Omni Shoreham, and Hilton Washington, Washington, D.C.

April 3-7, 2011

ACI Spring Convention
Marriott Tampa Waterside and Westin Harbor Island, Tampa, Fla.

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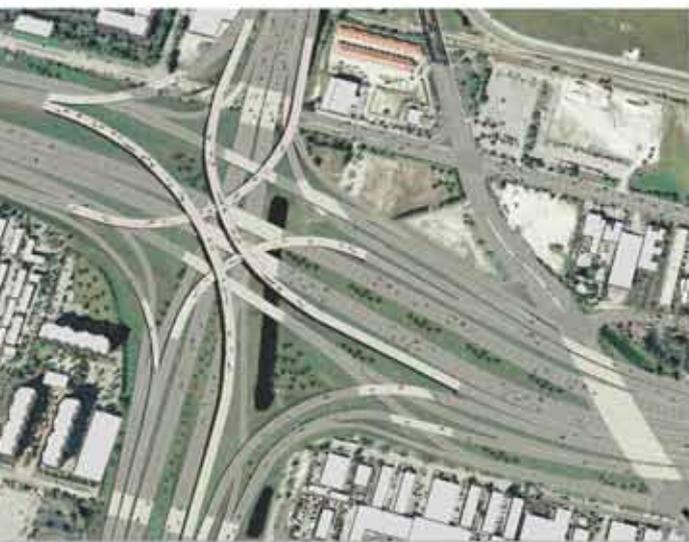


Palmetto Section 5 – SR-826 (Palmetto Expressway) / SR-836 (Dolphin Expressway) Interchange, Miami, Florida

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Section 5 – SR-826/SR-836 Interchange, Miami, Florida

FINLEY is designing and providing the construction engineering on four high-level segmental bridge ramps that traverse the core of the interchange for this \$558 million design-build-finance project. The segmental bridge ramps will be precast, balanced cantilever and erected with a launching gantry by DEAL/Rizzani De Eccher USA. The design offers unique challenges integrating underlying roadways, canals and MOT requirements into the layout of these segmental bridge ramps. FINLEY is working with BCC Engineering, Inc, the lead design firm and the joint venture of Community Asphalt Corporation, Condotte America, Inc and The de Moya Group, Inc.

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Blending Design and Construction

by Craig A. Shutt

FINLEY served as the primary engineering-design firm for Saddlebrook Construction Inc., which builds bridges for The Cliff Communities, a series of high-end residential communities in the Carolinas. The bridges consist of precast, prestressed concrete voided slabs transversely post-tensioned, with spans ranging from 25 ft to 60 ft.

Photo: Saddlebrook Construction Inc.

FINLEY Engineering has grown rapidly by blending bridge design and construction needs into a successful whole

Only 6 years old, FINLEY Engineering Group Inc. has experienced rapid success both nationally and internationally with a wide range of bridge projects. The key to its success, Managing Principal Craig Finley says, comes from blending bridge design skills and construction engineering to maximize constructability.

That approach has helped the Tallahassee, Fla.-based firm grow from one employee when it opened its doors in late 2004 to 30 employees today. The company has experienced 30% to 70% annual growth since then, and this year anticipates growing by another 80%. "We have the backlog of projects to make that happen," Finley says. "The only thing hampering us is finding good people."

Even that challenge will be eased by the company's reputation, which saw it named one of the nation's 25 Best Structural Engineering Firms to Work For in 2008 by *Structural Engineer* magazine.

The company got started after Finley resigned as head of the Bridge & Tunnel Division of Parsons Corp. The firm in 2001 had acquired Finley McNary Engineers, which Finley co-founded. "I had always wondered what it would be like to work for a mega-sized,

engineering-contracting firm," he explains. "We had a lot of successes during my time there. One day I'd do engineering work, the next day contracting work, and every day was exciting."

50 Projects in 50 Months

But he spent more time on traveling and paperwork than engineering and projects. "I missed being involved in innovative bridge work that coupled design and construction." That hasn't been a concern since, as FINLEY's client list quickly grew, along with its staff. In 2005, the firm added Jacques Combault as technical director; Cheryl R. Martin joined in 2005 as principal in charge of finance and administration, and Jerry M. Pfunter came aboard in 2007 as principal senior bridge engineer and assistant technical director. In its first 50 months, FINLEY was involved in the design and construction engineering on 50 bridge projects.

"The biggest benefit we offer clients is a combination of strong engineering skills with a technology background, which creates a practical approach to construction," Finley explains. "When we start to design a bridge, a key element is how it can be constructed faster and more efficiently. We have

the ability to work with both designers and contractors to adapt a bridge design so that potential construction issues are identified and addressed early in the process. To add value, we believe all bridge designs must identify and address these critical engineering requirements."

The firm rarely performs traditional construction engineering work, he stresses. "The typical impression is that a construction engineer provides the means and methods, or the procedures, for how the bridge will be constructed," he explains. "We try to incorporate the contractor's means and methods into the design. It requires a higher level of understanding of the construction process than that usually done by bridge engineers."

An example is the I-64 Kanawha River Bridge in West Virginia. Completed this year, the project's 760-ft-long main span features the longest concrete box-girder span in the United States. Pfuntner, FINLEY'S lead bridge engineer on the project, provided technical support and construction engineering consulting during the prebid phase and then supplied full construction engineering services during construction. The services included modifying plan details to improve constructability, design assistance, and preparing the construction analysis, construction manual, geometry-control manual, and working drawings. For more on the project, see the article in the Winter 2009 issue of *ASPIRE*.™

Design-Build Plays to Strengths

The rise of design-build projects has played to the company's strengths, Finley notes. "The change in procurement to favor design-build delivery systems allows owners to take advantage of contractors' unique skills, and our skills often complement the

'To add value, we believe all bridge designs must identify and address these critical engineering requirements.'



The Palmetto and Dolphin Expressway (SR 826/836) infrastructure project in Dade County, Fla., includes four high-level segmental bridge ramps constructed in the balanced cantilever method. The project includes a total of 46 bridges. Rendering: Touchstone Architecture.

contractor's own." About 80% of the company's projects are contractor-led, which includes design-build projects and aiding with a value-engineering idea proposed by the contractor.

The company is doing more work with bridge owners, including state DOTs. "Owners are seeing the value of moving projects ahead more quickly and addressing the means and methods early in development. Some of our work with DOTs involves preliminary studies that are pure design or cost estimating."

One early analysis occurred with a 280-ft-long approachway bridge and two accessway bridges (485 ft and 487 ft long) in the Delaware River for the new Conoco Phillips ship dock near their refinery in Trainer, Pa. Working with Hudson Construction Consultants, FINLEY provided conceptual, preliminary and final design work, analyzing three superstructure alternatives (structural steel beams, precast concrete beams, and precast segmental sections). The design-build project was designed with prestressed concrete beams, a precast

FINLEY served as construction engineering consultant on the I-64 Bridge over Kanawha River in Kanawha County, W.Va. The bridge features the longest concrete box-girder span in the United States at 760 ft, plus 460-ft and 540-ft side spans and five approach spans. Five piers are situated on land and two on the river's edge. Photo: Brayman Construction Corporation.





The new ship dock at Conoco Phillips' facility in Trainer, Pa., features a 280-ft-long approachway bridge with typical spans of 45 ft, two accessway bridges with lengths of 485 ft and 487 ft, and typical spans of 60 ft. The bridges, for which FINLEY served as engineer of record and provided conceptual studies and alternatives, feature precast, prestressed concrete beams and a precast concrete deck. Photo: Hudson Construction Consultants.

concrete deck, and constructed on a tight timeframe.

In addition to constructability and the speed of construction that is inherent in that goal, owners are looking for aesthetics and durability in their bridges today. The aesthetic designs that FINLEY provides can be seen in the scenic bridges created for The Cliffs Communities, a series of high-end residential developments in North and South Carolina. The bridges, ranging in span lengths from 25 ft to 60 ft, feature precast, prestressed concrete voided slabs transversely post-tensioned. Aesthetic details include rock veneer facing on all barriers, natural preservation of creek beds, and an arched stone façade with matching lighted end posts.

Added Durability Needed

Durability, especially minimizing cracks and crack widths, also is a key goal. Service life is a very important issue to owners. They want to boost service life from 50 years to 75 and even to 100 years. An example of the durability being achieved is apparent in the Indian

River Inlet Bridge in Delaware Seashore State Park in Sussex County, Del. FINLEY provided construction engineering and the erection equipment design for Skanska USA Civil Southeast Inc. The 2600-ft-long cable-stayed bridge features a 900-ft-long clear span over the inlet and 1700 ft of bridge decking over land.

The bridge will have a minimum 100-year service life, achieved in part with the help of maintenance procedures that include extensive corrosion analysis and a corrosion control plan. A "zero tension" requirement for all members both during construction and for the completed bridge supports the 100-year service life.

International Success

FINLEY has had significant success overseas, with work in the Middle East and Africa. It has completed three projects, comprising 16 precast segmental bridges, in Israel alone.

These include the Benyamina Bridges, composed of eight spans of short line, match-cast precast concrete segmental girders erected in balanced cantilever. The firm also worked on Road 431, a portion of the Cross Israel Highway that comprises four precast concrete segmental box-girder bridges.

"Israel is very developed in its use of concrete materials and techniques," he says. "American concrete technology is easily transportable for companies that work closely with American firms. The United States does a good job of being a leader in the world for concrete bridge designs."

FINLEY also is pursuing opportunities in South America. "Some say that North American bridge professionals need to

'We're very interested in preservation work. It's an exacting area, and it has a lot of potential.'

The 2600-ft-long Indian River Inlet Bridge in Sussex County, Del., was designed to achieve a 100-year service life with the help of a detailed evaluation of several aspects, including a latex-modified concrete overlay, low permeability concrete, and epoxy-coated reinforcement. Pretensioned and post-tensioned precast concrete transverse deck beams span between the cast-in-place concrete edge girders. Photo: Skanska USA Civil Southeast Inc.



'Owners are seeing the value of moving projects ahead more quickly and addressing the means and methods early in development.'

either focus intensely on Canada and the United States or package our skill sets to work internationally. I think we're good at doing both, and we see a lot of potential, especially in the southern hemisphere," according to Finley.

The firm maintains a balance between North American and international clients. Several U.S. projects to start soon will tip that balance back after several years of international business dominating. "We're a small company, so it's easier for us to be successful with two or three projects in other parts of the world. We can adjust quickly to take on new projects."

The company's work in the United States is increasing, in part due to the American Recovery and Reinvestment Act (ARRA) of 2009. FINLEY is currently working on a \$36-million cast-in-place runway ramp at the Tampa International Airport that was one of the first ARRA projects approved. The 300-ft-long bridge features cast-in-place, post-tensioned, haunched box girders.

FINLEY is working with the joint venture of Community Asphalt Corporation, Condotte America Inc. and The de Moya Group Inc. on the \$558-million Palmetto and Dolphin Expressway (SR 826/836) infrastructure project in Dade County, Fla., an ARRA-funded project that will include four high-level segmental bridge ramps that traverse the interchange's core. The bridges vary from 1100 ft to 2540 ft long and from 46 ft to 48 ft wide. All of the bridges are supported on 24-in. square precast, prestressed concrete pile foundations and cast-in-place concrete piers and caps. The precast concrete segmental ramps will be constructed using the balanced cantilever method with a launching gantry by DEAL/Rizzani De Eccher USA. BCC Engineering is the lead designer for the project.

"A competitive economy helps our business," Finley notes. "Owners and contractors are interested in finding someone who can identify efficiencies or a better way to construct the project. Our business is stronger when the competition is tougher."

More of the firm's projects involve segmental construction. Finley continues, "We have a lot of background with segmental concrete projects, and the demands that owners are placing on bridges often lead in that direction. They want to fabricate bridges away from the site, minimize impact on traffic, and create long-term serviceability."

Improvements in erection technology have aided this work. "The sophistication of equipment has changed rapidly. Launching gantries, travelers, heavy-duty cranes, all have really advanced quickly."

"We're very interested in preservation work. It's an exacting area, and it has a lot of potential, because there are new materials being used. The ability to come back to a project 20 years later and make some improvements represents a good market for us and is a growth area." Grouting specifications in particular have improved in recent years, he notes, and some of the segmental bridges that followed earlier guidelines have needed retrofitting with new materials that will last much longer.

With these growth areas targeted, the company is looking to open a second office on the West Coast, possibly in the Northwest, by September. "I think we're

missing an opportunity there without having an office that allows us to stay closer to our clients."

Achieving this goal will require adding new people, which should be aided by the *Structural Engineer* award. The firm follows an open-book management style, posting its financial results, and sharing a percentage of profits. "We're small enough that we can create a personal touch and work with each employee to create flexibility in hours and benefits that suit their needs. That approach helps everyone stay engaged and committed."

The key is to find employees who can embrace FINLEY's blend of bridge design engineering and construction engineering. It's a blend of art and science that requires more than the tactics of how to build a bridge.

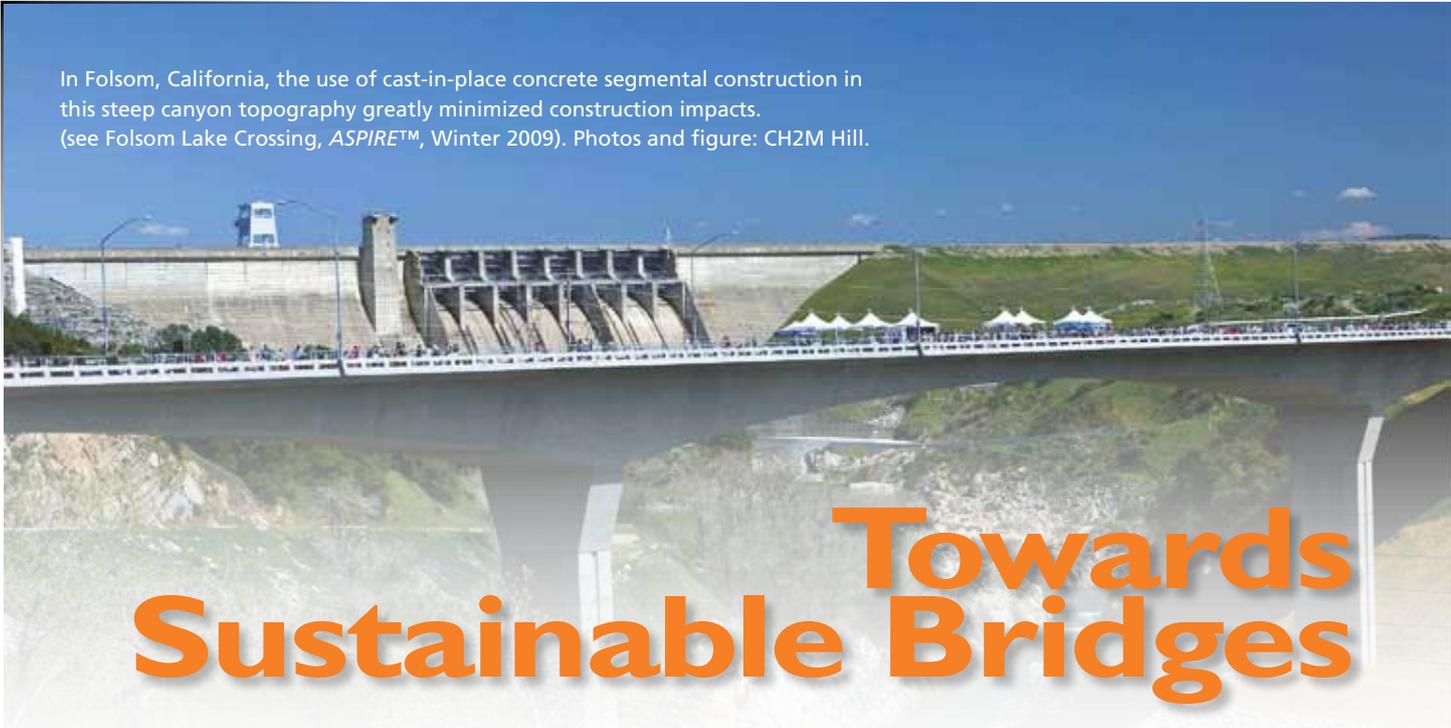
MORE ON FINLEY

For information on other project work by FINLEY Engineering Group, see the articles in ASPIRE magazine on the Lee Roy Selmon Crosstown Expressway (Fall 2007), South Fork Eel River Bridges (Confusion Hill Bridges) (Summer 2008), the Kanawha River Bridge (Winter 2009), and the 4th Street Bridge (Fall 2009). Issue archives can be found at www.aspirebridge.org.



FINLEY is providing construction engineering for the 4th Street Bridge in Pueblo, Colo., which is being built over 28 active railroad tracks. Photo: Robert Heavilin, Flatiron Constructors Inc.

In Folsom, California, the use of cast-in-place concrete segmental construction in this steep canyon topography greatly minimized construction impacts. (see Folsom Lake Crossing, *ASPIRE*[™], Winter 2009). Photos and figure: CH2M Hill.



Towards Sustainable Bridges



by Jeralee L. Anderson,
University of Washington
and Joe Showers, CH2M Hill

Bridges are a critical component of our national highway infrastructure. The phenomenal replacement cost of our aging national inventory of approximately 600,000 highway bridges is estimated to be on the order of one trillion dollars. These structures, which are the backbone of our national highway system, have seen increased traffic volumes and environmental exposures that were not imagined during their original design and many have surpassed their expected service lives. As a result, approximately one quarter of the national bridge inventory is currently classified as “structurally deficient” or “functionally obsolete.” The increasing backlog of deficient bridges raises the daunting prospect of a major ongoing bridge repair, reconstruction, and replacement program that could extend far into the future. Faced with this problem, it is clear that the strategies of meeting lowest initial construction cost and only

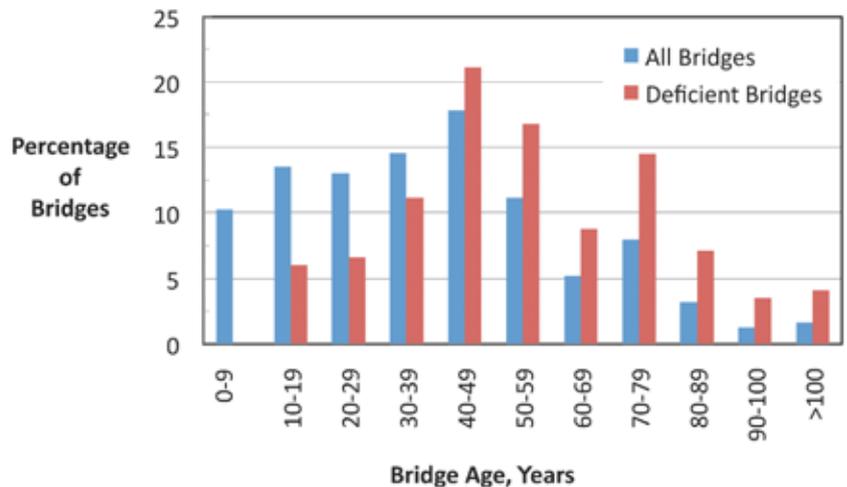
addressing operational requirements may no longer be the best approach for constructing a sustainable bridge infrastructure that will be a legacy we leave for subsequent generations.

Current bridge design and construction practice has evolved over time in response to many different challenges and changing standards, and the incorporation of new sustainability principles in practice will see a similar process. Unfortunately, there are no “silver bullets” to address contemporary issues like lack of project financing, increasing cost of energy, and limited key resources. These are complex

problems that will result in an evolution in how we design, build, and operate bridges. So what can we do now to develop a sustainable bridge infrastructure?

Strategies for Change

The good news is that sustainability is not difficult to implement. Many strategies exist that, when combined, can effectively and successfully achieve a more sustainable bridge as an end product. Approaching bridge design and construction with a different angle—one that uses a holistic (systems-thinking) perspective—can do more for the environment and society than simply



Percentages of the bridge inventory in the United States that fall within various age categories.

designing to meet basic functional criteria and environmental compliance.

Importantly, a life-cycle perspective must be used in the selection of materials, design details, and to define service life, maintenance criteria, and end-of-life requirements for every bridge. This can be done by using service life prediction models, life-cycle cost software, life-cycle assessment tools, and sustainability metrics like "Greenroads." These decision-making tools can evaluate environmental impacts upstream and downstream in the materials supply chain and analyze long-term, life-cycle costs.

For example, much of our domestic steel reinforcement production uses recycled scrap as opposed to virgin materials. There are also numerous opportunities to recycle concrete aggregates and other common construction materials. A life-cycle assessment would indicate that these recycled material choices have several sustainability benefits, including reduced energy consumption and the overall construction environmental footprint for water and air emissions. A life-cycle cost analysis would also show that these choices would likely reduce long-term costs as well. Life-cycle-based thinking offers a broader perspective that is based on thinking in terms of larger systems, and is better able to address more complex interrelationships than focused, reductionist design of parts and components of the bridge alone.

More than Recycling

Note that sustainability is more than simply recycling. There are many opportunities for bridge designers to minimize use of non-renewable energy in the design and construction process. For instance, considering implications for traffic delays and on-site equipment usage can ultimately reduce driver fuel costs, delays, contractor fuel costs, and worker exposure to unhealthy emissions. Similarly, alternative or rapid construction methods can also save time and emissions. On-site fuels could even be replaced with biofuels or hybrid equipment engines.

Also, different approaches such as adaptive bridge design, design for deconstruction, or some structure reuse strategies can help preempt costly



For the Fort Edmonton Footbridge in Edmonton, Alberta, Canada, a post-tensioned, precast segmental concrete deck system was selected for the suspended superstructure, to minimize field erection time and to provide for improved construction quality and long-term durability.

problems and rehabilitations due to natural hazards, climate change, and human behavior. Vehicle technology and transportation modal access can vary over the anticipated bridge life span. Providing the flexibility to accommodate changes in load capacity or deck geometry, pedestrian or bicycle traffic, or transit services is often an effective sustainable solution that also provides a robust, socially useful, and beneficial bridge. Additionally, designers can minimize long-term construction footprint impacts by considering the use of longer spans or more compact foundation systems, reusing original bridge footings for replacement projects, including prefabricated elements that are easy to deconstruct, or even building abutments that can be used for multiple types of bridges.

Additional Key Components

Two key components of more sustainable bridge construction practice are quality control and long-term performance monitoring. High, yet achievable, quality standards for bridge contractors provide the public stakeholders and owner-agencies insurance for an extended service life, and minimized future maintenance and repair needs. Beyond initial construction, though, performance should continue to be tracked regularly to preempt costly safety problems or catastrophic failures. There are a number of nondestructive testing technologies currently available that allow noninvasive investigation of bridge structural components. (see also "Advances in Nondestructive Evaluation and Structural Health Monitoring of Bridges," beginning on page 47).

Finally, think beyond satisfying only operational requirements. Humans are not the only end-users of the bridges. These large-scale structures can become habitat for and influence the behavior of other species beyond construction through their entire service life. Furthermore, bridges also have aesthetic and cultural value that extends beyond meeting functional needs. Bridges are among the most visually prominent objects within their surrounding environments and some of these structures will endure as an icon in their surrounding communities for future generations.

The Paradigm is Shifting

Decisions that we make today in managing our nation's 3.7 billion ft² bridge deck inventory have implications which extend far into the future. Sustainability is not difficult to manage, and the market is ripe for change. However, sustainability may challenge many of our basic ideas of what is a good and practical bridge design and encourages us to go beyond this existing knowledge. Often, it forces us to combine new and old ideas, or find innovative ways to make bridges better. This innovation starts with small choices made on everyday bridge projects by everyday bridge engineers and contractors. Ultimately, these choices will help shape bridge design, construction, and operation practice to be more sustainable for the benefit of ecosystems, economies, and people.

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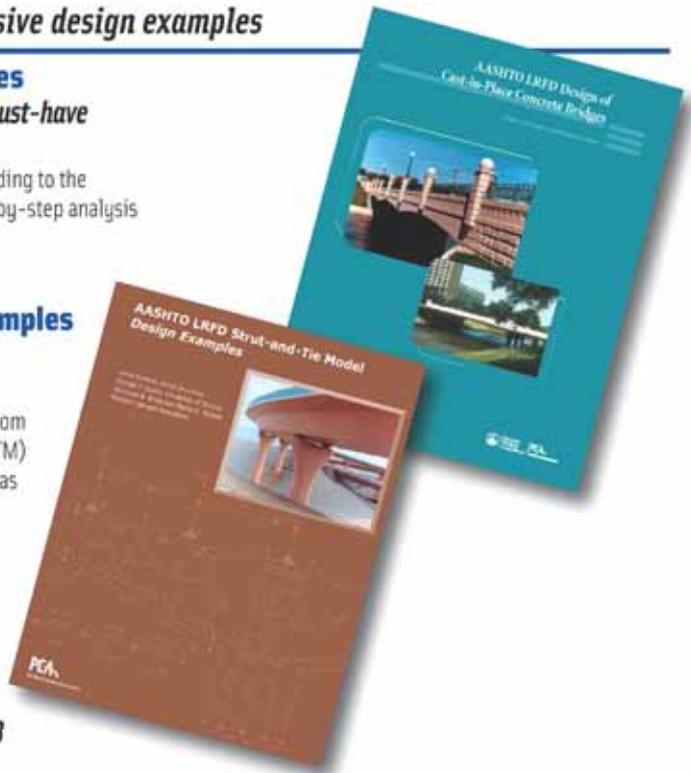
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PROJECT

BELLEAIR BEACH CAUSEWAY BRIDGE REPLACEMENT PROJECT

by Nelson E. Canjura, HDR Engineering, John Meagher, Johnson Bros./Misener Marine Joint Venture, and Antonio Hornik, Pinellas County Public Works Department

Incremental launching of long approach spans improves safety, reduces costs, and protects sensitive sea grass beds

The Belleair Beach Causeway provides an important link between the mainland and the beach communities of Belleair Beach, Belleair Shores, Sand Key, and North Indian Rocks Beach in Pinellas County, Fla. The causeway is a significant visual gateway for residents and visitors, provides recreational amenities, and most importantly, serves as a principal hurricane evacuation route for the barrier island.

Time and the elements had taken their toll on the causeway's two existing bridges, which were completed in 1950. A 324-ft-long, low-level bridge crossed the Relief Channel at the west end of the causeway, and a 1376-ft-long structure, including a double leaf bascule and approaches, crossed the navigable channel of the Intracoastal Waterway at the east end. Both were determined to have exceeded their original life expectancy. Maintenance and operating costs had steadily increased during the past decade due to deterioration of the concrete components and the bascule's structural steel components and machinery. In addition, the existing causeway bridges did not meet current design standards and were classified as "functionally obsolete."

A preliminary bridge type study led to selection of a low-level bridge crossing Clearwater Harbor to replace the Relief Channel bridge and a high-level bridge to

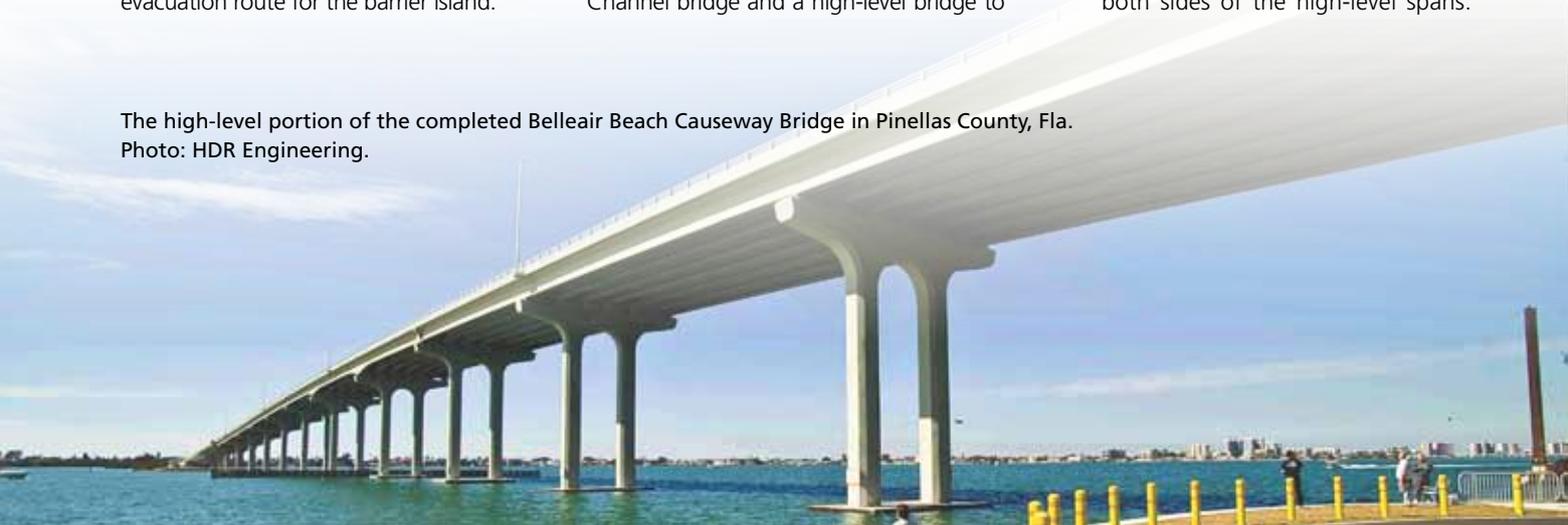
replace the Intracoastal Waterway bridge. Final design of the Belleair Causeway replacement bridges was completed in July 2006. Construction of the new replacement bridges started in March 2007 and the project was completed on December 20, 2009.

Incremental Launching of the Approach Spans

The new high-level bridge over the Intracoastal Waterway is 3350-ft long and can be subdivided into the following units:

- High-level spans—These spans consist of a 530-ft-long, three-span continuous structure over the navigational channel with 750-ft-long, five-span continuous units on each side.
- East and west approach spans—These spans consist of 660-ft-long, nine-span continuous structures on both sides of the high-level spans.

The high-level portion of the completed Belleair Beach Causeway Bridge in Pinellas County, Fla.
Photo: HDR Engineering.



profile

BELLEAIR BEACH CAUSEWAY BRIDGE REPLACEMENT / PINELLAS COUNTY, FLORIDA

BRIDGE DESIGN ENGINEER: HDR Engineering, Tampa, Fla.

PRIME CONTRACTOR: Johnson Bros./Misener Marine Joint Venture

PRECASTER FOR HIGH-LEVEL SPANS: Standard Concrete Products, Tampa, Fla., a PCI-certified producer

STEEL REINFORCEMENT: Gerdau Ameristeel, Tampa, Fla.

AWARDS: 2009 American Public Works Association Transportation Project of the Year—Branch, State & National Award Winner; Roads and Bridges Top Ten Bridge Project of 2010



Belleair Beach Causeway Corridor showing the two new bridges following completion.
Photo: E.C. Driver and Associates.

The vertical clearance requirements for the approach spans were governed by the need to provide a parking facility below the bridge that will accommodate boat trailers.

By far the most sensitive of the wetland resources present within the project limits was the vast seagrass communities that occur along both sides of the Belleair Causeway. While construction of the high-level spans over the Intracoastal Waterway was easily accessible by cranes on barges, the west approach span posed access issues due to the limited causeway width and seagrass beds along the bridge alignment.

The east and west approach spans were originally designed using the traditional cast-in-place concrete method; however, this method had the following disadvantages:

- Safety concerns with cast-in-place operations and post-tensioning (P-T) stressing performed up to 40 ft above ground level

- Higher cost of scaffolding erection and removal due to proximity to water and difficulty with construction access due to location within existing seagrass beds
- Settlement concerns due to high loads on the scaffolding
- Falsework system judged not cost effective

As an innovative method, the incremental launching technique was selected since it offered the following advantages:

- Improved safety with all operations (casting, P-T, etc.) at ground level
- No settlement issues during casting because the casting bed is supported on piles behind the abutment
- Minimized impacts to seagrass and mangrove communities
- Lower cost with value engineering providing a \$250,000 savings

The incremental launching construction method has achieved significant applications in Europe and Asia. However, only a few bridges in the United States have been constructed using this method. The Belleair Causeway Bridge is the first U.S. bridge constructed using the incremental launching approach for a superstructure consisting of post-tensioned concrete slabs.

Segments were cast and launched on a one-week cycle.

Launching System and Launching Sequences

The incremental launching system used for the Belleair Causeway project was developed by VSL. This system uses strand cables as the pulling elements. The jacking equipment—developed to exert up to 500 tons of pulling capacity—was positioned in front of

the end bents/abutments and pulled the launching post, which was fixed to the far end of the segment.

Prior to incremental launching of the approach spans, a launching pad was constructed behind the abutments and supported by 24-in.-diameter temporary steel pipe piles to eliminate settlement issues. Inverted-tee caps with polished stainless steel plates on top were placed on the pipe piles to form the launching pad support beams. Two additional concrete beams were placed between the launching beams to support the steel platform, which functions as the bottom soffit formwork for the P-T slab segment. Adjustable wood side forms were used for casting the wings of the segment.

Two 500-ton launching jacks with a stroke of about 10 in. were used in



The west approach showing launching pad, permanent and temporary piers, and access issues.
Photo: E.C. Driver and Associates.

SPLICED BULB-TEE GIRDER, PRECAST, PRESTRESSED GIRDER, AND INCREMENTALLY-LAUNCHED POST-TENSIONED CONCRETE SLAB BRIDGE / PINELLAS COUNTY PUBLIC WORKS, OWNER

POST-TENSIONING MATERIALS: VSL, Ft Lauderdale, Fla.

CONCRETE SUPPLIER: Florida Rock, Largo, Fla.

BRIDGE DESCRIPTION: A 3350-ft-long, high-level bridge with 75-ft vertical clearance at the navigation channel. Each 660-ft-long approach is a post-tensioned concrete slab launched incrementally; the 750-ft-long, five-span continuous units each side of navigation channel unit use Florida 78-in.-deep bulb-tees, and the 530-ft-long, three-span unit over the navigation channel uses post-tensioned, precast concrete spliced, haunched girders

BRIDGE CONSTRUCTION COST: \$72.2 million (incrementally-launched concrete slab bridge approximately \$120/ft²)

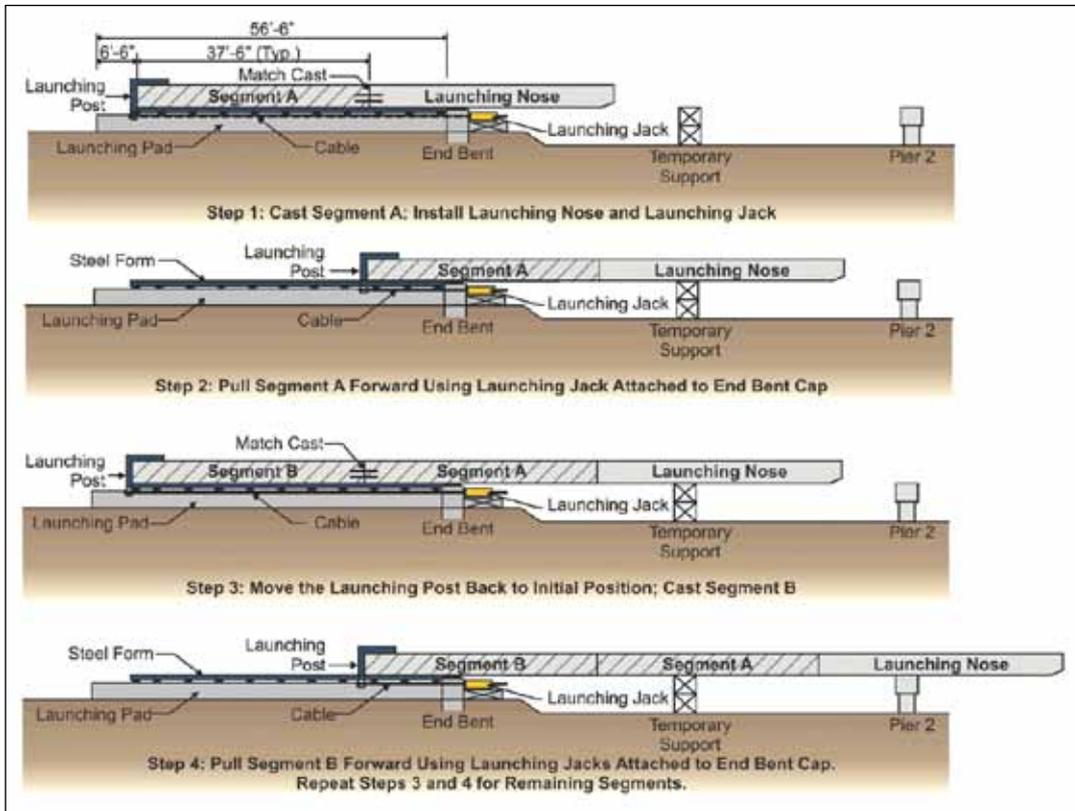


Illustration of facilities and launching sequence of the approach spans. Graphic: HDR Engineering.

front of the abutment. The jacks had a second set of wedges that held the strands and allowed the jacks to set up for a re-stroke. Depending on the section being launched, a complete launch took from 3 hours to 8 hours.

Each launching jack is connected to a launching post, which was fabricated utilizing W24x104 steel beams. Each launching post is located at the rear of each segment.

The launching nose was used to reduce the cantilever moments. The nose consisted of W36x230 sections, 50 grade steel, braced and connected by eight 1 3/8-in.-diameter P-T bars to the leading edge of the slab.

The final bridge span lengths are 75 ft with an end span of 60 ft;

however, temporary bents consisting of 2-ft-diameter steel pipe piles with a concrete cap were used to reduce the launching span to 37.5 ft. The launching nose is 24 ft long, approximately 60% of the launching span length. Compared to the slab section, the launching nose weight is approximately 5% of the equivalent slab length.

Temporary sliding bearings, consisting of 1/2-in.-thick reinforced neoprene with a Teflon coating, were used to allow the segments to slide over the stainless steel plates on top of the pier supports. The launching crews fed the temporary sliding bearings between the superstructure and the top of the steel plates during the launching. Lateral guides on the end bents and pier supports were installed to keep the



Launching jack in front of the abutment. Photo: E.C. Driver and Associates.



Launching pad before forms were installed. Photo: E.C. Driver and Associates.

Protecting the Environment

The Pinellas County Public Works Department has a long history of fostering environmental stewardship with respect to public works projects throughout the county (see article on Pinellas County on page 55). A prime example of this high regard towards the environment is the Belleair Beach Causeway Bridge Replacement project. A primary focus of the design and construction of the project was the protection of sensitive environmental features and endangered animal species. The decision to use incremental launching of the approaches by Johnson Bros./Misener Marine was based on maximizing safety within the limited access corridor and a commitment to minimize environmental impacts during construction. The method, while unique to the United States, showed that it can be a cost-effective means of construction while embracing improved construction quality, safety and a desire to protect the environment.



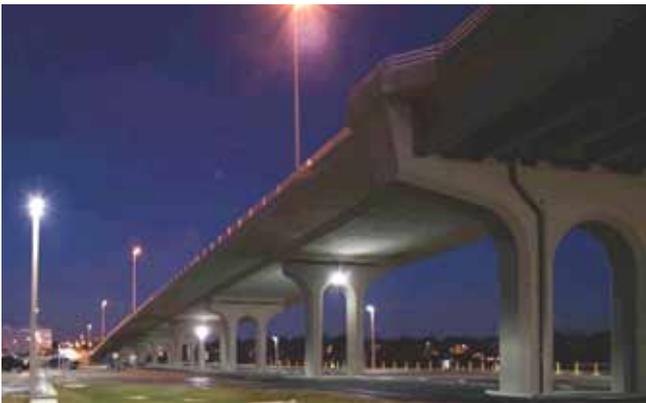
Launching nose at front of segment as it passes over a temporary pier and approaches a permanent pier. Photo: E.C. Driver and Associates.



Launching post at back end of segment. Photo: E.C. Driver and Associates.



Slab segments slide over pier supports. Photo: E.C. Driver and Associates.



View of the east approach slab from the boat ramp park below the bridge. Photo: HDR Engineering.



View of casting bed showing large number of post-tensioning ducts and ready for concrete placement. Photo: E.C. Driver and Associates.

segments moving in the desired direction as they were launched.

A 1/2-in. pedestal tolerance was accounted for in the launch longitudinally, with a 1-in. transverse tolerance at the pier.

The longitudinal P-T required for final conditions varied from 22 to 30 tendons. Transverse P-T was also required with tendons at 4.5 ft spacing.

Due to the requirements for concentric stresses required for incremental launching, temporary longitudinal P-T bars were provided for launching. The temporary P-T consisted of thirty-six to forty-eight 1 3/8-in.-diameter bars. These bars were only required during launching, and were not accounted for in the final capacity of the structure.

Finally, segments were cast and launched on a one-week cycle. Segments were formed and the reinforcement placed on Tuesday through Thursday and concrete placed on Friday. On the following Monday, transverse P-T tendons and longitudinal temporary P-T bars were stressed, the wood side forms were removed, and the new segment was launched.

Once the launching was completed, the temporary piers were removed and a secondary concrete placement was made at the pier's supports to enhance the appearance of the pedestals. The remaining bridge features, such as the traffic barriers, pedestrian railing, and the bridge lighting support platforms were added. Incrementally launching the approaches allowed the aesthetic

features of the bridge approaches to remain unchanged.

Nelson E. Canjura is vice president of HDR Engineering in Tampa, Fla., John Meagher is vice president of Johnson Bros./Misener Marine Joint Venture, Lithia, Fla., and Antonio Hornik is structures division engineer with Pinellas County Public Works Department in Clearwater, Fla.

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PROJECT

Kealakaha Stream Bridge Replacement

by David Fujiwara, Harold Hamada, and Eric Y. Matsumoto, KSF Inc., Gary Iwamoto, Hawaiian Dredging Construction Company Inc., and Ian N. Robertson, University of Hawaii

The completed bridge with existing structure in the background was opened to traffic on March 20, 2010. Photo: Glenn Koki, Hawaiian Dredging Construction Company Inc.

Cast-in-place and precast concrete combine to solve challenges at remote and beautiful construction site

Located on Hawaii Belt Road on the island of Hawaii, Kealakaha Stream Bridge traverses a 165-ft-deep and 610-ft-wide ravine. This structure is situated approximately 33 miles northwest of Hilo and provides for traffic traveling from Hilo to the northern part of the island.

Kealakaha Stream Bridge is a 720-ft-long, concrete bridge with a radius of curvature of 1800 ft, a 6.2% travel way superelevation, and a 3.46% vertical grade. The bridge has three spans—180 ft, 360 ft, and 180 ft. It is approximately 48 ft wide and

provides two 12-ft-wide travel lanes and two 10-ft-wide shoulders. Due to its close proximity to an active volcano, this bridge is subjected to high seismic activity. It was required to be designed for an acceleration of 0.4g.

Contract Plans

The original contract plans called for a three-span, single-cell box girder without a concrete overlay and with depths ranging from 10 ft to 20 ft. The 180-ft-long end spans were designed to be constructed on falsework. Due to the length required between piers and steep terrain below, segmental cantilever construction was selected as the best option for the 360-ft-long center span.

In order to increase the period of the bridge and to decrease foundation loads, the 22 ft 11½ in. by 6 ft 8 in. rectangular piers were designed to be 42 ft tall. In addition, precast concrete casings were required around the bottom of the piers to isolate them from the backfill. A significant

number of soil nails were required to stabilize the steep cuts needed to locate footings. These footings were supported by 5-ft - 0-in.-diameter drilled shafts.

Value Engineering Change Proposal

The contract was awarded in 2005. The contractor felt that a curved segmental box structure with a travel way superelevation plus shoulder slope with no topping was very difficult to construct. The slope, terrain, and environmental controls that the project would require, the deep foundations, and the soil nail walls, made access all but impossible. The contractor then contacted KSF Inc. to design a different bridge that would resolve the construction issues.

In 1996, the Washington State Department of Transportation (WSDOT) developed their W95PTG "super girder" which was capable of spanning

profile

KEALAKAHA STREAM BRIDGE / NORTH HILO, HAWAII

BRIDGE DESIGN ENGINEER: KSF Inc., Honolulu, Hawaii

PRIME CONTRACTOR: Hawaiian Dredging Construction Company Inc., Honolulu, Hawaii

PRECASTER: Central Pre-Mix Prestress Company, Spokane, Wash., a PCI-certified producer

POST-TENSIONING CONTRACTOR: AVAR Construction Systems Inc., Fremont, Calif.

GIRDER LIFTING JACKS: Enerpac, Milwaukee, Wis.

CONCRETE SUPPLIER: Yamada and Sons Inc., Hilo, Hawaii

REINFORCEMENT SUPPLIER: Associated Steel Workers Ltd., Kapolei, Hawaii

approximately 200 ft. The solution, then, became cast-in-place concrete variable depth box girders cantilevered from each pier with precast bulb-tee girders spanning between both cantilever ends for the center span and between the cantilever ends and the abutments for the end spans. Once the bulbtees were erected, the contractor constructed a conventional 8.5-in.-thick, cast-in-place concrete deck with the required slopes. The specified compressive strength of the deck was 6000 psi at 28 days.

Superstructure

The value-engineered superstructure consists of 100-ft-long and 205-ft-long WSDOT W95PTG precast, prestressed concrete bulb-tee girders and 150-ft-long cast-in-place concrete box girders above each pier. The framing of these superstructure units creates five chords to provide for the curved horizontal alignment. The three spans are made continuous with post-tensioning.

Due to sharply curved roads leading to the bridge site, the maximum length of precast girder segments that could be transported to Kealakaha Stream was 50 ft. The girders, which are 95 in. deep with a 4-ft 3-in.-wide top flange and 3-ft 4-in.-wide bottom flange, were cast in Spokane, Wash., and shipped to Hilo Bay and stored at a location 2 miles from the bridge site. To produce the required 100-ft and 205-ft-long girders, 50-ft-long precast concrete segments were spliced together and post-tensioned at the bridge site. A total of 48 segments was required. The 28-day concrete design compressive strength of these girders was 9000 psi.

Five-cell box girders were cantilevered in both directions from the two piers. The depth of these 150-ft-long girders ranged from 9 ft 9 in. to 18 ft 0 in. A total of 26 post-tensioning tendons, consisting of four 0.6-in.-diameter strands are located in the top slabs of each box girder.

Five-cell box girders were cantilevered from the two piers.

Base Isolation

Additional analysis of the structure determined that utilizing seismic base isolation would result in substructure cost savings. By increasing the dynamic period of the structure and thereby decreasing foundation loads, the footings were raised, the soil nails eliminated, and drilled shaft sizes were minimized.

Two friction pendulum seismic isolation bearings were installed on each abutment and pier. Each bearing has an 88-in. effective radius of curvature that results in a dynamic period of 3 seconds.

Displacement capacities are 12 in. at the abutments and 10 in. at the piers.

According to Dr. Anoop Mokha of Earthquake Protection Systems, "Friction pendulum bearings use the characteristics of a pendulum to lengthen the natural period of the isolated structure so as to mitigate the strongest earthquake forces. Since earthquake-induced displacements occur primarily in the bearings, lateral loads transmitted to the structure are greatly reduced."

Substructure

The value engineering change proposal did not change plan locations of the abutments and piers. However, seismic isolation allowed stiffer piers than those indicated in the original contract drawings. Therefore, footings were raised and pier heights were reduced by 28 ft 6 in. at Pier 1 and 21 ft 0 in. at Pier 2. This eliminated the need for costly soil nailed walls around the footings. Foundation sizes and drilled shaft lengths were altered as well. By maintaining vertical loads at the center of supports, thereby reducing bending moments, the quantity of drilled shafts was reduced significantly by 2226 lin. ft. Footing sizes were also reduced by over 60%.



The center span is shown under construction. One girder has been launched and a second is being assembled in the staging area.

Photo: Mark Joosten, Acrow Corporation of America.

720-FT-LONG, THREE-SPAN, POST-TENSIONED PRECAST SPLICED BULB-TEE GIRDER AND CAST-IN-PLACE CONCRETE BOX GIRDER BRIDGE / HAWAII DEPARTMENT OF TRANSPORTATION, OWNER

SEISMIC ISOLATION BEARING SUPPLIER: Earthquake Protection Systems Inc., Vallejo, Calif.

LAUNCHING TRUSS SUPPLIER: Acrow Corporation of America, Parsippany, N. J.

BRIDGE DESCRIPTION: Three-span bridge consisting of cast-in-place, haunched multi-cell box girders varying from 9 ft 9 in. to 18 ft deep, 150 ft long combined with 95-in.-deep WSDOT bulb-tee girders spliced from 50-ft-long segments to achieve 100-ft-long girders in the end spans and 205-ft-long girders in the center span, cast-in-place concrete deck, and seismic isolation bearings

BRIDGE CONSTRUCTION COST: \$27,000,000

50-ft-long precast concrete segments were spliced together and post-tensioned at the bridge site.



The 150-ft-long, cast-in-place concrete box girder above Pier 2 was cast on falsework and post-tensioned prior to launching the spliced girder drop-in span. Photo: Eric Y. Matsumoto, KSF Inc.



Two precast girder segments, 50 ft long, were set on falsework and spliced together for the end spans. Photo: Eric Y. Matsumoto, KSF Inc.

Construction Process

Construction began in March 2007. After installation of drilled shafts, footings, piers, and abutments were constructed. Next, the friction pendulum bearings were set in place.

Falsework was installed on the stream side of the piers to support the box girder construction. In order to minimize loads on the falsework, box girder construction was sequenced so that

the bottom slab and the two interior webs would support the remaining box construction. At the conclusion of the box girder construction, deck tendons were stressed.

The precast girder segments of the end spans were set on falsework, spliced, and post-tensioned. At each abutment, a continuous end diaphragm was cast. After the closure concrete between the precast girders and box girders was cured, six tendons each consisting of twenty-two 0.6-in.-diameter strands extending from abutments to the ravine end of the box girders were stressed to 483 kips each, 50% of final jacking force. Construction continued with installation of midspan diaphragms and cast-in-place slabs for the end spans. The six tendons were then stressed to 100% of the required jacking force of 967 kips. This post-tensioning, combined with tendons in the top slab of the box, supported all loads during construction of the center span.

The next challenge in this project was launching the 205-ft-long girders across the ravine. To assemble the girders, on the Hilo end span, girder segments were placed on a rail system consisting of wide flange members and rollers. These precast pieces were then spliced and post-tensioned. To address lateral stability concerns, a horizontal steel truss was placed over the middle 90 ft of the girder and two tendons of four 0.6-in.-diameter strands were placed and stressed in ducts in the top flange of the girder.

A launching truss was installed between the center span ends of the box girders. The spliced girders were then pulled across the ravine on the truss. Enerpac hydraulic strand jacks, placed 50 ft above the deck on shoring towers, lifted the girder above the truss. The truss was moved laterally and each girder was lowered to its final position. This process was repeated until all six girders were placed.

The precast girders were then spliced to the box girders and post-tensioned. Three stages of post-tensioning were conducted. In the first stage, a total of 12 tendons of twenty-two 0.6-in.-diameter strands were stressed to 483 kips each. Diaphragms were cast. Then, the 12 tendons were stressed to 100%



After each girder was lifted, the launching truss was moved laterally and the girder set in its final position. Photo: Eric Y. Matsumoto, KSF Inc.

of the required jacking force of 967 kips each. Next, the concrete deck was cast. In the third stage of post-tensioning, another twenty-two 0.6-in.-diameter strand tendon in each girder line was stressed; then the shoring was released and removed.

Conclusion

Awareness of innovations, such as availability of deep girders and seismic isolators, leads to more options in design and construction of bridges. The options can result in easier construction of complex structures and in increased cost savings.

Kealakaha's remote location, steep terrain, seismic activity, and daily deluge of rain created a challenging environment for construction. However, the collaborative effort of all parties involved resulted in a successful completion of the project. Kealakaha Stream Bridge was opened to traffic on March 29, 2010.

David Fujiwara is vice-president, Harold Hamada is a technical consultant, and Eric Y. Matsumoto is a project engineer at KSF Inc. in Honolulu, Hawaii. Gary Iwamoto is senior project manager with Hawaiian Dredging Construction Company Inc. in Honolulu, Hawaii, and Ian N. Robertson is a professor at the University of Hawaii at Manoa, Hawaii.

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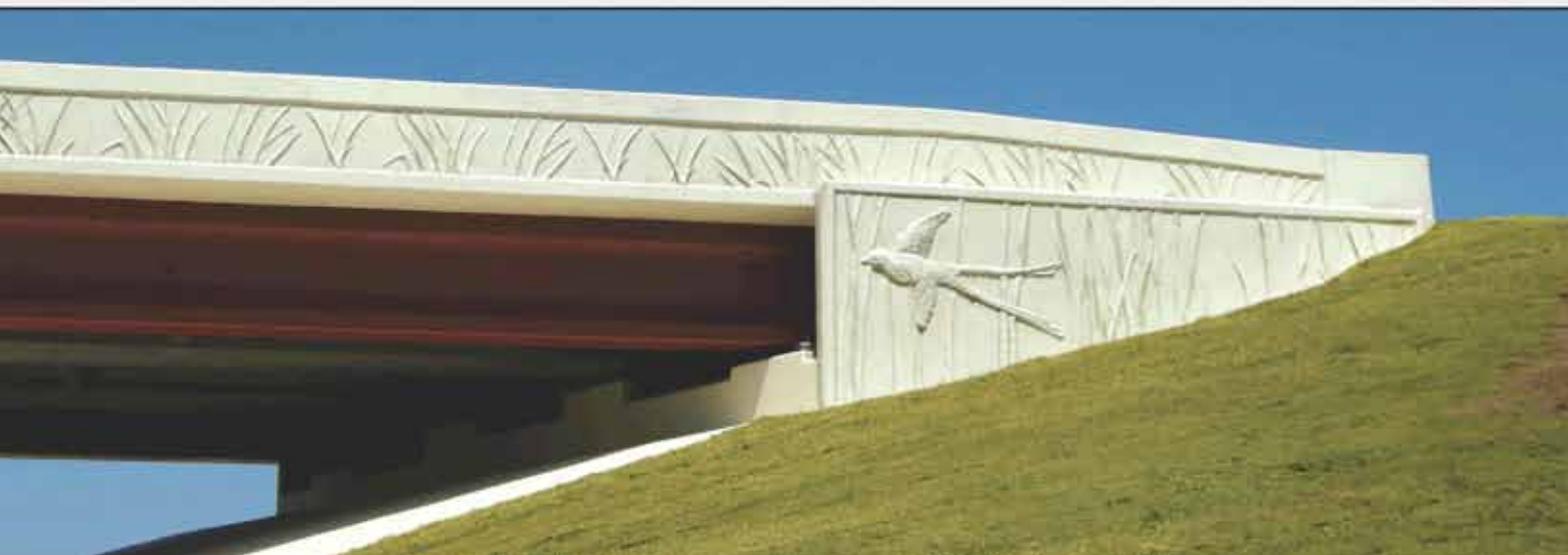
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Route 36 Highlands Bridge Replacement

The reverse curve alignment of the completed eastbound bridge is shown as observed from Pier 8 on the east bank. The westbound structure will follow the same plan and profile.

All Photos: J.H. Reid General Contractor, Unistress Corporation, or Dywidag Systems International–USA Inc.

by Dominic E. Salsa, J.H. Reid General Contractor and Joseph E. Salvadori, Dywidag Systems International–USA Inc.

New Jersey's Twin Precast Segmental Bridges

New Jersey's second precast concrete segmental bridge will serve as a gateway to the seashore towns of Sea Bright Borough and Sandy Hook and connect with Highlands Borough on the mainland, in Monmouth County, N.J. The nine-span twin bridges have main spans of approximately 232 ft. Each structure will be approximately 1611 ft long with a deck width of approximately 46 ft. The bridges cross the Shrewsbury River and will ultimately replace a functionally obsolete and structurally deficient 75-year-old, double-leaf bascule bridge. The eastbound structure is complete and open to traffic. The remainder of the bridge is scheduled for completion in 2010.

Until it was demolished earlier this year, the bascule bridge had 11-ft-wide lanes and lacked shoulders. The bridge's obsolescence created extensive congestion especially during the summer months when the shores along the Atlantic Ocean are visited by beachgoers. The bridge opened twice an hour for maritime traffic on the Shrewsbury. The new bridges will provide 65-ft minimum vertical clearances above mean high water in the navigation channel and upgrade the width of the travel lanes to 12 ft and add 8-ft-wide shoulders.

From the onset, community participation was important to the New Jersey Department of Transportation (NJDOT). In 2001, NJDOT established the Community Partnering Team (CPT) to inform community stakeholders and the public of project development and progress. As defined by NJDOT, the membership

of the CPT included municipal, organizational and agency members, invited guests, special task forces, and NJDOT staff. A steering committee comprised representatives from the Federal Highway Administration, NJDOT, local government, and the design consultant. CPT Task Forces were created for aesthetics, bike/pedestrian connections, environmental coordination, traffic, and communications. For more than a decade, NJDOT conducted numerous meetings with local officials and residents via the CPT.

In addition to the new bridges, the project will also include intersection improvements in Highlands and Sea Bright, pedestrian/bicycle access paths on and off the bridges, construction of two pedestrian bridges, and modifications to the Gateway National Recreational Area toll plaza at Sandy Hook.

profile

ROUTE 36 HIGHLANDS BRIDGE OVER THE SHREWSBURY RIVER / BOROUGHS OF HIGHLANDS AND SEA BRIGHT AND TOWN OF SANDY HOOK, MONMOUTH COUNTY, NEW JERSEY

DESIGN ENGINEER: Jacobs Civil Inc., Iselin, N.J.

CONSTRUCTION ENGINEER: McNary Bergeron & Associates, Old Saybrook, Conn.

CONSTRUCTION CONSULTANTS: GPI, Lebanon, N.J., and T.Y. Lin International, Alexandria, Va.

PRIME CONTRACTOR: J.H. Reid General Contractor, South Plainfield, N.J.

POST-TENSIONING CONTRACTOR: Dywidag Systems International–USA Inc., Pompton Lakes, N.J.

CONCRETE SUPPLIER: Ralph Clayton & Sons, Wall Township, N.J.

Substructure

Design Features

Seismic isolation bearings were the chosen superstructure supports at all substructure units due to the bridge's importance classification and the project seismic zone. The abutments are the conventional stem and backwall configuration and are supported by mass concrete pile caps on 14-in.-square precast, prestressed concrete piles. The concrete piles have a 5000 psi design compressive strength and have 75-ton and 169-ton allowable and ultimate capacities, respectively.

The piers were designed and constructed using precast concrete segments. Pier heights range from approximately 12 ft near the abutments to 58 ft at the navigational channel.

Each mainline pier comprised hollow precast rectangular match-cast box segments. The segments measure approximately 16 ft by 8 ft and range in height from 6 ft to, typically, 10 ft.

Piers 1, 2, and 8 are founded on 24-in.-square precast, prestressed concrete piles with a specified concrete compressive strength of 5000 psi and have 200-ton and 450-ton allowable and ultimate capacities, respectively. Foundation demands for the remaining piers required 6200 lin. ft of 54-in.-diameter cylinder piles with 7000 psi design compressive strength concrete and allowable and ultimate capacities of 475 tons and 950 tons, respectively.

The concrete pile cap footing on the cylinder piles was formed using floating concrete box forms that also served as templates to drive the piles. Contract drawings allowed either steel sheet piles or precast concrete. The contractor chose to use concrete. Twelve concrete box forms were cast by the contractor on the jobsite due to their size. The 10-ft-high boxes were 35.5 ft square, 22 ft by 35.5 ft, or 22 ft by 50 ft.



A precast concrete coffer dam shown as it is lowered into the water for the short trip to a bridge pier. The granite form-liner finish was required to match existing work at the site.

The new bridge will provide 65-ft minimum vertical clearances.

Superstructure Design Features

Featuring a reverse curvature horizontal alignment with 1000-ft and 650-ft radii, the bridge mainline superstructure is a nine-span concrete match-cast, single-cell, trapezoidal box girder. Each structure has a total length of 1610 ft 8 in. Span lengths range from 109 ft 4 in. for span 1 to a maximum of 231 ft 7 in. over the navigation channel. Remaining spans vary in length from 172 ft to 179 ft. The 65-ft vertical clearance over the navigation channel is achieved with vertical gradients of +5.7% to -6.5%.

Segment depths range from approximately 11 ft at piers 3, 4, and 5 and taper to a constant 7 ft in spans 4 and 5. Elsewhere, a constant depth of 8 ft is maintained, except at the east abutment end of span 9 which tapers down to 7 ft 6 in. to accommodate vertical clearance requirements under the structure.

Post-tensioning tendons were required to have a substantially high level of corrosion protection. Therefore, a post-tensioning

system designed for extended service life structures was provided. Corrugated, high-density polypropylene post-tensioning ducts were supplied for all internal tendons.

The tendon anchorages could accommodate four, twelve, or nineteen 0.6-in.-diameter strands. The actual number of strands used in each anchor varied based on application, span length, and structural demands. Generally



Precast pier segment erection proceeded quickly. Post-tensioning bars used to apply compression as the piers were erected are shown being inserted into the new segment. The bars were stressed after each segment was placed and then coupled to engage the subsequent segment.

TWIN, 1611-FT-LONG, PRECAST CONCRETE SEGMENTAL BOX GIRDER BRIDGES WITH PRECAST CONCRETE SEGMENTAL BOX PIERS / NEW JERSEY DEPARTMENT OF TRANSPORTATION, OWNER

PRECASTER, PIER AND BOX GIRDER SEGMENTS: Unistress Corporation, Pittsfield, Mass., a PCI-certified producer

PRECASTER, CYLINDER PILES: Bayshore Concrete Products, Cape Charles, Va., a PCI-certified producer

PRECASTER, SQUARE PILES: Precast Systems Inc., Allentown, N.J., a PCI-certified producer

STRUCTURAL COMPONENTS: 384 box girder segments 10-ft long by 46-ft wide with varying depths, 98 box pier segments 8 ft by 16 ft by 10-ft tall, 54-in.-diameter precast, prestressed concrete cylinder piles, 14-in.- and 24-in.-square precast, prestressed concrete piles, and precast concrete cofferdams

BRIDGE CONSTRUCTION COST: \$51,000,000 for the superstructure (\$340/ft²) and \$36,000,000 for the substructure



A match-cast superstructure segment shown at the Unistress precasting plant.



Segments were shipped from the precasting plant to the bridge site by barge, and were erected using a ringer crane and specially designed spreader beam. The stressing and installation platform was attached to the segments prior to lifting.



Segment erection was performed using the balanced cantilever construction method.

A post-tensioning system designed for extended service life structures was provided.

speaking, cantilever tendons ranged from fourteen to nineteen 0.6-in.-diameter strands while the bottom slab continuity tendons comprised eleven, fifteen, or eighteen 0.6-in.-diameter strands. The four 0.6-in.-diameter strand tendons were of the flat anchor style and were used transversely in the top slab and longitudinally for top slab continuity. The average segment is 10 ft long and 46 ft wide. Each segment required four transverse tendons that were installed and stressed by the precaster prior to shipment.

Segment Fabrication and Erection

The contractor is using a barge-mounted crane to erect the precast girder segments and pier column segments, which are manufactured in Pittsfield, Mass., and barged to the jobsite.

Segment casting began in September 2008 with the eastbound pier column segments and was completed in December 2008. Westbound pier casting began in May 2009 and was completed in December 2009 bringing a close to production of 98 substructure segments required for the project.

During pier segment erection, four 1 $\frac{3}{8}$ -in.-diameter post-tensioning tendons are used to obtain the required compressive stress across the segment joints. The bar tendons are continuous from footing to pier cap and are stressed as segments are placed. Bar couplers are used to lengthen the bars after each stressing operation in order to engage the subsequent segments. Once topped out, the piers are permanently post-tensioned with nineteen 0.6 in.-diameter and twenty-seven 0.6-in.-diameter vertical loop tendons. Designers elected to use epoxy-coated, 7-wire strands for these tendons. All tendons were grouted, including the 1 $\frac{3}{8}$ -in.-diameter bars, after stressing was completed.

Casting the 384 superstructure segments began in October 2008 and continued through June 2010. Production of the eastbound superstructure segments was completed August 2008.

Superstructure erection uses the balanced cantilever construction

Aesthetics Considerations

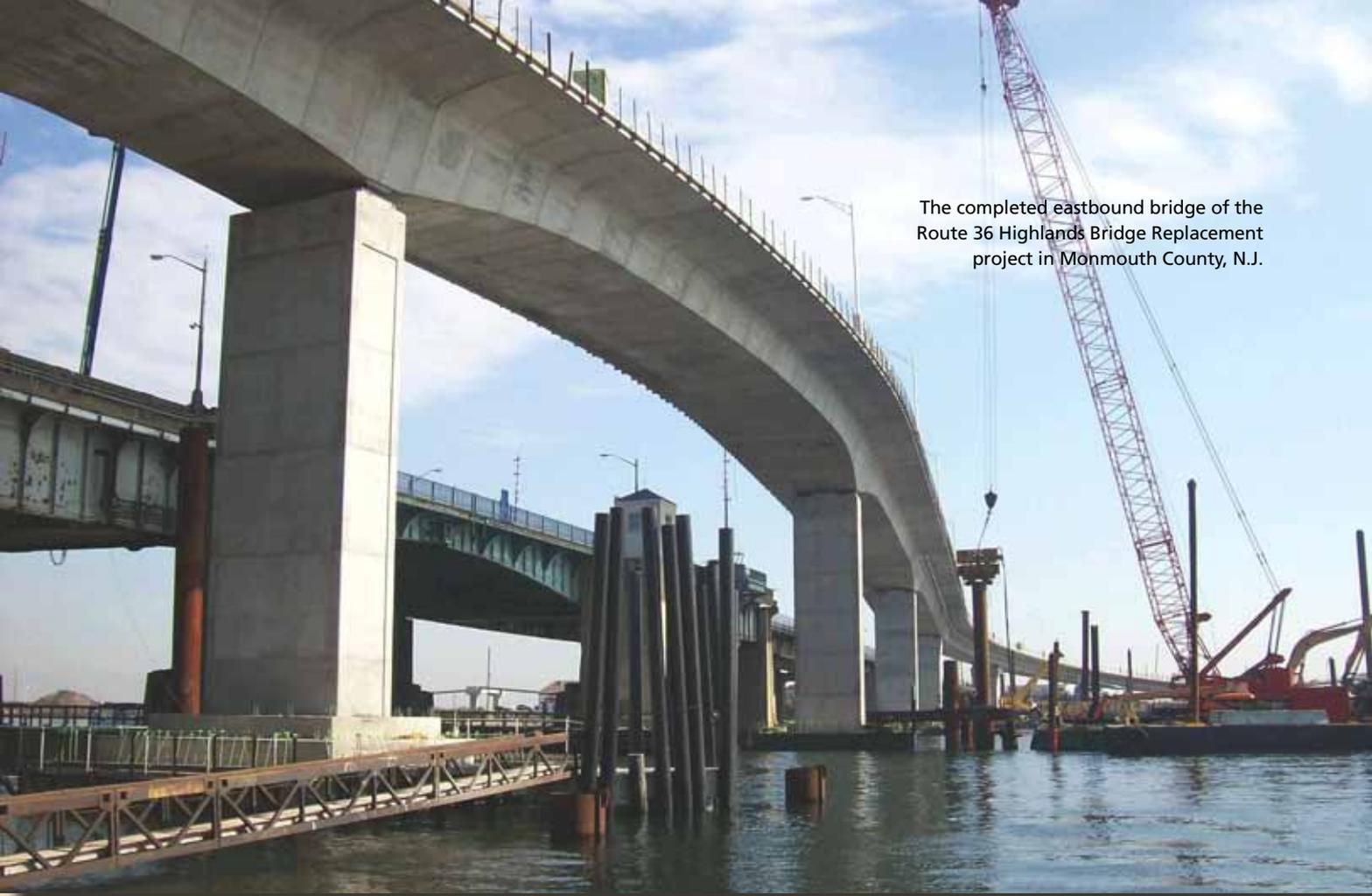
When completed, the project will include architectural features that reflect the historic setting and character of the existing bridge, including two monuments located at the bridge abutments. As defined by the New Jersey Department of Transportation, these features include:

- Decorative fish tiles replicated from the existing bridge to be located on the pylons and light pole pilasters
- Five-bar open steel rectangular railing to enhance the openness of the bridge and provide unobstructed views of the Atlantic Ocean.
- Rustications and reveals in the pier columns and formliner finishes on the waterline footings.

method. Although the river current and coastal tide presents a daily challenge while erecting segments, the contractor has managed this challenge successfully. After epoxy adhesive is applied to the segment face, the segment is lifted from the barge. Similar to the segmental pier construction, six 1 $\frac{3}{8}$ -in.-diameter bars are used to apply the necessary compression across the superstructure segment joints. Over 615 tons of 0.6-in.-diameter strand (120 tons epoxy coated), as well as over 163,000 lbs of 1 $\frac{3}{8}$ -in.-diameter, GR150 bars are being supplied for the project.

Segment erection of the westbound river piers started in March 2010, with superstructure erection not far behind. Superstructure and substructure segment erection will occur concurrently and anticipated project completion is the end of 2010.

Dominic E. Salsa is project engineer for J.H. Reid General Contractor in South Plainfield, N.J., and Joseph E. Salvadori is Northeast regional manager for the post-tensioning business unit of Dywidag Systems International—USA Inc. in Pompton Lakes, N.J.



The completed eastbound bridge of the Route 36 Highlands Bridge Replacement project in Monmouth County, N.J.



AESTHETICS COMMENTARY

by Frederick Gottemoeller

Waterfront communities faced with replacing an existing drawbridge by a fixed, high-level bridge often overestimate the visual impact of the additional height and underestimate the visual benefit of removing the existing low-level bridge. Because of the long spans made possible by post-tensioned segmental concrete construction, people will be able to see right through the Route 36 Bridge and enjoy near and distant views. At the same time, the removal of the low-level drawbridge and its forest of piers will open up water-level views that haven't been seen since its construction. The whole bay will be visually reunited.

The horizontal and vertical geometry of a bridge is often obscured by topography or buildings, and its visual impact unseen. In fact, the geometry describes a ribbon in space with interacting curves that can make the ribbon itself attractive, or not. In a long viaduct, especially over water, the potential aesthetic power of the geometry becomes obvious. The curves required to get the Route 36 Bridge up and over the channel give the structure an attractive flowing, undulating appearance. They show signs of having been refined to do exactly that. The segmental box exactly follows these curves, reinforcing their impact.

The segmental box brings still more to the table. Because the box is both trapezoidal and haunched, the soffits of the boxes vary in width, making the intersections of the box sides and soffits three-dimensional curves in space. These curves visually interact with the curved horizontal and vertical alignments of the bridge, creating wavelike forms that, with their reflections in the water, frame the views beyond. Given the visual quality and complexity of the superstructure, the designer has sensibly kept the piers simple, so that the superstructure remains the star of the show.

All of this may seem abstract, but people recognize the effect. I've shown photos of similar bridges at community meetings and had people spontaneously applaud. And the great thing is that it is all accomplished with the lines and shapes of the structure itself; nothing needed to be added or pasted on.

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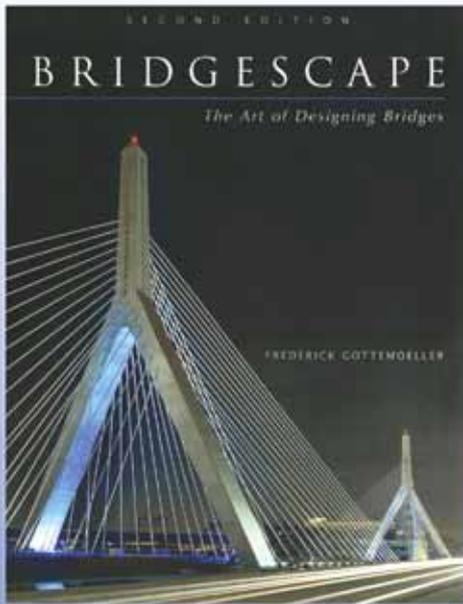
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Author, Frederick Gottemoeller, PE, RA, is a world-recognized expert and consultant on the aesthetics of bridge design. His celebrated bridges include the new Woodrow Wilson Bridge in Washington, D.C., and the Clearwater Memorial Causeway in Clearwater, Fla.

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by Thomas R. Barnard and Ahmad M. Abdel-Karim, AECOM

Three-girder
'trough' cross
section spans
longitudinally while
concrete slabs
span transversely
between girders

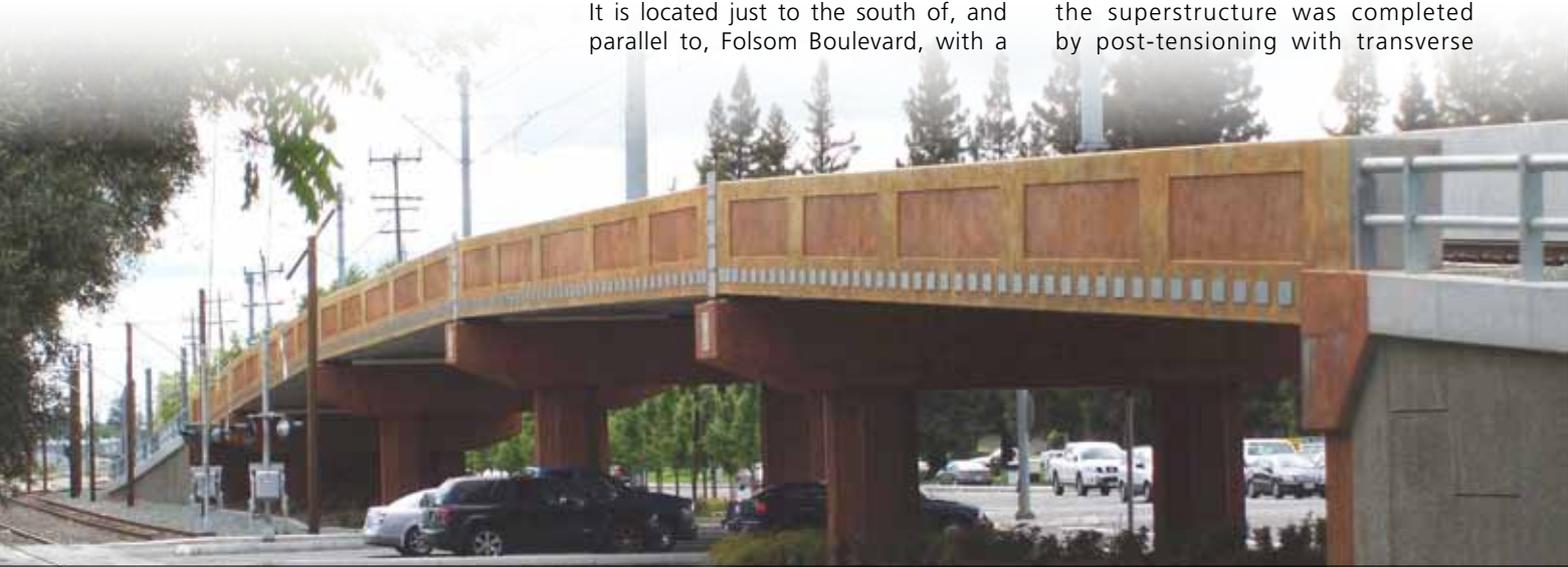
Creating effective noise and visual barriers to light-rail train (LRT) traffic, while providing pleasing aesthetics that don't disrupt the community's ambience, pose significant challenges for urban planners. The recent precast concrete structure over South Watt Avenue in Sacramento, Calif., provides an example of how these challenges can be met with an innovative "trough" cross section.

The five-span, 540-ft-long project resulted from the South Watt Area Transportation Study (SWATS), which evaluated the entire Watt Avenue corridor. The SWATS study produced a list of short- and long-term upgrades necessary to improve safety and efficiency for the corridor's transportation system. Among these changes were modifications to create a grade separation between two light-rail tracks and highway vehicles at the South Watt/Folsom Blvd. intersection. It is located just to the south of, and parallel to, Folsom Boulevard, with a

parking area for the Manlove Light Rail Station in the intersection's southeast corner. In addition, a freight railroad line runs parallel with the LRT tracks and Folsom Boulevard.

To accommodate the long-term plan for the Watt Avenue Corridor, the structure also had to accommodate a future grade separation between South Watt Avenue and Folsom Boulevard. As a result, the substructure was designed to allow South Watt Avenue to be lowered by up to 20 ft.

The grade-separation structure features a "trough" cross section, consisting of three precast, prestressed concrete girders spanning in the longitudinal direction, and precast, prestressed concrete slabs spanning between adjacent girders in the transverse direction. After erection, the deck-slab panels were joined through longitudinal post-tensioning. Their integration into the superstructure was completed by post-tensioning with transverse



The five-span, 540-ft-long light-rail train project over South Watt Avenue in Sacramento, Calif., features an innovative "trough" cross section of through-girders that reduced construction time, improved aesthetics, and limited road closures. All Photos and Drawing: AECOM.

profile

SOUTH WATT AVENUE LIGHT-RAIL BRIDGE / SACRAMENTO, CALIFORNIA

ENGINEER: AECOM, Sacramento, Calif.

PRIME CONTRACTOR: Viking Construction, Rancho Cordova, Calif.

BRIDGE DESCRIPTION: A five-span, 540-ft-long light-rail bridge that features a "trough" cross section consisting of three precast, prestressed concrete girders spanning in the longitudinal direction, and precast, prestressed concrete slabs spanning between adjacent girders in the transverse direction.

tendons, which also pass through the girders and closure pours. Finally, the longitudinal tendons in the girders and slabs were stressed to produce the required composite system capacity.

The concept reflects the flexibilities of precast concrete commonly used to solve difficult site constraints or staging requirements. But the bridge also highlights an important benefit of precast concrete that is often overlooked, by transversely integrating the all-precast concrete cross sections to create a "super girder." This concept

This concept opens the door for a new generation of all-precast concrete 'super girders.'

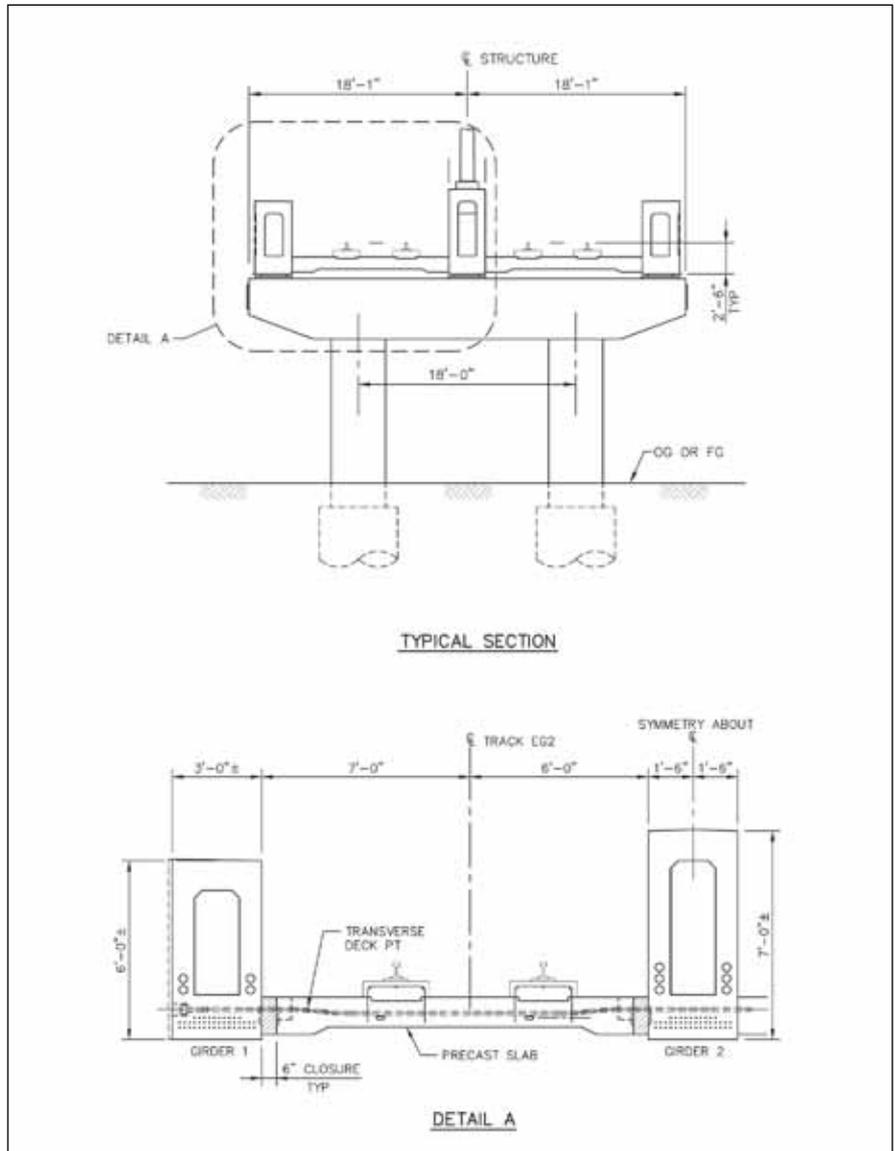
opens the door for a new generation of all-precast "super girders" fabricated in segments, transported, and then field-assembled into a single deck element. The added flexibility of these systems allows them to economically meet a wider range of functional requirements.

Evaluation Considerations

Although light-rail passenger-vehicle structures share many characteristics with those carrying freight trains, the magnitudes of the loadings to which they are subjected are more similar to loadings for highway vehicles. The lighter loads make it possible to evaluate structure types used for highway grade separations, broadening the options. For this project, multiple structure types were evaluated to determine the most practical design.

Options were evaluated on a variety of factors, comprising:

- Overall construction duration
- Impact on intersection traffic
- Safety
- Proximity to operating tracks
- Continuity of LRT operations



Cross section of the through-girder light-rail bridge.

- Roadway clearance—temporary and permanent
- Construction cost
- Bridge aesthetics
- Superstructure depth and associated profile
- Proximity to the station and its impact on profile
- Precast, prestressed concrete I-girders
- Precast, prestressed concrete bulb-tee girders
- Cast-in-place box girders
- Steel I- or through-girders
- Cast-in-place concrete troughs
- Precast, prestressed concrete troughs

Seven superstructure types were considered:

- Precast, prestressed concrete box beams

540-FT-LONG PRECAST CONCRETE LIGHT-RAIL BRIDGE / SACRAMENTO COUNTY DEPARTMENT OF TRANSPORTATION, OWNER

PRECASTER: Con-Fab California Corp., Lathrop, Calif., a PCI-certified producer

BRIDGE CONSTRUCTION COST: \$24 million (including the roadway improvements, LRT power and communications systems, at-grade crossing protection, Union Pacific Railroad freight track relocation, intersection signal work, and site restoration/landscaping)



Girder end zones required strut-and-tie techniques during design to provide more reliable, economical details.

While many of these options met the basic requirements for functionality, it became clear early in the process that the site constraints, especially vertical clearances and approach grades, could be economically met using only a precast or steel-plate girder superstructure.

Through-girders, typically used in railroad crossings, are less commonly used for LRT grade separations. The most prominent feature of the trough section is that the girders project above the deck. This contrasts with conventional structure sections, where the girders support the deck from below. As a result, the structure depth required for a trough section is substantially less than for conventional types. This means the profile grade can be lowered, reducing costs associated with a raised-profile grade.

Concrete-trough (or through-girder) bridges can be constructed by a variety of methods. The most common type consists of a cast-in-place concrete trough section, with sloped sides. The deck soffit of a cast-in-place trough-girder bridge is relatively thick and often requires post-tensioning to span between girders. Precast concrete trough sections provide a viable alternative in situations where it is necessary to minimize falsework requirements and traffic impacts.

The precast concrete girders were trucked to the site and staged nearby so they could be erected during weekend overnight lane closures.

Advantages for the precast concrete trough are that it provides a low profile, expedites construction time, minimizes impact to intersection traffic, and provides high fascia girders to act as sound barriers. However, the barriers also obstruct passengers' views, and the designs can be moderately complex to construct.

The prefabrication of the structural system reduced the number and duration of complete closures to 3 weekends.

Attention Paid to Stresses

Special attention was paid in the design to ensuring that the stresses and deformation of the all-precast, multi-component deck met the required criteria. For example, the quantities of pretensioning and post-tensioning steel in the girders and slabs were carefully selected to satisfy the stress limit states during the various construction stages, while minimizing deflection. Keeping the girder deflections to a minimum reduced the chances of error in predicting the girder profile at any given time, and thereby reduced the potential for encountering excessive differential cambers.

The trough design aided durability in several ways. The combination of transverse and longitudinal post-

tensioning minimized cracking, which reduced susceptibility to reinforcement corrosion. The use of glass-fiber reinforced plastic (GFRP) reinforcement in the direct fixation plinths further improved corrosion resistance.

The lack of a cast-in-place concrete deck and end diaphragm to tie the girders together and provide housing and support for the post-tensioning anchorages required in-depth analysis and design. In addition, the shape of the girder's end block and the concentration of load effects from bearing and post-tensioning resulted in highly irregular stress fields within the end regions. As a result, the girder end zones were investigated using strut-and-tie techniques to provide a more reliable, economical design.

The tolerance for fabrication errors is reduced in direct proportion to the number of components involved. All components had to be fabricated to ensure they matched with each other in the field and with the site-cast concrete foundation and substructure. Both transverse and longitudinal joints had to align perfectly to receive the post-tensioning tendons required to tie the composite structure together.

Many of these issues were related to the girder fabrication, longer-than-usual storage periods, and transportation and erection schemes. Additional issues surfaced during the erection of the slab panels and the integration of all precast girder-slab components into a single "super-girder" section.



The structure depth required for a trough section is substantially less than for conventional types.

Site Complexity Posed Challenges

The greatest challenge for the designers and contractor involved the site's multi-modal nature. The design was driven by site constraints, such as clearance and grade requirements, as well as the need to maintain freight rail and vehicular traffic while not interfering with the ongoing station operations. The difficulty of constructing a grade separation in close proximity to operating light-rail and freight tracks created significant complexities. Close coordination between the contractor and railroad operations was required to ensure construction activity did not encroach into the operating envelope without appropriate warrants in place.

Fortunately, the Union Pacific Railroad spur at the site did not have significant traffic (three or four trains per week). To ensure no difficulties, the Sacramento County Department of Transportation construction management and inspection staff, along with the contractor, coordinated any encroachment into the freight rail operating envelope with the railroads operations personnel.

Closing South Watt Avenue even for a few days created a major disruption for drivers, as well as for personnel in the Sacramento County DOT. The prefabrication of the structural system reduced the number and duration of complete closures to 3 weekends.

Construction involved creating a shoofly detour to allow trains to operate outside

the construction zone, so the precast concrete structural elements could be erected without disrupting traffic. Girders were trucked to the site and temporarily stored so they could be erected overnight. The longitudinal girders were erected during three weekend night closures, while precast deck slabs were installed during normal working hours. The longitudinal girders were post-tensioned following the erection and stressing of the transverse slab tendons. Once the bridge was erected, tracks were installed and station modifications were completed. Then traffic was shifted onto the new structure and the shoofly was removed.

The construction of this bridge shows the feasibility of using a through-girder or "trough" type superstructure composed of precast concrete components integrated into a composite system via post-tensioning. The engineer's continuous involvement during the various construction stages proved critical to avoid otherwise costly problems and to achieve success. This design offers great potential for the future for other municipalities facing these light-rail challenges.

Thomas R. Barnard and Ahmad M. Abdel-Karim, are project managers with AECOM, formerly DMJM Harris, in Sacramento, Calif.

For more information on this or other projects, visit www.aspirebridge.org.



Installation of the precast concrete deck slabs took place during normal working hours.



The grade-separation structure features a "trough" cross-section, consisting of three precast, prestressed concrete through-girders spanning in the longitudinal direction, and precast, prestressed concrete slabs spanning between adjacent girders in the transverse direction.



After erection, the deck-slab panels were connected with cast-in-place concrete closure strips and longitudinal post-tensioning. They are integrated into the superstructure by post-tensioning transverse tendons, which also pass through the girders and longitudinal closure pours.



The difficulty of constructing a grade separation in close proximity to operating light-rail and freight tracks created significant complexities.

PROJECT

THE DAVID KREITZER LAKE HODGES BICYCLE PEDESTRIAN BRIDGE

by Tony Sanchez, T.Y. Lin International

The Lake Hodges Stress Ribbon Bridge. All Photos: T.Y. Lin International.

On May 15, 2009, the world's longest stress ribbon bridge opened in San Diego, California. The David Kreitzer Bicycle Pedestrian Bridge uses high-strength cables embedded in an ultra-slim concrete deck to span nearly 1000 ft across Lake Hodges, and it does so with grace and respect for the site and sensitive lake habitat.

Unique Design

The stress ribbon bridge type is unique regionally as there are only six examples in North America and only about 50 worldwide. At Lake Hodges, it has proven to be the perfect bridge for the site. Prior to Lake Hodges, a stress ribbon bridge of this length had never before been constructed.

At Lake Hodges, the stress ribbon enabled the long spans required for a three-span design. With spans of 330 ft, it gracefully stretches 990 ft between abutments with only two piers in the lake. And it does this with a deck that is only 16 in. thick. The result is a thin ribbon of concrete with an amazing depth-to-span ratio of 1:248.

Asset to the Community

The bridge provides a crossing for hikers, cyclists, joggers, and bird watchers and allows access to the extensive trail system on the north and south shores of the lake. It provides a significant enhancement to the region by adding both a transportation and recreational resource. By eliminating

a 9-mile detour in the system and improving public access to surrounding trails and recreational facilities, the bridge has become a vital link in the 55-mile-long Coast to Crest Trail within the San Dieguito River Valley Open Space Park.

The bridge also provides a safe crossing for bicycles. Prior to the bridge, bicycle commuters had to cross Lake Hodges on the shoulder of the busy I-15 freeway, which posed a safety concern. Now these commuters use the new bridge to safely cross the lake on a dedicated path away from vehicular traffic.

Design Complexities

Although the bridge is simple in appearance, its analysis and design were very complex. Since the bridge behaves as a cable, it is geometrically non-linear. This made linear-elastic analysis—the standard for most bridges—inappropriate. Since the bridge was constructed segmentally, a stage construction analysis was required to track the stresses that were locked in during construction. Further, since the bridge is made of concrete that is post-tensioned and has no expansion joints, the bridge accommodates expansion and contraction by a rise or fall of each span. Thus, the effects of concrete creep and shrinkage and thermal loading were critical. These effects were accounted for by performing a time-dependent creep and shrinkage analysis that included thermal loading.

The bridge was modeled stage by stage to represent the construction sequence, and then live load, temperature, and wind loads were applied. Next the analysis stepped through 50 years of creep and shrinkage and the loading process was repeated. In the end, the critical load case was 50 years of creep and shrinkage plus live load on all three spans and a temperature drop of 35 °F.

A dynamic analysis was performed to evaluate the bridge under wind, seismic, and vibrational loads. A detailed wind study was performed, which included wind tunnel testing. Critical in the wind study was the torsional response of the bridge, which can be excited through buffeting as strong winds pass transversely over the deck. The results showed the bridge would be stable at the maximum wind speed of 85 mph predicted for the site.

The results of the seismic analysis showed the bridge would stay elastic under the maximum credible earthquake. This is surprising for a bridge in California, but somewhat intuitive for the stress ribbon design. With a 16-in.-thick deck, this bridge has relatively low mass, and is restrained laterally by 12 large cables. In essence, the structure is one large seismic cable restrainer.

For the vibration analysis, a simplified approach from the British and Canadian bridge codes was used. The

profile

DAVID KREITZER, LAKE HODGES BICYCLE PEDESTRIAN BRIDGE / SAN DIEGO, CALIFORNIA

CONCRETE SUPPLIER: Palomar Transit Mix, Escondido, Calif.

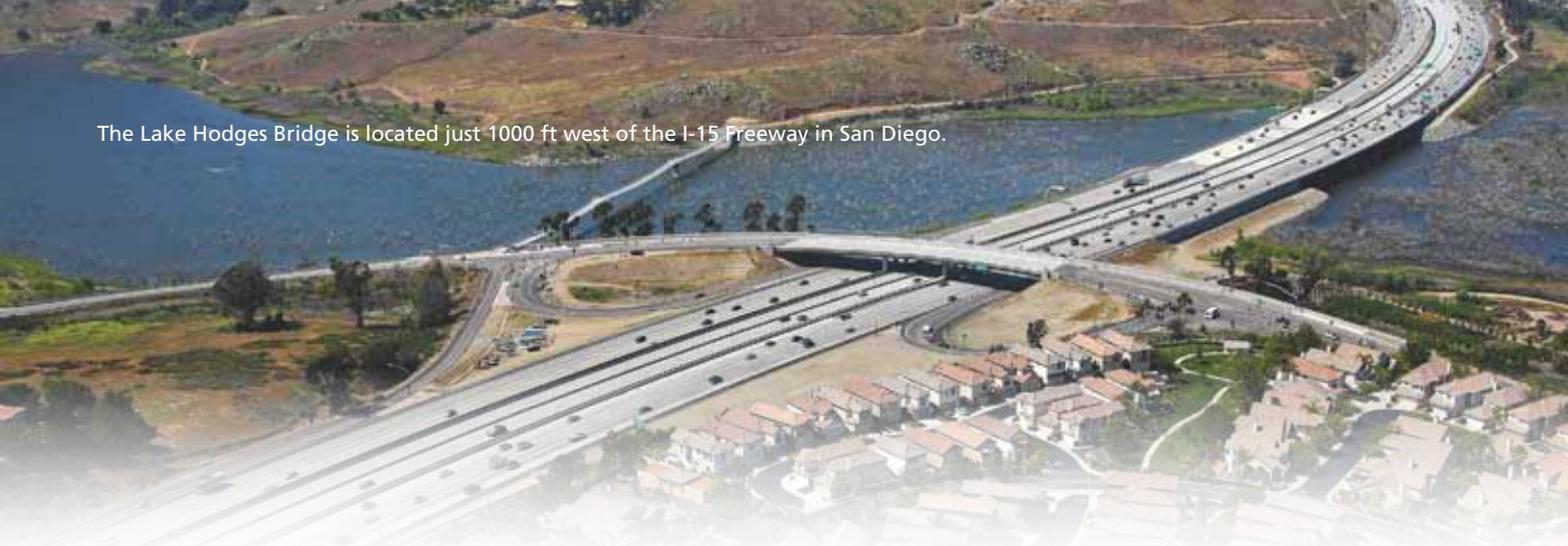
PRECASTER: U.S. Concrete, San Diego, Calif.

POST-TENSIONING CONTRACTOR: Dywidag-Systems International, Long Beach, Calif.

BRIDGE DESCRIPTION: 990-ft-long, three-span stress ribbon bridge, 14 ft wide and 16 in. deep

BRIDGE CONSTRUCTION COST: \$8.5 Million (\$550/ft²)

The Lake Hodges Bridge is located just 1000 ft west of the I-15 Freeway in San Diego.



results showed the accelerations from pedestrians walking, running, or even jumping up and down on the bridge would be well within acceptable limits.

Construction

The construction was divided into three phases to meet funding and environmental constraints. The south abutment was constructed in the first phase, from September 2006 to March 2007. The contractor then moved off site in accordance with the environmental requirements related to the breeding season of endangered birds.

In the second phase, from September 2007 to March 2008, a construction trestle was built to gain access to the piers. Sheet pile cofferdams were constructed and steel piles were driven for the pier foundations. Next, concrete seals were placed and the coffer dams were dewatered to facilitate the balance of the pier construction.

The north abutment was also constructed in this second phase by excavating down to sound rock and placing a concrete leveling course. A reinforced concrete structural abutment was placed on top of the leveling course. Next, 15 anchors were drilled through the leveling course and into rock. Each anchor was tensioned to 1100 kips. After completing the piers and north abutment, the contractor once again moved off site.

The bridge deck was constructed from September 2008 to May 2009, in the third and final phase. The contractor utilized the trestle as a work platform for placing the cables and panels. First the bearing cables were installed from abutment to abutment and over the steel saddles at the piers. Each of the six bearing cables comprised nineteen 0.6-in.-diameter, 270 ksi prestressing strands. The six tendons were tensioned to a total force of 4300 kips.

Next, the deck panels were suspended from the bearing cables using high-strength bars near the corners of each panel. A total of 87 panels, each 10 ft long, 14 ft wide and 16 in. thick, were used. The design compressive strength of the concrete was 6000 psi. Longitudinal troughs were built into the panels to provide a place for the bearing and post-tensioning cables.

Once the panels were in place, the post-tensioning ducts and tendons were installed in the longitudinal troughs above the suspension cables. Again six tendons were used, this time with twenty-seven 0.6-in.-diameter strands each. Formwork was then constructed for the final 20 ft of each span. Concrete was placed in the transverse joints between panels, in the longitudinal troughs and in the open-end regions.

Once the cast-in-place concrete reached the specified strength of 6000 psi, the bridge was post-tensioned with 4600



One of 87 precast concrete panels is shown during the typical erection procedure.



Concrete is placed in the longitudinal trough that was cast in the panels.

THREE-SPAN, STRESS RIBBON BRIDGE / SAN DIEGUITO RIVER VALLEY OPEN SPACE PARK JOINT POWERS AUTHORITY, OWBER

STRUCTURAL COMPONENTS: 87 precast concrete deck panels, 10 ft long, 14 ft wide, and 16 in. thick; six 19-strand bearing cables; six 27-strand post-tensioning tendons, two cast-in-place concrete piers on H-pile foundations, one rock anchor abutment on the north end, and one pile abutment on the south end with four 8-ft-diameter concrete cast-in-drilled-hole piles.

AWARDS: PCI's 2009 Design Award for Best Non-Highway Bridge; California Construction, Best of 2009, Best Small Project; ACEC 2010 National Award; CRSI 2010 Bridge Design Award; National Engineer Week, 2010 Outstanding Civil Engineering Project Award



An early rendering of the David Kreitzer Lake Hodges Bicycle Pedestrian Bridge illustrates its appearance “floating” above the water.



In the dry condition, the bridge appears to “nest” above the trees.



The bridge model undergoing wind tunnel testing.

kips of force. This put the deck into compression and increased its stiffness.

Conclusion

On May 15, 2009, hundreds of people were in attendance for the official grand opening and ribbon cutting ceremony. In its first year of operation, the bridge has been well used by the public. The reactions and comments from its users, which include hikers, joggers, recreational bicyclists, and commuters, have been extremely positive. This bridge was a challenge to design and construct, but the results have been well worth it. This elegant bridge is perfectly suited to the site and provides the people of the region

with a beautiful and useful crossing of which they can be proud. Further, the structure has a unique place in the field of engineering—the world’s longest stress ribbon bridge.

Tony Sanchez is senior bridge engineer at T.Y. Lin International, San Diego, Calif.

For more information on this or other projects, visit www.aspirebridge.org.

Environmental and Context-Sensitive Solutions

The San Dieguito River Park Authority hired T.Y. Lin International to design a functional and beautiful bridge for pedestrians and bicyclists. However, a good design at this site needed to be consistent with the Park Authority’s core values of protecting the natural waterways, sensitive lands, and threatened and endangered species.

The stress ribbon is the ultimate eco-friendly design. Because it can span 330 ft, only two piers were needed. Since the bridge was built by placing precast panels on bearing cables, no falsework was required. This further reduced the impact to the sensitive habitat. Additionally, the stress ribbon design makes effective use of each material: concrete in compression, steel in tension. This results in a minimal use of materials. In this sense, the bridge is a very “green” design.

In addition to environmental issues, aesthetics were important in the selection of this bridge type, and the stress ribbon proved to be the perfect visual compliment to the site. Early sketches and renderings showed the stress ribbon worked beautifully in both wet and dry conditions. The bridge “floats” above the water when the lake is full, and “nests” above the willow trees when the lake is dry. Visually, its slender deck has the smallest impact. From a distance the bridge almost disappears. Up close, its complementary curves fit beautifully into the rolling terrain around the lake. The long spans and thin deck result in a very light bridge that blends into the natural setting.

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PROJECT

MINNESOTA'S PRECAST COMPOSITE SLAB SPAN SYSTEM

This is Bridge 66004, TH 60 over the Cannon River in southern Minnesota after completion.
Photos: Minnesota DOT.

by Moises C. Dimaculangan and Tony Lesch, Minnesota Department of Transportation

With aging bridge infrastructure and higher levels of traffic on roadways, the demand for bridge replacement and rehabilitation is very high. For this reason, there is a need to look for innovative ways to rapidly construct longer lasting bridges while reducing traffic disruption. One solution is prefabricated bridges. The Minnesota Department of Transportation (MnDOT) has embarked on the development of such a system. The system can provide an effective and economical design concept that can be implemented for new bridges and the rehabilitation of existing bridges.

In 2004, MnDOT state bridge engineer, Dan Dorgan, participated in an International Scan Tour sponsored by the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the National Cooperative Highway Research Program. The Prefabricated Bridge Elements and Systems scan team visited Japan, the Netherlands, Belgium, and France. The objective was to look for innovative ways for rapid construction of bridges while minimizing the impacts

on the traveling public. The focus areas of the scan were prefabricated bridge elements and systems that minimize traffic disruption, improve work zone safety, minimize environmental impact, improve constructability, increase quality, and reduce life-cycle costs. The Scan Team identified 10 technologies for implementation in the United States.

Poutre Dalle System

One practice in particular that showed promise in innovation of rapid construction was the Poutre Dalle System from France. This system consists of shallow, precast, prestressed concrete inverted-tee beams that are placed directly adjacent to each other. The beams are connected across a longitudinal joint that is established through the use of 180-degree reinforcement hooks that protrude from the sides of the webs. Cast-in-place (CIP) concrete is placed between the beam webs and over the top of the beams to form a solid composite cross section.

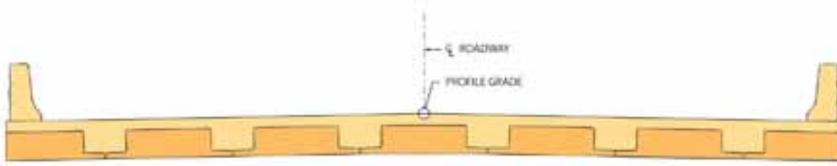
In Minnesota, CIP concrete slab span construction has a long history and a

useful place in the bridge inventory where shallow depth structures are desired. But construction of the traditional slab span bridge can require large amounts of time and labor due to curing periods and formwork construction and removal. Impressed with the Poutre Dalle System, MnDOT began developing a similar system for use on Minnesota highways as a potential alternative to CIP slab span structures.

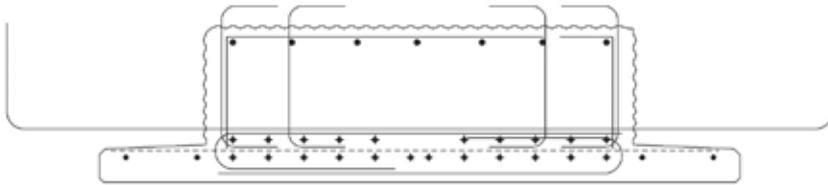
Minnesota's System

Bridge engineers in the MnDOT Bridge Office started the design process by first roughing out some initial design concepts that were discussed with several local precast beam fabricators. The team then created a partnership with researchers from the University of Minnesota. In a series of design workshop forums, the designers and researchers worked together to develop design details and an outline for a parallel Minnesota bridge research project. The research project was multifaceted research intended to instrument a pilot bridge to verify the design assumptions and to conduct additional research on beams in the university's laboratory.

Bridge No., Trunk Highway No., Bridge Name, and Location	04002, T.H. 72 over the Tamarac River, Waskish	13004, T.H. 8 over Center Lake Channel, Center City	33008, T.H. 65 over the Groundhouse River, Kanabec Co.	33005, T.H. 65 over the Ann River, Kanabec Co.
Year Built	2005	2005	2007	2007
Total Length	143'-11"	72'-5"	90'-8"	112'-5"
Width	50'-4"	76'-2"	66'-0"	47'-4"
Span Lengths	44'-11", 54'-1", 44'-11"	22'-0", 27'-0", 22'-0"	29'-7", 30'-4", 29'-7"	36'-5", 36'-10", 36'-5"
f'_c Precast and CIP, psi	6500, 4000	6500, 4000	6500, 4000	6000, 4000
Fabricator (PCI-certified producer)	County Materials, Roberts, Wis.	County Materials, Roberts, Wis.	County Materials, Roberts, Wis.	County Materials, Roberts, Wis.
Contractor	Robert R. Schroeder Construction Co., Glenwood, Minn.	Lunda Construction Co., Black River Falls, Wis.	Redstone Construction Co., Mora, Minn.	Redstone Construction Co., Mora, Minn.



A transverse section through a bridge using the MnDOT Precast Composite Slab Span system.



The cross section of a typical MnDOT Precast Composite Slab Span beam.

The new system is a combination of precast, prestressed concrete beams and the traditional concrete slab span system. The design team has referred to the new system as the Precast Composite Slab Span (PCSS) system. Similar to the Poutre Dalle system, it consists of a series of adjacent precast, prestressed concrete inverted-tee bridge beams that also serve as stay-in-place formwork for the CIP portion of the deck, eliminating formwork construction in the field. It also simplifies construction with innovations such as “drop in” reinforcement cages over the longitudinal joint connections between the precast sections. In addition to an overall reduction in construction time, the system provides other advantages including improved quality control, greater safety, and reduced environmental impact at the site. MnDOT’s PCSS system is used for short span bridges (20 ft to 45 ft), a configuration that has been served by CIP slab span bridges.

During development, some design assumptions were made early on with

the understanding that research would be necessary to validate the assumptions. The prestressing steel was designed using the AASHTO LRFD Bridge Design Specifications, Third Edition, 2004. Because the system is intended to act as a monolithic superstructure such as a slab span, the live load distribution was based on the Equivalent Strip Width for Slab-Type Bridges (AASHTO LRFD Bridge Design Specifications, Article 4.6.2.3). Similarly, the layout of the mild reinforcement in the CIP portion of the superstructure was designed similar to the top reinforcement of a CIP slab span bridge.

Pilot Projects

MnDOT implemented this new technology with two pilot projects in 2005. Bridge No. 04002 is located on MN Highway 72 over the Tamarac River near the rural, northern Minnesota town of Waskish. Bridge No. 13004 is located on U.S. Highway 8 over Center Lake Channel in Center City, just north of Minneapolis-St. Paul. The university research team



View of a longitudinal joint between precast sections before installing field-placed reinforcement.



View of a longitudinal joint after the placement of the “drop-in” reinforcing cage.

Bridge No., Trunk Highway No., Bridge Name, and Location	6679, T.H. 76 over the South Fork of the Root River, Houston Co.	49007, T.H. 238 over the Swan River, Morrison Co.	49036, T.H. 238 over Pike Creek, Morrison Co.	66004, T.H. 60 over the Cannon River, Rice Co.
Year Built	2007	2009	2009	2009
Total Length	n/a	104'-2"	72'-2"	124'-5"
Width	30'-0"	39'-4"	43'-4"	47'-4"
Span Lengths	19'-0"	34'-1", 34'-10", 34'-1"	23'-5", 24'-2", 23'-5"	40'-5", 40'-10", 40'-5"
f'_c Precast and CIP, PSI	4000, 4000	6500, 4000	6000, 4000	6000, 4000
Fabricator (PCI-certified producer)	County Materials, Roberts, Wis.	Cretex Concrete Products Maple Grove, Minn.	Cretex Concrete Products Maple Grove, Minn.	Minnesota Construction Harmony, Minn.
Contractor	MnDOT Bridge Maintenance	Lunda Construction Co., Black River Falls, Wis.	Lunda Construction Co., Black River Falls, Wis.	Minnesota Construction Harmony, Minn.



A precast concrete section being lowered into place adjacent to another during the rehabilitation of Bridge 6679.

instrumented and monitored the Center City bridge as part of the system development. The results of the field and laboratory study confirmed the system's durability and verified the slab span design assumptions. The projects revealed that the PCSS system is a practical and economical accelerated construction alternative to CIP slab span construction.

After a year in service, researchers detected cracking in the deck above the longitudinal joint between precast sections. Transverse cracks were also discovered over the pier locations, which may require ongoing maintenance. The strains at these locations have been monitored and have increased over time. According to researchers, these cracks appear to be the result of thermal gradient effects. As part of the project, they will continue to monitor the sensors and at the same time review and comment on the latest design methodology implemented by MnDOT.

Further Implementation

Because results from the initial field implementation projects were relatively favorable, six more bridges were planned and constructed in Minnesota with the intent to improve the system. Modifications were proposed by the researchers and lessons learned from the initial projects were incorporated. Three "2nd generation bridges" were designed and built in 2007. In order to phase in the design changes, only a few of the proposed modifications were incorporated into the 2nd generation bridges. Specifically, the changes involved modifications to the mild reinforcement in the girders. In 2009, three additional "3rd generation bridges" were designed and constructed that included a large number of the modifications with the hopes of reducing cracking. The most significant change was to make the bottom flanges of the beams thinner in order to reduce the amount of area causing the reflective cracking. Research test results also indicated that the thinner flanges helped improve the transverse load

distribution of the system. Other notable modifications included:

- Increasing the chamfer sizes on the edges of the beam
- Increasing the transverse deck reinforcement bars using closer spacing
- Assuring the direct placement of the drop-in reinforcement cage such that it was staggered with the bars protruding from the beams
- Providing fixed anchorages between the superstructure and the substructure at the supports for the center 21 ft on both sides of the bridge center line and placing flexible foam around the anchorage dowels to allow lateral movement beyond the center 20 ft
- Moistening the precast beams before placement of the CIP deck
- Adding welded wire reinforcement to the longitudinal joint between beams

A new study by the University of Minnesota research team is currently mapping the cracks that have developed. The plan is to revisit four bridges in the spring and summer of 2010 and 2011 and monitor any changes. Based on the findings of this study, the research team should have a better understanding of the nature of the cracks and their effect on durability. They will evaluate the performance of the system and propose final changes to the PCSS standard design and construction details.

Costs

There have been seven new bridges built and one rehabilitated using the PCSS system. Aside from the initial pilot projects, all of the bridges that were constructed showed only a slight incremental cost increase. On average, the cost of using the PCSS system was approximately 10%-15% higher than a comparable CIP slab span bridge. However, the savings in construction time was often substantial. There is potential to shorten construction time by 20% to 40%. Under the correct circumstances, the added cost can be easily justified by the significant construction timesavings. Lengthy road closures or extended construction periods are often very costly to area residents and local businesses, especially in Minnesota's tourist areas. Innovative construction techniques that allow for shorter delays are typically looked upon favorably.

MnDOT's PCSS project has shown that a precast, prestressed concrete superstructure system is an economical and effective practice for rapid bridge construction. The continued development and utilization of rapid construction techniques has the potential to revolutionize bridge construction and MnDOT is planning to use this technique on four more bridges in the near future.

Moises C. Dimaculangan and Tony Lesch are senior engineers at the Minnesota Department of Transportation Bridge Office in Oakdale, Minn.

For more information on this or other projects, visit www.aspirebridge.org.



On Bridge 04002, a precast concrete beam is being moved into place alongside five sections that have already been erected. The typical 6 ft 0 in. beam width can be changed to accommodate bridge width.

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.

IN THIS ISSUE

<http://maintenance.transportation.org>

A copy of the final report titled *Guidelines for Selection of Bridge Deck Overlays, Sealers and Treatments* mentioned on page 45 may be downloaded from this AASHTO Subcommittee on Maintenance website.

http://www.dot.state.fl.us/emo/pubs/Historic_FL_Bridges1.shtm

Visit this Florida Department of Transportation address for a copy of "Historic Bridges of Florida" mentioned in the Pinellas County article on page 55.

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.

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.

Bridge Technology

www.aspirebridge.org

Previous issues of *ASPIRE™* 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

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

This website contains 61 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://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/20-07\(229\)_FR.pdf](http://onlinepubs.trb.org/onlinepubs/archive/NotesDocs/20-07(229)_FR.pdf)

An NCHRP report titled *Bridge Construction Practices Using Incremental Launching* is available at this web address. The report includes a review of current practice, a manual of best practice, and a strategic plan for increasing use of the incremental launching method.

NEW <http://www.fhwa.dot.gov/unknownfoundations/>

This new Federal Highway Administration website offers users a quick and easy source of guidance and reference information on

bridges with unknown foundations. The site's resources include information on research, training opportunities, reports, and other publications and FHWA guidance documents.

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.

<http://knowledge.fhwa.dot.gov/cops/ep.nsf/home>

Come join the FHWA's online Information Exchange for Bridges at this website, which offers information on innovative products and processes for bridge construction. The report titled *Connection Details for Prefabricated Bridge Elements and Systems* is available.

www.nhi.fhwa.dot.gov/about/realsolutions.aspx

Presentations from a monthly seminar series offered online by the Federal Highway Administration National Highway Institute are available to listen to or download from this website. Guest speakers discuss challenges they have faced in the field and innovative solutions used to address those challenges. Seminars relevant to bridges include Probability-Based Design and Rating Methodologies, I-70 Overpass Beam Failure, New Technologies in Driven Piles, and Use of Self-Propelled Modular Transporters.

www.specs.fhwa.dot.gov

This site serves as a clearinghouse and electronic library where users can search, review, cross-reference, and download the most current specifications, construction manuals, and drawings. Materials on the site have been submitted by state departments of transportation and other agencies and include access to specifications, construction manuals, and standard drawings.

Bridge Research

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.

NEW http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_645.pdf

NCHRP Report 645, *Blast-Resistant Highway Bridges: Design and Detailing Guidelines* explores code-ready language containing general design guidance and a simplified design procedure for blast-resistant reinforced concrete bridge columns. The results of experimental blast tests and analytical research on reinforced concrete bridge columns are reported.

http://www.trb.org/news/blurb_detail.asp?id=9627

NCHRP Report 628, *Self-Consolidating Concrete for Precast, Prestressed Concrete Bridge Elements* explores recommended guidelines for the use of self-consolidating concrete (SCC) in precast, prestressed concrete bridge elements. The report examines the selection of constituent materials, proportioning of concrete mixtures, testing methods, fresh and hardened concrete properties, production, and quality control issues, and other aspects of SCC.



Guidelines for Selection of Bridge Deck Overlays, Sealers, and Treatments

by Paul D. Krauss,
John S. Lawler,
and Kimberly A. Steiner,
Wiss, Janney, Elstner
Associates Inc.

The selection and use of bridge deck rehabilitation methods varies widely throughout the United States. Some agencies have developed guidelines but they are limited in scope and detail. While each state likely views the need for deck repairs differently, a set of guidelines based on a general consensus of Department of Transportation (DOT) engineers throughout the country, backed by research and experience, is useful in promoting more consistent and universal procedures for decision making. A recent National Cooperative Highway Research Program (NCHRP)¹ study conducted a survey of transportation agencies and developed just such a methodology for selecting bridge deck treatments for different bridge deck conditions and deck materials.

Survey of Transportation

Agencies

The guidelines were developed based on a survey sent to all U.S. DOTs and Canadian highway agencies to obtain information on what criteria are used to make repair decisions about deteriorating bridge decks. A primary goal of the survey was to identify methodologies and procedures used by agencies to guide decisions regarding bridge deck maintenance and repair. These processes vary widely in complexity and many are unwritten or take the form of simple tables or flowcharts. Some procedures reference bridge inspection methods such as the National Bridge Inventory (NBI) condition ratings² or Pontis element condition ratings.³

The survey showed that repair methods vary between highway agencies and often are based on a few limited techniques with which the agency is familiar. Further, the extent of tolerable damage varies widely between states with the decision to consider full deck replacement triggered when surface distress exceeds from 20% to over 50% of the total deck area. Therefore, the NCHRP Guidelines¹ proposes decision levels and repair techniques that are a general composite of those reported by the agencies. The guidelines were also developed to be flexible to allow individual states to easily modify the decision levels and repair options. While a particular repair option may work well in one part of the country, since the agency has had success specifying the repair and local contractors have the proper equipment and experience to install it successfully, the same technique may not be well suited for another agency because the local experience is not available and would have to be developed.

Selection of Repair Options

The selection of the various deck repair options is performed in two steps. First, the general category of repair that is needed is determined based on the current deck condition. The deck characterization process is driven by assessing the following factors:

1. **Percent Deck Deterioration and NBI Condition Ratings** – determined by the percent of non-overlapping area of patches, spalls, delaminations, and copper-sulfate half-cell potentials more negative than -0.35V and the National Bridge Inventory condition rating based on examination of the top and bottom deck surfaces.



Bridge with lane closed to perform a deck condition survey.
All Photos: Wiss, Janney, Elstner Associates Inc.



Deck spalls, delaminations, and patches due to corrosion of reinforcement.



Core sample showing transverse deck crack intersecting an embedded reinforcing steel bar.

2. **Estimated Time-to-Corrosion** – expressed as the estimated time until sufficient chloride penetration occurs to initiate corrosion over a given percentage of the deck area.
3. **Deck Surface Condition** – consideration of the deck surface condition related to drainage, surface scaling, abrasion loss, or skid resistance problems.
4. **Concrete Quality** – related to evidence of alkali-silica reaction (ASR), delayed ettringite formation (DEF), freeze-thaw damage, and concrete strength issues.

The guidelines provide a table that considers these deck characterization factors to facilitate a decision on one of the following four repair categories:

1. **Do Nothing** makes sense for a deck in satisfactory condition with little corrosion risk in the next 10 years or for a deck that is programmed for replacement in the near future.
2. **Maintenance** may include patching, crack repairs, or use of a concrete sealer. This option is best for decks showing little or no serious distress and with little risk of deterioration in the near future.
3. **Protective Overlay** is appropriate if the deck has moderate deterioration or is likely to have deterioration in the near future, and the deck is not in need of immediate replacement. Bonded overlays provide a new wearing surface so deck surface conditions, such as cross-slope and grade, joint transitions, drainage problems, abrasion resistance, skid resistance, or surface scaling problems, can be improved. Deep milling can be used to remove deteriorated wearing surfaces and chloride contaminated deck concrete.
4. **Structural Rehabilitation** may include partial-depth or full-depth deck replacement. Deck Replacement is selected when the deck has serious deterioration, concrete durability problems, needs strengthening, or a combination of factors that indicate other rehabilitation methods are not suitable.

Decks that are exposed to deicers but have accumulated little chloride are good candidates for sealers or membranes. Decks that have high chloride concentrations in the near surface but little chloride at the reinforcement level are good candidates for surface milling to remove the chlorides and then application of an overlay. The service life of decks with high levels of chloride close to the level of the reinforcement can be extended with overlays, but long-term performance may be reduced since cor-

rosion will likely continue at a slow rate. Decks with very high chloride contents, on-going corrosion, and damage are good candidates for partial- or full-depth deck replacement. Further, in addition to knowing the level of chloride contamination, it is important to understand if the concrete has serious durability or strength concerns before selecting a repair option.

Second, the best repair material option within a category is selected based on various site conditions, such as traffic constraints, dead load or overhead clearance limitations, remaining service life, general exposure conditions, construction constraints, skid resistance, concrete cover, contractor experience, planned future work, cost, or other conditions. In addition, the guidelines provide methods and information useful to help evaluate the deck condition; prepare the deck for sealing, crack repair, or other rehabilitation methods; and estimate relative costs and durability of the various deck rehabilitation methods.

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3. *Guide for Commonly Recognized (CoRe) Structural Elements*, American Association of State Highway and Transportation Officials, Washington, DC, 2002.

Paul D. Krauss is principal, John S. Lawler is senior associate, and Kimberly A. Steiner is senior associate, all with Wiss, Janney, Elstner Associates Inc. in Northbrook, Ill

Louisiana's Bridge Preventive Maintenance Program

by **Danny Tullier,**
Louisiana Department of Transportation and Development

The Louisiana Department of Transportation and Development (LADOTD) believes that an aggressive and strong preventive maintenance program is needed to slow the deterioration processes at work on our bridge structures. As a result, LADOTD initiated the Bridge Preventive Maintenance Program in early 2006 to help extend bridge service lives.

In July 2007, the Federal Highway Administration (FHWA) approved this program, which focuses on bridges in good structural condition, but are deteriorated, damaged, or exhibiting deficient elements.

LADOTD's goal is to apply systematic, cost-effective treatments to existing bridge elements to preserve their current condition and delay deterioration. A portion of the Highway Bridge Program (HBP) funds is used to perform various approved bridge preventive maintenance activities such as:

- joint repair and replacement
- bearing repair and replacement
- localized deck repairs
- spot painting
- deck sealing
- grid deck section repair or localized section replacement
- concrete spall repair on pedestals, bents, caps, piling, piers, and columns
- bridge deck drainage repair

Specific work is selected based on a systematic process approved by the FHWA. The bridge inventory and inspection data are utilized as a source of information for making selections.

Since the program began, LADOTD has let a total of 14 bridge preventative maintenance projects at a cost of \$5.7 million. The majority of these maintenance contracts have been deck



A 3-in.-thick concrete overlay was applied to this six-span bridge under the LADOTD preventative maintenance program.

All Photos: Louisiana Department of Transportation and Development.

joint rehabilitation on interstate bridges. Other projects have included a thin deck overlay on U.S. 90 just outside the New Orleans area and deck spall repairs on I-10 between Baton Rouge and Lafayette. The state is currently involved with other maintenance projects to spot paint a bridge over a large river crossing and to replace failing elastomeric bearing pads.

Louisiana is currently implementing a Bridge Management System using the AASHTOWare computer program Pontis. The state is nearing completion of the 2-year cycle of bridge inspections, at which time all bridges will have element-level data in the program. The 2-year cycle is expected to be complete by July 2010.

The LADOTD recognizes the importance of a well-maintained transportation system and is striving to utilize a portion of the HBP funds to extend the service life of the bridge infrastructure.

Danny Tullier is manager of the Bridge Preventative Maintenance Program of the Louisiana Department of Transportation and Development, Baton Rouge, La.



This is a failed steel armored expansion joint that was eligible for repair, and the joint following rehabilitation with polymer concrete.

Advances in Nondestructive Evaluation and Structural Health Monitoring of Bridges

by Larry D. Olson and Yajai Tinkey,
Olson Engineering Inc.

New sonic-based nondestructive evaluation (NDE) technologies, developed from impact echo (IE) scanning research, are now available to bridge engineers. These technologies address corrosion concerns in post-tensioning (PT) tendons due to voids in ducts and delaminations in concrete bridge decks. Radar-based structural health monitoring technology has developed from interferometric phase radar research for noncontact monitoring of displacements and vibrations of bridges and other structures and even landslide movements.

Sonic Impact Echo Scanning for Structural Concrete Integrity

Point-by-point IE tests have been used to detect voids in PT tendon ducts and concrete deck delaminations due to corrosion of reinforcement. However, the use of IE testing has



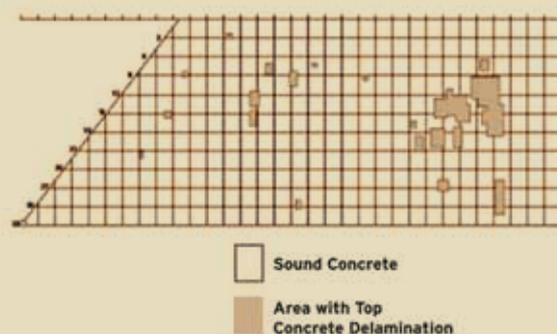
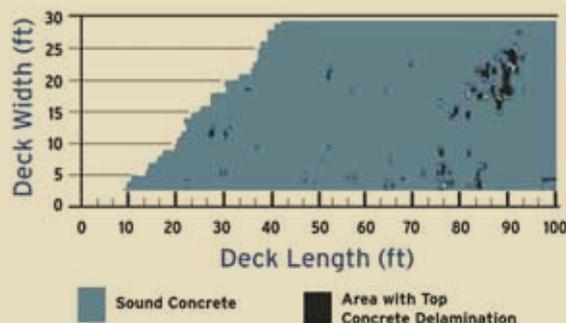
Bridge deck scanner (BDS) towed behind a vehicle.

been limited due to the comparatively slow rate of the point-by-point testing. Research by the authors has resulted in the advancement of IE scanning tests for faster evaluation of structural concrete conditions. IE scanning tests can now be conducted using either a handheld rolling impact echo scanner (IES) or a Bridge Deck Scanner (BDS) attached behind a vehicle for testing larger surface areas with rougher surface conditions. Research was conducted with both the IES and BDS systems under funding from the National Cooperative Highway Research Program—Innovations Deserving Exploratory Analysis (NCHRP-IDEAS).

With the IES and the BDS systems, readings may be taken as close as 1 in. and 6 in. respectively along a scan line. Recent test results showed good correlation between a shallow delamination map obtained from the BDS system and acoustic sounding using a chain drag. The typical time required for testing a 36-ft-wide and 300-ft-long bridge deck with points on a grid of 1 ft by 0.5 ft is approximately 3 to 4 hours.

Interferometric Phase Radar for Structural Monitoring

Non-contact interferometric phase radar is available to measure the displacement and vibration of bridges. The use of the interferometric phase radar with the Imaging By Interferometric Survey System for Structures (IBIS-S) allows for rapid monitoring during load testing of bridges. IBIS-S is a system using innovative microwave radar that was developed



A top surface delamination map from the BDS system (left plot) and the traditional chain drag acoustic sounding results comparison (right plot).

by IDS of Pisa, Italy, in collaboration with the Department of Electronics and Telecommunication of Florence University. The IBIS-S system precisely measures structural displacement with a precision of up to 0.0004 in. and vibration frequencies from 0 to 100 Hz. The system can simultaneously measure the displacement response of several points on bridges and other structures with high accuracy as long as clear reflecting surfaces can be identified (or installed) at least 1.6 ft apart. In addition to its non-contact feature, the new displacement and vibration measuring system provides other advantages including quick set-up time, a wide frequency range of response, and portability. A case history from a demonstration test of the IBIS-S system performed on a post-tensioned, curved, precast concrete box girder bridge in Golden, Colo., is included in the referenced paper. The primary objective of the demonstration was to measure the deflection time-histories and maximum deflections of the bridge under normal automobile and truck traffic loading. Due to the noncontacting nature of the system and operational range, all testing was performed with no traffic disruption and minimal field support requirements.

Summary

IES has been found to provide accurate detection of voids in ducts of post-tensioned bridges and can be readily applied in hand-scanning large areas of bridge walls and decks. Recent research and consulting has built on the IES method to provide a BDS that is capable of providing high-quality data on concrete bridge decks for accurate location of distress. The IBIS-S system can be rapidly deployed for short-term displacement and vibration monitoring. This facilitates the use of short-notice, economical static and dynamic load tests as well as measurement of operating displacements and ambient vibration measurements.

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Larry D. Olson is principal engineer and Yajai Tinkey is associate engineer with Olson Engineering Inc. in Wheat Ridge, Colo.

A detailed paper on this topic by Larry Olson was presented at the 2010 Federal Highway Administration Bridge Engineering Conference: Highways for LIFE and Accelerated Bridge Construction, April 8 and 9 in Orlando, Fla. By permission of FHWA, it is available at the **ASPIRE™** website, www.aspirebridge.org, click on "Resources" and select "Referenced Papers."



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DEPLOYMENT OF ULTRA-HIGH-PERFORMANCE CONCRETE TECHNOLOGY

by Dr. Benjamin A. Graybeal with M. Myint Lwin,
Federal Highway Administration

The previous issue of *ASPIRE*[™] provided an overview of ultra-high-performance concrete (UHPC) and introduced the Federal Highway Administration's (FHWA)'s research and deployment efforts. This article expands the discussion to include the specific deployment efforts completed and those underway in the United States.

From the previous article, "UHPC refers to a class of exceptionally durable and strong cementitious composites, usually containing fiber reinforcement and exhibiting self-consolidating properties. UHPC has been used in Europe and Asia in building vehicular bridges, pedestrian bridges, and other types of structures."

The aging of highway bridges in combination with traffic congestion related issues has created a situation where the need for bridge owners to repair, replace, and construct durable bridges is greater than ever. There is a strong demand for new solutions to existing problems, and the advanced mechanical and durability properties of UHPC open many new avenues toward these solutions.

First Deployments

The Mars Hill Bridge in Wapello County, Iowa, was the first UHPC bridge on a public road in the United States. This three-girder bridge spans 108 ft and uses 42-in.-deep precast, prestressed UHPC girders. The Iowa Department of Transportation (IowaDOT) modified the girders from the standard Iowa bulb-tee design by using thinner flanges and narrower webs. The traditional shear reinforcement was also eliminated because testing at FHWA's Turner-Fairbank Highway Research Center and Iowa State University demonstrated that the UHPC,

with its steel-fiber reinforcement, was sufficient to resist the design loads. Among other things, this project demonstrated the viability of casting UHPC bridge girders in a conventional precast concrete plant. The bridge opened to traffic in 2006. More details of the Mars Hill Bridge are given in the Summer 2007 issue of *ASPIRE*.

A similar deployment was completed at the Cat Point Creek Bridge near Warsaw, Va., in 2008. This 82-ft-span bridge used 45-in.-deep prestressed concrete I girders. The Virginia Department of Transportation (VDOT) used their standard bulb-tee girder shape and, like the Mars Hill Bridge, eliminated the use of normal steel shear reinforcement. The five UHPC girders were included in the second span of this 10-span bridge.

Optimized Girder Deployment

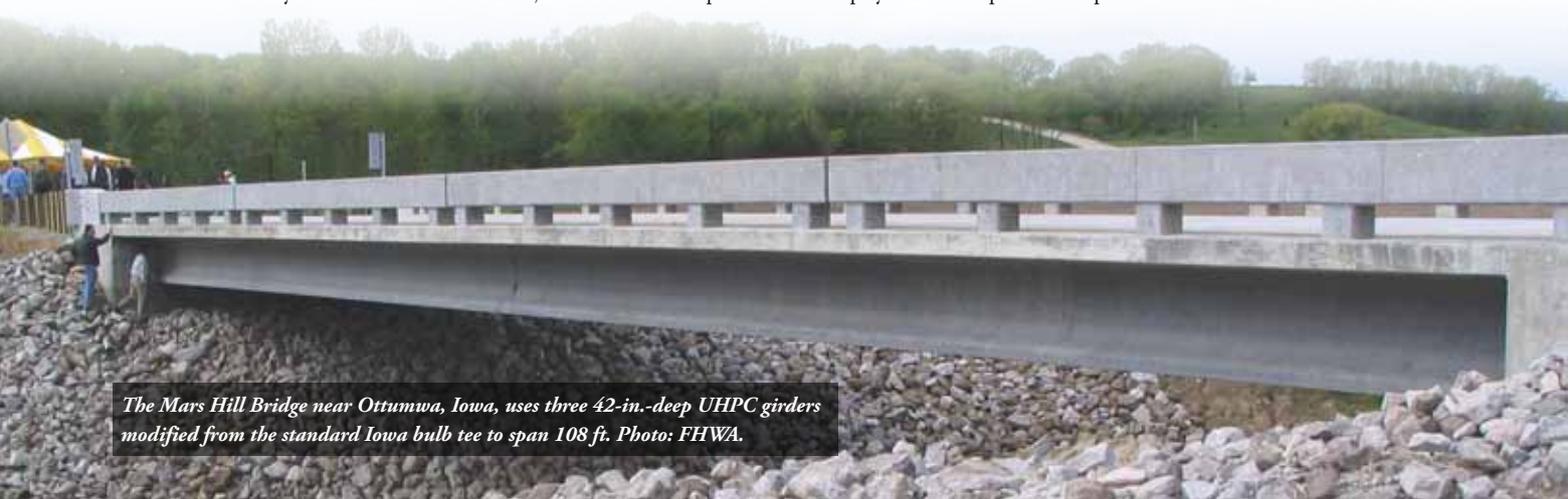
The initial research and deployment of UHPC technology in the United States demonstrated the capabilities of the material and the feasibility of component fabrication for infrastructure projects. Moreover, these projects also demonstrated that the development of new, structurally optimized girder shapes is warranted if the mechanical and durability properties of UHPC are to be efficiently engaged in superstructure elements. FHWA initiated a research program aimed at developing a precast, prestressed deck bridge girder component applicable to typical U.S. highway bridges. The result of this project was the pi girder, a 33-in.-deep, deck-bulb-double-tee girder that can span up to 87 ft. This component facilitates the accelerated construction of durable infrastructure systems. The IowaDOT completed the first deployment of the pi

girder in a bridge near Aurora, Iowa. The Jakway Park Bridge used three abutted adjacent pi girders in its main span. It opened to traffic in 2008. More details of the Jakway Park Bridge are given in the Winter 2010 issue of *ASPIRE*.

Precast Deck Connections

The advanced mechanical properties of UHPC have also proven capable of advancing the state-of-the-art in bridge component connection technology. In recent decades there has been a push toward accelerating bridge construction through the use of precast components; however, joining these components in the field with durable, robust connections has sometimes proven problematic. The bond properties of UHPC have created an opportunity to re-engineer connections, especially at the deck level, in an effort to construct robust, simple, and durable details.

The New York State Department of Transportation is playing a leading role in using UHPC to create splice connections between deck-level components. During the summer of 2009, they constructed two bridges using this type of connection detail. The first bridge, located in Lyons, used UHPC to create the deck-level connection between adjacent deck-bulb-tee prestressed concrete girders. This 6-in.-wide connection across which the reinforcement is spliced, is filled with field-cast UHPC. More details are given in the Fall 2009 issue of *ASPIRE*. The second bridge used UHPC to connect together conventional precast concrete deck panels. Located near Oneonta, the deck panels were placed on steel stringers, then the extended reinforcement was spliced within a 6-in.-wide UHPC connection.



The Mars Hill Bridge near Ottumwa, Iowa, uses three 42-in.-deep UHPC girders modified from the standard Iowa bulb tee to span 108 ft. Photo: FHWA.



Adjacent deck bulb tees being aligned for level prior to field-casting a UHPC longitudinal joint on the State Route 31 Bridge over the Canandigua Outlet in Lyons, N.Y. Photo: New York State DOT.



The Cat Point Creek Bridge near Warsaw, Va., uses standard VDOT bulb-tee UHPC girders, 45 in. deep, spanning 85 ft. Photo: FHWA.

Concurrently, there is a research effort ongoing at FHWA that focuses on the mechanical and durability properties of these deck-level connection details. Results to date from cyclic structural loading of full-scale connections have demonstrated very good performance.

Bridge Re-decking System

The exceptional durability of UHPC also presents opportunities for directly addressing the pressing need for bridge deck replacements around the nation. An FHWA analytical study, combined with previous experience in the United States and abroad, has led to the development of a structurally optimized precast UHPC deck panel. The two-way ribbed panel (i.e., waffle panel) is approximately 30% lighter than a conventional concrete deck panel and is significantly more durable. Engaging the connection details discussed above allows for the accelerated construction of an all-UHPC deck.

This system is being put to the test currently in Iowa where a bridge will be constructed in the summer of 2010. Coreslab Structures Inc. of Omaha, Neb., received a Highways for LIFE grant to lead a project further developing this concept. They are working with the IowaDOT, Wapello County, Iowa State University, and Lafarge North America Inc., to test and deploy the concept. Fourteen waffle panels will be used to deck the 60-ft-long, 33-ft-wide bridge over Little Cedar Creek in Wapello County.

Conclusion

Advanced structural materials, such as UHPC, open doors to new structural systems and construction techniques that can assist in the rehabilitation and reconstruction of highway bridges. To date, UHPC has been deployed in five U.S. highway bridges, and additional deployments are planned. UHPC has been demonstrated as a viable alternative for both precast components and field-cast connections. As familiarity with UHPC increases, additional deployments of existing concepts and development of new concepts are anticipated. UHPC presents great opportunities to construct durable, resilient infrastructure systems.



Jakway Park Bridge near Aurora, Iowa, is the first project to use the optimized pi girder. It is 33 in. deep and spans 87 ft. Photo: FHWA.



State Route 23 over Otego Creek near Oneonta, N.Y., features conventional precast concrete deck panels with extended reinforcement spliced in 6-in.-wide connections using UHPC. Photo: FHWA.



A laboratory test deck panel like the ones being used for Little Cedar Creek Bridge in Wapello County, Iowa. Photo: Iowa State University.

EDITOR'S NOTE

The FHWA UHPC Research Program is managed by the Bridge Design and Construction Team at the Turner-Fairbank Highway Research Center in McLean, Va. Further information on research and deployment of UHPC technology can be obtained by contacting Dr. Graybeal at bgraybeal@dot.gov or 202-493-3122.



ADVANCES IN CONCRETE BRIDGES

in Iowa

by Ahmad Abu-Hawash, Norman McDonald, Kimball Olson, and Kenneth Dunker,
Iowa Department of Transportation

For more than a century, Iowa has seen concrete bridges built with steadily advancing technology—cast-in-place (CIP); reinforced; precast, prestressed; high-performance (HPC); self-consolidating (SCC); post-tensioned; ultra-high-performance (UHPC); and combinations of technologies to accomplish accelerated bridge construction (ABC).

The history of Iowa's concrete bridges began in the late nineteenth century with the first CIP reinforced concrete Melan arch bridge, built when arches were popular for their efficiency and beauty. Soon after the Iowa State Highway Commission (IHC) was established early in the twentieth century, the IHC developed plans for several series of standard CIP reinforced concrete slab and beam bridges. These standard plans were created in the same era as the proprietary and competing concrete arch designs of James Barney Marsh and Daniel B. Luten.

Precast and Pretensioned Bridges

In the early 1950s, the bridge office developed standard designs for several new concrete bridges, often in conjunction with the Iowa Highway Research Board (IHRB). There were the H1 and H2 CIP reinforced concrete girder and continuous girder series for spans to 67.5 ft and 100 ft, respectively, and the J10 precast reinforced concrete series (reinforced channel slabs) for spans up to 30 ft. In 1954, the bridge

office recognized the advantages of precast, prestressed concrete beams with the H10-series for spans up to 42.5 ft. As with all of the state-developed standard bridges, these were built by counties and cities as well as by the state. Updated versions of the H-series are still in use today.

The family of standard beams developed in the 1950s has grown to cover a wide range of span lengths and superstructure depths. The newest set of bulb-tee beams provides a competitive alternate for medium-span bridges. These bulb-tee beams have proven to be a perfect solution for many two-span overhead structures, multiple-span urban viaducts, and the approach spans of major river crossings. Attributes of the new beams include AASHTO Load and Resistance Factor Design (LRFD) compliance, low permeability (< 2500 coulombs), high strength (up to 9000 psi), efficient design with longer spans (up to 155 ft), wider beam spacings (up to 9.25 ft), and an aesthetically pleasing shape. It is interesting to note that the majority of Iowa bridges utilize precast, prestressed concrete beams. In fact, prestressed concrete was the material of choice for bridges over the interstate system.

High-Performance and Self- Consolidating Concretes

In early 2000, as a part of the reconstruction of I-235 in Des Moines, the Iowa Department

of Transportation (IowaDOT) introduced HPC and SCC. Although HPC and SCC have been used widely in the United States, deploying these mixtures in Des Moines was not a simple task. A group of IowaDOT engineers from various disciplines, along with the Federal Highway Administration (FHWA), collaborated on developing mix designs and construction specifications that were suitable for central Iowa. The HPC mix designs had to utilize locally available aggregates, and meet new design requirements in terms of strength and permeability. Many challenges were encountered along the way, including a lack of local experience in producing mixtures such as HPC; implementation of a new aggressive policy on starting curing procedures for concrete within minutes after placing; and dealing with harsh winter conditions.

The I-235 experience laid the groundwork for statewide implementation of HPC, which is currently being used on major reconstruction projects in western Iowa (I-29/I-80 in Council Bluffs) and eastern Iowa (I-74 in the Quad Cities and U.S. 20 in Dubuque). These projects include several Missouri River and Mississippi River crossings. Although HPC has not been officially adopted for statewide use, many elements of HPC are being added to traditional mixtures. This can be attributed to the successes achieved on the I-235 project. Furthermore, some changes to IowaDOT's construction specifications were made to take advantage of

*The Marsh rainbow arch bridge constructed in 1914 across the Raccoon River near Lake City has three 80-ft-long spans.
Photos and drawings: IowaDOT.*



Bridges have become a prime focus of aesthetic enhancement efforts.

the proven practices, such as improved concrete curing methods.

Iowa has earned a good reputation for bridge deck longevity despite the harsh winter environment and the use of deicing chemicals. This success can be attributed to its proactive use of deck overlays. In the late 1960s, Iowa introduced a low-slump dense overlay. The 1.5-in. to 2.0-in.-thick layer has provided excellent protection for bridge decks that were built with uncoated reinforcing steel. In fact, deck replacement projects have been rare in Iowa. Some decks have received multiple overlays prior to replacement. Recently, an alternative HPC overlay mix design was introduced to take advantage of common HPC benefits. Unlike the low-slump overlay mix, the new HPC deck overlay mix does not require specialized mixing and casting equipment because it can be cast using standard deck construction techniques and equipment, thus reducing cost. The biggest advantage of using HPC in deck overlays is the elimination of nuclear density testing and its associated safety and security issues.

Accelerated Construction and Ultra-High-Performance Concrete

Similar to the nationwide trend, precast concrete has played a major role in accelerated bridge construction (ABC) in Iowa, primarily with the use of precast deck panels, beams, pier caps, and abutment footings. The ABC efforts in Iowa began in 2006 when two local system bridges were constructed in Boone and Madison counties using precast superstructure and substructure

components. This effort continued with the construction of 24th Street over I-29/I-80 in Council Bluffs. In 2009, a third totally precast bridge was built in Buena Vista County. The use of precast concrete has since been expanded to include bridge pavement approaches in Iowa. (See *ASPIRE*,™ Spring 2007.) So far, precast concrete panels have been used in two approach roadway projects, and a third will be constructed in 2010.

Another advance in concrete use in Iowa occurred in 2005, with construction of the first UHPC bridge, in North America. Between 2005 and the present, three different types of UHPC superstructure components have been investigated for use in three Iowa bridges—bulb tee girders, pi-girders, and waffle deck panels.

Iowa has earned a good reputation for bridge deck longevity.

The first was a single-span, 110 ft long by 27 ft wide, Wapello County bridge (Mars Hill Bridge) with a cross section that consisted of three bulb-tee girders designed with concrete compressive strength of 24,000 psi and an allowable tensile stress at service of 600 psi. A typical UHPC mixture utilizes steel fibers in lieu of conventional shear reinforcing bars and has compressive strength that generally ranges from 16,000 psi to 30,000 psi. The tensile strength, usually neglected in concrete, can be as high as 1700 psi. The second bridge (Jakway Park Bridge) utilized a unique pi-shaped girder superstructure and was built by Buchanan County in 2008. In 2010, a third bridge with a UHPC waffle-shaped deck panel system will be built in Wapello County. It will also use field-placed UHPC to connect panels to panels and panels to girders. More details on the Wapello and Buchanan County bridges are given in



In O'Brien County, near Shelton, precast paving approach panels were installed on both ends of a new highway bridge to demonstrate rapid construction while eliminating settlement at the abutments. Each section was approximately 77 ft long and 28 ft wide.

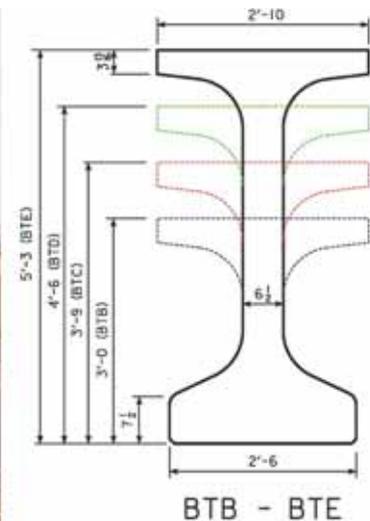
ASPIRE Summer 2007 and Winter 2010 issues, respectively.

The IowaDOT is currently working with Iowa State University (ISU) to investigate and test a new concept for a hybrid UHPC/HPC deck panel. The ISU/IowaDOT team has also investigated and field tested a UHPC H-pile for use in deep foundations, and a second phase of research is in progress.

Gateways and Enhancements

In recent years, the IowaDOT has become more responsive to the concerns of citizens about the appearance of state infrastructure projects. Bridges have become a prime focus of aesthetic enhancement efforts, especially when projects are built in and near communities. Routine structures are often considered by local municipalities to be community gateways, and the IowaDOT has tailored enhancement schemes to address these subjective project parameters. Occasionally, these aesthetic solutions become customized expressions of the communities in which they are situated. Instead of using an enhancement cookbook of ready design features, each effort has been uniquely

The new standard bulb-tee beams were installed in many bridges over I-235 in Des Moines.





An illustration of community gateway enhancement of a three-span, precast, prestressed bulb-tee beam bridge in Algona, Iowa, is U.S. 169 over the East Fork of the Des Moines River. The sculpted concrete aesthetic features capitalize on the city's railroad heritage.

orchestrated to design a project that strongly reflects aspects of its unique context.

Major interstate corridor reconstructions such as I-235 through Des Moines, I-29 through both Council Bluffs and Sioux City, and I-74 through the Quad Cities have all included aesthetic enhancements as a significant component of the planning and design process. Other individual bridge replacement projects in cities such as Algona, Keosauqua, Ankeny, and Bellevue have delivered community gateway solutions with unique aesthetic themes.

Concrete bridges are a mainstay on the Iowa highway system and will continue to improve with research, advancing concrete technology, and aesthetic enhancements.



Precast UHPC waffle slab deck panels passed the testing program shown here at Iowa State University and are part of the design for a Wapello County bridge to be constructed in 2010.



Full-width deck panel placement at the 24th Street project site in Council Bluffs, the first Highways for LIFE project in Iowa.



Renderings of I-29 mainline bridges over local streets in Sioux City, projected for construction in 2014.

Concrete bridges are a mainstay on the Iowa highway system.

Ahmad Abu-Hawash is chief structural engineer, Norman McDonald is state bridge engineer, Kimball Olson is aesthetic bridge specialist, and Kenneth Dunker is transportation engineer specialist, all with the Iowa Department of Transportation in Ames, Iowa.

Iowa Bridges Timeline

1894

Melan reinforced concrete arch bridge, Lyon County

1904

Iowa State Highway Commission (IHC) established

1906

Standard plans developed for reinforced concrete box culverts

1913

IHC separated from Iowa State College

1920

Standard plans for I-Series reinforced concrete tee-beam bridges

1950

Iowa Highway Research Board (IHRB) established

1954

Standard plans developed for H10-Series precast, prestressed concrete beam bridges

1954

Standard plans developed for precast concrete channel slab bridges

1974

Iowa Department of Transportation established

2000

HPC and SCC methods and materials developed and used

2004–2005

Bulb-tee standard beams developed

2005

Mars Hill UHPC bulb-tee bridge built in Wapello County

2006

Precast concrete pavement approach slabs used in O'Brien County

2006

ABC project built in Boone County

2008

Jakway Park UHPC precast pi-girder bridge built in Wapello County

2010

UHPC precast waffle deck panel bridge to be built in Wapello County



The inspiration for articulation and coloring of the concrete elements of this two-span bridge, First Street over I-29 near Sergeant Bluff, came from nearby examples of Prairie School architecture.

Pinellas County's Bridge Program

by Thomas M. Menke and Peter J. Yauch, Pinellas County, Florida

Pinellas County, located in the West Central Region of Florida, encompasses 280 square miles and has 24 separate municipalities plus a large unincorporated area. With approximately 940,000 residents, the county is the most densely populated county in the state. The major cities are St. Petersburg and Clearwater, and its white sandy beaches are internationally known.

On the county's road network, there are a total of 140 bridges that are owned and maintained by Pinellas County Public Works. Like most counties in this part of Florida, the majority of the bridges are concrete. The oldest bridge in the inventory, the Shore Drive Bridge, is a unique concrete arch-type bridge constructed by the Luten Bridge Company of York, Pa., in 1923. This bridge has been identified as having historical significance and is included in the "Historic Highway Bridges of Florida," a publication by the Florida Department of Transportation (FDOT). It can be seen at http://www.dot.state.fl.us/emo/pubs/Historic_FL_Bridges1.shtm.

The current economic climate has directed the county's focus toward maintenance of existing infrastructure by extending service life through the use of a Bridge/Asset Management and Preventative Maintenance programs. The Bridge Management program begins with the county receiving biennial bridge inspection reports issued by the FDOT through their Local Bridge Inspection program. The county bridge engineer reads and assesses these reports, follows up with a field verification of listed deficiencies, and programs the work required to make repairs. The magnitude of the repairs is evaluated to determine whether they can be done in-house or require contracted labor.

The Preventative Maintenance program features three-person work teams, who cycle

through the entire bridge inventory on an annual basis, performing specific maintenance tasks, including cleaning and painting of the structure, servicing bridge expansion joints, and cleaning bridge drainage systems. Another three-person work team is used to perform minor repairs such as spalls and delaminations, pile jacket construction, seawall cap repair, and repair of slope pavement washouts.

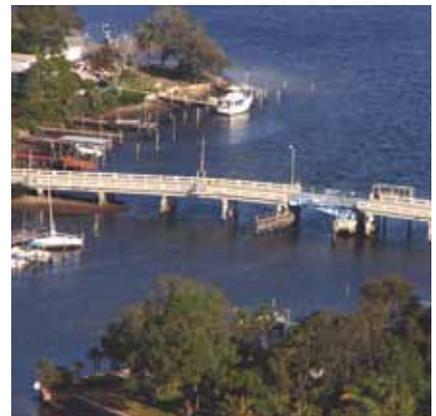
Pinellas County is fortunate to have a Capital Improvement program that is primarily funded through an infrastructure sales tax (known as *Penny for Pinellas*). This program is used to improve infrastructure within the county, and has funded one bridge replacement per year over the last 5 years, including the Belleair Beach Causeway Bridge featured on page 16. These replacement projects have all been concrete bridges. They have proven to be the more economical alternative to structural steel, especially when used to construct smaller-span bridges, which is the typical county bridge. They also offer more durability to resist the harsh environmental conditions seen on the West Coast of Florida.

Lower property taxes and decreased sales tax collections have caused local budgets to shrink. Regardless of the size of the overall budget, bridge needs are a high priority. The Bridge Program helps Pinellas County realize this goal by ensuring the most efficient use of available funding to maintain, repair, and replace its bridges.

Thomas M. Menke is senior engineer in the Structures Division and Peter J. Yauch is director of public works and transportation, Public Works Department, Pinellas County, Fla.

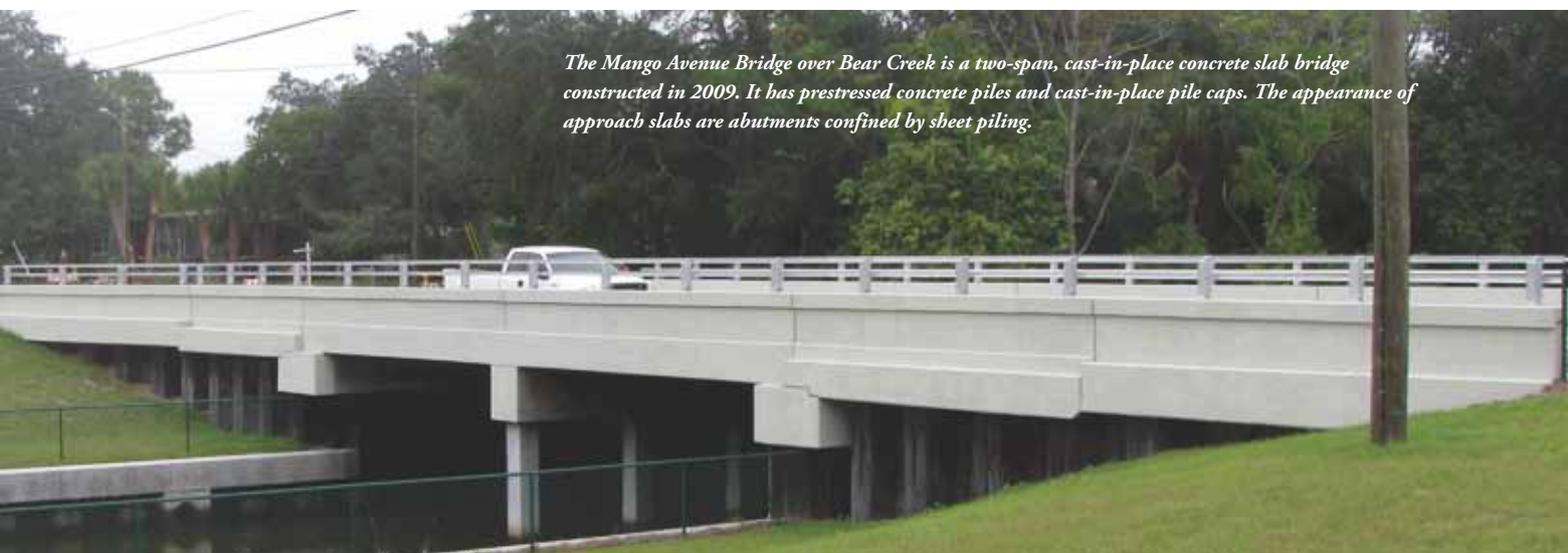


The Shore Drive Bridge was constructed in 1923 by the Luten Bridge Company.



Beckett Bridge over Whitcomb Bayou is a bascule bridge constructed in 1922. Its cast-in-place concrete slab approaches were constructed in 1965 on precast concrete piles that remain in good condition.

The Mango Avenue Bridge over Bear Creek is a two-span, cast-in-place concrete slab bridge constructed in 2009. It has prestressed concrete piles and cast-in-place pile caps. The appearance of approach slabs are abutments confined by sheet piling.



2010 Interim Revisions Related to Concrete Structures Part 2



by Dr. Dennis R. Mertz,
professor of civil engineering,
University of Delaware

The 5th Edition of the AASHTO *LRFD Bridge Design Specifications* was published recently. This new edition includes five interim revisions related to concrete structures that the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Bridges and Structures (SCOBs) considered and adopted at their annual meeting in New Orleans, La., in July of 2009. Technical Committee T-10, Concrete Design, developed Agenda Items 9, 10, 12, 14, and 15 over the past several years and moved them to the subcommittee ballot for consideration in New Orleans. Agenda Items 9, 10, and 12 were reviewed and discussed in the previous issue of *ASPIRE*TM. The final two items are described in this article.

Agenda Item 14 deals with crack-control reinforcement for the strut-and-tie model of Article 5.6.3.6. This reinforcement controls crack widths and ensures ductility so that the development of straight concrete struts is possible. While the ratio of reinforcement area to concrete area is still taken as not less than 0.003 in each direction, the first sub-item provides equations that clarify the zones over which the reinforcement is required. Many designers consider this amount of steel to be extreme. Recent research suggests that 0.003 is appropriate but this revision may reduce the required reinforcement through more precise specification of the application of the provisions. The second sub-item includes a modification to the commentary and adds a figure illustrating the distribution of crack-control reinforcement in a concrete strut.

Agenda Item 15 modifies Article 5.8.3.4.2 and includes four sub-items. The first sub-item clarifies the definition of ϵ_s in the notation for use in Article 5.8.3.4.2. Previously, the definition stated that the strain was in the nonprestressed tensile reinforcement when the strain should be a function of both the nonprestressed and the prestressed tensile reinforcement present in the section. The second sub-item clarifies this definition in the article itself.

Previously, Article 5.8.3.4.2 required the designer to ignore nonprestressed reinforcement terminated at a distance less than the development length from the section under consideration, while elsewhere in the article the designer is allowed to logically use the nonprestressed reinforcement in proportion to its development. Sub-item 3 of Agenda Item 15 eliminated this contradiction. Finally, sub-item 3 and sub-item 4, added absolute-value signs to two comparisons of M_u to $(V_u - V_p)d_v$, so that the proper comparison is made.

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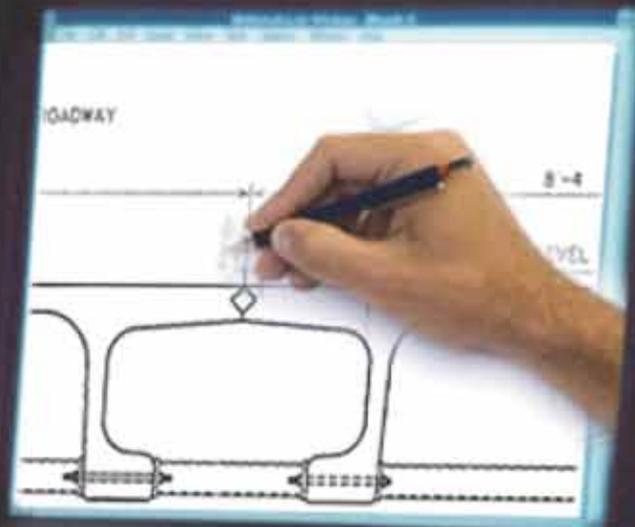
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Connection Details for Prefabricated
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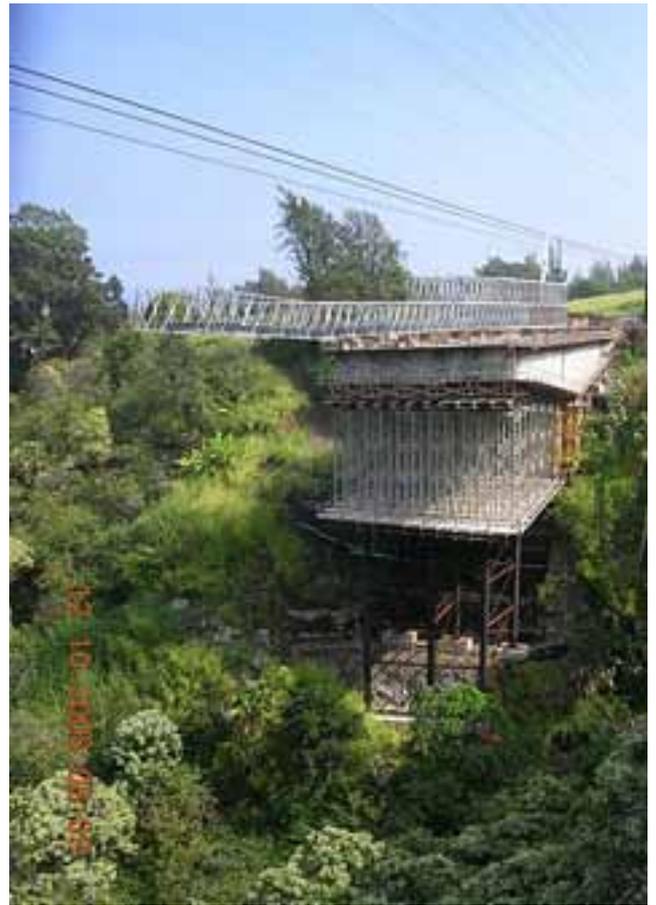
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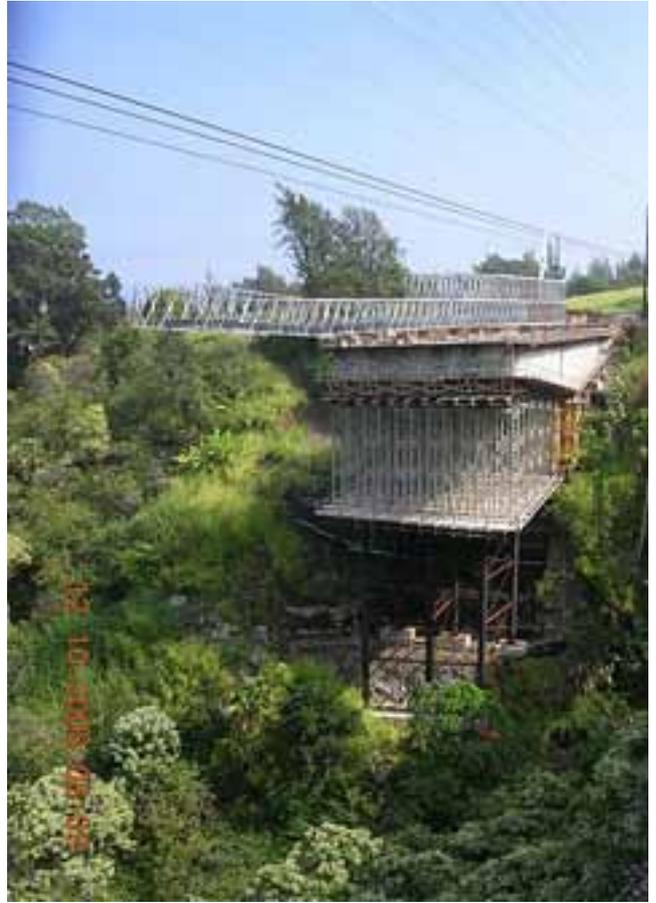
PROJECT / KEALAKAHA STREAM BRIDGE REPLACEMENT



PROJECT / KEALAKAHA STREAM BRIDGE REPLACEMENT



PROJECT / KEALAKAHA STREAM BRIDGE REPLACEMENT



PROJECT / ROUTE 36 HIGHLANDS BRIDGE REPLACEMENT



Balanced cantilever construction of the eastbound bridge as viewed from the eastern shore.



Shown here is a 19 strand wedge plate after lock-off at the anchorage of a vertical pier tendon. Special wedges were provided that gripped the strand through the epoxy coating. Use of these wedges promoted field labor savings and maintained an uncompromised epoxy coating rather than stripping epoxy from the strand ends for wedge bite.

PROJECT / ROUTE 36 HIGHLANDS BRIDGE REPLACEMENT



PROJECT / THE DAVID KREITZER LAKE HODGES BICYCLE PEDESTRIAN BRIDGE



PROJECT / MINNESOTA'S PRECAST COMPOSITE SLAB SPAN SYSTEM



At Bridge 66004, a precast concrete beam is lowered onto the substructures. The diamond pattern in the concrete provided a roughened surface to assist with composite action. Presently, a roughened surface is provided on all contact surfaces except the tops of the flanges.



This is Bridge 66004, TH 60 over the Cannon River in southern Minnesota after completion.



Completed Bridge 04002, TH 72 over the Tamarac River in northern Minnesota during the early fall season.



The Aurora Avenue Bridge in Shoreline, Wash. incorporates public art into the concrete walls to enhance the aesthetic appeal of the bridge approaches.



The Fred Howard Park Bridge is a three-span precast, prestressed concrete slab bridge using prestressed concrete piles and cast-in-place pile caps. It was constructed in 2010.