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FALL 2013

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West 7th Street Bridge

Fort Worth, Texas

I-4/SELMON EXPRESSWAY CONNECTOR

Tampa, Florida

CRAIG CREEK BRIDGE

Red Bluff, California

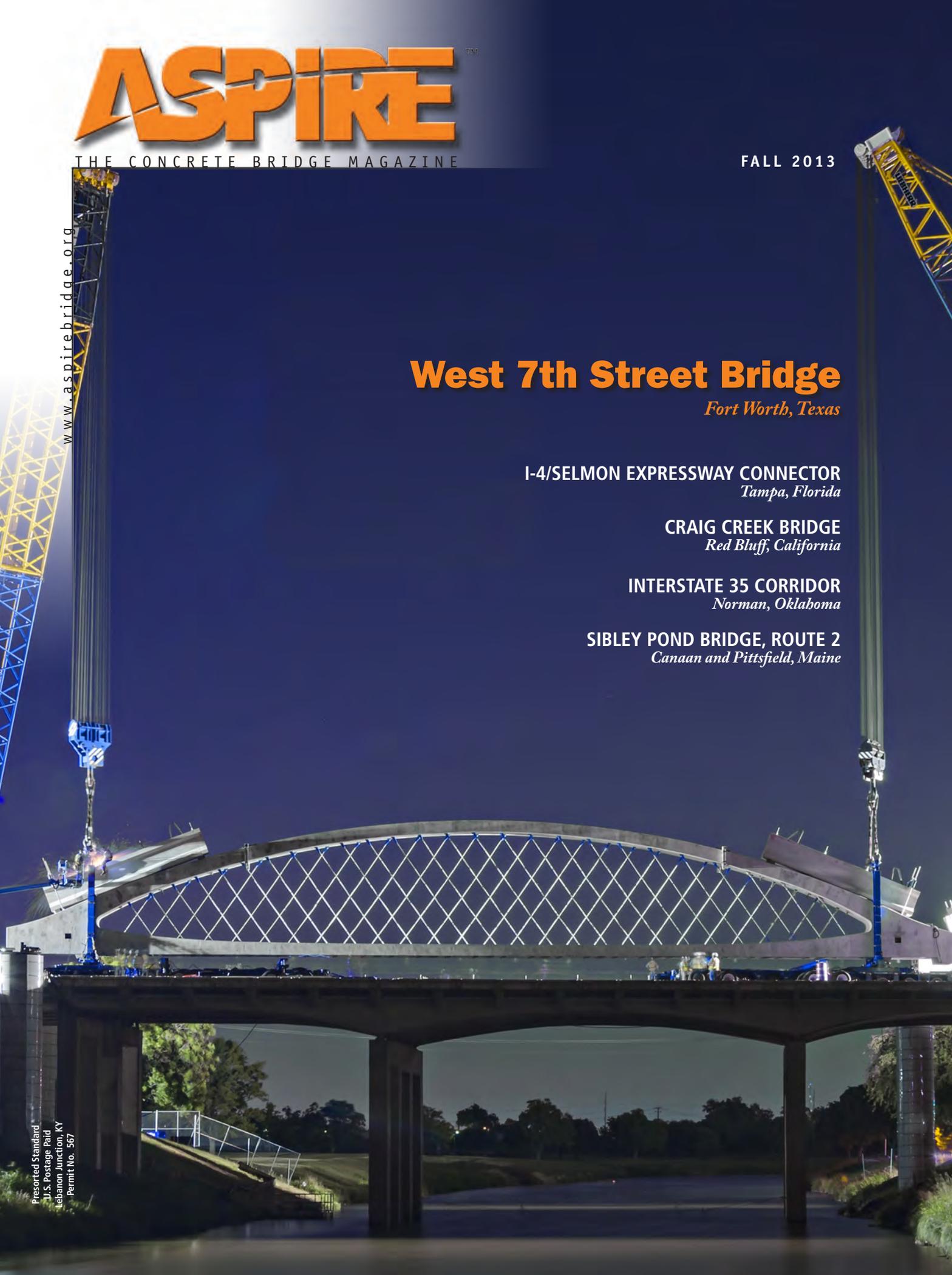
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Photo: SDR Engineering Consultants Inc.

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Photo: PCI

You better have teamwork, or you better be perfect

William Nickas, *Editor-in-Chief*

Recently, I was approached by some concerned concrete design engineers because they were not getting all the data needed to decide on a system being considered for a new expressway. When policymakers lack data, they can be skewed into an action that is unwarranted. This type of feedback caused me to reflect on how my career has left me with certain entrenched principles... You better have teamwork, or you better be perfect.

As I have editorialized before, my principles have come from many places. When I reported to my first job right out of college, I was ready to roll. Like most of us, it did not take long to identify how much on-the-job training (OJT) was still going to be required. Soon enough, I settled into the bridge design office where it did not take long to recognize why the squad leaders sitting closest to the doors were in-charge. Going to coffee breaks and eating lunch together proved to expand my OJT experience. Listening to these veterans of more than 25 years, each discussing recent and past bridge challenges, certainly shaped my future. Very often, they had developed an instinct on where to look or whom to ask for potential solutions.

Today, with the available internet search tools, engineers have volumes of data at their fingers. Our training has taught us to ask diligent questions like:

- is this creditable?
- is this relative to my concern?
- is this objective?
- is there a bias here?
- are the data current and complete? and
- are the conclusions supported with the presented data?

Engineers often believe that the natural process of creating and submitting an evolving project (30, 60, 90, and 100% plan reviews) will expose any concerns. This is not always the case when you are trying something new.

Innovation really means using our best engineering solutions (standards of practice and codified tools) in a creative unbridled manner that best meets the project needs. The American Association of State Highway and Transportation Officials and the Transportation Research Board committees are formally commissioned and routinely come together as teams in a large league to advance technologies, find solutions, and exchange knowledge. Over the last year, the FHWA hosted a series of regional meetings (known as Peer2Peer exchanges) where neighboring states gathered and hosted diversified bridge engineers from other corners of the nation.

These exchanges facilitated discussions between state agency engineers and representatives of the steel, composite, and concrete industries. These exchanges also molded new relationships. One visiting engineer said, "I came all this way not to tell you what to do but I am here to show you what can be done" and those seeds are now bearing fruit. In small breakout meetings, the visiting bridge engineers could share details of lessons learned in a round table fashion, forging new long-lasting exchanges. These informal groups are still working to maximize positive energy through effective resource utilization with continuity and flexibility. With each department of transportation comes certain time tested practices. Many of the concepts and details shared in these FHWA-hosted meetings are now being adapted to meet the needs of the local jurisdiction. Having these new contacts to gather feedback, however, allows the change agent within his or her bridge department to not worry about having to be perfect because he or she is part of a new team.

As you see state highway bridge departments change and adapt new concrete technologies please let the *ASPIRE*TM team know. Please continue to send in your great concrete projects so that you too can expand your realm of exposure and become part of a growing team and always remember: you better have teamwork or you better be perfect. 



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Arch setting at night of the West 7th Street Bridge in Fort Worth, Tex.

Photo: Liam Frederick Photography.

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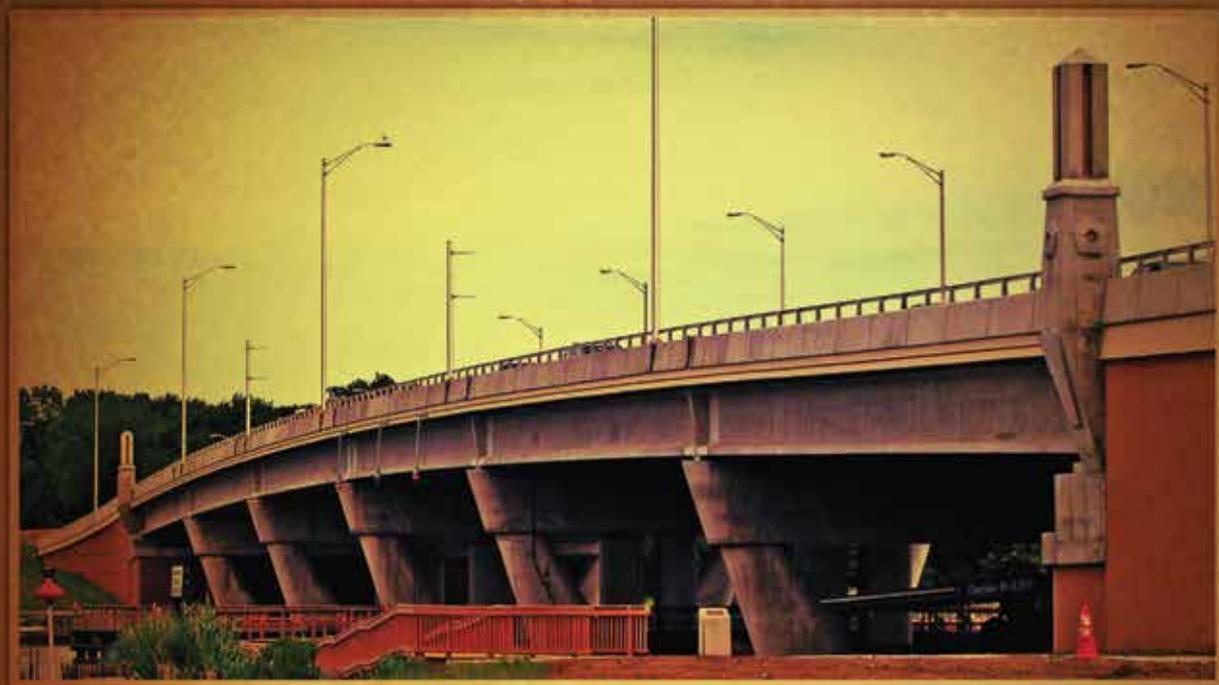


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CONCRETE CALENDAR 2013/2014

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

September 21-25, 2013
PCI Annual Convention and Exhibition and National Bridge Conference
Gaylord Texan Resort & Convention Center
Grapevine, Tex.

September 30-October 2, 2013
ACAA 2013 Fall Meeting
Pinehurst Resort
Pinehurst, N.C.

October 2-4, 2013
PTI 2013 Committee Days
Austin Marriott North
Round Rock, Tex.

October 19, 2013
ASA Fall 2013 Committee Meetings
Hyatt Regency & Phoenix Convention Center
Phoenix, Ariz.

October 20-24, 2013
ACI Fall Convention
Hyatt Regency & Phoenix Convention Center
Phoenix, Ariz.

October 28-29, 2013
ASBI 25th Annual Convention
Portland Marriott Downtown Waterfront
Portland, Ore.

December 8, 2013
ASTM Symposium on Ultra-High Performance Concrete
Hyatt Regency Jacksonville Riverfront
Jacksonville, Fla.

January 12-16, 2014
93rd Annual Meeting Transportation Research Board
Marriott Wardman Park, Omni Shoreman, and Hilton Washington
Washington, D.C.

January 20, 2014
ASA World of Concrete 2014 Committee Meetings
Las Vegas Convention Center
Las Vegas, Nev.

January 20-24, 2014
World of Concrete 2014
Las Vegas Convention Center
Las Vegas, Nev.

March 19-21, 2014
DBIA Design-Build in Transportation
San José Convention Center
San José, Calif.

March 22, 2014
ASA Spring 2014 Committee Meetings
Grand Sierra Resort
Reno, Nev.

March 23-27, 2014
ACI Spring Convention
Grand Sierra Resort
Reno, Nev.

April 14-15, 2014
ASBI 2014 Grouting Certification Training
J. J. Pickle Research Campus
The Commons Center
Austin, Tex.

June 22-27, 2014
2014 AASHTO Subcommittee on Bridges and Structures Meeting
Hyatt Regency
Columbus, Ohio

September 6-9, 2014
PCI Annual Convention and Exhibition and National Bridge Conference
Gaylord National Resort and Convention Center
Washington, D.C.

October 25, 2014
ASA Fall 2014 Committee Meetings
Hilton Washington
Washington, D.C.

October 26-30, 2014
ACI Fall Convention
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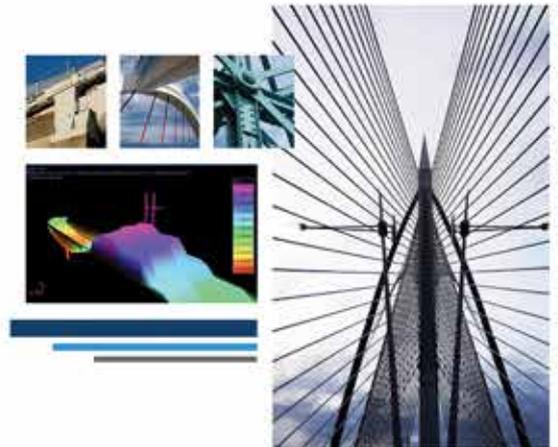
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READER RESPONSE



Editor,

I really enjoyed your editorial in the Summer 2013 issue of ASPIRE™. I plan to share it and discuss it with our key people in Tampa. We have always tried to be open to trying new products and innovative methods. We are flexible to carefully trying new things, while locking in the best of the old things. Sometimes we stand pat and sometimes we change. Sometimes it's a fine line to walk. We may not be perfect, but we are carefully improving our products, systems and services over time.

Mike Quinlan
Vice President/General Manager
Coreslab Structures (Tampa) Inc.
Tampa, Fla.

Editor,

Kudos to you for your thoughtful editorial, "Don't Let the Perfect Be the Enemy of the Good," in the Summer 2013 Issue of ASPIRE. From my life experiences, referred to in your piece, too many engineers and agencies embrace just the opposite philosophies:

- What if we experience a problem, despite our best efforts?
- It wasn't invented here.
- Let's do extensive research before we commit.

From my life experiences, referred to in your piece, too many engineers and agencies embrace just the opposite philosophies:

- **What if we experience a problem, despite our best efforts?**

- **It wasn't invented here.**
- **Let's do extensive research before we commit.**

Engineering should be all about improving design and construction through sound reasoning and thoroughly thinking a concept through. Engineering is not an exact science requiring the absolute, the perfect or resolution of all issues before taking any action.

Your reference to the quote from Voltaire brought to mind another quote attributed to General George Patton that he expressed in the French vernacular, "Audace, audace, toujours audace." (Be bold, be bold, always be bold.)

Edward P. Wasserman
Modjeski and Masters
Nashville, Tenn. 

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April 14-15

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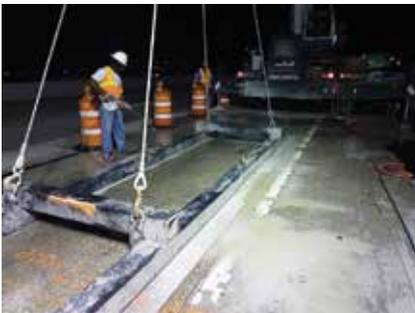
More Than Engineering

Evolution of owner concerns, new materials, and changing needs have expanded the analysis and techniques used by SDR to replace or rehabilitate bridges

by Craig A. Shutt



The completed full-depth deck replacement for the Highway I-75 project near Tampa utilizing sawed in carbon reinforcement connections. All photos: SDR Engineering Consultants Inc.



This photo shows sawing of the deck panel and attaching the lifting frame to the section for removal of existing deck during a nighttime replacement operation.



The existing I-75 deck was removed during a nighttime replacement operation.



The new full-depth deck panel is ready for installation for the Highway I-75 project near Tampa.



The panel is aligned in place and shimmed 1.4 in. higher than the existing deck to allow for future grinding, ensuring a smooth travelling surface.

As budgets shrink and needs increase, bridge engineers are expanding their expertise to meet a growing array of bridge rehabilitation and construction challenges. At Structure Design & Rehabilitation (SDR) Engineering Consultants Inc. in Tallahassee, Fla., bridge rehabilitation has been a major focus of the firm since its 1992 inception. This has required strong emphasis on having vast knowledge of nondestructive testing (NDT), new repair materials and methods, accelerated methods of bridge construction, and development of custom software programs to address special details and damage assessment that are not available through the use of traditional design software.

“Software integration and creating custom designs using new materials and techniques have become vital to resolving bridge issues,” says Dr. Mohsen Shahawy, principal and founder. “The ability to diagnose existing conditions within a bridge has become paramount to achieving success in the bridge industry. With so many considerations about rehabilitating or replacing a bridge quickly and economically, more than engineering skill is required to complete these projects efficiently.”

Diverse Expertise

SDR’s diversity in experience is reflected in Shahawy’s professional history and vision for the future of bridge engineering. He began his career in Switzerland in the 1970s, working as a design and construction engineer on communication towers and a tunnel connecting Italy to Switzerland. He then moved to Amoco Petroleum in Egypt, where he designed offshore structures. Later, in Canada, he studied at Queen’s University and The University of Manitoba and worked as a forensic engineer.

In 1986, he joined the Florida Department of Transportation's (FDOT's) newly-established bridge-assessment and testing center. The unit was created after the original Skyway Bridge collapsed after being hit by a ship in the early 1980s, resulting in a statewide focus on strengthening resources in the evaluation, assessment, and load-testing of Florida's deficient bridges. In 14 years at FDOT, he investigated and tested more than 400 bridges, varying from simple reinforced concrete slab bridges to cable-stayed bridges.

During this time, he acquired extensive knowledge of bridge assessment, NDT methods, non-linear, finite-element modeling, and effective bridge-rehabilitation techniques. In 1992, he opened SDR to take advantage of this expertise. Today, SDR operates three offices, in Tallahassee; Dallas, Tex.; and Baton Rouge, La., and has 24 employees, most of whom are engineers.

FDOT has been a significant user of both cast-in-place and precast concrete structures, he notes. "In the late 1980s and early 1990s, Florida led the nation in constructing prestressed and post-tensioned bridges. We pushed the limits for span length, the use of prefabricated concrete superstructures and substructures, and produced a host of other innovations."

Verification testing was an integral part of bridge design, he adds. "FDOT, through its test facilities, led the nation in concrete research, and many of its findings were incorporated into the *LRFD Bridge Design Specifications*," he says. "Participating in the design, instrumentation, testing, verification, and construction to reach a successful finished product is the dream of every engineer and we have been doing exactly that routinely."

Finding the correct solution involves more factors today, especially the speed of construction. "Owners are now more than ever aware of the impact of bridge construction time on disruption of neighboring communities and businesses and are demanding utilization of new accelerated construction techniques," Shahawy explains. "Faster construction also translates to fewer accidents and

enhanced safety for the workers and public."

These changes have favored prefabricated concrete designs, he adds. "Concrete elements can be quickly assembled to form standard shapes, minimizing forming and labor costs, and reducing lane-closure time. Even at a higher initial cost, the use of prefabricated systems on bridges subjected to high volumes of traffic may be justified, because it avoids excessive lane-closure times and public disruption."

'Concrete elements can be quickly assembled to form standard shapes, minimizing forming and labor costs, and reducing lane-closure times.'

Rehabilitation Grows

The decision to rehabilitate or replace a bridge depends on many parameters, but most often is controlled by the life-cycle cost of each alternative, he says. "In highly congested areas, replacing a bridge might be the cost-effective solution, but rehabilitation instead of replacement is often the desired solution due to the level of disruption and impact on the public."

SDR has seen steady growth in bridge rehabilitation over the past decade. "We see these activities growing at a faster rate due to limited budgets and aging infrastructure. Few new bridges are being built today, with most work focused on replacing or renovating existing bridges."

For instance, traditional deck replacement often requires partial- or full-lane closure for extended periods. In highly congested urban areas, lane closure during peak traffic hours can create costly detours and business disruptions. In these cases, rehabilitating bridges that can remain open during peak traffic hours provides significant benefits.



Fascia girder of adjacent box girder overpass repaired with carbon-fiber reinforced polymer.



Completed box girders repairs.

An example is the recently completed deck-replacement project on Interstate 75 near Tampa, Fla., where the owner required no lane closure during peak traffic hours. SDR designed an innovative system that allowed the replacement of the concrete decks with only partial lane closures between 11 p.m. and 6 a.m.

Full-depth reinforced concrete panels were placed on the supporting girders and tied together. Working at night only, crews saw-cut sections of the existing deficient deck, removed them, and installed new panels that matched the created opening. The bridge was completely open to traffic each day, with more new panels installed each night. The design used traditional precast reinforced concrete panels, high-strength and fast-setting polymer concrete, and carbon fiber reinforced polymers (CFRP).

"This innovative use of materials, combined with engineered accelerated-construction techniques, was essential for the successful completion of the project within schedule and budget," Shahawy says. "Mock-up testing of the installation and extensive testing of the performance of the polymer materials were critical components necessary for successful application."



Deteriorated drop-in span hinge location before repair.



Completed carbon-fiber reinforced polymer repairs of the drop-in span and cantilever spans.



Carbon-fiber reinforced polymer hinge strengthening completed and painted with gray color UV protective coating.

“Engineers need to be fully versed in all the steps required for diagnosing deteriorated conditions. These situations often require NDT such as infrared thermography, polarization resistance, concrete covermeter, and chloride ion penetration analysis coupled with

extensive non-linear analysis. Accurate determination of the structural conditions is essential in predicting the remaining life, effectiveness of the repairs, and proper cost analysis. There is a need for better knowledge of the assessment process and the array of new materials available to repair bridges efficiently and SDR is focused on these aspects,” he says.

An example illustrating utilization of the above aspects is the recently completed rehabilitation of the Assawoman Bay and St. Martin bridges in Ocean City, Md. These prestressed concrete bridges have 139 and 97 spans, respectively, and were constructed in 1971. Initial engineering assessment recommended the replacement of both bridges, however, utilizing a multitude of NDT techniques coupled with advanced analysis, the SDR team performed a detailed evaluation and developed a cost-effective rehabilitation scheme that was accepted by the owner. Targeted structural strengthening of limited numbers of AASHTO and box girders using CFRP coupled with replacement of the severely deteriorated AASHTO girder drop-in span was completed within six months at a fraction of the estimated replacement cost.

New Materials Arise

Rehabilitation projects require diagnostic expertise, as well as in-depth knowledge of new materials and techniques. “There is a need for better knowledge of the assessment process and the array of new materials available to repair bridges efficiently, and SDR focuses on these aspects,” Shahawy says. “Over the past decade, it has become evident that significant advancement in production of efficient and durable polymers and coatings has been made. There is a new generation of high-performance materials that can help achieve enhanced durability and performance.”

‘There is a new generation of high-performance materials that can help achieve enhanced durability and performance.’

These innovative advanced construction techniques are opening new approaches to rehabilitation of infrastructure, he notes. “Prefabricated systems that use materials such as high-strength concrete, high-strength/corrosion-resisting steel, and fiber-reinforced plastics are changing rehabilitation strategies. Although some of these materials and systems can be costly compared to traditional ones, as the concepts of life-cycle cost analysis and user costs are included in the replacement algorithm more regularly, acceptance of the often proprietary and more expensive systems will certainly increase.”

This new generation of concrete materials, such as self-consolidating concrete and high- and ultra-high-performance concrete, offer alternatives due to increased durability and strength. “Where we used 3-ksi strength concrete for cast-in-place bridge elements, we now routinely get 5 ksi,” he says. “Compressive concrete strength of prestressed girders can now be provided at 10, 12, or even 24 ksi, where it used to be 6 ksi.”

Those improvements, along with the increased use of 0.6- and 0.7-in.-diameter strands, provide significantly more strength, allowing girder lengths to extend from 150 ft to as much as 200 ft, creating new engineering options. “Essentially design requirements today are set forth to ensure enhanced long-term performance and minimized future maintenance needs through strategies such as minimizing cracking and moisture penetration, minimizing the number of expansion joints, using low-permeability concrete, and increasing concrete cover.”

Software Development

As bridge demands have grown and changed to focus on complex engineering principles that are often times not well documented or analyzed, Shahawy found that existing software programs weren’t providing the necessary requirements for damage assessment of local elements and their impact on global bridge performance. “Most often, analyzing the effect of impact damage or deterioration requires various computer programs and is

highly dependent on the experience of the evaluator," he says. "This lengthy process is not suitable for rapid bridge assessment, where a decision is needed on whether a full or partial closure of the bridge is required."

Most engineering software is designed for new and replacement bridges, he notes. "Rehabilitation requires different design calculations, because you are working with an existing bridge for which you are removing some elements, simulating the structural damage, and determining the effect on the global performance. Especially when accidents are involved, decisions on the extent of repairs versus full replacement must be made rapidly."

'Rehabilitation requires different design calculations.'

In 2004, Shahawy founded an independent company, Smart Bridge Tech Inc., to engineer infrastructure repair and rehabilitation software. The firm's software, some of which is now marketed publicly, compiles an entire rehabilitation project in an efficient platform.

The firm's damage assessment software provides unique and sophisticated analysis capabilities to accurately determine the magnitude of damage suffered by concrete structural elements due to vehicular impact or corrosion. The analysis techniques and non-linear finite-element model software is designed to deal with this specific issue, utilizing a global analysis approach of the bridge. Concrete section and steel area loss of both flexure and shear reinforcement can be modified or removed from the global model. The bridge is then analyzed with the simulated damage to establish an accurate capacity assessment.

An example of rapid bridge evaluation and repairs is the repair and replacement of the Florida Turnpike over SR 561 Bridge. The bridge suffered extensive damage due to a fire that required a complete closure of the



An example of column repairs for the Florida Turnpike over the SR 561 Bridge.



Another view of the repaired columns and pier caps that were part of the rehabilitation project for the Florida Turnpike over the SR 561 Bridge.

bridge. Rapid structural evaluation and assessment recommended the replacement of the severely damaged girders in the fire damaged span and CFRP rehabilitation of the severely damaged columns and pier caps. The span replacement and substructure repairs were completed with 11 days, a record time considering the damage level.

Improvements to computer analysis, along with innovations in systems and materials, will allow engineers to resolve challenges more efficiently. "Sustaining research must be pursued to develop better-performing and cost-effective systems utilizing these new materials," he says. "There also

must be more efficient collaboration between departments of transportation, consulting engineers, researchers, and contractors toward advancing these new materials. They must share concerns, originate research projects, and clearly define objectives of projects. Those actions will lead to better and more standardization and design guidelines for practicing engineers in the future." 

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

The Designer's Role in the Transportation Design-Build Process

The creation of valuable partnerships

by Kevin R. Eisenbeis, Burns & McDonnell



The design-build project delivery method has emerged as a valuable mechanism to improve vital infrastructure in a timely, affordable manner. By its nature, the design-build process requires teaming and coordination of design and construction activities to achieve a successful conclusion. With a thorough understanding of project scope, team capabilities, and related constructability issues, designers are better equipped to develop innovative and cost-effective solutions. The designer can take steps throughout the process to facilitate winning, designing, and constructing the project. This article highlights key elements the designer should understand to maximize designer contribution to the project's success. Considerations outlined apply to projects of all sizes, from large signature bridges to small, short-span structures.

Designers are better equipped to develop innovative and cost-effective solutions.

A Winning Proposal

Success of a design-build teaming arrangement and project delivery begins with a thorough understanding of the project scope, goals, and challenges. Owners often depend on the design engineer and contractor to evaluate project features, constraints, environmental issues, geotechnical conditions, traffic and right-of-way related issues, and much more. The designer can assist in translating the owner's desires to the contracting partners. Coordinating an understanding of the project requirements with the owner's key interests is fundamental to developing a winning proposal.

A second, and equally vital consideration, is an understanding of



Precast concrete girder companion bridges carry 127th Street over Interstate 35 and adjacent rail lines in Olathe, Kans. All photos: Burns & McDonnell.

the design-build contractor's preferred construction methods and capabilities. Although means and methods of construction are typically at the contractor's direction, designing to the efficiencies of the contractor's methods, equipment, and materials can reduce construction cost and time.

Consider the changing dynamic in today's procurement environment. Design-build opportunities, once reserved for large projects, are now occurring on a much smaller scale in the transportation industry. The opportunity of smaller design-build projects opens a door to new and different teaming arrangements. To develop effective solutions and assure success, the designer must understand the contracting partner's unique experiences and methodologies.

Due consideration of the owner's scoring system, and how it affects the team's potential to win the project, is also imperative. A decision to not pursue may be more cost effective than pursuit of a low-cost bid situation where innovation and design is not appropriately valued. Likewise, the risk involved versus the potential rewards must be considered.

Design Phase

Once the scope and contractor expertise is understood, the designer can strive to develop innovative and economic solutions, leading to faster construction, lower costs, fewer traffic delays, and minimal public and environmental impacts. An owner that truly understands the flexibility involved in the design-build process is open to new ideas, alternative details, and other specifications. It is the designer's job to apply these alternative concepts appropriately and provide the owner with supporting information necessary to ensure the quality of the project.

All aspects of the design should consider constructability. Input from contractors, precasters, and suppliers regarding methodology is essential to achieve efficient, practical designs. Simplification of the design often results in simplified, lower-cost construction. The best ultimate solution is ideally the aggregate of many smaller, coordinated decisions.

Typically, all aspects of design-build happen faster than conventional design-bid-build delivery, and often this condensed scheduling is the reason design-build is the preferred delivery method. Critical decisions are



Precast concrete, curved Nebraska University (NU) girders carrying Interstate 470 eastbound connector road over U.S. 50 at Lee's Summit, Mo.



Designer led, design-build was used to construct multiple small bridges for the owner, ATK, in Independence, Mo., in the less than \$1M category.



A 3200-ft-long, curved precast concrete solution eliminated multiple at-grade rail crossings at the Capitol Parkway West in Lincoln, Neb.



U.S. Highway 75 reconstruction project in McKinney, Tex. shows TX46 and TX62 girders spanning the East Fork of the Trinity River.



Precast concrete girder spans provide economy over floodplains in the Route 370 Missouri River Bridge at St. Charles, Mo.

made throughout ranging from the determination of overall bridge type and span layout to the selection of specific expansion joints, bearings, and other details. Because of the accelerated process, attention to quality control and quality assurance of both design and construction is paramount.

Changes happen fast and flexibility is required. Plans can be delivered in smaller sets to accommodate construction scheduling. The design engineer must be responsive to the contractor, aware of owner's needs, and be available to the team at a moment's notice to contribute to the design-build project success. A properly staffed and qualified design team is essential to develop an optimal design and to meet the schedule demands of the design-build process.

Construction Phase

Once construction begins, the design engineer's role can vary. At a minimum,

the role can include reviewing shop drawings and responding to an occasional field question. The design-build process will usually require more interaction between the designer and the contractor. Contractors often continue to seek innovative and alternate construction methods even after final plans have been submitted.

"Equal or better" change orders can be submitted to the client throughout the project. The change orders allow the contractor to manage costs and schedule and sometimes provide a cost savings to the client. The designer should anticipate plan revisions during the construction phase. The contract between the designer and the contractor should document how plan revisions will be addressed. The designer's role can also include more involvement in construction-related design such as temporary shoring, falsework, and bridge-erection procedures.

The process can be rewarding.

Conclusion

A good understanding of the designer's role on design-build projects is critical to achieve a successful project. Although design-build can be demanding due to schedule and staffing requirements, the process can be rewarding. Valuable partnerships are created with contractors and closer relationships can be developed with clients. Design-build also provides the opportunity to play a key role in all phases of a transportation project. 

PROJECT

Connecting Interstate 4 and the Selmon Expressway

Major project in Tampa, Fla., uses a variety of segmental construction methods

by Thomas A. Andres and Richard W. Frank, Florida Department of Transportation, and John McShaffrey, AECOM



Rendering of the project that shows the completed Interstate 4/Selmon Expressway connector drawn into its location within an actual aerial photo. All photos: Florida Department of Transportation.

The Interstate 4 (I-4)/Selmon Expressway Connector project located in Tampa, Fla., connects two major east-west, limited-access corridors in a major Florida city. Though not originally part of the Tampa Interstate Study master plan that began in 1987, the connector was

later added to the plan and ultimately advertised for construction on June 8, 2009. Construction began on March 1, 2010. Traffic is expected to begin using the facility by the end of 2013 and the project should conclude by the spring of 2014.

When it opens to traffic, the connector will provide a vital transportation link between the Selmon Expressway (a tolled facility) and I-4. It will also feature a direct I-4 connection to and from the Port of Tampa. Truck-only lanes are an important component of the project, which will remove through-truck traffic from local roadways in the Ybor City area—one of only two National Historic Landmark Districts in Florida—within the city of Tampa. This direct cargo link will be one of the first of its kind in the United States and will serve to route commercial traffic and hazardous cargo away from the Ybor historic district.

This project is primarily a viaduct connection between I-4 to the north and the Selmon Expressway to the south, including complex interchanges at both of these highways. It spans multiple local streets, State Road 60, and railroad tracks and spurs critical to commerce and the Port of Tampa. The connector includes a series of separate ramps created to improve the regional movement of traffic throughout the Tampa Bay area. The project completes an important regional link in the Tampa interstate system by providing an alternative route for commuters, improving the ability to evacuate in advance of hurricanes, and by aiding emergency response providers.

profile

I-4/SELMON EXPRESSWAY CONNECTOR / TAMPA, FLORIDA

BRIDGE DESIGN ENGINEER (NORTH INTERCHANGE): Parsons Brinkerhoff, Tampa, Fla.

BRIDGE DESIGN ENGINEER (SOUTH INTERCHANGE): Atkins North America, Tampa, Fla.

SUBCONSULTANT: FIGG Bridge Engineers Inc., Tallahassee, Fla.

PRIME CONTRACTOR: PCL/Archer Western, a Joint Venture, Tampa, Fla.

CONSTRUCTION ENGINEER: Corven Engineering, Tallahassee, Fla.

CIVIL ENGINEER: Cardno TBE, Clearwater, Fla.

CONCRETE SUPPLIER: CEMEX, Tampa, Fla.

PRECASTER: Standard Concrete Products, Tampa, Fla., a PCI-certified producer, and Mack Industries, Astatula, Fla.

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



One of the project's many columns constructed using "bottom-up" concrete placement.

The project involves 35 bridge structures. Florida bulb-tees with a cast-in-place concrete decks are used for most of the tangent portions. Precast concrete segmental construction—utilizing both balanced cantilever and span-by-span construction methods—tie into the highways at either end. Other construction that is part of the project widens or rehabilitates existing bridges using Florida U-beams and Type IV AASHTO beams.

Innovation Is Key

This highly complex project has faced numerous challenges throughout design



Segmental and bulb-tee bridges are seen in this photo looking south. It also shows mechanically stabilized earth wall construction, a concrete deck placement, and a look at the toll gantry across all lanes.

and construction. Innovation has been the key to financing, designing, and constructing the improvements. This article presents some of the details of procurement and financing methods, materials, equipment, and construction methods that have been critical in bringing this project to fruition.

Bidding and Financing

The project literally would not have gotten off the ground had outside-the-box bidding and financing methods not been developed. The procurement process combined the conventional design-bid-build process (A+B bidding) with an innovative build-finance procurement approach. This bid-finance approach was authorized under private-public partnership legislation passed by the Florida Legislature and signed into law by the governor in 2004. This unique contractor-financing component allowed the advancement of the project to construction at a time when

the national and local economies were struggling and most of the needed cash was not readily available.

The original \$389.5-million dollar price tag for construction of this project is funded with approximately \$87 million of economic stimulus dollars, as well as other federal and state funds. About \$298 million is being financed by the contracting team, with deferred state payments to the contractor extending into 2017.

To promote competition between the steel and concrete industries, the bid package included these four options:

- a. All steel box-girder bridges
- b. All segmental concrete bridges
- c. Steel box-girder bridges for the interchange ramps and Florida bulb-tee bridges for the viaduct
- d. Segmental concrete bridges for the interchange ramps and Florida bulb-tee bridges for the viaduct

FLORIDA DEPARTMENT OF TRANSPORTATION/FLORIDA'S TURNPIKE ENTERPRISE, OWNERS

OTHER SUBCONSULTANTS AND SUBCONTRACTORS: Ameristeel, Tampa, Fla.; Beijing Wowjoint Machinery Co., Beijing, China; DEAL, Italy; EFCO, Des Moines, Iowa; McNary Bergeron, Broomfield, Colo.; Old Castle Southern Group, Temple Terrace, Fla.; PCL Construction Services, Orlando, Fla.; and Watson-Bowman, Amherst, N.Y.

BRIDGE DESCRIPTION: 35 separate bridge structures utilizing segmental post-tensioned, box-girder construction, Florida bulb-tee beams, AASHTO Type IV beams, and Florida U-beams; the longest segmental box-girder structure is 5060 ft.

STRUCTURAL COMPONENTS: 1159 concrete drilled shafts ranging in diameter from 36 to 90 in. and varying in length from 49 to 183 ft, 246 footings with at least four shafts in each footing, 280 columns, 12 bridge structures used precast, post-tensioned, segmental concrete box girders utilizing both span-by-span overhead launching truss and balanced cantilever construction methods. Twenty-three bridge structures used Florida bulb-tees, Florida U-beams, and AASHTO Type IV girders with an 8-in.-thick, cast-in-place concrete deck

BRIDGE CONSTRUCTION COST: The present value of the total project is \$411,696,543. The bridge square foot cost ranges from \$229.98 to \$72.39 with an average of \$148.80.

The winning bidder selected option d, which includes 23 of the project's 35 bridges. Of the 23 bridges, 12 are segmental and 11 are Florida bulb-tee spans. The segmental bridges include both span-by-span and balanced cantilever construction.

To put the magnitude of the project in more perspective, it is helpful to consider the following:

- 1159 concrete drilled shafts, ranging from 36 to 90 in. in diameter, were installed in highly variable soil stratum.
- 246 footings were used with at least four shafts in each footing.
- 280 columns were needed to support the bridges.

Columns were constructed using a bottom-up method for placing concrete. The bottom up process involved an injection point near the base, with additional injection points incrementally spaced along the height of the column. Once the concrete level had passed the next injection point, the pump hose was moved to the next location and the concrete injection continued. Occasional pulses of form vibration were used to consolidate the concrete. This method produced a high level of quality and required fewer workers. The tallest pier rises more than 87 ft above the ground and typical column dimensions for the rectangular piers are 6 by 5 ft, 8 by 5 ft, and 8 by 7 ft.

Segmental Construction

A total of 2929 segments were required to complete the segmental portion of this project. An off-site, short-line segment casting facility was constructed and used to manufacture 2765 individual precast concrete segments, using six typical-segment beds and two pier-segment beds. The remaining 164 segments were comprised of cast-in-place concrete elements to close and complete individual spans. Typical segments are 9.5 ft deep and vary in length from 9.2 to 10 ft. The segments range in width from 30 ft 1 in. to 47 ft 3½ in.

The manufactured precast concrete segments were trucked to the project site and hoisted into place by large cranes or two segment lifters that were employed for the balanced cantilever



Segment lifters work in tandem during balanced cantilever construction.

sections and a gantry used for the span-by-span sections.

The contractor chose to utilize these segment lifters for balanced cantilever construction at some pier locations. Project geometric constraints and traffic restrictions on the underlying roadways would have required very large ground-mounted crawler cranes because of the required lifting reach and the segments weights. The use of segment lifters increased production rates of the balanced cantilever construction, decreased traffic impacts, and eliminated mobilization times associated with large ground-mounted crawler cranes.

Another advantage of using segment lifters is the ability to lift the segments from any point along the cantilever. For the cantilevers constructed in this project, the lifters moved in sequence so that balance was maintained at all times. Concrete counterweight blocks—weighing as much as 450,000 lb—were placed on the outside radius of the pier segments to stabilize the curved cantilevers. More than two-thirds of the project uses balanced-cantilever construction, accounting for 104 spans. The longest cantilevers consist of 28 segments and have a span length in excess of 250 ft.

The span-by-span overhead gantry truss was chosen by the engineering designer to better accommodate the variable span lengths and the horizontal

curvature within the project, as well as to better address ground-level constraints. The span-by-span precast concrete segments were lifted by the gantry from below with hangers and then aligned. When the complete span of segments was in place, groups of segments within the span were coated with epoxy at the joints and then stressed together with temporary post-tensioning bars. This process was repeated until all segments within the span were stressed. Closure concrete was placed and permanent post-tensioning installed and stressed. The span was then lowered onto bearings and the truss launched to the next span.

Of the 12 segmental, post-tensioned concrete box girders, two of the longest are ramp S (truck only lanes)—which consists of 31 individual spans totaling 5060 ft in length—and ramp B (eastbound I-4 to eastbound Selmon Expressway), which consists of 27 spans totaling 4785 ft.

Tolling and Partners

The project will also include a state-of-the-art toll facility with an all-electronic toll collection system that will allow for traffic to maintain highway speeds and for maintenance of toll equipment without disrupting traffic. The electronic open road tolling will be done through SunPass and toll-by-plate tolling at one location—the massive toll gantry between I-4 and State Road 60. Florida's Turnpike Enterprise will manage the tolling system and will maintain the

AESTHETICS COMMENTARY

by Frederick Gottemoeller



Directional ramps at major freeway interchanges are often called “flyovers,” a recognition of the curved aerial paths that high-speed vehicles take as they make their way from one freeway to the other. Concrete box girders are uniquely suited to this type of bridge.

the vehicles above.

In a large interchange, if the ramp widths are sufficiently standardized, there is often enough length of bridge to support the costs of specialized segmental forming. The longer spans and narrow pier shafts of segmental construction allow more options for pier placement and minimize the need for straddle bents. Segmental ramp bridges also have great aesthetic potential. If the pier shafts are kept thin and the pier caps are no wider than the soffit of the box girder, all the dominant lines of the structure—the deck edges, the overhang/web intersections, and the soffit edges—are parallel to the curvature of the ramp. Indeed, they reflect the trajectories of

their appearance from below also is pleasing to drivers passing through. Major interchanges are inherently confusing places, with drivers having to weigh multiple path choices while competing for road space with other drivers that are occupied likewise. Wide openings between the ramp piers maximize sight opportunities for drivers passing below, while the simple, clean lines of the structure are quickly grasped and easily understood, so that the bridges do not distract drivers.

The I-4/Selmon flyover ramp bridges take advantage of all of this potential. The spans are long and the number of pier shafts are relatively few. The webs are sloped and the box widths are minimized, which means that the pier cap width and the pier shaft width are also minimized. Drivers can easily see between the thin and widely spaced piers to the signs and ramp choices beyond. The minimal box width, sloped webs, and resulting long overhangs also allow more daylight to penetrate the spaces below the bridges. Because of this, drivers have an easier time recognizing traffic patterns and potential hazards. Relatively thin and widely spaced as they may be, there are still a lot of piers and a lot of pier caps in the I-4/Selmon interchange. Because they are simple geometric shapes with a minimum amount of detail, their potential for visual distraction is minimized and the overall appearance remains consistent. The height and prominence of the bearings is a welcome touch. At each pier, the box girders rest on two relatively small, raised pads.

From many angles a bit of sky is visible between the pier caps and the girder soffits. The girders appear to be very light in weight. They look like they are floating in the air, actually “flying over.” For drivers, traversing major interchanges will always be somewhat stressful. The I-4/Selmon Interchange’s open views, seemingly lightweight girders, simple shapes, and, most of all, congruence of the lines of the bridges with its traffic patterns, make this interchange less so.

roadway. Project partners are the Florida Department of Transportation (District Seven), Florida’s Turnpike Enterprise, the Tampa-Hillsborough County Expressway Authority, and the Federal Highway Administration. 

Thomas A. Andres is assistant state structures design engineer and Richard W. Frank is construction project manager with the Florida Department of Transportation in Tallahassee and Tampa, respectively, Fla., and John McShaffrey is the public information officer for Florida Department of Transportation District Seven interstate and Selmon Expressway construction projects with AECOM in Tampa, Fla.

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Design and Construction of Segmental Bridges for High-Speed Rail

by Jacques Combault, Finley Engineering Group Inc.

The famous Japanese Shinkansen railway network started operating in 1964 and has been progressively improved with the objective of operating at a speed of 300 km/h (186 mph) or more. Since the Shinkansen's beginning, many countries have implemented high-speed rail (HSR) as an easy link between cities. The first section of the French TGV opened to traffic between Paris and Lyon in 1981. The operation of the 345-km-long (214-mile) Taiwanese HSR, which runs most of the time on viaducts at 300 km/h (186 mph), started in 2007. Today, HSR has become a reality in Asia, Europe, and North America, resulting in the construction of large infrastructures that are designed for dense and heavy rail traffic at speeds never before reached.

Since its creation in 1981, the French TGV developed throughout France. The South Europe–Atlantic (SEA) line is currently under construction between Tour and Bordeaux, with the anticipation of daily operation at 350 km/h (217 mph). As part of this system, many bridges had to be built according to various construction techniques and the latest refinements of the available technology in the field of prestressed concrete bridges.

Design of Railroad Bridges

The design of railroad bridges has many unique considerations when compared to the design of road bridges:

- The loads are sudden and heavy.
- The regular distribution of heavy concentrated loads running at various speeds may generate substantial dynamic effects, which cannot be ignored.
- Horizontal forces generated by the moving loads, due to track curvatures or swaying on the

rails (nosing effect, also known as the coning action), as well as acceleration and braking forces, cannot be neglected.

- The bridge design is unavoidably impacted by the rail-structure interaction when continuous welded rails (CWR) are used, which have to be evaluated according to the International Union of Railways (UIC) code.

This last consideration is of fundamental concern during the design of HSR bridges. The track type, as well as the configuration and mechanical properties of the structure, govern the combined response of the structure and tracks to

- deflections and displacements of the superstructure under vertical and horizontal loads,
- differential deformations between rails and structure due to temperature and acceleration or braking forces,
- variable horizontal forces generated along the rails, and
- stresses in the rails, which cannot impair the track strength and profile.

Available Concepts

Due to the main design considerations previously mentioned, Taiwanese HSR bridges generally consist of a box cross

section about 13 m (43 ft) wide that provides space for two tracks and catenary supports. General design rules for railroad bridges significantly differ from those of road bridges. For example:

- Heavy loads and corresponding dynamic effects cause the bridge to be designed for a span length-to-depth ratio of 12 to 14.
- The rail-structure interaction favors the design of short spans. Long, continuous spans require rail expansion devices that impact the behavior of the train on the track.

This is why Taiwanese HSR viaducts, which are located on flat areas, mainly consist of sections made of simply supported box girders. This means that the Taiwanese HSR viaducts have

- short span lengths, and
- many piers and many bearing devices, but no rail expansion devices.

High-speed trains may also have to cross large and deep valleys. In such cases, pier spacing and span lengths have to be increased. This also requires that the superstructure be continuous and rail expansion devices are unavoidable.

For example, the HSR system near Avignon, France, required two unusual HSR bridges made of 100-m-long (328-

The Taiwanese high-speed railway running on a long series of viaducts.
Photo: VINCI Construction Grands Project-France.





Twin 1000-m-long (3280-ft), high-speed railway, viaducts crossing the Rhone River near Avignon (France). Photo: VINCI Construction Grands Project-France.

ft) spans to cross the Rhone River. Similarly, the Medway River crossing in the U.K. necessitated a bridge having a 152-m-long (499-ft) span for the Channel Tunnel rail link (CTRL) between Paris and London.

Construction of Concrete Railroad Bridges

With easy access and good soil conditions, short-span railroad bridges can be readily built. Prefabrication of full-span-length units and placing those units using appropriate launching equipment is a construction method that is implemented frequently worldwide.

Taiwan's north-to-south HSR project link includes 251 km (156 miles) of elevated bridge structures. Full-span precast concrete components and launching erection techniques have been used on 73% of these elevated structures to achieve speedy placement, shortened construction periods, and better quality control.

Continuous HSR bridges undoubtedly offer interesting opportunities in terms of construction methods. At the end of the 1990s, seven HSR viaducts were built between Lyon and Marseille in Southern France. Classical construction methods were used for these viaducts; the most frequent method used was incremental launching.

Approaches of the Mediterranean high-speed railway Ventabren Viaduct in southeast France during launching. Photo: VINCI Construction Grands Project-France.

Incremental launching is well adapted to the construction of constant-depth box girders for HSR as long as the span-to-depth ratios of these bridges are much lower than those of road bridges. The use of incremental launching for building HSR bridges started at the end of the 1970s when the first French HSR link was being constructed.

Incremental launching has been successfully implemented for many of the large HSR bridges that were built as part of the French TGV extension linking Paris to the north and to the southeast of France. Incremental launching was sometimes combined with cast-in-place balanced cantilever



On the left, the Channel Tunnel rail link viaduct crossing the the Medway River in the UK. Photo: VINCI Construction Grands Project-France.



Full-span construction technique showing placing a precast concrete box unit. Photo: SYSTRA.

construction when span lengths were not compatible with incremental launching capabilities. Balanced cantilever and incremental launching were also combined when other exceptional construction techniques, such as rotation, had to be used to cross existing motorways with as little traffic disturbance as possible.



Balanced cantilevers of the main bridge of the Ventabren Viaduct to be rotated across one of the most congested motorways in France. Photo: VINCI Construction Grands Project-France.

Precast Concrete Segmental Construction of Railroad Bridges

The most significant achievement in the construction process of large HSR bridges happened at the end of the 1990s with the construction of the 1500-m-long (4921-ft) viaducts crossing the Rhone River near Avignon. Consisting of 100-m-long (328-ft) spans, these viaducts are made of precast concrete segments that were assembled according to the balanced cantilever construction process. Segments were erected using a 225-m-long (738-ft) launching gantry with a capacity of 170 metric tons (187 U.S. tons) and external continuity post-tensioning tendons. Match-cast segments were designed and assembled according to the state-of-the-art in the field of precast concrete segmental construction, which meant that there was no sand blasting of the match-cast faces and no thick epoxy joints.

The good performance of the Avignon Viaducts lead to the use of precast concrete segmental technology for seven bridges of the extension of the French TGV towards the southwest

Placing the first spans using the progressive construction technique with temporary cables on the South Europe-Atlantic Viaducts. Photo: VINCI Construction Grands Project-France.

part of France, which is presently under construction. All seven bridges are similar. Each is about 500 m (1640 ft) long and mainly consists of 47-m-long (154 ft) spans. The box girder for each bridge is 3.9 m (12.8 ft) deep.

The 1340 precast concrete segments that are necessary for the project are being produced in a plant located near Poitiers. The assembly of these segments is being done according to the segment-by-segment, progressive-placing method, a construction process



developed and implemented for the first time by Campenon Bernard at the end of the 1970s.

Indeed, progressive segment-by-segment construction using temporary stay cables is a competitive alternative to incremental launching because

- it does not require heavy equipment,
- segment placing is easy and fast, and
- there are no creep effects because segments are assembled in their final configuration.

In addition, this method is well adapted to external prestressing and bridges built that way are typically of high quality.

Conclusion

For more than 40 years, the construction of large bridges has been marked by prefabrication of box-girders in match-cast sections and assembly of these segments using powerful equipment, either cranes or movable launching gantries, or temporary stay cables. Associated with modern, well-designed prestressing systems (combining both internal and external post-tensioning tendons), this technique has been continuously improved and is, nowadays, extremely successful thanks to the quality and reliability of the structures built that way.

Several millions of square meters of road bridges have been built all over the

world using precast concrete segments, with the increased demand for better performances in terms of erection speed and quality.

For more than 15 years, most of the elevated rail structures have been built using the span-by-span assembly method for the placing of precast concrete sections. Clearly, the seven bridges of the SEA HSR will require prefabrication and assembly of a huge number of segments. The progressive placement method is yet another way that HSR bridges can be built. Over the years, precast concrete segmental construction has proved to be applicable to any kind of railroad bridge.



Jacques Combault is technical director at Finley Engineering Group Inc. in Tallahassee, Fla.

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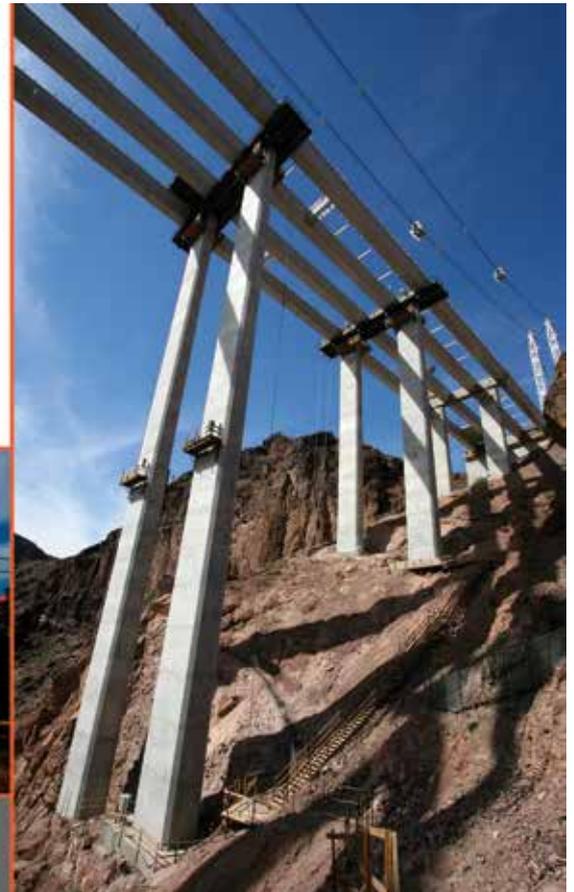
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PROJECT

West 7th Street Bridge

Creating a new gateway in Fort Worth

by Dean Van Landuyt, Texas Department of Transportation

When the city leaders of Fort Worth determined that the existing West 7th Street Bridge connecting downtown to the cultural district could not be rehabilitated, they turned to the Texas Department of Transportation (TxDOT) for ideas. The route serves as a gateway to museums designed by such

luminaries as Phillip Johnson, Louis Kahn, Tado Ando, and Renzo Piano. Increased development and pedestrian traffic mandated that in addition to carrying four lanes of traffic, two 10-ft-wide sidewalks be added for an overall width of 88 ft. Adding to the challenge was the requirement that the

bridge be out of service for no more than 150 days and the cost be kept to approximately \$200/ft².

The selected superstructure consists of precast, post-tensioned concrete arches; precast, pretensioned concrete floor beams; precast, pretensioned



Floor beams in place for the West 7th Street Bridge. Photo: Texas Department of Transportation.

profile

WEST 7TH STREET BRIDGE / FORT WORTH, TEXAS

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

GENERAL CONTRACTOR: Sundt Construction Inc., San Antonio, Tex.

CONSTRUCTION ENGINEER: Infinity Engineering USA Inc., Tampa, Fla.

PRECASTER: Heldenfels Enterprises Inc., San Marcos, Tex., a PCI-certified producer

READY-MIX CONCRETE SUPPLIER: TXI Inc., Fort Worth, Tex.

POST-TENSIONING CONTRACTOR: VSL Structural Inc., Hanover, Md.

concrete deck panels; and a cast-in-place concrete deck.

Precast Arches

Precast concrete girder bridges currently account for 95% of the newly constructed spans in Texas. TxDOT engineers thought it possible to design what is believed to be the world's first precast concrete network tied-arch bridge that could be cast off site and assembled quickly. It would be important to utilize as many of the existing precast concrete girder bridge ideas as possible, namely pretensioned concrete floor beams and precast, stay-in-place concrete deck panels, but the real key was developing a buildable precast concrete arch.

Through arches, rather than deck arches, were selected for clearance over the Trinity River, a park, and a city street, as the six spans would create a rhythmic, processional approach for motorists as they traveled between the two districts. Two planes of tightly spaced diagonal hangers would create a psychological barrier for pedestrians and act as diffusers for a series of light fixtures embedded between them.

The 4-ft 9 $\frac{3}{4}$ -in. hanger spacing allowed each floor beam to be supported by four hangers, but most importantly, eliminated the need for longitudinal stringers; a standard 8 $\frac{1}{2}$ -in.-thick deck could easily span the 9 ft 7 $\frac{1}{2}$ in. distance between beams. The tight weave also lowered the force on each hanger and reduced the flexural stresses in both the rib and tie so they could be lighter and a pedestrian-friendly scale could be maintained. Stainless steel was chosen for the hangers because of its clean and tactile quality, reflective properties, low maintenance, and ability to be cast partially into concrete without fear of corrosion.

Transporting the arch on the existing bridge. Photo: Texas Department of Transportation.

The obvious challenge was to determine how to economically precast and transport a 163.5-ft-long, 280-ton concrete arch. Solutions began to appear after recognizing that casting an arch on its side is simpler than casting it upright and that contractors are becoming more comfortable undertaking heavy, unusual lifts. Every attempt was made to make the elements as slender as possible to minimize weight. Furthermore, the span-to-rise ratio was set at only 0.13 to keep the center of gravity very low and to minimize stability problems on the four-block route from the casting yard to the bridge site. The shallow 23.5 ft height at the crown also made rotating the arches less difficult.

Because nearly all the elements are precast, precision casting was essential, especially for the arch and floor beams. Making all the spans the same length and managing roadway vertical curve geometry demands with adjustable floor beam plinths made the concept possible—all 12 arches



The arches were erected on both sides of the existing bridge to minimize closure times. Photo: Texas Department of Transportation.

could be identical. One of the largest obstacles to overcome was ensuring that the diagonal hangers were able to pass cleanly through steel tubes cast into the tie at a 55-degree angle. The tube lengths ranged from 2.1 to 4.3 ft making their location and orientation critical if the 1 $\frac{3}{4}$ -in.-diameter hangers were to connect from the tie beam



CITY OF FORT WORTH, OWNER

OTHER SUPPLIERS: Stainless steel fabrication: GST Manufacturing, Haltom City, Tex.; arch rotating and transport: Burkhalter Rigging Inc., Columbus, Miss.; arch and column forms: Aluma Systems Inc., Toronto, Ontario, Canada; floor beam forms: Hamilton Form Company, Fort Worth, Tex.; bearings: RJ Watson Inc., Alden, N.Y.

BRIDGE DESCRIPTION: A six-span, 981-ft-long bridge with precast concrete arches, precast concrete floor beams, precast concrete, stay-in-place deck panels, and a cast-in-place concrete deck

STRUCTURAL COMPONENTS: Twelve 4-ft-6-in.-wide arches, one-hundred and two 86-ft 4-in.-long floor beams, 4- and 6-in.-thick precast concrete deck panels with a nominal 4 $\frac{1}{2}$ -in.-thick cast-in-place concrete deck, 7-ft-3-in. by 5-ft-6-in. oval columns, and 7-ft-diameter drilled shafts

BRIDGE CONSTRUCTION COST: \$209/ft²



Floor beam setting. Photo: Texas Department of Transportation.

to link plates cast in the rib as much as 25 ft away. Another challenge was ensuring that 1¾-in.-diameter, post-tensioning rods that would connect the floor beams to the arch could pass through galvanized-steel tubes.

TxDOT bridge designers were well-aware that cracking the arch was a real possibility during handling and, if it occurred, would lower the rib-buckling limit. As a result, two 19-strand, 0.62-in.-diameter-strand tendons were added to the rib and four 19-strand, 0.62-in.-diameter-strand tendons were added to the tie. The contractor used a specially designed lifting tower with multiple spreader beams to distribute the lifting forces. Vibrating wire gages installed by researchers at The

University Texas at Austin confirmed that stress levels have so far been in reasonable agreement with design calculations and the few areas that were in tension were well below the modulus of rupture. The arches were moved by self-propelled modular transporters and used the narrow existing bridge as a haul road.

Another major design challenge centered on the fact that the arches would be set end-to-end with only a 4-in. gap, thereby leaving no opportunity for field post-tensioning. As a result, 100% of the longitudinal tie post-tensioning (3666 kips total stressing force) needed to be installed while the arches were still in the casting yard. Because the arch self-

weight generated less than 25% of the axial service tension in the tie, the slender element experiences tremendously high compression forces prior to placing floor beams and other subsequent gravity loads. In order to reduce the unbraced length and prevent any lateral movement of the 2 by 4.5 ft tie during stressing, a series of small curves were added to the ducts causing regular contact with the tendons.

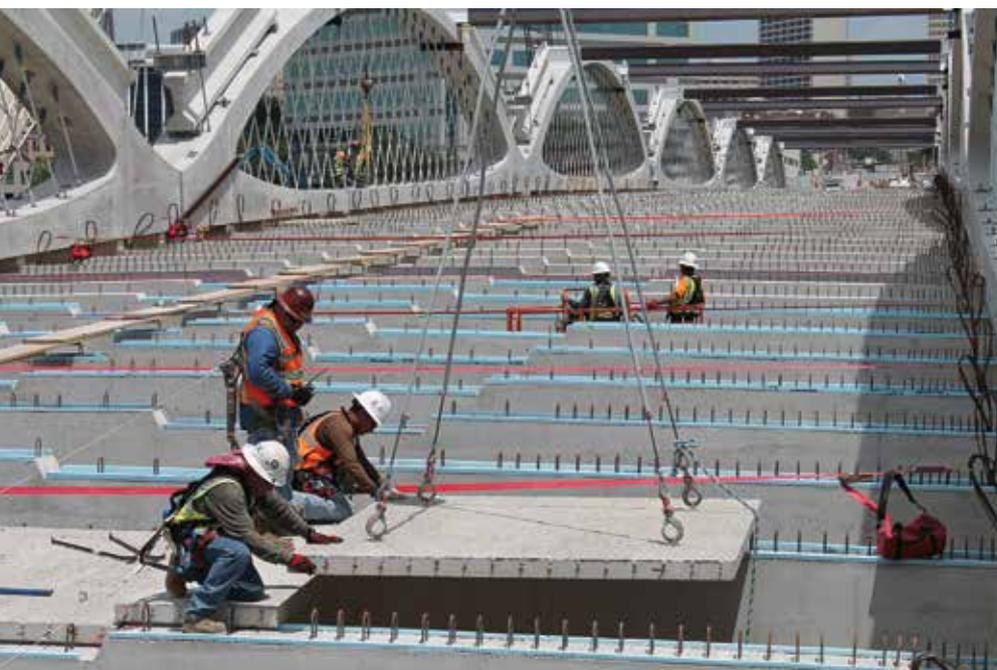
For speed, cost, and appearance, no rib cross-bracing was used. Fortunately, the 4.5-ft width required in the tie and knuckle to accommodate all the embedded elements proved sufficient; a three-dimensional non-linear buckling model, that included the hangers, floor beams, and deck, verified the stability of uncracked, unbraced ribs.

Floor Beams

Designers chose to use pretensioned concrete floor beams for their quick installation, durability, cost, low-maintenance, and aesthetics. The floor beams have a constant width of 1 ft 4 in., a nominal depth of 5 ft 6 in. at midspan, and a minimum depth of 3 ft at the arch with a taper down to 1 ft 9 in. at the end of the cantilever. Two different strand layouts were used: thirty-two ½-in.-diameter strands in the first two and last two beams in the span and twenty-four ½-in.-diameter strands in the interior 13 floor beams.

The connection of the floor beam to the arch is a critical component of the bridge as it needs to carry both tension and moment, reconcile two non-match-cast concrete surfaces at each end of the floor beam, and prevent the intrusion of water. The solution was to cast two rectangular steel-tube sleeves into the beam 3 ft 2 in. apart. Companion rectangular tubes were cast into the arch tie and knuckle at the same spacing but rotated 90 degrees about the longitudinal tube axis. This allowed for the largest possible range of misalignments that will house a 1¾-in. diameter, post-tensioning bar.

Workers install the precast concrete deck panels on the West 7th Street Bridge. Photo: Texas Department of Transportation.



To account for non-planar surfaces, an approximately ½-in.-tall bed of epoxy grout was placed on top of the floor beam plinths located underneath both arches. The floor beams were then raised up until contact with the arch was made all around the 1-ft 4-in. by 4-ft 2-in. bed of epoxy grout. After the grout reached a compressive strength of 4 ksi, the two post-tensioning bars at each arch were stressed to 105 ksi and the steel tubes grouted. **A**

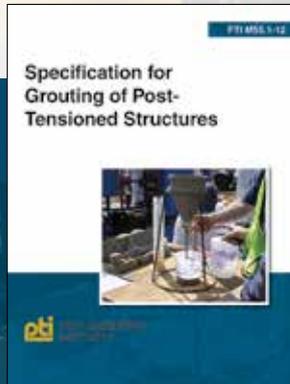
Dean Van Landuyt is a senior design engineer with the Texas Department of Transportation.

EDITOR'S NOTE

Strand with a diameter of 0.62 in. per ASTM A416 is now available on a limited basis and engineers should contact their local strand suppliers in the project area to determine hardware and strand availability.

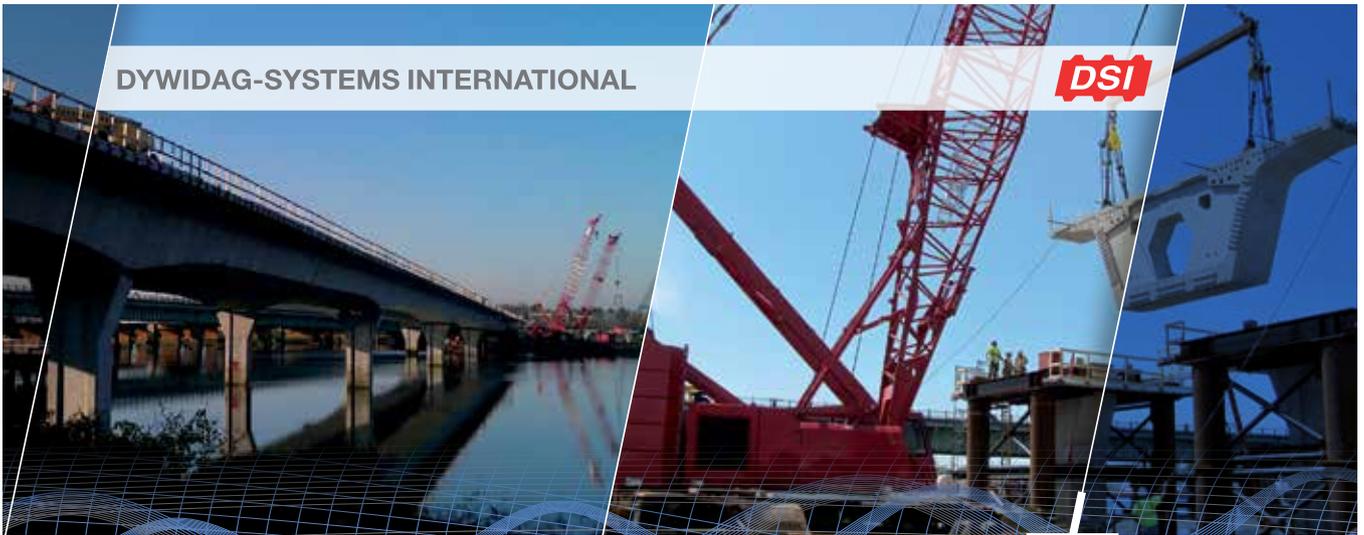
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PROJECT

Accelerated Bridge Construction over Craig Creek

Every day counts in improving mobility

by Sonny Ferreira, Caltrans



The new 108-ft-long, Craig Creek Bridge, built in 2011 with a crack-free deck and a three-day cure. All Photos: Caltrans.

Replacement of the Craig Creek Bridge carrying State Highway 99, near Red Bluff, Calif., began in the fall of 2011 as the California Department of Transportation (Caltrans) undertook its third official accelerated bridge construction (ABC) project under the Federal Highway Administration's (FHWA's) Every Day Counts initiative. This initiative is designed to identify and deploy innovation aimed at shortening project delivery, enhancing the safety of our roadways, and protecting the environment.

The Caltrans project included replacement of an aging, scour-critical,

three-span bridge with a single-span structure. Bids were opened on April 20, 2010, with the intent of replacing the old bridge between July 15 and October 15 in two phases, keeping one-lane traffic on each half of the bridge. As bid, this would require temporary shoring for the roadway and temporary bents to support the old bridge while carrying traffic as the other half gets demolished; thereby, allowing the first stage of the new bridge to be constructed.

Traffic would be handled with a combination of temporary traffic signals and flaggers. One-lane traffic would then be shifted to the first stage of the

new bridge while the remaining old bridge would be removed and replaced. In order to complete the bridge as planned in two stages within the short construction window permitted by the regulatory agencies, ABC technology using prefabricated bridge elements and systems (PBES) components, was selected over conventional construction methods.

The bridge design comprised 11 adjacent 3.5-ft-deep by 4-ft-wide precast, prestressed concrete box beam units; a 5-in.-thick, cast-in-place concrete deck; precast concrete abutments and wingwalls; and twelve 2-ft-diameter, cast-in-steel-shell (CISS) concrete piles. The designer chose a 4 ksi site-cast concrete deck to provide composite action, in part due to concerns of differential live load deflections between adjacent box beam sections affecting long-term deck durability.

After girders were set in place, five 1³/₈-in. high-strength tie rods were installed, with one at each end diaphragm and the 1/4 span points, and the girders were snugged together by stressing the rods to 20% of the total post-tensioning force. After girders were snug, the 18-in.-deep longitudinal keyways were grouted with nonshrink grout and the grout was allowed to reach 5 ksi strength before bringing each rod to the final post-tensioning force of 130 kips. Tie rod ducts were then grouted and exterior bearing plate blockouts were filled with structural concrete and finished to match the rest of the girder.

profile

CRAIG CREEK BRIDGE / RED BLUFF, CALIFORNIA

BRIDGE DESIGN ENGINEER: California Department of Transportation, Sacramento, Calif.

BRIDGE CONSTRUCTION ENGINEER: California Department of Transportation, Chico, Calif.

GENERAL CONTRACTOR: Blaisdell Construction Inc., Anderson, Calif.

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

READY-MIX CONCRETE SUPPLIER: A&A Concrete, Chico, Calif.

POST-TENSIONING CONTRACTOR: Schwager Davis Inc., San Jose, Calif.



Preplaced cast-in-steel-shell concrete piles were excavated and cut-off to grade.



Precast, prestressed concrete box beams that were 106 ft long, weighing 106,000 lb, were set with two cranes from the abutments. Traffic was stopped seven to 15 minutes to make picks from the temporary bridge.



Cast-in-place, high-performance concrete deck being placed using a concrete mix containing a shrinkage-reducing admixture and macro fibers.



Each precast concrete abutment was fabricated in two pieces, with each piece weighing 72,000 lb.

Challenges Provide Opportunities

Delays in the contract award process caused the contract to be awarded late in the 2010 construction window. With shop plans to be prepared and girders to be cast, it was not prudent to begin the demolition and carry traffic on half of the old bridge over the winter and into the next construction season. The decision was made to begin that work during the 2011 summer window. This delay to the start of the project allowed the construction team the time to carefully consider options for completing the project safely, correctly, and quickly.

Contractor Improves Safety, Reduces Cost and Time

The project's general contractor enthusiastically embraced the ABC

concepts and furthered the project goals of reducing traffic delays, environmental risks, construction time, and cost by proposing out-of-sequence work and submitting a value engineering change proposal (VECP) to the original plans.

Since the new foundation was beyond the footprint of the old bridge, the contractor proposed to construct the piles outside the construction window. By using steel shells 9 ft longer than required, they could be driven through the existing roadway without first excavating to the bottom of the footing. In four days, the foundation piles were driven, drilled, reinforcing cages installed, and concrete placed. Pea gravel was used to fill the extra length of pile and the tops were paved over. Traffic then flowed uninterrupted for 10 months over the piles prior to being excavated and cut off to grade.

The VECP changed the traffic staging plans by eliminating the timed, one-way signalized control and instead deployed a temporary rented bridge with continuous flagger control diverting the one-lane traffic around the worksite entirely. The temporary rented bridge was assembled and launched in 2½ days and rested on previously placed temporary footings. Construction

and paving of the roadway detour took another two days, and once the traffic was off the old bridge, demolition could begin in a single move-in.

Rerouting traffic around the footprint of the bridge gave the contractor the opportunity to approach the work in a more efficient manner. Having a larger material storage area was safer and increased production. Accomplishing the work in a single stage reduced direct costs, overhead costs, move-ins of subcontractors, construction time, time traffic was restricted to one lane, and related traffic impact costs. Traffic safety, convenience, and flow through the work zone were increased by utilizing flaggers 24/7 for the detour. Workers provided the ability to be more responsive to the traffic, and a heightened awareness was present as compared to the planned timed signal control. Due to the significant reduction in impacts to the motorists, the contract provides that the contractor is entitled to 60% of the VECP savings, sharing 40% with the state.

Value Engineering Creates Opportunities

With the VECP pending, the next challenge was: "if we could tear down an old bridge and rebuild a new one in its place in three weeks, why can't we

CALIFORNIA DEPARTMENT OF TRANSPORTATION (CALTRANS), OWNER

TEMPORARY BRIDGE: Mabey Inc., Sacramento, Calif.

PILES: E.P. Jarrett Foundation Co. Inc., West Sacramento, Calif.

BRIDGE DESCRIPTION: A single 108-ft-long, precast, prestressed, transversely post-tensioned concrete bridge on cast-in-steel-shell pile foundation

STRUCTURAL COMPONENTS: Eleven 3½-ft-deep by 4-ft-wide, 106-ft-long adjacent precast, prestressed concrete box beams, four precast concrete abutments and precast concrete wingwalls, and composite cast-in-place concrete deck and barrier rail, founded on twelve 24-in.-diameter, 65-ft-deep cast-in-steel-shell piles

BRIDGE CONSTRUCTION COST: \$1,047,000 (\$220/ft²)



Craig Creek Bridge deck shows no cracking nearly two years after construction completion. Deck concrete contains a shrinkage-reducing admixture and fibers, and was subjected to a shortened curing period.

figure out a way to reduce concrete curing time requirements from the standard seven-day water cure and still end up with a high quality deck?" The week-long moist curing time requirement creates a dead spot in the construction schedule, contrary to the fundamental concept of ABC, and the operational tempo of the contractor's crew is disrupted. A quick literature search did not reveal any current research or methods relating to this need. It was not surprising, since anything less than a seven-day water cure is not typical in the bridge engineering world.

This prompted a 2011 Caltrans construction-evaluated research study, "Bridge Deck Concrete Improvements & Cure Strategies Proposed for Accelerated Bridge Construction," using some of the state's portion of the VECP savings to fund the construction components of the effort. This research study proposed a three-day water cure using previous experience and successes in formulating concrete designs to reduce early-age concrete deck cracking.

Prototype requirements for a high-performance deck and curing specification suitable for ABC were developed and implemented. To allow for future grinding to facilitate the crack investigation portion of the research study, and to make

provisions for an additional ordered change to a quiet deck specified by grooving, a sacrificial ½-in.-thick layer was added to the deck thickness.

ABC Deck and High Performance Curing

The 4 ksi compressive strength, ABC high-performance deck concrete with a three-day curing period required a mix design using a shrinkage-reducing admixture (SRA) at a dosage rate of 96 fl oz/yd³, a water-reducing admixture at a dosage rate of 49.4 fl oz/yd³, and polyolefin macro fibers at a dosage rate of 3 lb/yd³ with 705 lb/yd³ of Type II cement, and a water-cement ratio of 0.39.

Concrete cylinder strengths were 3.2 ksi at two days, 4.0 ksi at four days, 4.5 ksi at seven days, and 5.9 ksi at 28 days. The newly placed deck was cured using a sprayed-on poly-alpha-methylstyrene white pigmented curing compound applied at 150 ft²/gal. and the water method. The wet cure was applied for three days using soaker hoses covered with a curing medium. On the third day, another heavier coating of curing compound was applied to the damp deck surface at 100 ft²/gal. and was allowed to set up for a couple of hours to prevent damage or pick-up from vehicles before being opened to traffic. This helped to seal the concrete so that hydration continued.

Seven weeks later, a diamond drum grinder was used to remove the curing compound and surface paste to aid in finding and mapping cracks prior to grooving for a smooth riding, quiet deck. There were no visible cracks, and there are still no cracks two years later. For an additional material cost of less than \$40/yd³ (\$18/yd³ for fibers and \$18.75/yd³ for SRA) or \$3600 total, a crack free concrete deck was built and cured in less than half the customary curing time.

There were no visible cracks, and there are still no cracks two years later.

Team Delivers Success

By partnering together and creating opportunities from the many challenges that faced the project, the construction team exceeded the goals of the original plans. Utilizing a small construction crew without a lot of long or extra shifts, the contractor was able to remove and replace the old bridge and return traffic to the mainline highway in 29 days without sacrificing quality. By using PBES components, innovative construction methods, and deploying innovative construction approaches, mobility of goods and traffic was improved, safety was enhanced, environmental impacts were reduced, and the project delivery was shortened, all at a cost savings. This project demonstrates how contractors and owners should work together to achieve great things and make advances in the industry. The high-performance deck concrete and curing method used on this project will have applicability on many future projects, making the public the big winner. 

Sonny Ferreira is a senior bridge engineer with Structure Construction, Division of Engineering Services for the California Department of Transportation (Caltrans) in Red Bluff, Calif.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

You Can't Afford the Risk



Image Courtesy of Louisiana Department of Transportation and Development

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The PCI State-of-the-Art Practice Report on Precast/Prestressed Adjacent Box Beam Bridges

This report (SOP-02-2012) presents the state-of-the-art practice on adjacent precast, pretensioned adjacent box-beam bridges. This report is relevant for Accelerated Bridge Construction, new bridge construction, or superstructure replacement projects.

The PCI State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels

The *PCI State-of-the-Art Report on Full-Depth Precast Concrete Bridge Deck Panels* (SOA-01-1911) is a report and guide for selecting, designing, detailing, and constructing precast concrete full-depth deck panels for bridge construction. This report is relevant for new bridge construction or bridge-deck replacement.

The PCI State-of-the-Art Report on Curved Precast Concrete Bridges

This report details the application of curved precast concrete bridge design, fabrication, construction techniques, and considerations through the study of 12 related projects. The document was written and intended to provide bridge owners, designers, fabricators, and engineers an up-to-date reference in developing precast concrete bridge solutions for curved geometric situations.

www.pci.org/epubs

PROJECT

Interstate 35 Corridor

Eight consecutive I-35 bridge designs showcase Oklahoma's history

by James J. Handy Sr. and Steven Weitzman, Creative Design Resolutions Inc.

The Interstate 35 (I-35) corridor widening project in Norman, Okla., is proving to be another seminal effort in the field of aesthetic master planning because of the unusual concentrated focus on sequential bridges and highway walls within a single community. Highway travelers and pedestrians will gradually discover the history and story of the city while commuting through this north-south interstate corridor. Each bridge and highway wall tells part of the overall story of the City of Norman.

The project began when the Oklahoma Art in Public Places Division (OAIPP) engaged an aesthetic design firm to develop an aesthetic master plan for the I-35 corridor. Gary Ridley, secretary of transportation, Oklahoma Department of Transportation (ODOT) wrote of the role of the aesthetic design firm, "You have provided ODOT with initial

design concepts, helped us through the community involvement process, worked closely with our highway contractors, and provided us with a high-quality product in a timely manner that adds value to the end product that can't be achieved in any other way." The intention was to create an inventory of designs that can be incorporated throughout the greater highway system.

The introduction of aesthetics into the transportation system is an important step in enhancing the quality of life for both the community and for people visiting the city. The exploration and development of aesthetic transportation design is an increasingly essential component of successful transportation projects. In increasing numbers, departments of transportation across the country have collaborated with designers to integrate aesthetics into their transportation infrastructure.

Eight interchanges are included in the design of the I-35 corridor aesthetic master plan. The project includes aesthetics for one set of retaining walls, two bridges that will be retrofitted, and six bridges that will be demolished and rebuilt. All designs will be based on Norman, Okla., culture and aesthetics. By widening I-35, the ODOT and the city of Norman desired to

- provide additional capacity for traffic without sacrificing too much of the remaining natural environment,
- encourage safety along this highway corridor by introducing additional pedestrian amenities, and
- promote community identity through the implementation of aesthetics for a series of transportation enhancements.

The most successful transportation projects employ context-sensitive solutions during the initial aesthetic design

Bridge	Theme	Description
U.S. 77 Interchange	Prairie	Prairie lands and the natural environment before settlements
Tecumseh Street Bridge	Tecumseh the Shawnee Nation	Shawnee Nation and their renowned Chief Tecumseh, for whom the street is named
Rock Creek Road Bridge	Horses in Motion	The quarter horse industry as well as the historic cowboys' horses; Rock Creek Road leads west towards Norman horse farms.
Robinson Street Bridge	Railroad	Importance of the railroad in the City of Norman's history; Robinson Street crosses the railroad tracks and leads east towards the Santa Fe Railroad depot.
Main Street Bridge	Land Run of 1889	Historic claiming of land and settlement; this bridge leads to historic downtown Norman.
Lindsey Street Bridge	University of Oklahoma	Extension of the Cherokee Gothic style of architecture found at the university, which is accessed by Lindsey St.
SH-9 East Interchange	Lake Aquatics	This bridge draws inspiration from nearby Lake Thunderbird, which is accessed by SH-9 East.
SH-9 West Interchange	Agriculture and the Chickasaw Nation	Agriculture and ancient Chickasaw designs; agricultural fields and the Chickasaw Nation are near this bridge.

profile

INTERSTATE 35 CORRIDOR / NORMAN, OKLAHOMA

CLIENT: Oklahoma Art in Public Places Division, Norman, Okla.

MASTER PLAN DESIGN CONSULTANT: Creative Design Resolutions Inc., Brentwood, Md.

SPECIALTY STAIN AND FORM-LINER FABRICATOR: Creative Form Liners Inc., Brentwood, Md.



The aesthetics for the U.S. 77 Interchange represent the prairie lands and the natural environment before settlements. All photos: Creative Design Resolutions Inc.

phase, and throughout each step in the development process. This makes a variety of design options available right from the start. For the I-35 corridor project, the community, project team, and other interested stakeholders were assembled before any designs were implemented.

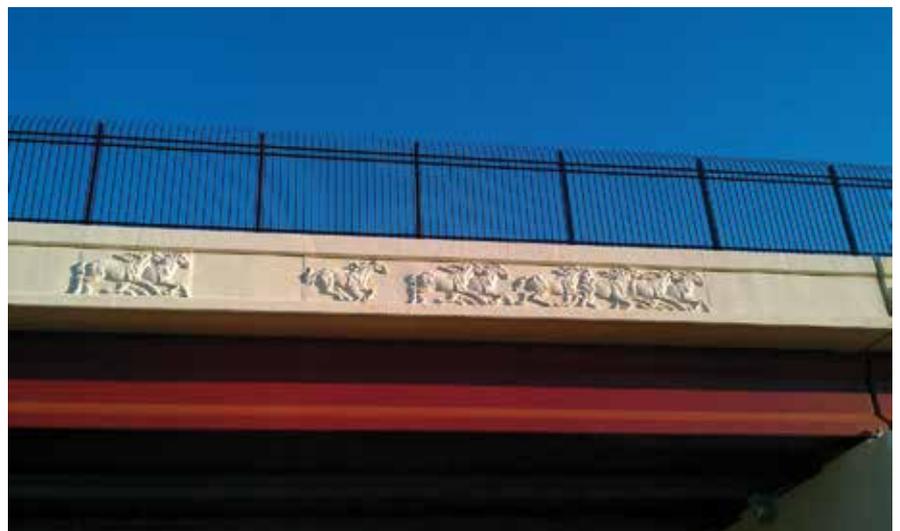
In mid-2008, the OAIPP organized a representative group of community members to serve on the aesthetic design committee and held an initial meeting to collect the community's interests, visions, and goals for the I-35 corridor. At the same time, the OAIPP contracted with an aesthetic design firm to develop the designs and serve as the liaison between the project team and the community.

Information from the committee's first meeting was combined with research data to develop potential themes for the corridor, and create conceptual designs that could be used for the individual bridges.

The following factors were taken into account in developing the overall design theme before beginning to select the various theme options for each bridge:

- General location of the bridges,
- Historical demographics of the area,

The aesthetics for the completed Rock Creek Road Bridge reference Oklahoma's quarter horse industry, as well as the historic cowboys' horses.



OKLAHOMA DEPARTMENT OF TRANSPORTATION AND CITY OF NORMAN, OWNERS

BRIDGE DESCRIPTION: Eight bridges and one retaining wall with features based on the culture and aesthetics of Norman, Okla.



A close-up of the mural for a mechanically stabilized earth wall that will be part of the Main Street Bridge, which is under construction.



The aesthetics for the Main Street Bridge depict the historic claiming of land and settlement.

- Traffic assessment,
- Vast and deep Native American heritage,
- Past and present cultural growth and diversity, and
- Pioneer settlement implications that helped develop the culture and industry of the City of Norman.

In November 2008, the themes and designs were shared with the committee to stimulate feedback and discussion. During this meeting, the committee selected themes for each of the eight bridges listed in the table on page 30.

By the end of 2008, the committee, the project team, owners, and the aesthetic design firm had successfully developed aesthetic designs for each bridge and the retaining wall.

Currently, three of the eight bridges in the aesthetic master plan, are complete: U.S. 77 Interchange, Rock Creek Road Bridge, and SH-9 West Interchange. The Main Street Bridge is under construction, Construction on the SH-9 East Interchange is slated to begin in the fall of 2013, the Lindsey Street Bridge is set to start in 2014, and the Tecumseh Street Bridge and Robinson Street Bridge will be scheduled later.

History, culture, tradition, architecture, and various other community-oriented inspirations have guided the development of the aesthetic enhancements for the I-35 corridor project. As set forth through the supervision of the City of Norman and the ODOT, all designs originate from thorough research. This research includes studies of the region, community

suggestions and responses, as well as other published studies. By consulting published studies, transportation solutions are found that widen the highway without sacrificing too much of the natural environment, while also encouraging pedestrian safety and promoting community identity.

Through the process of developing the aesthetic solutions, it quickly became apparent that the thematic plan carried from bridge to bridge and along highway walls not only celebrates the unique value of Norman's history, but also represents the state of Oklahoma. The aesthetic solutions provide vehicular traffic and pedestrians a way to discover and visually read the story of this city and state, while making their commute a more-beautiful experience. 



James J. Handy Sr. is national sales & marketing director and Steven Weitzman is president and CEO of Creative Design Resolutions Inc. in Brentwood, Md.

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The aesthetics for the completed SH-9 West Interchange illustrate agriculture and incorporate ancient Chickasaw designs.

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

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

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

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

PROJECT

Sibley Pond Bridge, Route 2

Design-build bridge replacement project in Maine uses Northeast Extreme Tee

by G. Keith Donington and Hany L. Riad, Parsons Brinckerhoff



The 790-ft-long, two-lane bridge consists of ten 79-ft spans arranged in two 5-span continuous units spanning over a shallow pond. Photo: Lane Construction.

When the Sibley Pond Bridge required replacement, the project team used innovative design and the first use of the Precast/Prestressed Concrete Institute (PCI) Northeast Extreme Tee double-tee (NEXT D) beam section with full-depth integral deck, to open the bridge more than 10 months ahead of schedule. The NEXT D section had been newly developed by PCI Northeast in response to the Federal Highway Administration's (FHWA) nationwide initiative for accelerated bridge construction.

The 790-ft-long, two-lane bridge consists of ten 79-ft-long spans arranged in two 5-span continuous units. The bridge carries U.S. Route 2 between Canaan and Pittsfield, Maine, over a shallow pond. The pond's upper layers of organic material increase in depth towards its middle, and is underlain with glacial till and granite bedrock. Fixity is provided at each end of the bridge through semi-integral abutments.

Each of the nine intermediate piers are supported on single rows of four steel-pipe piles that flex as the structure expands and contracts around a single expansion joint located at the center of the bridge.

By limiting cast-in-place concrete construction to the pier diaphragms and 8-in.-wide closure strips between beam flanges, the NEXT D beams were rapidly erected using a gantry crane that rolled sideways from the old bridge and across the new piers. Durability was enhanced by using 8 ksi compressive strength, self-consolidating, precast concrete that included a corrosion inhibitor.

Close collaboration between the contractor, the beam designer, the precaster, and PCI Northeast took place during the project's early stages to optimize the final design details of these new beam sections. This collaboration facilitated maximum efficiencies in precasting, erection by a custom-built

gantry crane, and the quality necessary for a 100-year service life as specified by the owner.

Design Considerations

The replacement bridge was placed on a tangent alignment, partially overlapping the existing bridge near the abutments, but with sufficient width to maintain access to the old bridge during construction. The bridge was laid out with 10 equal 79-ft-long spans so that piles from the new bents would be well clear of those from the existing bridge with its 26-ft-long spans.

Early in the proposal phase, the contractor submitted an alternative technical concept to move Route 2 traffic to the south onto an at-grade detour roadway that followed a former alignment of the route. This required a 60-ft-long temporary bridge over the pond inlet. This detour relocated traffic safely away from the work area and enabled the existing bridge to be

profile

SIBLEY POND BRIDGE, ROUTE 2 / CANAAN AND PITTSFIELD, MAINE

BRIDGE DESIGN ENGINEER: Parsons Brinckerhoff Inc., Manchester, N.H., and Boston, Mass.

PRIME CONTRACTOR: The Lane Construction Corp., Bangor, Maine

CONCRETE SUPPLIER: The Lane Construction Corp., Bangor, Maine

PRECASTER: J.P. Carrara and Sons, Middlebury, Vt., a PCI-certified producer

used for contractor access, placement of concrete pier caps, and delivery and erection of the NEXT D beams. A detailed structural inspection and analysis was performed for the existing bridge, and several deteriorated existing piles were repaired with reinforced concrete collars, to ensure structural integrity during construction operations.

Beam Selection

The 36-in.-deep NEXT D beams were selected and made continuous for live load by providing continuity reinforcing steel using mechanical couplers over the interior supports. As shown in the typical deck section, the bridge cross section is composed of four 9-ft 4-in.-wide beam units with three 8-in.-wide closures with overlapping headed reinforcement.



By using high-performance/high-strength self-consolidating concrete, the precaster was able to consistently achieve an outstanding quality surface finish without any noticeable imperfections. Photo: Parsons Brinckerhoff.

Substructure Selection

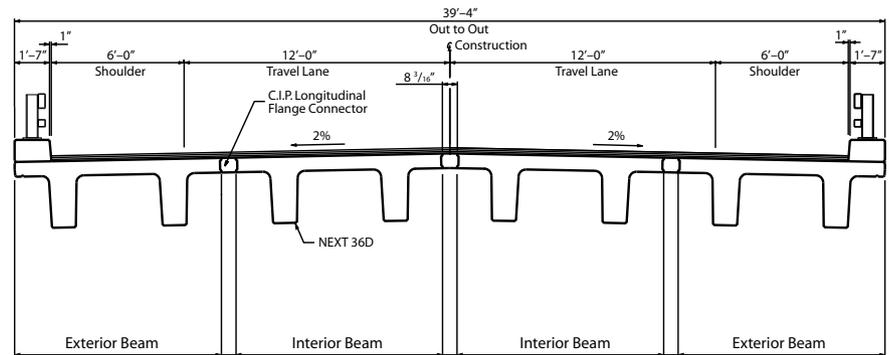
Each of the nine intermediate concrete pier caps are supported on single rows of four, 24-in.-diameter, concrete-filled steel pipe piles driven to bedrock. The beams are supported on elastomeric bearings, and stainless-steel dowels pin the continuity diaphragms to the pile caps. Each abutment is supported on two rows of steel H piles to provide longitudinal stability.

Beam Erection Considerations

Float-mounted erection equipment was not feasible due to the pond's shallow depth. The contractor determined that erecting the beams using a custom fabricated gantry crane was most cost effective. The gantry ran sideways from the old bridge onto the new piers to erect the beams instead of erecting the beams using two cranes supported on temporary pile platforms, as initially indicated during the technical proposal. The steel gantry crane rail support beam system was designed to span from the old bridge to, and along, the new piers. A typical beam erection sequence involved backing the 70-ton beams under the gantry crane.

Once the beam was lifted, the truck and beam dolly were removed from the bridge and a steel beam drop-in section was inserted transversely between the gantry legs to complete the beam rails. The gantry crane was then propelled sideways by synchronized electrical winches located at the piers. Spans were erected progressing from the abutments towards the center expansion joint pier for stability.

This erection method proved to be efficient. It took only one day to move the gantry crane from one span to the next. The contractor consistently remained ahead of the crane in setting extra rails, support pedestals, and concrete blocks. After the first spans were erected, the contractor was able to set a span of four beams within an eight-hour shift and achieve an overall turnaround time of two days per span.



The bridge cross section consisted of four 9-ft 4-in.-wide precast concrete NEXT D beam units that were 36 in. deep. The beams were made continuous for live load by providing continuity reinforcing steel over interior supports. Drawing: Parsons Brinckerhoff.

MAINE DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: 790-ft-long, 36-ft curb-to-curb width, 10-span precast double-tee-beam bridge, constructed as part of a design-build project

STRUCTURAL COMPONENTS: Forty 36-in.-deep NEXT D beams, two cast-in-place abutments supported on HP 14 x 89 piles, and nine cast-in-place pier caps each supported on four, 24-in.-diameter concrete-filled steel pipe piles

BRIDGE CONSTRUCTION COST: \$7.7 million

Final Design Innovations

Several innovative details were developed to achieve maximum efficiencies in precasting and erection procedures.

To maximize production of the precaster's form bed to three beams per placement and provide the necessary 15-in. horizontal clearance to accommodate the rails under the legs of the gantry erection crane, it was necessary to keep the ends of the beams free of all mild-steel reinforcement and strand protrusions.

For live load negative moment continuity over the piers, mechanical couplers were detailed to field splice the splice bars between adjacent beams. This required the precaster to align the bars from adjacent beams to tight tolerances. For the positive moment continuity reinforcement in the bottom of the beams, which normally is provided by overlapping extended prestressing strands, a special detail was developed using a steel end plate with field welded ASTM A706 mild-steel reinforcement.



High-performance concrete was used in the longitudinal closure joints. Photo: Parsons Brinckerhoff.



Mechanical couplers were used to connect continuity reinforcement over the interior supports. Photo: Parsons Brinckerhoff.



Each of the nine intermediate concrete pier caps are supported on single rows of four 24-in.-diameter, concrete-filled steel pipe piles driven to bedrock. The beams are supported on elastomeric bearings, and stainless steel dowels pin the continuity diaphragms to the pile caps. Each abutment is supported on two rows of steel H piles to provide longitudinal stability. Photo: Parsons Brinckerhoff.

Durability Considerations

The use of NEXT D beams maximized precast concrete and limited cast-in-place concrete construction in the superstructure to the longitudinal closure joints, the continuity diaphragms at the piers, and the curbs. Long-term durability was enhanced by using high-performance, high-strength, self-consolidating concrete (SCC) with 5.5 gal./yd³ of calcium nitrite corrosion inhibitors in the precast concrete beams. The precaster consistently achieved 10 ksi compressive strength concrete, although 8 ksi was specified for design. High-performance concrete with calcium nitrite was also specified for all field-placed concrete.

By using SCC, the precaster was able to consistently achieve an outstanding quality surface finish without any noticeable imperfections.

In accordance with the owner's policy, the use of mild-steel reinforcement was specified, with the exception of ASTM A1035 reinforcement for exposed concrete curbs and barrier transitions. Increased cover was necessary to meet the 100-year life requirement.

The roadway deck is protected with a hot machine-applied, high-performance waterproofing membrane system with a 3-in.-thick asphalt wearing surface. The steel pipe piles are protected with a shop-applied, fusion-bonded epoxy coating system extending from the top of the pile to 10 ft below the mud line.

Locating the expansion joint in the middle of the bridge at the crest of the vertical curve had benefits. It resulted in water draining away from the joint in both directions, thereby minimizing the potential for future leakage. The ends of the diaphragms at the joint are covered with a sheet membrane.

Conclusions

This challenging project required close collaboration among several parties to succeed. Excellent teamwork by the owner, contractor, precaster, designer, and PCI Northeast helped make the job a success. Through the use of an innovative beam section, alternative erection scheme, and customized detailing, the team was able to deliver a completed, cost-effective project faster and of higher quality compared to conventional techniques. **A**

G. Keith Donington is senior supervising structural engineer with Parsons Brinckerhoff in Manchester, N.H., and Hany L. Riad, PhD, is principal structural engineer with Parsons Brinckerhoff in Boston, Mass.

For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

Precast, Prestressed Concrete Overhang Panel System

by Manuel Padron Jr., Texas Department of Transportation



The completed Farm-to-Market Road 1885 Bridge over Rock Creek was the first bridge in Texas to use the precast, prestressed concrete overhang panel system. All photos: Texas Department of Transportation.

The Texas Department of Transportation (TxDOT) is constantly seeking innovative accelerated bridge construction methods that can reduce the impact to the traveling public, improve safety in the work zone, and reduce costs. TxDOT has a successful history of using precast, prestressed concrete panels (PCPs) as stay-in-place forms for the interior bays of bridge decks. However, the current practice for constructing the overhang sections requires the use of conventional overhang brackets and extensive formwork. An innovative precast, prestressed concrete overhang panel system has a potential to improve economy, safety, and speed of construction.

In 2008, TxDOT sponsored a research project to develop a precast, prestressed concrete overhang panel system for potential use in bridge construction. The results indicated that the flexural and shear capacities of the precast, prestressed concrete overhang panel system are comparable to those of a conventionally cast-in-place concrete deck. The precast, prestressed concrete overhang panel is a combination of a full-depth and partial-depth panel that extends from the first interior girder to the edge of the

slab. The full-depth portion of the panel extends the length of the overhang and terminates near the inflection point between the exterior and first interior girders. Also, the full-depth portion of the panel serves as a safe and convenient work platform and allows the screed to be placed directly over the girder line.

To allow for adjustment and grading of the panels during construction, leveling bolts are cast into the overhang panels. Composite action between the exterior girder and the precast, prestressed concrete overhang panel is provided by shear connectors that extend from the top of the girder into the shear pockets in the overhang panels. After the profile is established using the grade bolts, the cast-in-place concrete portion of the deck is cast. Finally, the haunch section over the exterior girders and the shear pockets are filled with non-shrink structural grout.

The precast, prestressed concrete overhang panel system was successfully implemented by TxDOT on the Farm-to-Market Road 1885 Bridge over Rock Creek in Parker County near Cool, Tex. Since this was the first project using the precast, prestressed concrete overhang panel system, no significant reduction in construction



Placing and aligning precast, prestressed concrete overhang panels used on the Farm-to-Market Road 1885 Bridge over Rock Creek.



The underside view of the Farm-to-Market Road 1885 Bridge over Rock Creek near Cool, Tex., shows the use of the precast, prestressed concrete overhang panel system.

time was observed due to the learning curve for all those involved. However, there was an improvement in safety due to the sturdy work platform provided by the precast, prestressed concrete overhang panels and the elimination for the need to set and remove overhang brackets and formwork. Overall, the precast, prestressed concrete overhang panel system worked well and shows great promise for deck construction in the future. 

Manuel Padron Jr. is a bridge design engineer with the Texas Department of Transportation in Fort Worth.

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SPMT Solutions

by Craig A. Shutt



For the Rawson Avenue Bridge projects, the two spans were constructed on opposite sides of the expressway.
Photo: Henry G. Russell Inc.

Constructing bridges off line and moving them into place offers key benefits to owners and contractors. As a result, more bridges are being designed and built using these techniques. This article is part of a series looking at some of the key considerations when using accelerated bridge construction (ABC) approaches to construct bridges. It describes the use of self-propelled modular transporters (SPMTs), which are becoming more popular with owners, designers, and contractors as they understand the concepts and see the advantages of ABC.

A single SPMT is a multi-axle platform operated through a computer-controlled system. Each axle line generally consists of four wheels arranged in pairs. Each pair of wheels can pivot 360 degrees around its support point. Consequently, an SPMT has complete freedom to move in all horizontal directions. These motorized vehicles, moving at walking speed, can lift and carry large and heavy loads, including entire bridge assemblies, from off-site locations to their final position. The SPMTs are then moved off site, allowing traffic to be restored within hours of completion. Otherwise, construction of the bridge is similar to that of a bridge built in its final location.

This moving equipment often is used when construction sites are restricted, and prefabricated components need to be assembled off site and moved into place along a route that is longer than is practical for slide pads or rollers to navigate. More engineering is required for this type of move due to the added complications.

SPMTs can be linked longitudinally or laterally to provide the number and configuration of axle lines required by the load.

Linked units can be synchronized to a central computer, providing four basic commands: steer, lift, drive, and brake. The dimensions of SPMT units vary depending on the make and number of axles and wheels.

When using SPMTs to move bridges, tolerances must be kept extremely tight. Minor deviations that can be corrected during typical bridge construction cannot be adjusted as the bridge is moving and being set. As a result, tolerances must be strict enough to avoid excessive stresses on the bridge yet reasonable enough to generate optimum moving speed. These tolerances must be specified, adhered to, and continually monitored.

States Expanding Use

Some states, notably Utah, offer manuals that provide guidance for using SPMTs. Utah Department of Transportation's Innovate 80 program involved the replacement of 12 structures using SPMTs and made ABC techniques its standard in 2010. Utah projects have used SPMTs to carry bridges over distances as great as 1.25 miles and over grades as steep as 6%.

SPMTs can provide a range of benefits. Most significant is the reduction in closure times, sometimes to as little as a few hours. This improves accessibility and reduces user costs while also improving worker safety.

Additional benefits arising from the prefabrication of components can include the following:

- Longer curing times for all concrete components
- Control over the environment at the construction site

- More controlled environment for casting components, which reduces maintenance and improves quality
- Fewer deck joints than with other ABC methods
- Less required material
- Public favor from improving speed of construction

Construction Examples

The first bridge constructed in the United States using SPMTs was completed in Volusia County, Fla., in January 2006. The Florida Department of Transportation's construction team used SPMTs to replace a bridge over an interstate highway. During this project, the existing Graves Avenue Bridge was lifted and moved to the side of Interstate 4 (I-4) in only 22 minutes using SPMTs.



Self-propelled modular transporters move the first span of the Rawson Avenue Bridge from its staging area to the bridge location. Photo: Adam Tyksinsk and Rudy King, Wisconsin Department of Transportation.



The first span of the Rawson Avenue Bridge is moved into its final location. Photo: Adam Tyksinsk and Rudy King, Wisconsin Department of Transportation.



The relative elevations and spacings of the beams in the bridge built in the staging area must match those of the final location. Photo: Adam Tyksinsk and Rudy King, Wisconsin Department of Transportation.

Two new 143-ft-long concrete bridge spans were built alongside I-4 instead of over the interstate, reducing the need for road closures and traffic disruptions. Weighing nearly 1300 tons, the new spans were moved into place with SPMTs. Using this approach saved about four months of closure time, greatly reducing impact to drivers. Traffic needed to be detoured for only two weekend nights, using rolling roadblocks.

Pioneer Crossing Interchange in Utah along Interstate 15 used SPMTs to move twin two-span, precast, prestressed concrete bulb-tee-girder bridges into place in 2010. The twin design allowed the bridge to remain open throughout construction.

Each span weighed approximately 2300 tons, representing the longest and heaviest documented concrete spans to be moved using SPMTs. Each span was supported at each end with dual SPMTs with 20 axles each, which resulted in each span being supported by 320 wheels. The SPMTs carried a system of cribbing and lateral bracing that supported the spans at the required vertical elevation. The bulb-tee girders were supported at the twentieth points from the ends of the spans.

The first span was set in October 2009, while the second was set in June 2010. Each span was placed with a single eight-hour traffic closure, significantly reducing user costs. (For more on this project, see the Winter 2011 issue of *ASPIRE*.™)

Rawson Avenue Bridge

A recent use of SPMTs took place in June 2013 when the Wisconsin Department of Transportation (WisDOT) reconstructed its Rawson Avenue Bridge along Interstate 94 in Oak Creek, just south of Milwaukee. The new \$4.2-million bridge was built in two staging areas on either side of the highway and then moved into place using SPMTs. The entire move required only a 12-hour highway closure, with each move itself requiring an estimated two hours.

The 188-ft-long bridge features two spans (98 ft 6 in. and 86 ft 6 in.) consisting of WisDOT wide-flange, prestressed concrete girders. With a width of 138 ft 2 in., the bridge has fourteen 45-in.-deep girders per span spaced at 10 ft 1 in. The intermediate support consists of multicolumn precast concrete piers with precast column caps, supported by spread footings. The spans weighed approximately 1545 and 1345 tons, including the 10-in.-thick deck, parapets, and sidewalks.

Each span was moved using two lines of SPMTs, with each line consisting of six SPMTs connected end-to-end. Each SPMT had six axles with four wheels per axle, providing 24 wheels per SPMT, 144 wheels per line, and 288 wheels for both lines. Each line of SPMTs supported a steel beam that ran along the bridge's width. Shims were used between the top of the steel beam and the underside of each concrete beam to accommodate differences in elevation.

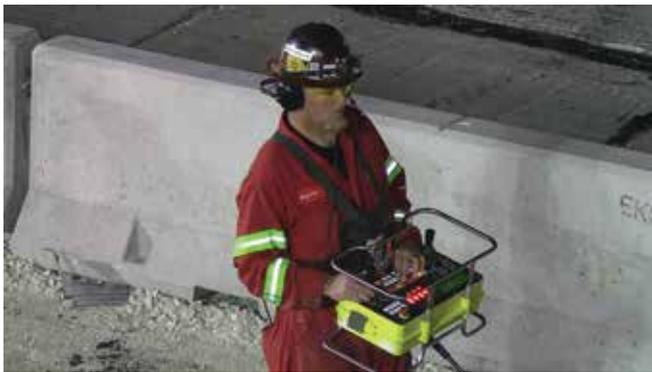
Relative girder elevations were maintained during the move. In the staging area, the supports were located at 6 in. from the girder ends. This location also served as the final bearing locations after the bridge move. During the move, supports were located approximately 16 ft 9 in. from the girder ends. This distance allowed the SPMT support system to be rolled into place while the bridge was supported by the temporary structures.

Superstructure capacities were examined to ensure the SPMT support locations did not cause excessive negative moment over the supports. This can occur because the SPMTs reduce the girder span lengths, reducing the positive moment at midspan. The contractor had flexibility in locating the supports and could have suggested alternative locations if needed but used the design engineer's locations.

Crews worked together to provide the necessary site-specific subgrade demands in the bridge staging areas and travel



Six self-propelled modular transporters in each line were used to move the Rawson Avenue Bridge. Photo: Adam Tyksinsk and Rudy King, Wisconsin Department of Transportation.



The movements of the self-propelled modular transporters are controlled by a single driver. Photo: Adam Tyksinsk and Rudy King, Wisconsin Department of Transportation.



Both spans of the Rawson Avenue Bridge were placed during a 12-hour overnight closure of the expressway. Photo: Adam Tyksinsk and Rudy King, Wisconsin Department of Transportation.

path, ensuring a smooth ride. This included determining the allowable soil loads and specifying ground improvements due to undesirable soils or loading conditions. Proof rolling was performed throughout the travel path, with underperforming areas undercut and backfilled with compacted fill. Steel plates were placed along the travel path to the interstate roadway.

Conditions Monitored

Weather was monitored throughout the move to ensure wind speeds never approached the 30-mph cutoff. A local weather-monitoring system provided current conditions prior to and throughout the move.

The superstructure's twist tolerance of 2 in. was continuously monitored throughout the move using taut piano wires. The wires were set about 2 ft off the bridge deck between diagonal corners and consisted of upper and lower line limits across one diagonal and a measurement line across the other diagonal. If the measurement line approached the limit lines, the SPMT was stopped so adjustments could be made.

Abutment and pier diaphragms were cast after the bridge was in place. This approach reduced the dead load to be moved and allowed continuity reinforcement to be placed over the pier to provide a monolithic and integral connection.

Completing a successful move with SPMTs in a limited time frame requires close coordination of all activities. These include controlling traffic, removing barriers between the staging area and the bridge site, providing illumination for night moves, ensuring availability of worker lifts for easy access, and ensuring ready access to backup equipment. It also is essential for the general contractor to work closely with the heavy-moving subcontractor from the project's inception. 

This is the fourth part in a series examining approaches to accelerated bridge construction. This report was produced with information that included interviews with Mike Dobry, principal structures engineer and Larry Reasch, vice president and manager of the structures department, at Horrock Engineers. Information also was derived from the Utah Department of Transportation's SPMT Manual and the Federal Highway Administration's December 2006 issue of Focus magazine. Information about the Rawson Avenue Interchange Reconstruction Project was obtained from Fact Sheets produced by the WisDOT as well as William Oliva and staff of WisDOT.

To learn more about self-propelled modular transporters (SPMTs), visit www.fhwa.dot.gov/bridge/pubs/07022/chap00.cfm. A copy of Utah Department of Transportation's *SPMT Manual* can be downloaded at <http://www.udot.utah.gov>. For additional photographs or information on this or other features, visit www.aspirebridge.org and open "Current Issue."

Using Bridge Life-Cycle Cost Analysis Tools for MAP-21

by Nathaniel Coley and M. Myint Lwin, Federal Highway Administration



This article is a follow-up to the article titled “Map-21 and Bridge Life-Cycle Cost Analysis” published in the Summer 2013 issue of *ASPIRE*.™ This article describes the project-level, life-cycle cost analysis using the Federal Highway Administration (FHWA) bridge life-cycle cost analysis (BLCCA) software tool. An example illustrates application of the tool to compare the life-cycle costs for rehabilitation versus replacement of a bridge. The FHWA BLCCA software tool is a powerful tool for performing various levels of project cost analysis and comparative studies. It is ideal in support of making project level strategic investment decisions.

FHWA BLCCA Software Tool

Bridge project engineers consider various investment strategies on a project level. The strategies primarily include:

- investing in the repair of existing bridge deterioration,
- preservation activities that extend service life and delay major investments, or
- replacing a bridge that has advanced deterioration.

For this purpose, FHWA offers the BLCCA software tool. This tool helps engineers perform an analysis of each strategy for a specific bridge so that, in comparison, the strategy that provides the desired performance with the best potential life-cycle cost scenario can be selected. Specifically, the BLCCA software calculates the present value of costs of alternative investment strategies applied over a specific time horizon.

The BLCCA software tool is based in Microsoft Excel. It includes worksheets organized into four separate areas: summary, data, settings, and reports and models.

Each group of worksheets provides specific details about the analysis. For example, the summary worksheet provides a synopsis of the analysis results and hyperlinks to relevant worksheets. The worksheets in the data area display details about elements and costs for alternative strategies.

To run the software, the analyst simply opens the file and selects the data set to link to, selects the bridge of interest from the list of bridges, and begins inputting the specifics about each

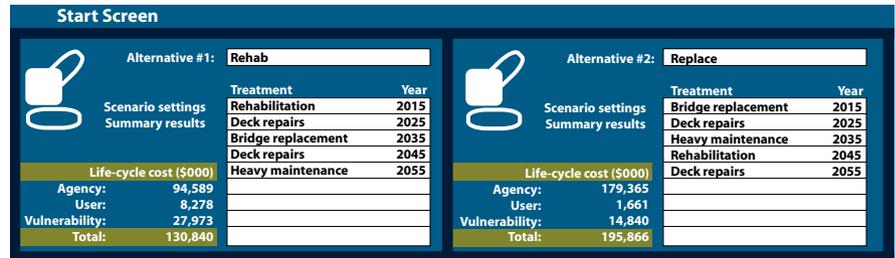


Figure 1: An example comparing the life-cycle costs for rehabilitation versus replacement of a bridge using the Federal Highway Administration bridge life-cycle cost analysis (BLCCA) software tool. Diagram: FHWA.

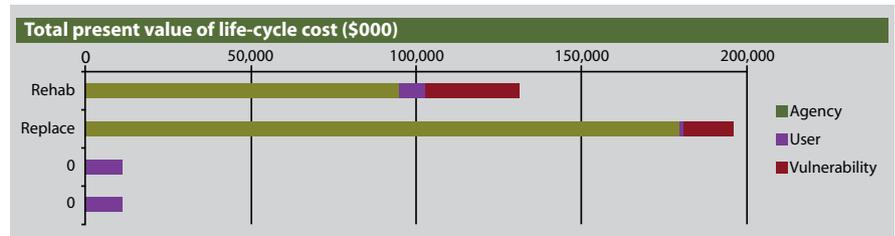


Figure 2: The outcome from an example comparing the life-cycle costs for rehabilitation versus replacement of a bridge using the Federal Highway Administration bridge life-cycle cost analysis (BLCCA) software tool. Diagram: FHWA.

alternative. It allows users to select data about a specific bridge along with its in-service condition ratings from either the National Bridge Inventory (NBI) or Pontis data set.

Specific life-cycle actions such as rehabilitation, deck repairs, or replacement can be selected for alternative strategies that the user identifies. Using these inputs, the software applies deterioration algorithms to each element associated with the bridge and displays a summary of the performance of each investment strategy over the user-specified time horizon. The element deterioration algorithms and costs were refined from data collected on bridges nationwide and provide recommendations of bridge performance for use by the analyst. Each attribute can be overridden or customized by the analyst by simply entering values in pertinent fields. In the absence of expert knowledge, the recommendations provide a good gauge. The user can revisit other specific aspects of the analysis and refine inputs such as costs, dates that actions occur, or add additional actions as necessary.

Copies of the BLCCA software will be available for download from FHWA by request beginning in October 2013. It is placed on the local

machine along with the specific (NBI) data set. FHWA provides access to NBI data sets on its webpage at <http://www.fhwa.dot.gov/bridge/nbi/ascii.cfm>.

Illustrative Example

An example analysis using the software to compare the life-cycle costs for performing rehabilitation versus replacing a bridge is depicted in Figure 1, which shows the scenario for each strategy.

The software estimates the agency costs for each of these activities needed to restore each affected element to acceptable performance levels. Specifically, it maps the selected actions (for example, heavy maintenance) to element level activities to calculate costs.

The user can define the particular aspects of the new bridge by selecting relevant elements of the new bridge such as steel beams or prestressed concrete girders.

The outcome of the analysis is depicted in Figure 2. The bar graph displays the present value of the total costs for the two alternatives. Costs are color delineated by direct agency costs for materials or construction, user costs, and vulnerability costs.

Basically the results show that the net present value of alternative 1, the rehabilitation strategy, is \$130.8 million versus \$195.9 for alternative 2. Initial cost of replacement is \$166 million (versus \$21 million for rehab), but the increased cost is partially offset by reduced user costs from widening, reduced costs associated with seismic vulnerability, and reduced agency maintenance costs. Risk features of the software could also be used to explore various uncertainties of input variables such as quantities of materials or dates when actions occur.

Closing Remarks

Many life-cycle cost analysis tools are available to help bridge engineers focus on the long-term impact of their decisions. The FHWA BLCCA software tool, based on NCHRP Project 12-43, is a powerful tool for performing various levels of cost analysis and comparative studies. Its strengths are the elemental deterioration algorithms, costs associated with restoring required

performance from the level of deterioration, and its risk features. A comparison of various types of tools is available on FHWA's webpage at <http://www.fhwa.dot.gov/publications/publicroads/05nov/09.cfm>.

The Federal Highway Administration offers a Bridge Investment 101 workshop that discusses software tools, and other resources for analyzing bridge investments. Please visit FHWA's economic resources internet webpage at <http://www.fhwa.dot.gov/infrastructure/asstmgmt/invest.cfm> or contact Nat Coley at 202-366-2171 or ncoley@dot.gov for additional information. 

Lwin to Retire after 40 years

Myint Lwin has announced that he will retire from the Federal Highway Administration (FHWA) at the end of September. Since the beginning of ASPIRE™ in 2007, Myint has contributed 27 articles about the ongoing activities of the FHWA. For this, we thank him.

As Director, Office of Bridge Technology and State Bridge Engineer for Washington State, Myint has always worked closely with the concrete bridge industry to assure safe, efficient, sustainable, and economical bridges. He has always been receptive to new ideas and new ways to cooperate with industry. His attendance at every bridge conference was almost a certainty.

On behalf of the concrete bridge industry, we wish Myint good health, happiness, and success in his retirement.

EDITOR'S NOTE

More information on Myint Lwin, including a presentation titled "Concrete in my Life," is available at www.aspirebridge.org. Click on and open "Resources."

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ABC Pilot Project in Collier County, Florida

White Boulevard Bridge Replacement

by Marlene Andria Messam
Collier County, Florida



Profile view of bridge at the eastern end—looking north. All Photos: Collier County, Fla.

White Boulevard is a two-lane, undivided rural roadway located in a residential area in the northeast corner of the Golden Gate Estates Community in Collier County, Fla. The old four-span prestressed concrete slab bridge was built in 1965 and carries White Boulevard over the Golden Gate Main Canal. In recent years, the structure had fallen into disrepair. An independent condition assessment study was performed in 2008 and together with the Florida Department of Transportation (FDOT) biennial inspection report, the recommendation was that the bridge needed to be replaced.

The vision of Collier County is in line with the national vision for accelerated bridge construction (ABC), including accelerated project delivery, reduced impacts to residents, improved safety during construction, and implementation of innovative techniques that will provide a durable and high-quality product. Another vision was to develop a modular “standard” bridge that could be used at 11 additional canal crossing sites identified for replacement in the 2008 study.

The replacement White Boulevard Bridge has three equal spans of 42 ft and an overall bridge length of 128 ft, which includes the integral backwalls. The White Boulevard Bridge will accommodate two 12-ft-wide lanes (one in each direction), 4-ft-wide bicycle lanes/shoulders, 6-ft-wide sidewalks, and traffic railings. This

results in a total out-to-out width of 46 ft 2 in. and a curb-to-curb width of 32 ft.

The final design makes use of prefabricated concrete elements for all major portions of the bridge. Cast-in-place concrete elements on the bridge are the approach slabs and the sidewalks. The proposed three-span superstructure consists of 18 modified FDOT, precast, prestressed concrete, double-tee beams topped with a waterproofing membrane and a 3-in.-thick bituminous overlay. The beams are adjacent

deck beam elements, where the top flange of the double tee is used as the structural deck for the bridge.

The bridge has both longitudinal and transverse closure joints. The joints are made with lapped headed reinforcing bars and non-shrink grout. Transverse joints, which are designed to provide live-load continuity at the intermediate bents, eliminate the need for deck expansion joints between the spans. The proposed substructure consists of precast concrete abutment and pier bent caps supported on square precast, prestressed concrete piles. Precast concrete wing-walls are utilized to retain grade around the abutment bent caps.

The contractor was allowed 240 days or approximately eight months to complete this project. Because this is a pilot project, strict time constraints were not applied to the contractor in order to reduce risk, lower costs, and to build experience and an understanding of ABC techniques. In the future, it may be possible to build a similar bridge in 45 days or less. Using conventional construction techniques, it is estimated that this project could have been completed in 10 to 15 months from letting to substantial completion of construction. 



Florida double tee getting ready to be set.



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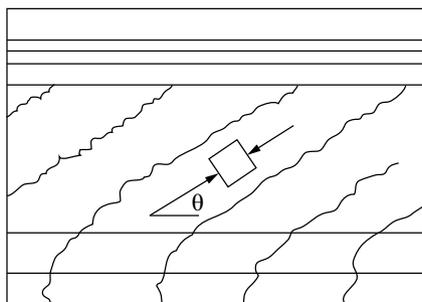
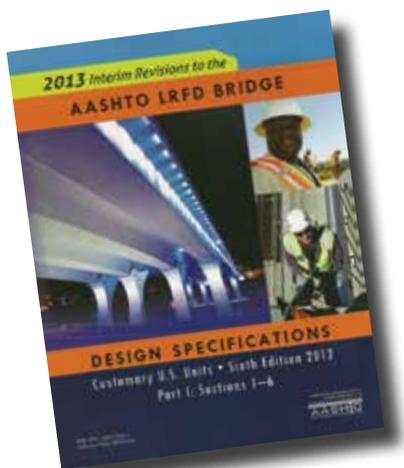
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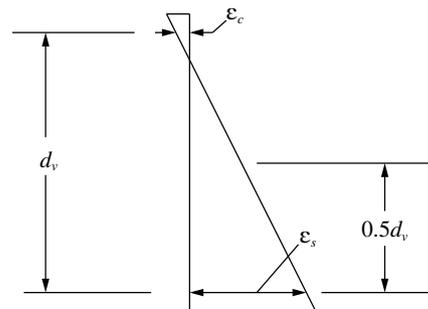
How Does Cracked Concrete Carry Shear?



by Dr. Dennis R. Mertz



Diagonal Cracks. Figure: PCI.



Longitudinal strains. Figure: PCI.

The modified-compression field theory (MCFT) model was introduced in the 1st edition of the *AASHTO LRFD Bridge Design Specifications* as a shear-resistance sectional model appropriate for both reinforced and prestressed concrete members. The MCFT of Article 5.8.3.4.2 of the *LRFD Specifications* is a model for predicting shear resistance of cracked concrete members.

Concrete that is subjected to shear cracks along a diagonal line. In the vast majorities of concrete, these cracks occur along an interface between the aggregate and the paste creating a rough crack surface. The crack surfaces transmit shear through the mechanics of aggregate interlock.

The variable, β , is defined as a “factor indicating ability of diagonally cracked concrete to transmit tension and shear.” As β increases, the shear resistance increases. The shear carried cross the crack and acting parallel to the crack is a function of the crack width, the maximum aggregate size, and the compressive stress perpendicular to the crack.

Further, the crack width is a function of the longitudinal strain and the crack spacing. Applying equilibrium, compatibility, and constitutive relationships, the shear resistance can be determined iteratively. This is a complicated calculation not appropriate for codification. To complete the discussion, θ , defined as the “angle of inclination of diagonal compressive stresses,” is merely a function of the longitudinal strain. As the longitudinal strain increases, θ increases in accordance with Equation 5.8.3.4.2-3 as shown below.

In the 1st edition of the *LRFD Specifications*, this complicated calculation was represented by the iterative application of simple tables of β and θ . These tables now appear in Appendix B5 of the *LRFD Specifications*.

In the 2008 interim revisions to the *LRFD Specifications*, a direct calculation of β and θ was introduced, eliminating iteration. The development of these simplified provisions assumes that the shear stresses are uniformly distributed over the shear area, the direction of the principal compressive stresses remains constant with depth, and the shear resistance can be determined at a single location in the web.

The *LRFD Specifications* Equation 5.8.3.4.2-3 defines θ as:

$$\theta = 29 + 3500 \epsilon_s$$

where ϵ_s is the net longitudinal tensile strain at the centroid of the tension reinforcement. For members without shear reinforcement, the *LRFD Specifications* Equation 5.8.3.4.2-2 defines β as:

$$\beta = \frac{4.8}{(1 + 750 \epsilon_s)} \frac{51}{(39 + s_{ve})}$$

where s_{ve} is the effective crack spacing, which is a function of crack spacing and maximum aggregate size. Through the simplification, the crack width has been removed from explicit consideration, but its influence has been retained. Code writers do not typically specify or calculate crack widths so that theoretical widths do not become used as performance measures.

For members with shear reinforcement, the effective crack spacing is assumed to be 12 in. and the final term in Equation 5.8.3.4.2-2

becomes unity resulting in Equation 5.8.3.4.2-1:

$$\beta = \frac{4.8}{(1 + 750 \epsilon_s)}$$

Thus, an in-depth examination of the simplified provisions of the *LRFD Specifications* Article 5.8.3.4.2 reveals that the MCFT shear resistance of a cracked section is based upon its ability to transmit shear across the crack through aggregate interlock, which is a function of crack width and aggregate size. For members without transverse reinforcement such as footings and slabs, the designer must be certain that the aggregate size used in the calculation of shear resistance is the size actually used in construction because the aggregate size enters into the calculation.

Furthermore, for higher-strength concretes, where cracks tend to pass through the aggregate, aggregate size has no influence. As such, the developers of the MCFT have suggested that the maximum aggregate size be taken as zero for compressive strengths greater than 10.0 ksi. Even with this assumption, the MCFT model of the *LRFD Specifications* is just as accurate and conservative for members cast with specified concrete compressive strengths greater than 10.0 ksi as it is for members cast with specified strengths less than 10.0 ksi. Δ

EDITOR'S NOTE

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