ASPIRE™

THE CONCRETE BRIDGE MAGAZINE

Spring 2010

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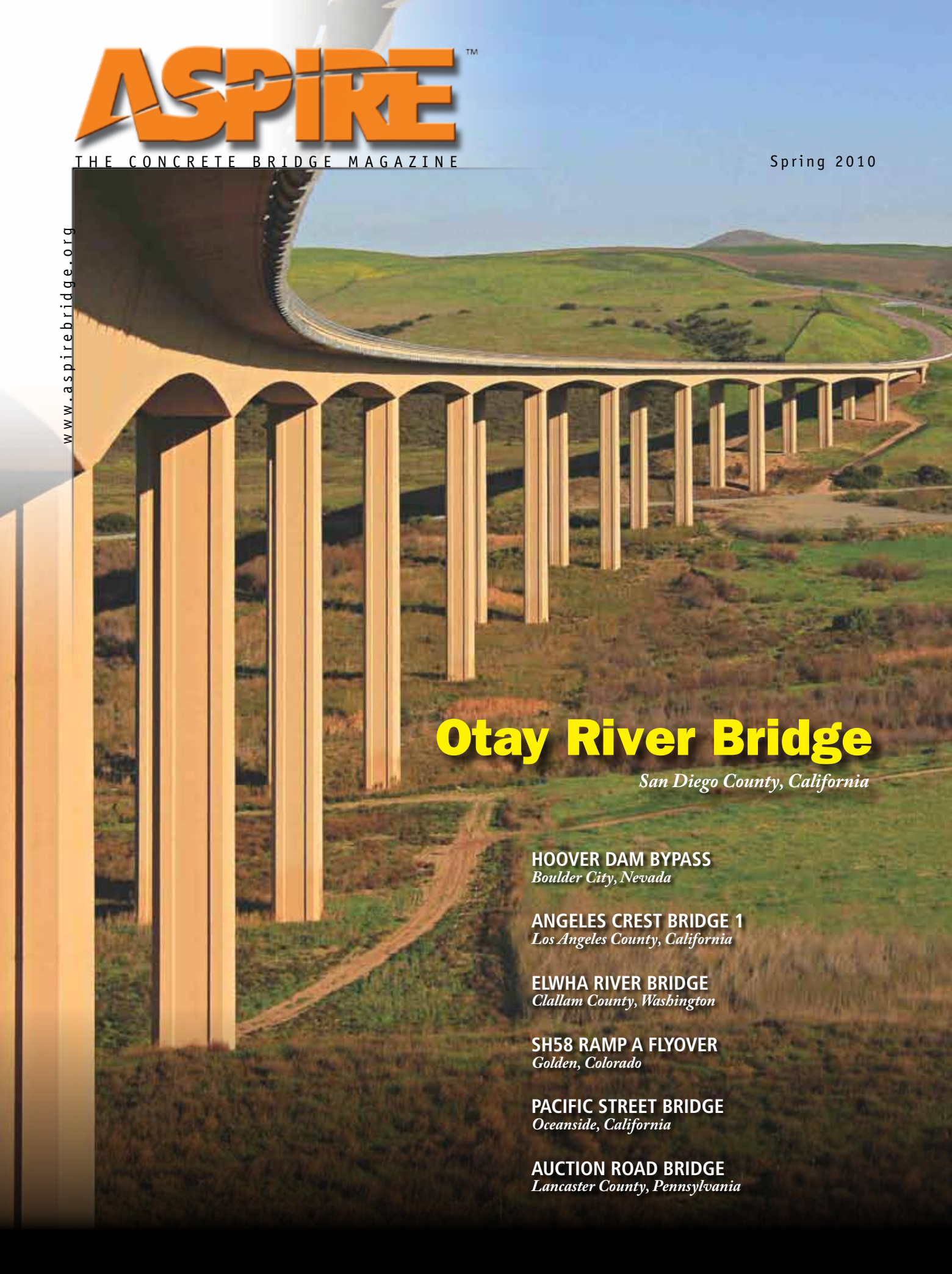


Otay River Bridge

San Diego County, California

HOOVER DAM BYPASS
Boulder City, Nevada

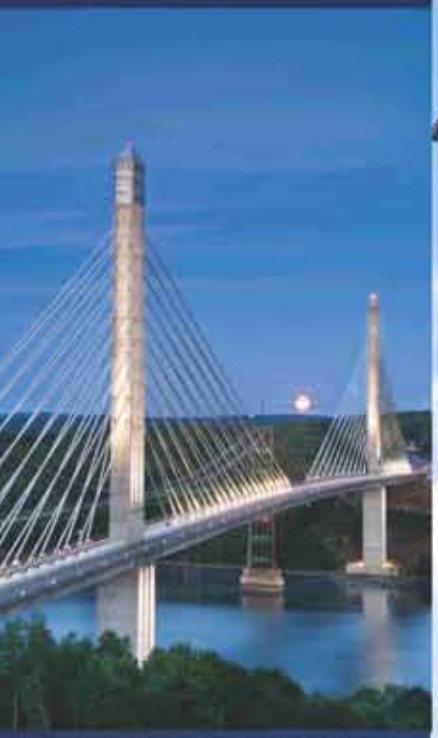
ANGELES CREST BRIDGE 1
Los Angeles County, California

ELWHA RIVER BRIDGE
Clallam County, Washington

SH58 RAMP A FLYOVER
Golden, Colorado

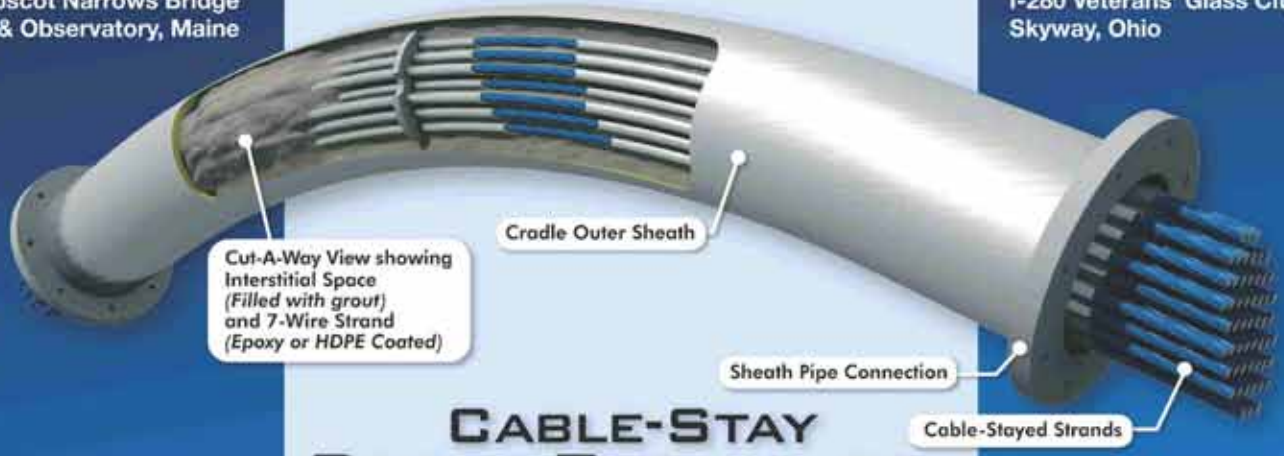
PACIFIC STREET BRIDGE
Oceanside, California

AUCTION ROAD BRIDGE
Lancaster County, Pennsylvania



Penobscot Narrows Bridge & Observatory, Maine

I-280 Veterans' Glass City Skyway, Ohio



Cable-Stay Bridge Technology

The FIGG Cable-Stay Cradle System™ Invention – first used in the I-280 Veterans' Glass City Skyway, Ohio & Penobscot Narrows Bridge & Observatory, Maine – was designed to revolutionize cable-stay bridges. The cradle is one unit that goes through the pylon. Among the cradle's many benefits are that it allows for unlimited stay sizes and makes it possible to remove, inspect and replace individual stay strands. Awards include: the 2007 ASCE Charles Pankow Award for Innovation, the NOVA Award from the Construction Innovation Forum, the 2006 NSPE New Product Award and the 2006 Modern Marvels Invent Now Top 25 Inventions (selected from 4000 entries)

FIGG

1.800.358.3444 ∫ www.figgbridge.com

OWNER: **Maine Department of Transportation**
DESIGNER: **FIGG**
CONTRACTOR: **Cianbro/Reed & Reed, JV**

The world's tallest public bridge observatory at the top of the 420' western pylon provides 360 degree vistas of Maine for visitors from May through October. The cable-stay bridge features a 1,161' main span and was opened to traffic on December 30, 2006. Aesthetics selected by the community center around a bridge theme of "Granite, Simple and Elegant". This bridge has received numerous awards, including the George S. Richardson medal from the International Bridge Conference and the ASBI Bridge Award of Excellence.

OWNER: **Ohio Department Of Transportation**
DESIGNER: **FIGG**
CONTRACTOR: **Bilfinger Berger Civil Inc.**

Toledo's landmark cable-stay bridge features 612.5' spans on either side of a single pylon and incorporates stainless steel cable casings and a pylon with four sides of glass on the top 196'. The custom glass reflects the community's vision and honors their heritage in the glass industry. At night, LED lights behind the glass create dramatic lighting celebrating seasons and holidays. This bridge opened to traffic in June 2007 and has received numerous awards including the NCSEA Outstanding Project Award and the ASBI Bridge Award of Excellence.

CREATING BRIDGES AS ART®

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Social, Economic, and Ecological Benefits of Sustainable Concrete Bridges

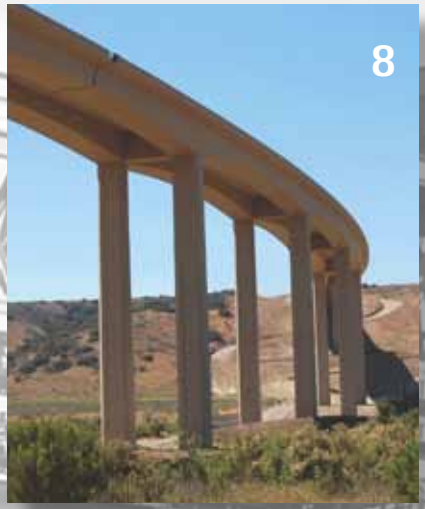

Photo: International Bridge Technologies.

Preliminary rendering: Kiewit, HNTB, and FIGG.

Rendering: Central Federal Lands Highway Division, Federal Highway Administration.

Features

Departments

Photo: International Bridge Technologies.

Advertisers Index

EDITORIAL

Photo: Ted Lacey Photography.

"An Embarrassment of Riches..."

John S. Dick, *Executive Editor*

Some of the excitement of being involved with *ASPIRE*™ magazine is receiving information about the unique and sometimes daring bridges that are being built around the country. Many of these designs would have been thought to be unbuildable a decade ago. Most of the solutions incorporate notable aesthetic provisions and long-term performance enhancements, and some are located where gaining access becomes one of the major engineering accomplishments. This issue features a mixture of such projects.

As an example of the wonderful projects being presented, we asked Fred Gottemoeller to review the projects worthy of his insightful "Aesthetics Commentary." He responded that the issue contains "an embarrassment of riches." You can read his note in the Reader Responses on page 4.

We endeavor to bring you the best and most innovative projects. We consider it our privilege to deliver the "riches" that are increasingly gracing the nation's landscape. Further, we find it gratifying that the innovative designers, the owner agencies, and the builders eagerly share the designs and construction details that make these projects so interesting and the information so valuable.

A firm that is creating such lasting designs is International Bridge Technologies (IBT) in San Diego, Calif. Just 10 years old, but originating from deeper roots, this group operates from six international offices and has already left its mark among noteworthy bridges. The designer FOCUS begins on page 8.

The Hoover Dam Bypass, Colorado River Bridge is taking shape to be one of the country's most recognizable bridges and most amazing recent engineering accomplishments. David Goodyear of T.Y Lin International explains that, with an arch span of 1060 ft, the project had many design and construction challenges to overcome. The article begins on page 16.

Not far from Los Angeles, the Angeles Crest Bridge 1 was required to span a mountain wash. But, to get 208-ft-long girders to the site required innovation every step of the way. Jose Higareda of the California Department of Transportation explains the development of the project beginning on page 20.

The state of Oregon boasts some of the nation's most scenic roads and bridges. Its history with concrete bridges goes back to the early part of the twentieth century. The history is chronicled starting on page 48 by Ray Bottenberg with the Oregon Department of Transportation.

"If we could just curve those precast concrete girders…!" Well, the state of Colorado is doing just that. Together with innovative techniques brought to the challenge by Gregg Reese of Summit Engineering, the state is making use of curved girders to create durable, high-performing, cost-effective bridges and ramps. One of the latest, I-70 to SH58 Interchange Ramp A, is described beginning on page 28.

Innovation can be found in many quarters. The Federal Highway Administration's (FHWA)'s "Bridge of the Future" initiative has identified promising materials and technology. A material undergoing more development is ultra-high-performance concrete (UHPC). In the first of a two-part article, FHWA explains what UHPC is, how it may be useful in the future and where it has been used for bridges to date. See the article that starts on page 46.

And there are more very interesting projects. The Elwha River Bridge in Washington State (page 24), the Pacific Street Bridge in Oceanside, Calif. (page 34), and the Auction Road Bridge in Pennsylvania (page 40) round out this issue's impressive bridges. Don't pass up the profile of Grant County, Wash. (page 53) and its experience with concrete solutions as well.

Be sure to tell us about your projects. We would love to hear about them. It's easy to drop us a line from www.aspirebridge.org. You can help also by completing a brief survey there that will give us guidance about *ASPIRE*. All previous issues of *ASPIRE* can be viewed or downloaded from the website.

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POSTMASTER
Send address changes to *ASPIRE*:
200 W. Adams St., Suite 2100
Chicago, IL 60606
Standard postage paid at Chicago, IL, and additional mailing offices.

ASPIRE (Vol. 4, No. 2),
ISSN 1935-2093 is published quarterly
by the Precast/Prestressed Concrete Institute
200 W. Adams St., Suite 2100
Chicago, IL 60606.

If you have a project to be considered for *ASPIRE*, send information to *ASPIRE*,
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Cover
Otay River Bridge, San Diego County, California
Photo: Mike Palhegyi.

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

Editor,
Nice write up about Spencer Creek Bridge in ASPIRE™ [see ASPIRE Winter 2010, p. 16]. It turned out great and was a great job to be a part of. The article and pictures did a good job explaining the engineering and construction involved. Hope to work with both [the designer and the precaster] more in the future.

Roger Silbernagel
Slayden Construction Group Inc.
Stayton, Ore.

Editor,
When you first sent me the list of projects for this issue I realized that the magazine would contain an embarrassment of riches. All of the bridges are worth comment. It's clear that the competitions sponsored by PCA and PCI and that ASPIRE itself are encouraging better bridge design throughout the U.S. I'm honored to be a small part of it.

With these riches in mind, I feel that I should say a word about why I have commented on the bridges that I did. The Hoover Dam Bypass Bridge is the obvious candidate for commentary in this issue. It is an excellent bridge and an impressive accomplishment. It will also get much attention from many directions over the next few years. The more modest bridges also deserve attention, especially where they pioneer new ideas (the Ramp A Flyover) or fit perfectly into a sensitive environment (Pacific Street). So I have chosen to comment on them, with full confidence that the Hoover Dam Bypass will not be neglected.

I can't wait to see what you will be bringing to the next issue.

Fred Gottemoeller
Bridgescape LLC
Columbia, Md.

Editor,
I have been following the Gratz [Route 22] Bridge [see ASPIRE Winter 2010, cover, and pp. 10-11] closely as I am a bridge engineer at KTC. Great Article!!

J. C. Pyles
Kentucky Transportation Cabinet
Frankfort, Ky.

[Editor's Reply]
We expect to publish a more detailed article about this bridge in a future issue.

Editor,
I plan to use some articles from ASPIRE Magazine as part of a bridge engineering course this spring. I was wondering if there is an easy mechanism for me to access previous issues of the magazine. The web link seems to only allow access back to Spring 2007. I am particularly interested in the AASHTO LRFD column authored by Professor Dennis Mertz.

Brian D. Swartz
Buchnell University
Lewisburg, Pa.

[Editor's Reply]
Professor…
ASPIRE was launched with the Winter 2007 issue (the only one not on the web). I have attached the Dr. Mertz LRFD article from that issue.

[Professor Swartz' Response]
Thanks for your quick reply. I didn't realize ASPIRE was such a new magazine. I think ASPIRE is a great resource for the classroom. It contains a lot of reading available about new technologies and interesting aspects of bridge engineering. It is also a good source of case studies that get the students more excited—they enjoy seeing real-world applications of the textbook principles. I have particularly found Dr. Mertz's column to cover complex concepts in straightforward language that is helpful for use in class. It's great that it is on the web and easily accessible for the students!

EDITOR'S NOTE

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

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

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

Dr. Dennis R. Mertz is professor of civil engineering at the University of Delaware. Formerly with Modjeski and Masters Inc. when the *LRFD Specifications* were first written, he has continued to be actively involved in their development.

Raymond Paul Giroux has spent 30 years with Kiewit Corporation and is district quality manager in Concord, Calif. Much of his work has been on heavy civil projects. He is a member of the American Society of Civil Engineers and the Transportation Research Board. He has also been involved with ASCE history and heritage efforts and chaired their committee celebrating the 125th anniversary of the Brooklyn Bridge in 2008

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

MANAGING TECHNICAL EDITOR

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

Photo: Ted Lacey Photography.

CONCRETE CALENDAR 2010

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

April 12-13
2010 ASBI Grouting Certification Training
J.J. Pickle Research Campus, The Commons Center, Austin, Tex.

May 23-27
AASHTO Subcommittee on Bridges and Structures Annual Meeting
Grand Sheraton Hotel, Sacramento, Calif.

May 29 – June 2
Third International fib Congress and Exhibition
PCI Annual Convention
PCI-FHWA National Bridge Conference
Gaylord National Resort & Convention Center, National Harbor, Md.

June 6-9
International Bridge Conference
David L. Lawrence Convention Center, Pittsburgh, Pa.

June 14-19
PCI Quality Control & Assurance Schools, Levels I, II & III
Sheraton Music City Hotel, Nashville, Tenn.

June 22-23
ASBI Construction Practices Seminar
Orlando, Fla.

July 11-15
Fifth International Conference on Bridge Maintenance, Safety and Management
International Association for Bridge Maintenance and Safety (IABMAS)
Loews Philadelphia Hotel, Philadelphia, Pa.

September 23-26
PCI Committee Days
Westin Hotel, Chicago, Ill.

October 11-12
2010 ASBI 22nd Annual Convention
The Westin Bayshore, Vancouver, British Columbia, Canada

October 24-28
ACI Fall Convention
The Westin Convention Center, Pittsburgh, Pa.

December 1-3
TRB-FHWA 7th International Bridge Engineering Conference: Improving Reliability and Safety
Grand Hyatt, San Antonio, Tex.

FOCUS

INTERNATIONAL BRIDGE TECHNOLOGIES Lives up to its Name

by Craig A. Shutt

The 2890-ft-long Second Vivekananda Crossing in Calcutta, India, uses the extradose concept, which features precast concrete box girders that work with low-angle stay cables. It provides a new and developing concept for medium-span bridges with clearance issues.
Photos and renderings: International Bridge Technologies.

Focus on new concepts being used around the world keeps IBT growing in its 10th year

International Bridge Technologies (IBT), celebrating its 10th anniversary of operation this year, embodies its name in virtually every project it undertakes. Its record of accomplishments around the globe already has been notable, and it expects its approach to innovation and international work will continue. Some of that work will come via advancements in concrete material and construction techniques, which IBT uses in a high percentage of its projects.

"We've found there's a lot of value in trying to be ahead of the curve of creating new ideas for bridge construction," says Chris Hall, one of IBT's three founders. "We've had considerable success in our 10 years and have seen a lot of growth. We believe it derives from our willingness to be open to new solutions. Everyone wants to be innovative, of course, but we've had many opportunities, especially through the design-build process, to work outside the box with contractors and not be told 'no.' "

The company's expertise with concrete construction techniques has a strong foundation. IBT was founded in San Diego by Daniel Tassin, Michael Smart, and Hall. The three gained experience at Jean Muller International Inc. (JMI), whose founder developed the technique of precast concrete segmental bridge construction. "His focus was always on marrying new construction techniques to efficient designs," Hall says. Muller, in turn, studied under Eugene Freyssinet, the inventor of modern prestressing techniques.

"Our historical relationship with design-build contractors has really created the framework for practical innovation." says Hall. "Being close to construction lets us understand the issues that need to be addressed in our designs. More important are the relationships built over time. Through successful collaborations, we have established the trust that allows our concepts to advance into practice."

Five International Offices

In just one decade, the company has grown to encompass employees working from five offices around the world: San Diego, USA; Bangkok, Thailand; Mexico City, Mexico; Vancouver, Canada; and Abu Dhabi, United Arab Emirates. From those locations, the company has designed projects in Canada, Puerto Rico, India, Abu Dhabi, Mexico, Australia, Jamaica, and the United States.

"Our name was an intentional decision on our part to ensure we focused on technological aspects of construction," Hall explains. "At JMI, our emphasis was specialty projects, and that has carried over." The company's first project, in Taiwan, was in partnership with JMI. The project consisted of a 120-mile-long elevated high-speed rail line, which was constructed with cast-in-place concrete.

The project exemplifies the way IBT approaches its projects, says Hall. "The owners had a prescribed solution using full-span precast concrete box girders," he explains. "We studied the goals and the materials, and we found what we considered a more constructable alternative." They developed a Movable Scaffolding System (MSS) to cast the concrete superstructure. "It made construction of the spans more efficient and eliminated transportation issues of hauling large box girders to the site."

Another notable international project is the Second Vivekananda Crossing in Calcutta, India. A 2890-ft-long precast concrete segmental bridge with typical spans of 361 ft, it represents a relatively new concept: an extradosed bridge, which is described as a combination between a girder and a cable-stayed bridge, using a stiff box-girder that works with low-angle stay cables. "We were one of the first North American firms to have designed this bridge type, and maybe the first to have one open to traffic," Hall says. "Although its application is fairly narrow, it represents a good concept for medium-span bridges that have clearance issues."

North American Projects

One of the most honored of its American projects is the Otay River Bridge in IBT's hometown of San Diego. The 3325-ft-long bridge was constructed 150 ft above grade over an environmentally sensitive river valley. The twin 12-span structures feature precast concrete variable-depth box girders constructed using the balanced-cantilever method, the first such bridge to open to traffic in the state. More details of this project are provided in the Spring 2007 issue of *ASPIRE*.™

Precast concrete segmental designs offer good behavioral characteristics in high-seismic zones.

"Caltrans was concerned about the performance capabilities of this type of bridge in a high-seismic zone, as there wasn't much history," Hall explains. But tests conducted at the University of California–San Diego showed "precast concrete segmental designs are very desirable for these applications, with very good behavioral characteristics in high-seismic zones." The state now is considering more projects built in this manner.

Another project featuring precast concrete segmental box girders was completed at nearly the same time. The Sound Transit Central Link Light Rail System in Seattle, Wash., featured in the Fall 2007 issue of *ASPIRE*, contains 4.2 miles of elevated guideway carrying twin tracks with continuously welded rails fastened to the top of the structure. Two stations are located along the alignment, which passes through environmentally sensitive areas.

The precast concrete girders feature a unique V-shaped triangular cross section developed specifically for this project, Hall notes. The design optimized superstructure quantities and reduced the visual impact when observed from ground level.

"Precast concrete segmental construction is commonly used for elevated transit, especially overseas, because these projects often are constructed in congested corridors, where delivering precast components alleviates site disruption," he explains. "But we realized that these designs use box sections that waste a lot of material in the bottom half of the section. The V-shape design thinned down the concrete quantities significantly and improved the visual appearance. It was a good solution, both technically and aesthetically."

'We've found there's a lot of value in trying to be ahead of the curve.'

Several Vancouver Projects

The firm also has done considerable international work in Vancouver, Canada, where it opened its newest office. The city, which hosted the 2010 Winter Olympics, committed to a number of large bridge and infrastructure projects as part of British Columbia's Gateway Program. Begun in 2003, its aim is to facilitate movement of people, goods, and transit through the city. "Vancouver wants to become a key international port city, and they used the Olympics as a catalyst," Hall says.

Tassin and other IBT engineers, while at JMI, worked with Canadian officials on projects such as the Confederation Bridge to Prince Edward Island, a landmark precast concrete segmental bridge and the Millennium Line extension to Vancouver's light rail system. "We had a good presence in Canada, and a lot of good engineering work comes out of good relationships."

A project currently underway is the 6801-ft-long Port Mann Bridge carrying the 10-lane Trans Canada Highway across the Fraser River, which IBT is designing in collaboration with T.Y. Lin International. The crossing includes a 2789-ft-long, cable-stayed bridge with a main span of 1542 ft and 4012-ft-long

The 3325-ft-long Otay River Bridge in San Diego, Calif., features twin variable-depth box girders connected by a transverse diaphragm at the piers and cast-in-place slab along the bridge's centerline. The 640 trapezoidal box girder segments, erected via the balanced-cantilever method, used a self-launching overhead gantry to minimize site disruptions.

The Sound Transit Central Link Light Rail System in Seattle, Wash., uses precast concrete girders with a unique V-shaped triangular cross section developed specifically for this project. The design optimized superstructure quantities and reduced the visual impact when observed from ground level.

'A lot of good engineering work comes out of good relationships.'

precast concrete segmental box girder approaches built using balanced cantilever construction above the water and span-by-span construction over land.

Cable-Stayed Bridges Grow

IBT has completed two other cable-stayed projects using this same combination of materials in the city, the Coast Meridian Overpass and the Pitt River Bridge. "These are often called 'steel' cable-stayed bridges because the main bridge structure has steel girders, but there's a large amount of concrete included in them, with precast concrete deck panels and cast-in-place concrete pylons and foundations," Hall notes. "It's a bit of a misnomer to call them 'steel' when concrete plays such a critical role. You really can't beat concrete, particularly for compression elements."

Together with AECOM, the company recently completed the design of an all-concrete cable-stayed structure for the 2600-ft-long Indian River Inlet replacement bridge near Delaware Seashore State Park. The design features two 240-ft-tall concrete pylons on either side of the deck, each supporting a single plane of stays. It will provide a 950-ft-long main span over the inlet with 1650 ft of bridge deck over the land. All supports will be placed out of the water, due to the extreme scour experienced by the existing bridge. The bridge will be supported by 36-in.-square precast concrete piles.

The design provides a minimum 100-year service life, a critical component for officials and the key reason for the all-concrete design. Achieving this goal required adding several features, including epoxy-coated steel reinforcement, stainless-steel embedments, low-permeability concrete, and a latex-modified overlay. In addition, the superstructure was designed for zero tensile stress under service loads.

"Long-term maintenance costs were a major concern, and the owner decided upfront that maintaining a steel structure would be too costly." The design incorporates innovative construction methods, with the deck sections above land supported on falsework, and a traveler used over the water. The floor beams are cast-in-place over the water whereas precast beams are used over land.

"Using concrete for all of the components produces a slight premium on initial costs," Hall says. "But when owners are looking at the total life-cycle costs, then concrete cable-stayed designs are very competitive." Owners, unfortunately, are forced to put a premium on initial costs instead of being able to factor costs over a longer horizon. "It's hard to get past the initial cost," he says. "But there's an evolution occurring, and owners are becoming more aware of the positive impact that cable-stayed designs can have." They're still gaining a foothold in the United States though, so

'Owners are becoming more aware of the positive impact that cable-stayed designs can have.'

The 2600-ft-long Indian River Inlet replacement bridge features an all-precast concrete cable-stayed superstructure with a projected 100-year minimum service life. Owners required concrete to ensure low long-term maintenance costs throughout the structure's life.

states are still hesitant to consider them. Cable-stayed designs also must fight their reputation. "They're often considered 'landmark' designs, which equates to being fancy—which means expensive." In fact, the concept was developed in post-war Germany to exploit material efficiencies. "The market for stays and stay hardware is robust, and increasingly competitive, which can create a very cost-effective and efficient design, especially for spans longer than 500 ft. This has added advantages where slightly longer spans can help mitigate impacts to a sensitive environment."

Owners Demand Speed

Owners are studying options more closely as designs are proven in the field and costs are reconsidered. They also are demanding one other element: faster construction. "Speed has taken a huge leap forward," Hall says. In part, the design-build delivery approach has been a factor. "Design-build teams have proven the process can be sped up and demonstrates that schedules can be compressed," he explains. "Now, owners are seeing that high-quality bridges can be safely constructed a lot quicker than they realized—and they want that compressed time."

That expectation leaves little room for maneuvering. "It's reaching a point of equilibrium, where the push for speed has begun to obscure potential cost efficiencies," he notes. "There is a sweet spot between cost and speed that has to be acknowledged, and squeezing too tightly can have an impact on cost that isn't worth the time gained. It's a judgment call on each project."

The motivation to finish bridges quickly is easy to understand, he adds. Much of America's aging infrastructure—built in the 1950s with a 50-year life span—is reaching the end of its service life. But swapping old for new can be difficult with communities built around these access points. "Bridges, especially concrete ones, have shown a lot of resilience to date, but you can squeeze out extra service life for only so long."

New Designs Tested

IBT is currently testing a technology in Massachusetts, where the 248-ft-long Randolph Department of Conservation and Recreation (DCR) Access Road channel bridge is being designed with precast concrete components to replace a four-span steel girder structure. The short-span bridge features two large edge girders that will serve as the roadway barriers, reducing material and increasing vertical clearance. The bridge's total depth will be 5 ft 4 in., including barriers. "It offers an opportunity for a quick replacement on a small span by bringing in a few precast concrete components and assembling them quickly on site," he explains.

'There is a sweet spot between cost and speed that has to be acknowledged.'

New concrete technologies are aiding new designs. "Concrete is both science and art," Hall says. "More and more is being done to improve its capabilities." For instance, significant efforts are underway to enhance performance of concrete decks by expanding and refining concrete properties to create more durable structures with lower concrete permeability.

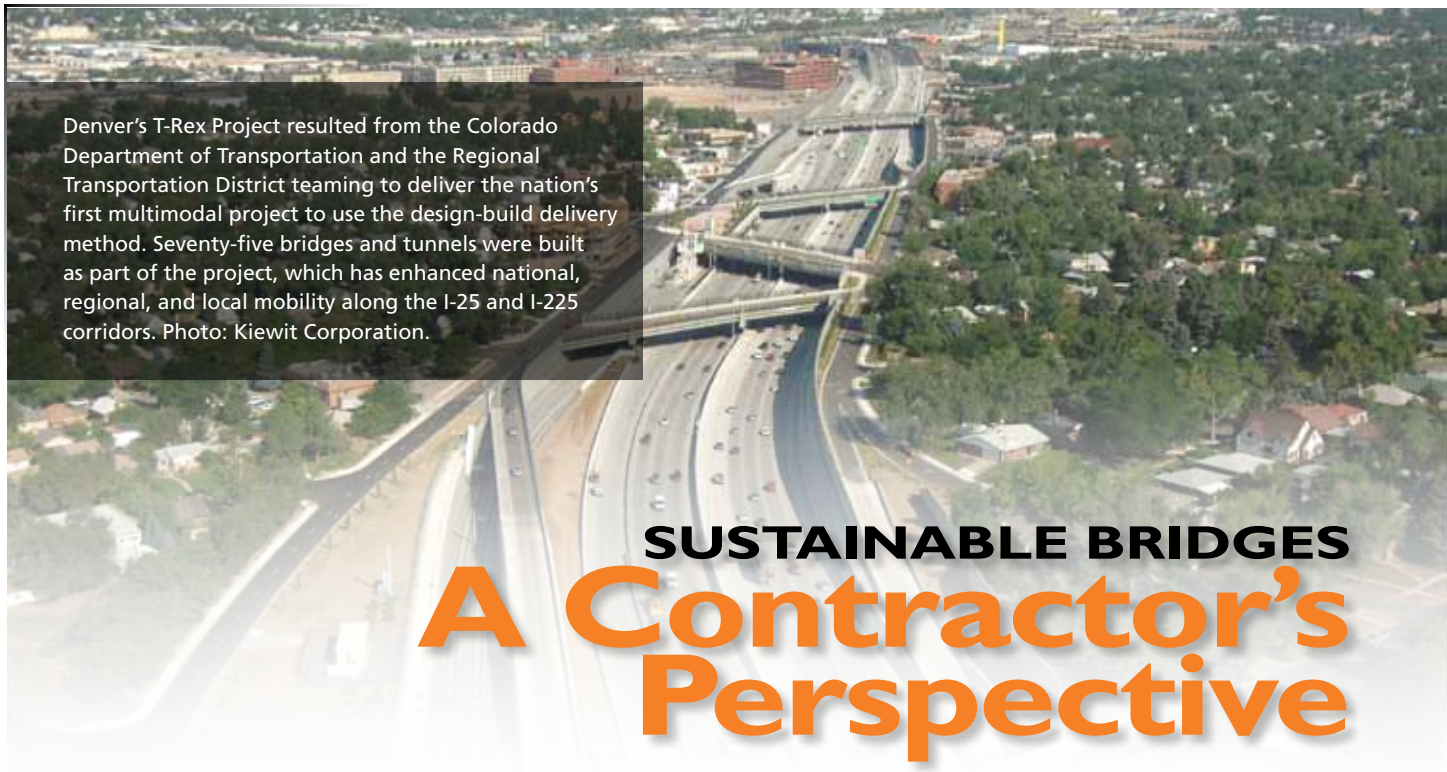
"The condition of decks is the most visible aspect of the bridge's condition to users, and it's the first part to go because of the wear and exposure," he says. "Modifications to the mix designs can really aid that aspect and provide better concrete products." Self-consolidating concrete also is producing new solutions and its use will continue to grow, he adds.

Hall expects more concrete technologies to arrive in the future. "Concrete segmental bridge projects have seen a lot of success," he notes. "The DOTs and bridge owners are still building their level of comfort with the capabilities of segmental construction as more are built and a record of their service life grows. We believe precast segmental designs still have a lot of potential for expanding even further."

"There is still a lot of opportunity to innovate and explore new design and construction options," Hall says. "We honestly didn't know for certain how true that would be when we started out 10 years ago. But we found there are definitely ways to take bridge concepts to the next generation so that owners benefit, time is saved, and projects are delivered at a lower cost."

'There is still a lot of opportunity to innovate and explore new design and construction options.'

The DCR Access Road over Route 24 Bridge in Randolph, Mass., now underway, uses two large edge girders as roadway barriers, reducing materials and increasing vertical clearance. The low profile adds 2.5 ft to the vertical clearance without altering the approach grade.



Denver's T-Rex Project resulted from the Colorado Department of Transportation and the Regional Transportation District teaming to deliver the nation's first multimodal project to use the design-build delivery method. Seventy-five bridges and tunnels were built as part of the project, which has enhanced national, regional, and local mobility along the I-25 and I-225 corridors. Photo: Kiewit Corporation.

SUSTAINABLE BRIDGES
A Contractor's Perspective

The entire construction team must do its part to ensure sustainable design is effective

by Raymond Paul Giroux,
Kiewit Pacific Co.

For generations, building good bridges has proved to be a moving target, as design criteria and standards evolve to meet society's changing needs. Recently, designs have been further complicated by society's increasing demands on bridge infrastructure in the face of dwindling resources. As a result, we hear more and more about the need for "sustainable solutions" in the bridge market. To achieve this goal, all on the construction team must do their part.

Those efforts are complicated by the lack of a generally accepted definition of a "sustainable bridge" or a simple litmus test to determine if a bridge design is sustainable. Criteria for sustainable bridges have proven to be somewhat complicated, vague, and at times controversial. Yet sustainable bridge development is essentially about stewardship of our resources and making smart bridge decisions that not only meet society's current needs but also their needs in the future.

We face the challenge of maximizing transportation funding in difficult economic times, with an ever-aging bridge inventory and a growing demand for infrastructure. While bridges are built locally, each plays a role in the bigger picture of strategic regional and national infrastructure planning. Accordingly, proper management of our bridges is essential to achieving sustainable bridge solutions on a national, regional, and local level.

We all need to be aware of the big picture, but we each can do more to achieve the final goal. First and foremost, everyone involved must stress "life-cycle" costs and economy as the primary goal in bridge design.

Sustainable Examples Abound

We are beginning to see this "big-picture strategic" thinking around the country. Denver's I-25 Transportation Expansion provides an excellent example of sustainable infrastructure development. Known as the "T-Rex" project, it used a unique collaboration between the Colorado Department of Transportation and the Regional Transportation District to become the nation's first multimodal project to use the design-build delivery method.

Completed in 2006, the $1.28-billion Kiewit Corporation-led joint venture reconstructed 17 miles of I-25 and I-225 and constructed 19 miles of double-track, light-rail transit lines, 13 light-rail stations, three parking structures, eight interchanges, and more than 75 bridges and tunnels. All construction was performed to minimize disruption to the public and the environment.

Missouri's "Safe and Sound" initiative, an ambitious upgrade to the state's 10,000-plus bridges, focuses on approximately 1100 structures in poor to serious condition. With an emphasis on safety, mobility, efficiency, and value, Missouri Department of Transportation officials packaged 554 bridge replacements into a single design-build contract. The $487-million contract was awarded in May 2009 to KTU Constructors, comprising Kiewit Corporation, Traylor Bros. Inc., United Contractors Inc., HNTB Corp., and The LPA Group Inc.

More and more we see owners placing emphasis on sustainable solutions as part of a well planned infrastructure program. In planning Honolulu's new 20-mile-long elevated rail line that will connect West Oahu with downtown Honolulu, the City and County of Honolulu placed an emphasis on sustainable solutions. In Kiewit Pacific's 2009 winning design/build proposal, concrete piers and precast concrete guideways provided many sustainable elements and opportunities for aesthetic treatments.

Concrete: A Green Solution

Materials used in bridges need to be continually evaluated and researched to create improvements. In this regard, concrete proves to be a "green" bridge material by almost any measure:

- The use of supplementary cementitious materials such as fly ash, slag, and silica fume
- Carbon dioxide (CO_2) sequestration capability (ability to absorb CO_2)
- The energy cost of production (reinforced concrete is 2.5 Gigajoules/metric ton (GJ/t); steel: 30 GJ/t)
- Low solar reflectance compared to asphalt, creating reduced heat-island effect in urban areas
- The recyclability of concrete and reinforcing steel

Other advanced bridge materials may also improve the sustainability of our bridges:

- Ultra-high-performance concrete (UHPC), offering 25,000 to 30,000 psi with correspondingly high tensile strength
- Self-consolidating concrete and lightweight concrete
- Improved reinforcing steels (high strength and corrosion resistant)
- Carbon dioxide-absorbing materials
- Recycled materials and recyclability of materials

Improvements in sustainability will also come from improving means and methods to build our bridges, which will reduce environmental impacts and road-user impacts. Some of these methods will include the use of erection trusses, balanced-cantilever methods, prefabricated assemblies, and self-propelled modular transporters (SPMTs).

Focus on Life Span

Bridges currently provide an average life span of 40 to 45 years, with decks replaced every 20 years. Doubling this life span would dramatically improve the overall sustainability of bridges. Extending service life will start with adoption of various options for improved design details:

- Simplification of details
- Adaptable substructure designs
- Consideration for bridge inspection, monitoring, and maintenance
- Allowance for future modifications and retrofitting mass transit
- Consideration of utility corridors along bridge alignments
- Focus on context-sensitive solutions

The City and County of Honolulu placed an emphasis on sustainable solutions for Honolulu's new 20-mile elevated rail line. Concrete offered many advantages to meet the needs of the project. Preliminary rendering: Kiewit, HNTB, and FIGG.

Extending service life will start with adoption of improved design details.

Key Questions to Answer

The February 2009 issue of *Civil Engineering* featured a special section suggesting "Guiding Principles for Critical Infrastructure." The authors noted, "We tend to take our infrastructure for granted until something goes wrong—often terribly wrong." To that end, it suggested some hard questions for all of us to consider:

- Have we ignored the need to manage and communicate risks?
- Have we failed to consider critical infrastructure as part of a complex system?
- Have we neglected to call for upgrades as conditions have changed?
- Have we allowed the intertwined pressures of cutting time from schedules and reducing costs to prevail over the principle purpose of our built infrastructure—to protect the safety, health, and welfare of the public?

Improving the sustainability of our bridges will not come from one change in federal regulations, nor from one new structural analysis, one new super bridge material, one new design detail, one new construction method, nor one new maintenance procedure. Clear vision and improved sustainability for bridge projects will come from all of us in the bridge industry working toward a common goal.

This article was taken from a more detailed paper presented by the author at the Construction Research Congress, "Building a Sustainable Future," held in Seattle, Wash., April 5-7, 2009. The full paper can be downloaded from the ASPIRE™ website: www.aspirebridge.org, click on "Resources" and select "Referenced Papers."

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ESCSI
Rotary Kiln Produced
Structural Lightweight Aggregate

Expanded Shale, Clay and Slate Institute

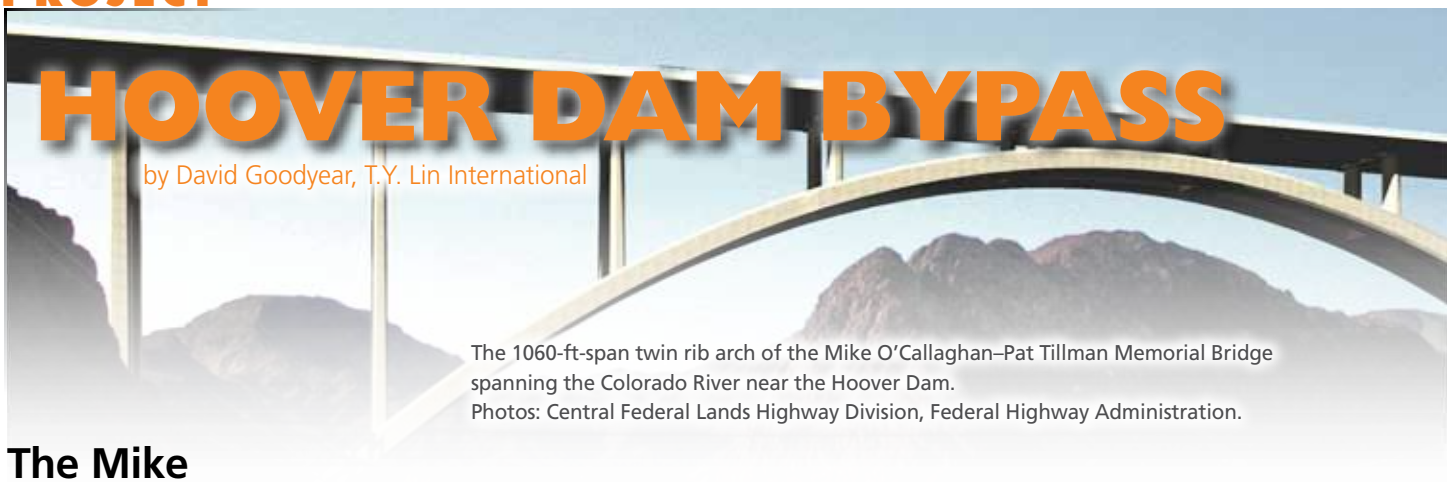
The Expanded Shale, Clay & Slate Institute (ESCSI), the international trade association for manufacturers of expanded shale, clay, and slate lightweight aggregates has recently updated its website, www.escsi.org. We invite you to visit.

The website includes a number of informative ESCSI documents as well as papers and documents from other sources. These resources can be found under the individual sections and then clicking the literature and technical documents tabs. Several papers from the lightweight concrete workshop held at the 2009 International Bridge Conference in Pittsburgh, Pa., are posted on the website along with the sessions from the 2010 Concrete Bridge Conference that were devoted to lightweight concrete. The papers address topics such as code provisions, internal curing, the cracking tendency of lightweight concrete decks, seismic design and other research topics.

The institute is proud to be one of the sponsors of *ASPIRE*™ magazine. ESCSI members look forward to assisting owners, designers and concrete producers in using lightweight concrete for bridges, pavements and other civil engineering projects.

HOOVER DAM BYPASS

by David Goodyear, T.Y. Lin International



The 1060-ft-span twin rib arch of the Mike O'Callaghan–Pat Tillman Memorial Bridge spanning the Colorado River near the Hoover Dam.
Photos: Central Federal Lands Highway Division, Federal Highway Administration.

The Mike O'Callaghan–Pat Tillman Memorial Bridge at Hoover Dam set to open Fall 2010

A project team of five U.S. government agencies, lead by the Central Federal Lands Highway Division of the Federal Highway Administration (CFLHD) collaborated to develop a highway bypass to the existing U.S. Highway 93 over the Hoover Dam. The existing highway route over the dam mixed the throng of tourists for whom the dam is a destination with heavy highway traffic and commercial trucking. The blend of these two created hazards and hardships for both, and served as a bottleneck for commerce along this major north-south route.

Project Development

A consortium of firms working under the moniker of HST (HDR, Sverdrup, and T.Y. Lin International) teamed with specialty sub-consultants and CFLHD to deliver the final design for 1.6 km (1 mile)* of approach roadway in Arizona, 3.5 km (2.2 miles) of roadway in Nevada, and a major 610-m (2000-ft) -long Colorado River crossing about 450 m (1475 ft) downstream of the historic Hoover Dam.

Bridge Type Screening Process

With the selection of an alignment so close to Hoover Dam, the new bridge will be a prominent feature within the Hoover Dam Historic District, sharing the view-shed with one of the most famous engineering landmarks in the United States. The environmental document set a design goal to minimize the height of the new bridge crossing on the horizon when viewed from both the dam and Lake Mead. The State Historic Preservation Officers for both Nevada and Arizona—both members of the Design Advisory Panel—emphasized the need to complement and not compete with the architecture of the dam.

CFLHD took full advantage of prior studies and public processes to focus on the alternatives that met all the design objectives. As a result of this screening process, the type study proceeded with only deck arch options.

Major Design Features

The final design went through an evolution of form dictated by the engineering demands on the structure to arrive at the twin rib-framed structure. At the outset of design it was assumed that earthquake loading would control the lateral design of the bridge. A project specific probabilistic seismic hazards analysis was conducted in order to assess the range of ground motion associated with return periods appropriate for design. A 1000-year return period was selected resulting in a design basis peak ground acceleration of 0.2g.

Wind was also a major environmental loading condition from the outset of design. During the preliminary design phase, a site wind study was conducted to correlate the wind speeds at the bridge site with those at the Las Vegas Airport in the valley. With this correlation, the long-term statistics from the airport were used to develop site wind speeds for design. As

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** The Mike O'Callaghan–Pat Tillman Memorial Bridge at Hoover Dam was designed using SI units. Conversions are included for the benefit of the reader.*

profile

MIKE O'CALLAGHAN–PAT TILLMAN MEMORIAL BRIDGE (HOOVER DAM BYPASS, COLORADO RIVER BRIDGE) / BOULDER CITY, NEVADA

BRIDGE DESIGN ENGINEER: T.Y. Lin International, Olympia, Wash., in collaboration with HDR Engineering, Omaha, Neb.

CONSTRUCTION ENGINEERS: OPAC, San Francisco, Calif., and McNary Bergeron, Denver, Colo.

PROJECT DELIVERY: Central Federal Lands Highway Division, Federal Highway Administration, Denver, Colo.

PRIME CONTRACTOR: Obayashi PSM, JV; San Francisco, Calif.

CONCRETE SUPPLIER: Casino Redi-Mix, Las Vegas, Nev.

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

BRIDGE BEARINGS: R.J. Watson, Buffalo, N.Y.

A consortium of firms teamed with specialty sub-consultants and Central Federal Lands Highway Division to deliver the final design.

a result, the 3-second wind speed of 56 m/sec (125 mph) was used. Dynamic studies resulted in a gust loading factor of 2.4, which collectively resulted in wind controlling the design for lateral forces. Therefore, the ensuing design for seismic resistance was based on essentially elastic criteria.

Arch Framing

The 1060-ft-span, 70 MPa (10,100 psi) concrete arch is an efficient element for gravity loads in its final form. There were two aspects of design that resulted in twin ribs instead of a typical single box section for this arch. The first is one of practical construction. A single box would be almost 20 m (66 ft) wide, and weigh approximately 30 metric tons/m (20 kip/ft). This section size would rule out a precast segmental option.

The second aspect is the matter of performance under extreme lateral forces. At the time the framing plan was devised, the level of seismic ground motion had not been determined. A single arch rib would leave no opportunity for tuning stiffness or for providing for frame ductility, whereas twin ribs could provide an excellent means of creating ductile Vierendeel links that could otherwise fully protect the gravity system of the arch.

Spandrel Framing

The composite steel-concrete superstructure was selected for speed of erection and to reduce the weight on the arch. The spacing of spandrels was an extension of the concept to erect the bridge using a highline (tramway) crane system. Above 100 kips, there is a jump in highline cost, so the decision was made to target a 100 kip maximum weight for major superstructure elements. The span was set in the range that a high-line crane could deliver the steel box sections, which resulted in a nominal 37-m (121-ft) span. This span also allows steel girders to be set within the range of most conventional cranes, if an alternative erection system had been selected. The statical system includes sliding bearings for the short, stiff piers over the arch crown, and similar piers near the abutments. This was necessary due to the large secondary moments developed in these piers from creep deflections of the arch, and also produced a more even distribution of longitudinal seismic forces among the piers.

Following closure of the arch, the spandrel columns were set using the high-line crane. Superstructure girders are shown being erected.

Pier Cap Framing

Integral concrete pier caps were selected over steel box cap sections. These provided lateral bracing of the spandrel columns and ultimate stability to the flexible columns in the longitudinal direction. Concrete was selected over steel due to the higher maintenance and inspection costs associated with fracture critical steel diaphragms, even though steel caps might have a lower first cost.

Open Spandrel Crown

An open spandrel crown was selected over the option of an integral crown. A special consideration was that the

CAST-IN-PLACE CONCRETE SEGMENTAL ARCH WITH PRECAST CONCRETE SEGMENTAL COLUMNS / NEVADA AND ARIZONA DEPARTMENTS OF TRANSPORTATION, OWNERS

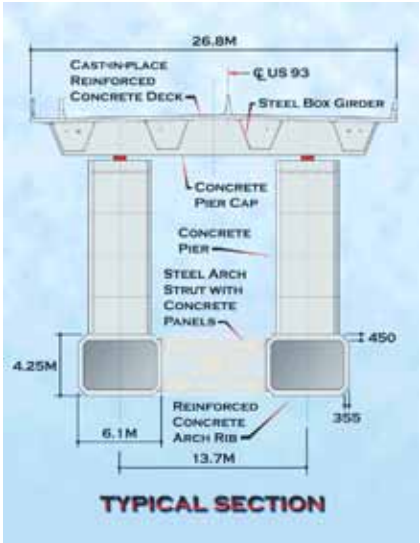
REINFORCEMENT SUPPLIER: Harris Rebar, Phoenix, Ariz.

FORM TRAVELER: NRS, Bangkok, Thailand

BRIDGE DESCRIPTION: A 1900-ft-long bridge over the Colorado River at Hoover Dam, with a 1060-ft-long concrete arch main span, up to 302-ft-tall precast concrete segmental columns, and cast-in-place concrete deck.

STRUCTURAL COMPONENTS: The arch is a twin rib hollow box section with Vierendeel struts connecting the twin ribs. Columns are twin precast concrete segmental box structures. The roadway deck is a steel-concrete composite box girder frame with integral post-tensioned, cast-in-place concrete pier caps.

BRIDGE CONSTRUCTION COST: $114 million



This is a typical section through the twin-rib arch and roadway showing the piers and integral pier cap.

composite steel deck would result in a very abrupt, mechanical looking connection with an integral crown. Equally significant was the high rise of the arch. When studied in either concrete or steel, an integral crown solution looked blocky and massive at the crown, and ran counter to the architectural goal of lightness and openness when viewed from Lake Mead.

Cross Section Forms

The height of the tallest tapered spandrel columns is almost 92 m (302 ft). Wind studies included considerations of drag and vortex shedding on the main structural sections exposed to the long canyon fetch from over Lake Mead. Studies showed that substantial advantage could be gained both in terms of vibration and drag by chamfering the corners of both the columns and the arch. While this adds somewhat to the complexity of construction, the benefit in terms of reduced demand and material savings were substantial.

Construction Methods

As with any large bridge structure, the dead load design is dominated by the assumptions of a construction scheme. The typical approach in the United States is to select an erection scheme, but to show it in the plans only schematically, and defer responsibility for both the scheme and the details to the contractor. The design management team decided that this structure was so unique that the typical approach could prove counterproductive in several respects. A substantial length of time for reviewing and approving an erection scheme might delay the project. The management team also believed that more informed bids could be developed if there was a more complete erection scheme shown with the plans. Therefore, the decision was made to show a complete erection scheme for dead load on the plans and allow the contractors to use that scheme or their own.

Both precast and cast-in-place concrete methods were permitted for the arch and spandrel columns. The contract was written to allow alternative methods of erection, however the columns across the entire bridge were to be of a single type (precast or cast in place) in order to conform to the time-dependent assumptions inherent in design.

Construction

The first challenge for the construction team was creating a foothold for foundation construction. Climbing on the side of the cliff 800 ft over the river below was difficult enough, but excavating (and doing so within the loss limits in the specification) was an incredible challenge. The subcontractor who met this challenge was Ladd Construction from Redding, Calif. They not only met the tight schedule for this work, but completed the excavation allowing about half of the rockfall into the river that was permitted.

Initial bridge construction began with footing and abutment work, and in the precast yard outside of Boulder City where the contractor set up their own facility to precast the columns. Column segments were trucked to the site as needed for erection, and set into place using both the high-line crane and conventional cranes located at the highway hairpin in Nevada.

The first precast pier segment, supported by the high-line crane is erected on its footing.

Four form traveler headings were operated in concert for the cast-in-place concrete arch. After an initial learning curve, the contractor reached a reliable cycle of 2 weeks, and often exceeded that on segments that did not contain a temporary stay for erection.

The arch was closed in August 2009 within an impressive ¾-in. tolerance at closure. Spandrel columns were erected using the high-line crane, and superstructure girders continue to be set. The bridge is scheduled for opening in the Fall 2010.

David Goodyear is senior vice president at T.Y. Lin International, Olympia, Wash.

Progress on construction and additional background can be viewed online at www.hooverdambypass.org.

The tallest of the tapered spandrel columns is almost 92 m (302 ft) tall.

An illustration to show the use of cable stays to construct the arch segments and the position of the high-line crane.

Searching for a practical solution

ANGELES CREST BRIDGE 1

by Jose Higareda, California Department of Transportation

Heavy runoff along with sliding debris overwhelmed drainage systems and caused major damage to the roadway along scenic Route 2 northeast of the city of Los Angeles within the Angeles National Forest. Much of the damage occurred during the spring thaws of 2006 and 2007.

Transportation officials with the California Department of Transportation (Caltrans) looked for economical and more durable repairs for the route. At the Angeles Crest Bridge 1 location where the roadway was washed out, they were faced with limited practical solutions. From the onset, the steep and loose terrain made it difficult to perform adequate subsurface investigations. Geologists were confined to work within the reach of their drill rig and from where the roadway was sturdy enough to support the equipment.

The girders were shipped to the site in three segments and spliced together on the ground.

Several alternatives were considered but ultimately, Caltrans opted to use 208-ft-long spliced precast, prestressed concrete girders to bridge the gap in the roadway. The girders were shipped to the site in three segments and spliced together on the ground near the bridge location. This avoided the need to construct temporary bents on the unstable slope in order to splice the girders in place. The long-span girders allowed the structure to bypass the area of geotechnical uncertainty. The abutments were placed away from known fracture planes in the rock and were founded on stable ground. The intent was also to create a gap between the structure and the natural chute of sliding debris allowing the debris to slide under the structure.

The single-span, simply-supported structure provides the added benefit of not having intermediate supports that could transmit earth loads to the structure during a seismic event. This is important given that the bridge location is situated in a high seismic area (peak ground acceleration of 0.7g and maximum credible earthquake of 8.0). Engineers needed only to confine the structure laterally at the abutments and provide sufficient seat length to prevent the girders from being dislodged.

Construction Logistics

Caltrans felt it was essential to consult with the precast concrete industry early on to study the construction challenges that this type of structure presented. The industry was represented by the Precast/Prestressed Concrete Manufacturers Association of California (PCMAC) who provided assistance with feasibility studies.

Two of the chief concerns were the transportation and erection of the girders. The girders spliced and fully loaded with rigging weigh nearly 180 tons each. PCMAC confirmed that erection was feasible if cranes could be staged at each abutment. It was determined that to install the girders, a 500-ton-capacity hydraulic crane at 91% margin and a 330-ton-capacity conventional crane at 88% margin would be required.

It was not, however, feasible for either crane to reach across from one abutment to the other while lifting one end of a girder. The swing radius for the cranes had to remain as short as

The Angeles Crest Bridge 1 northeast of the city of Los Angeles within the Angeles National Forest. Photos: Caltrans.

profile

ANGELES CREST BRIDGE 1 / LOS ANGELES COUNTY, CALIFORNIA

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

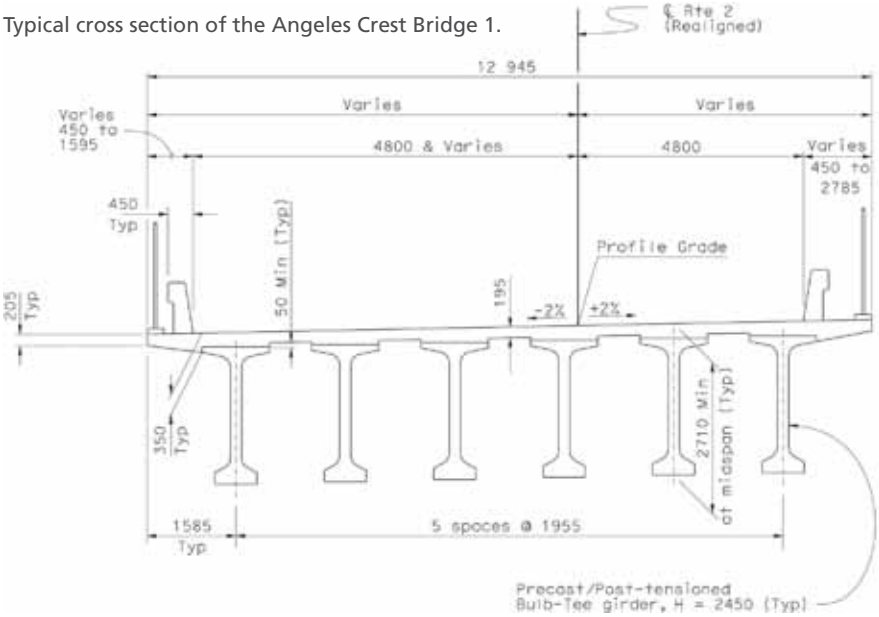
PRIME CONTRACTOR: Griffith Company, Brea, Calif.

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

CONCRETE SUPPLIER: Cornerstone Materials, Palmdale, Calif.

AWARDS: *PCI 2009 Design Award for Best Bridge Project (Spans More than 150 ft)*

Typical cross section of the Angeles Crest Bridge 1.



possible. This meant the girders needed to be either spliced adjacent to the bridge location one at a time, launched across the gap on a truss positioned on both abutments, or hauled close enough to both abutments so they could be lifted by the cranes from each end. Finally, a plan was developed to temporarily shore up what remained of the existing roadway just enough to be able to haul the assembled girders close to both abutments.

A staging area was established less than a mile downhill from the bridge site to receive the individual girder segments that arrived from the precasting yard.

At the staging area less than a mile downhill from the bridge, girder segments were aligned and forms placed for the closure joints.

Here the girders were braced on supports, aligned, and spliced. When concrete in the splices cured to the specified strength, the girders were loaded onto specialized equipment used to move the assembled girders from the staging area to the bridge. A Goldhofer six-line, single-wide hydraulic platform trailer was used to support each end of a girder. A prime mover (tractor) pulled the girders up the hill with 55,000 lb of force. Using hydraulics, the trailers were individually controlled to keep the girders plumb and as level as possible during transport.

At the bridge site, the abutments were constructed and one end of each partially buried to allow the haul truck to drive over them and move the girders into position near the cranes. The girders were unloaded onto the abutment seats with flanges nearly touching one another. After placing all the girders on the exposed portions of abutments, the buried portion was cleared. Next, the temporary haul road which occupied the same space as part of the abutments and superstructure was removed. Finally, the cranes spaced the girders in their final positions along the abutments.

The girder is shown in the Pomeroy casting yard prior to installing the steel side form. All three segments for one girder were cast at one time.

The first stage post-tensioning was done in the staging area. The bottom tendons needed to be stressed simultaneously from opposite ends of the girder to prevent eccentricity.

Structural Components

The bridge measures 208 ft long by 42 ft wide with a structure depth of 8.9 ft. It has a 2% cross slope and 5.4% longitudinal slope. A cast-in-place, composite concrete deck was placed over the six bulb-tee girder lines.

The abutments are each founded on a single row of 4-ft-diameter, cast-in-drilled-hole (CIDH) piles. Recognizing that the abutments would need to be constructed in cut and in rock, the footprint of the abutment was minimized to limit the amount of excavation by allowing the stem of the seat-type abutment to act as a cap for the CIDH piles.

SINGLE-SPAN, PRECAST, PRESTRESSED CONCRETE SPLICED BULB-TEE GIRDER BRIDGE / CALIFORNIA DEPARTMENT OF TRANSPORTATION, OWNER

POST-TENSIONING CONTRACTOR: DSI, Long Beach, Calif.

BRIDGE DESCRIPTION: A simple-span bridge with 208-ft-long, precast, prestressed concrete bulb-tee girders spliced together from three segments at a remote site in the Angeles National Forest

BRIDGE CONSTRUCTION COST: $2,376,192; $272/ft^2 of deck area

A special tractor and trailer were required to transport the girders from the staging area to the bridge site through several sharp turns.

The bridge clear span length of 204 ft warranted a structure depth of about 10 ft using the guide depth-to-span ratio of 0.05 for a simply-supported bulb-tee girder structure. The girders should ideally have had a depth of about 9 ft. However due to the weight limitations, 8-ft-deep girders were used instead. The use of a shallower girder resulted in reducing the spacing between girders to support the design loads.

Shallower girders required a concrete compressive strength of 8500 psi (at 56 days). The concrete strength requirement of 8000 psi (at 56 days) for the closure pours was higher as well. Achieving this strength is typically not a problem. However, the structure is located at an elevation of 6500 ft above sea level in a freeze-thaw environment so there was the additional requirement for 6% (±1.5%) air entrainment. Air entrainment reduces the strength of high strength concrete. While it was not an easy task, both the committed precast concrete manufacturer and the general contractor managed to provide the required concrete for the girders and closure pours.

The individual girder segments were pretensioned for transportation. The assembled spliced girders were post-tensioned in two stages. The first stage of post-tensioning took place after the closure concrete achieved the required strength at the staging area. During the first stage, four of the six ducts per girder were stressed to 2330 kips total. Final stressing took place once the girders were on the abutments and securely braced. The final force was 3560 kips per girder. End diaphragms and intermediate diaphragms were cast after stressing was complete.

Caltrans felt it was essential to consult with the precast concrete industry early on to study the construction challenges.

Cranes were positioned over abutments and lifted the girders from trailers that were pulled across the temporary haul road.

An assembled spliced girder is shown being driven over Abutment 1.

The temporary haul road crosses the uphill end of the abutments to allow delivery of materials including the assembled girders.

The temporary haul road crosses the uphill end of the abutments to allow delivery of materials including the assembled girders. Note the braced forms and bridge over the forms. Once girders were delivered, the road was removed and the full abutment unearthed.

Jose Higareda is a senior bridge engineer with the California Department of Transportation, Sacramento, Calif.

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

BATTLING THE TERRAIN

by Greg Bennett, Warren Hallam, and Scott Nelson, Parsons Construction Group

The Elwha River Bridge in Clallam County, Wash., used cast-in-place segmental concrete to meet significant challenges of terrain. The bridge includes a lower pedestrian deck consisting of precast concrete bulb-tee girders and deck panels. Photos: Parsons Construction Group.

Constructing the new Elwha River Bridge in Washington State required confronting steep, rocky banks, as well as flooding and environmental restraints

The terrain surrounding the remote site posed considerable challenges.

Replacing the deteriorated Elwha River Bridge in Clallam County, Wash., with a new segmental cast-in-place concrete design gave rise to a variety of challenges to ensure the project balanced the needs of the local community, historic-preservation groups, and the tribal jurisdictions. Foremost was the need to overcome severe terrain and other natural obstacles. Another constraint included suspending a pedestrian deck beneath the superstructure. These site-specific challenges required a tremendous effort even before construction of the bridge could be addressed.

The $19.7-million structure replaced a 1914 steel-truss bridge closed to traffic in 2007 because of advanced deterioration. Listed on the National Register of Historic Places, the one-lane Elwha River structure had been downgraded to load-restricted after serious structural deficiencies were found in 1992. In 2003, the county hired BergerABAM Engineers to begin the design process. Bids submitted exceeded the original budget and an innovative combination of funding sources was needed before construction could proceed.

Design of the replacement bridge included a main vehicular structure and a separate pedestrian and bicycle deck. The main structure is 589 ft long and features cast-in-place concrete box girders built using the balanced cantilever and cast-on-falsework construction methods. The cantilever technique minimized disturbances to sensitive environmental areas along the river.

Access Proved Difficult

The terrain surrounding the remote site posed considerable challenges. Access to Pier 3 on the east bank required construction of a 2-mile-long access road that utilized an old railroad right-of-way. Access to Pier 2 on the west bank proved to be one of the most difficult aspects of the project. Situated on a rocky knoll approximately 50 vertical ft down a steep embankment from the existing west abutment, it was bounded to the north and east by vertical drop-offs and to the south by an existing crib wall of unknown stability that retained a previous landslide area.

Contract documents were silent about access means. As a result, Parsons had to design-build a ramp and work pad. Environmental constraints prohibited blasting, so specialized rock-grinding equipment was used in addition to conventional excavation methods. A provision to facilitate continuous access required a split-ramp design.

profile

ELWHA RIVER BRIDGE / CLALLAM COUNTY, WASHINGTON

DESIGN ENGINEER: BergerABAM Engineers, Seattle, Wash.

CONSTRUCTION ENGINEER: International Bridge Technologies, San Diego, Calif.

TRAVELER ENGINEER: John Parkin & Associates, Vancouver, Wash.

FASLEWORK ENGINEER: VAK Engineering, Beaverton, Ore.

PRIME CONTRACTOR: Parsons Construction Group, Sumner, Wash.

PRECASTER (PEDESTRIAN BRIDGE): Concrete Technology, Tacoma, Wash., a PCI-certified plant

The pedestrian bridge features 56 precast concrete deck segments below the main bridge and four deck bulb-tee approach girders along the river bank to transition to the Olympic Discovery Trail.

Substructure Design

With bridge demolition complete, work commenced on the substructure, which consisted of four piers. Piers 1 and 4 served as abutments and included pile caps supported by 4-ft-diameter drilled shafts ranging in depth from 21 ft to 35 ft. The Pier 4 cap was a stepped design to accommodate the sloping terrain. Piers 2 and 3 featured twin columns connected at mid-height by a stabilizing arch tie beam and supported below by 10-ft-diameter drilled shafts with depths of 59 ft and 80 ft, respectively.

A record-setting flood on December 3, 2007, briefly delayed the start of work at Pier 3. With the waters receded and cleanup complete, work proceeded with installing the drilled shafts. A 3-meter oscillator was used to drill at the interior piers and conventional drill rigs at Piers 1 and 4.

Construction of the above ground portion of the work began with the columns at Pier 3. They rose 70 ft from a base elevation near river level. Logistical concerns, along with splicing constraints for reinforcing steel, presented challenges during preplanning and construction stages. The steel cages were constructed full length (95 ft) on the ground and then placed via two-crane picks. A 100-kip shoring tower was placed between the columns to support the formwork and steel cages.

Superstructure Design

The superstructure comprises four main sections: Pier 1 segments, Pier 2 cantilevers, Pier 3 cantilevers, and six segments in Span 3 including Pier 4. The first and fourth sections were placed using the cast-on-falsework method. The two cantilever sections, other than the pier tables, were placed with a form traveler system.

Work on the superstructure began with the Pier 3 pier table. Steel forms were employed and placed on a work deck supported by 100-kip shoring towers. The pier tables were designed and built one-half segment out of balance to accommodate the subsequent traveler construction sequence. Overall dimensions are 30 ft 8 in. long and 31 ft 4 in. wide at the bridge deck with a depth of 15 ft at the centerline.

The pairs of cantilevers from Piers 2 and 3 include 15 segments each and extend 127 ft 6 in. from each of the piers. Typical segments were 14 ft 8 in. long. A final half-length segment included in each provides balance prior to placement of closure segments. Initial launches were difficult due to interference between the traveler system and external columns alongside the box's exterior.

At the same time, crews were working on the 78-ft-long cast-on-falsework section of Span 3. Initial plans called for placement of six separate segments. To simplify the work, site management opted to cast the entire span in three placements. The first closure segment was placed to connect Pier 3 cantilever and the cast-on-falsework section of Span 3. The two sides were aligned using a combination of the traveler system and steel beams set over the web walls and locked in place.

When it was no longer possible to pump concrete to the eastern heading of the Pier 2 cantilever from the excavated laydown area, Parsons worked with the design and construction engineers for approval to place the pump and concrete trucks near the end of the completed Pier 3 cantilever and reach across with the concrete pump boom.

Another challenge came with the superelevated, 185-ft-radius horizontal curve on the west end of the cantilever. A tight radius by form-traveler standards, it required altering the rear tie-down method and modifying the typical sleeve pattern for the connection rods.

Pedestrian Bridge Added

With the superstructure substantially complete, work began on the pedestrian bridge, which serves as the Elwha River's crossing for the Olympic Discovery Trail. The bridge is divided into two sections.

CAST-IN-PLACE CONCRETE BOX GIRDER BRIDGE WITH A SUSPENDED PEDESTRIAN BRIDGE THAT USED PRECAST FLAT PANELS AND PRECAST CONCRETE BULB-TEE GIRDER APPROACHES / CLALLAM COUNTY, WASH., OWNER

CONCRETE SUPPLIER: Fred Hill Materials, Sequim, Wash.

BRIDGE DESCRIPTION: Cast-in-place concrete box-girder bridge built using the balanced cantilever and cast-on-falsework methods, consisting of three spans: 133 ft, 255 ft, and 201 ft

POST-TENSIONING MATERIALS SUPPLIER: Dywidag Systems Inc., Long Beach, Calif.

BRIDGE CONSTRUCTION COST: $16.4 million

Cast-in-place concrete for the Pier 2 cantilever was pumped from the Pier 3 cantilever.

Throughout the work, safety was a key focus.

Section A consists of precast concrete panels suspended from the main superstructure where it spans the river. Section B, which runs perpendicular to the main structure, consists of four precast concrete deck bulb-tee girders on each side supported by drilled shafts, pile caps, and columns.

Section A comprises 56 precast concrete deck panels 8 ft long, 15 ft wide, and 10 in. deep connected to the main soffit above with steel rods and intermediate brace frames. The original joint design included 16 grout-injected reinforcement bar couplers at each panel. Concerns regarding constructability and schedule prompted Parsons to work with the design engineer to develop an alternative design using mechanical couplers to cut the number in half. Four intermediate brace frames consisting of 14 in. by 14 in. steel tube sections provide additional lateral support.

To place the precast segments, Parsons used an erection buggy. The top section included transverse steel beams supported by truck dollies and extending just beyond the width of the deck. The bottom section was a steel-beam-cradle assembly that carried a single precast panel. The two sections were connected via vertical steel cables, with hydraulic drums used to raise and lower the cradle. Once in place, crews positioned on the previously set panel made the joint connection with reinforcement couplers and welded tabs. A two-man crew in a 125-ft extension manlift made the clevis-pin connection at the bridge soffit.

Throughout the work, safety was a key focus, owing to the complexity of the project and the number of new and unknown factors involved. The construction team prided itself on its consistent reinforcement of a culture of safety, including emphasizing the need to plan each day's activities and identify specific hazards. This was an exceptional feat for a crew that began the project unfamiliar with balanced-cantilever procedures.

The efforts paid off with an attractive and efficient bridge that provides safe passage for hikers and a long-lasting structure for vehicles. The official opening took place on September 25, 2009, and nearly 200 spectators participated in the ceremonies. Among the event's highlights was a blessing from the Lower Elwha Clallam tribal leaders before the first cars crossed the river.

Greg Bennett and Warren Hallam are senior construction managers, and Scott Nelson is senior project engineer with Parsons Construction Group in Sumner, Wash.

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

After the Pier 3 cantilevers were complete, cranes were used to break the form travelers into 21 segments, which were transported across the river and reassembled so the segments for Pier 2 could be constructed.

SH58 Ramp A Flyover Bridge

by Gregg A. Reese, Summit Engineering Group Inc.

Colorado is using curved precast concrete U-girders to create cost-effective, long-span bridges where aesthetics and urban issues are key factors

The SH58 Ramp A Bridge in Golden, Colo., is the state's longest span using constant depth, precast U-girder construction.
Photos: Summit Engineering Group.

This approach provided efficiencies to both the contractor and precaster.

The State Highway (SH)58 Ramp A Bridge in Golden, Colo., features a state-of-the-art design using curved precast concrete bridge girders to overcome serious challenges that arise when creating complex interchange projects. This latest project, the fifth of six projects to date to use this technique in the state, demonstrates the benefits of this approach to construct cost-effective, complex, long-span structures in high-profile locations where aesthetics and urban geometrics are significant design considerations.

The ramp connects eastbound I-70 traffic to westbound SH58. As originally designed by CH2M Hill, the bridge was to feature curved, precast concrete girders with unique detailing. Summit Engineering value-engineered the design to feature details and cross-sections similar to those developed for previous projects. This approach provided efficiencies to both the contractor and precaster, which helped meet the numerous construction challenges presented by the difficult urban site. The 11-span bridge crosses Clear Creek, a bike path, three traffic openings, eastbound and westbound I-70, and eastbound SH58.

The Colorado Department of Transportation (CDOT) has promoted precast concrete as a viable alternative to structural steel and cast-in-place concrete, which typically have been used for complex interchanges. This project shows how that effort can pay off. Many of the innovative precast concrete design details used on Ramp A were devised for earlier Colorado projects and were further developed and refined during design.

The roadway consists of a 38-ft-wide deck that currently accommodates one traffic lane and two large shoulders, but was designed for three traffic lanes. Grades vary from +5.0% to -5.0% and cross slopes vary from +6.0% to -2.0% along the length of the structure.

The project includes the state's longest span using constant depth, precast concrete U-girder construction. Its superstructure features two lines of spliced, post-tensioned, precast concrete girders, divided into three units. Unit 1 consists of four continuous spans (153, 205, 235, and 186 ft) that cross Clear Creek, the bike path, and eastbound and westbound I-70. Unit 2 has three spans (147.5, 205, and 186 ft) that cross eastbound SH58. Unit 3 consists of four spans (187.5, 200, 200, and 188 ft). The bridge begins in a spiral curve in Unit 1, which continues through Unit 2 and transitions in Unit 3 to a straight section at the end of the bridge.

profile

SH58 RAMP A FLYOVER BRIDGE / GOLDEN, COLORADO

BRIDGE ENGINEER OF RECORD: Summit Engineering Group Inc., Littleton, Colo.

PROJECT ENGINEER OF RECORD: CH2M Hill, Englewood, Colo.

PRIME CONTRACTOR: Ames Construction Inc., Aurora, Colo.

PRECASTER: EnCon Bridge Co. LLC, Denver, Colo., a PCI-certified producer

POST-TENSIONING CONTRACTOR (LONGITUDINAL): VSL, Wheat Ridge, Colo.

Substructure Design Features

The superstructure is supported on expansion bearings at the abutments and interior expansion piers at each end of the superstructure units. Abutments, supported on a single line of 36-in.-diameter caissons, were designed as a traditional cap and back wall. Expansion piers, 13 ft x 6 ft, are supported on footings and a group of four 48-in.-diameter caissons.

Fixed interior piers were founded on two, side-by-side drilled shafts 48 in. in diameter to balance strength and longitudinal flexibility. Substructure flexibility and soil-structure interaction in the foundations were considered in the design thus eliminating the need for bearings at interior piers while accommodating creep, shrinkage, and thermal movements. Drilled shafts varied in length from 65 ft to 80 ft, with a minimum of 25 ft of embedment into bedrock. Fixed interior piers consisted of 13 ft x 4 ft rectangular shafts with 48-in.-diameter semi-circular ends. Pier heights varied from 16 ft to 45 ft.

Integral pier caps on all fixed interior piers resolved clearance issues and presented a lighter, consistent visual appearance. All integral pier caps were transversely post-tensioned and fully fixed to the superstructure. Expansion piers used a conventional hammerhead cap post-tensioned to enhance durability and provide a shallower design that blended aesthetically with the interior pier caps.

Precast Girder Designs

The superstructure consists of two lines of 86-in.-deep modified CDOT U84 concrete girders spliced near the quarter points of the typical span. The first and last pairs of girders in the spiral curve were cast at varying radii. The remaining girders in the central curve were cast with an 809-ft radius for both girder lines. The straight girders in Unit 3 were cast in a conventional girder form.

The superstructure contains 38 precast concrete girders (30 curved and eight straight) and 265 precast concrete deck panels. The curved girders were cast in special curved forms that conformed to the design radii. The forms were designed in discreet panels that had break points at each end adjusted to the necessary curvature. Girder lengths varied from 93 ft 2 in. to 119 ft 7 in. and weighed from 220 kips to 265 kips.

The project represented the third such project cast by EnCon Bridge Co. Vice President Jim Fabinski noted that this project went quite well, as everyone from all of the agencies involved understood the process by now, so they could focus more attention on honing details than on the process of casting the curved girder segments.

The girders were designed with varying levels of prestress in the bottom slab for handling and erection. Curved girders used post-tensioning tendons, while straight girders used conventional pretensioning. Bottom-slab prestress varied from fourteen to twenty-eight 0.6-in.-diameter strands. Bottom slab tendons in curved girders were stressed and grouted in the casting yard prior to shipping.

All girders were cast with diaphragms at each end incorporating access openings. The diaphragms provided anchorage locations for intermediate and bottom slab tendons. In addition, they provided a strengthened section for handling, as a temporary support, and to serve as an anchor location for torsional bracing during erection. Midspan girder segments were cast with 3-ft-thick diaphragms to accommodate top flange longitudinal tendons. Pier girder end diaphragms were 1 ft thick. Cast-in-place concrete splices, which matched the shape of the diaphragm section, were cast between girder ends.

The 11-span bridge, which crosses Clear Creek, a bike path, and three traffic openings, plus eastbound and westbound I-70, and eastbound SH58, features a circular curve with a radius of 809-ft that transitions through a spiral curve to a tangent section.

Integral pier caps on all fixed interior piers resolved clearance issues and presented a lighter, consistent visual appearance.

2115-FT-LONG PRECAST CONCRETE FLYOVER RAMP WITH MODIFIED CDOT U84 CURVED GIRDERS / COLORADO DEPARTMENT OF TRANSPORTATION, OWNER

POST-TENSIONING CONTRACTOR (PIER CAPS): DSI, Long Beach, Calif.

BRIDGE DESCRIPTION: Eleven-span bridge constructed with 30 curved and eight straight precast concrete girders with integral piers, 265 precast concrete deck panels spanning between girder webs, and a cast-in-place concrete deck

BRIDGE CONSTRUCTION COST: $30.8 million

The design provides the option of a full deck replacement in the future.

Post-Tensioning Details

The primary longitudinal post-tensioning tendons were placed in parabolic profiles along the full length of each unit. Ducts were centered in the precast concrete girder webs and continued through the cast-in-place closures. These ducts were difficult to position, Fabinski noted, to ensure clearance to the faces of the webs. To ensure proper alignment of the tendons, the company incorporated a special plastic chair that holds the ducts in the correct position and spacing during casting. That technique improved the casting of these pieces—and will continue to aid future projects.

Typical longitudinal post-tensioning consisted of four tendons of twelve 0.6-in.-diameter strands per web, which were anchored in cast-in-place concrete diaphragms at the abutments and expansion piers. In addition, 19 strand tendons were placed in the top flange of Unit 1 over the piers on both ends of the 235-ft-long span to increase the negative moment capacity. The top flanges were thickened in the typical section to provide room for 4-in.-diameter ducts for these tendons.

Negative moment tendon anchorages were placed in the inside face of the end diaphragms of the precast girders. The top-flange tendons were placed through the cast-in-place closures and additional reinforcing steel was added to resist anchorage forces. The 8 ¼-in.-thick bottom slab was thickened over the piers to 21 in. to improve the section efficiency and provide a larger compression block for ultimate strength.

Following erection, the precast girders were cast into the pier caps at all interior piers. Ducts were placed through the webs of the girders over the piers to provide for transverse post-tensioning of the caps. Shear keys were placed in both faces of the girders over the piers to enhance shear transfer in the interior pier diaphragms.

The precast girder sections at the end of each unit were notched to allow placement of a cast-in-place diaphragm at the abutments and expansion piers. A concrete diaphragm, 1 ft thick with an access opening, was used to transition from an 8 ¼-in.-thick bottom slab to a 21-in. section at the notch. This thickened "tongue" anchored the bottom slab post-tensioning in the curved girders and provided support during erection. Embedded bearing plates were precast into the bottom of the tongue section to facilitate bearing installation during erection.

Superstructure Erection

The girders were shipped on high-capacity trailers and set on falsework with large hydraulic and crawler cranes to handle the pieces with minimal disruption to traffic. The majority of the erection took place during road closures at night.

Falsework accommodated a variety of site conditions, including locations along Clear Creek and the bike path, which required benching into the existing stream bank to provide foundations for shoring towers. Three temporary straddle bents supported the girders at traffic openings over I-70 and SH58 due to the sharp skews at these locations. Temporary shoring of existing bridges over Clear Creek was required to support the cranes used to set the girders during erection.

Primary post-tensioning tendons were anchored in cast-in-place diaphragms at each end of a unit. The tongue section at the notched ends of the precast girders allowed a continuous diaphragm to be placed across the bridge's width. The end diaphragms were 4 ft thick and mildly reinforced. The diaphragms transversely connected the two girder lines at the abutments and expansion piers. The cast-in-place diaphragms became integral with the girder lines after longitudinal post-tensioning.

When erected, the precast girder tongue section supported the girders' weight on the permanent bearings. This detail greatly simplified erection and eliminated shoring towers at the abutments and expansion piers. The expansion pier diaphragms were detailed to allow stressing of both ends of the tendons using a short-stroke ram. After placement of pier caps, closures, diaphragms, and lid slabs, the superstructure became a continuous closed-cell box for the full length of

Two lines of 86-in.-deep modified CDOT U84 girders spliced near the quarter points of the typical span were used to construct the superstructure.

The project includes the state's longest span using constant depth, precast concrete U-girder construction.

each unit ready for post tensioning. After all longitudinal stressing was complete, tendons were grouted, falsework was removed, and the girders were prepared for the deck slab.

The superstructure girders support the fluid weight of the fresh concrete for the cast-in-place deck in an unshored condition. This approach reduces deck cracking in negative moment regions and provides the option of a full deck replacement in the future.

The success of this project and similar ones in Colorado over the last 5 years validates CDOT's vision of developing precast concrete as a viable option for complex, long-span interchange construction. CDOT has emphasized the use of standardized, commercially produced, precast concrete products to enhance the future economy and sustainability of this concept.

Gregg A. Reese is president of Summit Engineering Group Inc. in Littleton, Colo.

AESTHETICS COMMENTARY

by Frederick Gottemoeller

Large, multilevel interchanges are inherently confusing and stressful. Vehicles of all sizes hurtle along curved ramps in patterns that are unreadable at ground level. Drivers are continually trying to see ahead to what is coming next: sign, ramp, or merging vehicle. Within and contributing to this visual cacophony are the bridges themselves, and their phalanxes of piers.

Improving a confusing and stressful scene requires simplifying it. In the case of interchange bridges that means using fewer girders, fewer piers, and fewer columns within each pier. In addition to reducing the number of elements in the visual field this opens up view corridors through the interchange, so that drivers can anticipate what is coming next, and improves the safety of the interchange. Simplifying the features of the bridge itself further reduces the number of visual elements the driver must absorb. Ramp A brings new techniques and new technology to these goals.

First of all, the torsional stiffness of the U-girders allows only two girders in the ramp cross section. Then, splicing and post tensioning the girders allows for longer spans and fewer piers. Having only two girders to support, the piers themselves can be simple and straightforward. Since the girders are curved they can smoothly follow the curve of the ramp, so that all of the lines of the ramp are parallel to each other. Coloring the girders a darker color emphasizes this consistency, and makes the ramp appear thinner and thus the spaces below seem more open. The open, graceful appearance of this bridge will make this interchange easier and more enjoyable to use.

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

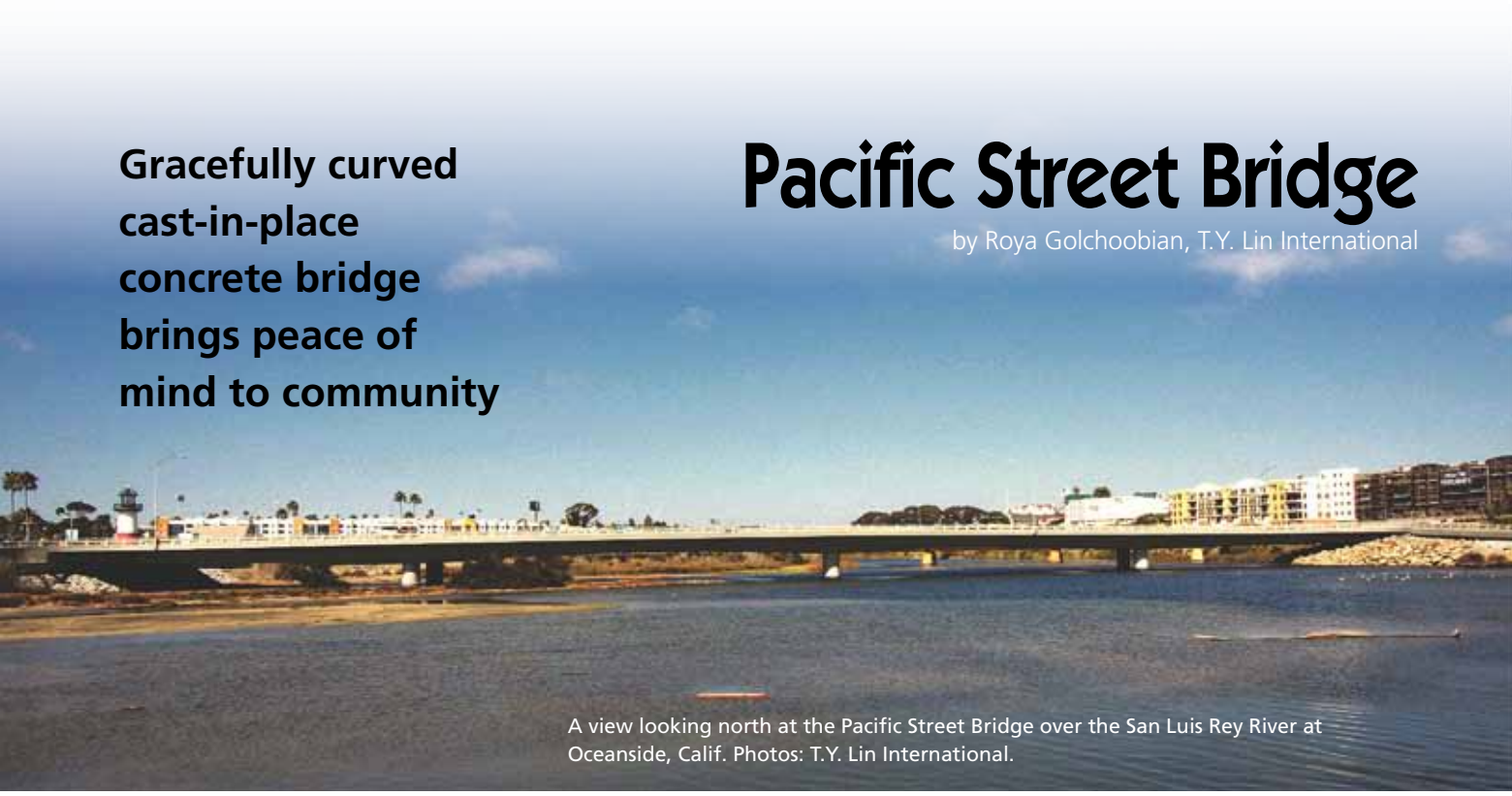
The ends of each precast concrete girder section were notched to allow placement of an integral cast-in-place diaphragm at the abutments and expansion piers.

PCI in cooperation with U.S. Department of Transportation Federal Highway Administration present the 2010 Bridge Conference

Pacific Street Bridge

by Roya Golchoobian, T.Y. Lin International

Gracefully curved cast-in-place concrete bridge brings peace of mind to community



A view looking north at the Pacific Street Bridge over the San Luis Rey River at Oceanside, Calif. Photos: T.Y. Lin International.

The graceful horizontal and vertical curves of the bridge gave new meaning to the beauty created by a concrete structure.

The Pacific Street Bridge spans over the San Luis Rey River at the mouth of the lagoon where the river meets the Pacific Ocean at Oceanside, Calif. The river is one of the major river systems in the County of San Diego, but was blocked off from the ocean by a low-flow crossing connecting the residential communities on the south side to the businesses on the north side of the river.

Contribution to the Community

The Oceanside Harbor is home to the businesses catering primarily to recreation, such as restaurants, shops, charter fishing, and beach rentals. The original low-flow crossing was the only direct north-south connection over the river in the heart of Oceanside. It was subject to flooding and recurring washout during every major storm, crippling the residents and businesses in the area. The Pacific Street Bridge replaced the unstable, temporary nature of the crossing and was designed to withstand the 100-year storm, bringing peace of mind to the residents and businesses in the area.

Design Challenges Addressed

The Pacific Street Bridge is a four-span, post-tensioned, cast-in-place concrete structure with a unique S-curve alignment spanning 635 ft over the San Luis Rey River. Consideration had to be given to impacts of the bridge construction method on environmentally sensitive habitats in the area, quality of air, the river's wildlife, and hydrology of the river. All had to be considered and incorporated into the bridge type selection and design.

The span lengths are 136, 181, 181, and 136 ft and the bridge is 53 ft 6 in. wide. The girder has a curved soffit with overall depth varying from 6 ft 3 in. at midspan to 8 ft 6 in. at the piers. The variable depth was selected to reduce the number of supports in the river and to create the illusion of an arched gateway to the ocean. The graceful horizontal and vertical curves of the bridge gave new meaning to the beauty created by a concrete structure.

The post-tensioning comprised three tendons in each web for a total of 12.

profile

PACIFIC STREET BRIDGE OVER SAN LUIS REY RIVER / OCEANSIDE, CALIFORNIA

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

CIVIL ENGINEER: Willdan Engineering, San Diego, Calif.

CONTRUCTION MANAGER: Harris & Associates, San Diego, Calif.

PRIME CONTRACTOR: Flatiron, San Marcos, Calif.

CONCRETE SUPPLIER: Palomar Transit Mix, San Diego, Calif.

AWARDS: *2009 Honor Award, San Diego/Imperial Chapter, American Public Works Association; 2009 Outstanding Project, San Diego Section, American Society of Civil Engineers; The Best of 2008, Award of Merit, California Construction Magazine*

Formwork for the inclined webs and east bulkhead is shown along with the placement of the reinforcement in the soffit and the locations of the post-tensioning tendons.

Each tendon contained thirty-seven, 0.6-in.-diameter strands. Concrete with a compressive strength of 4000 psi was used in the superstructure, columns, and piles. Other concrete used in the project had a compressive strength of 3600 psi.

The soffit of the box girder is 9.8 in. thick. The deck is also 9.8 in. thick and tapers to 7.9 in. at the edges of the cantilevers. Both vertical and inclined webs are typically 11.8 in. thick but vary up to 18 in. thick.

To reduce the impacts to the riverbed, bridge columns were supported on 7-ft-diameter, cast-in-drilled-hole single piles that penetrated 150 ft into the river bed. The use of drilled shafts instead of the conventional driven piles substantially reduced the level of construction generated noise, benefitting both residents and endangered species in the area.

Project Challenges

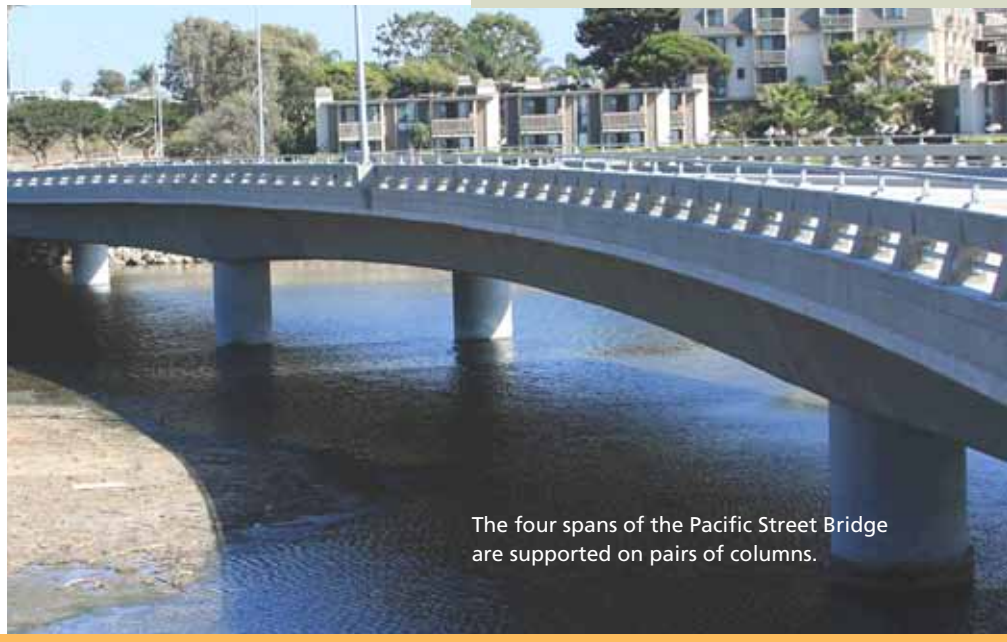
The bridge is located in the seismically active area of Southern California and near faults capable of generating earthquakes of 7.5 magnitude. The loose sandy soil in the river bed introduced additional challenges in design of the structure for withstanding seismically induced down drag forces of high intensity. Soil liquefaction and caving were other challenges of the design and construction at this site.

To withstand the 100-year storm, the bridge was constructed above the elevation of roadways on the south and north sides of the river. The profile of the roadways at both ends of the bridge was raised to meet the bridge elevations at the connection points. To meet the federal funding limitation placed on the approach roadway work for a bridge project, the profile modifications to the adjoining roadways had to be optimized to minimize the modification lengths and to touch down at the existing ground elevations before entering nearby intersections.

Environmental Impact

The river corridor is home to several state and federally listed threatened and endangered species of fish and wildlife. The blockage of the stream and tidal flow caused by the low-flow crossing had impacted the estuarine system. It resulted in deterioration of the typical function of a brackish water ecosystem and the reduction in diversity of species.

Removal of the crossing after construction of the Pacific Street Bridge and opening of the river to the ocean has increased the potential for migration, spawning, and establishment of important species of fish and wildlife in the river, including the once abundant and now absent steelhead trout and tidewater goby. Removal of the low-flow crossing also eliminated the recurring washout and depositing of roadway debris and asphalt into the ocean and lagoon.



The four spans of the Pacific Street Bridge are supported on pairs of columns.

CAST-IN-PLACE POST-TENSIONED CONCRETE BOX GIRDER / CITY OF OCEANSIDE, OWNER

POST-TENSIONING CONTRACTOR: Dywidag Systems International, Lakewood, Calif.

REINFORCEMENT FABRICATOR: CMC Fontana Steel, Lakeside, Calif.

BEARING SUPPLIER: D.S. Brown, North Baltimore, Ohio

EXPANSION JOINT SUPPLIER: Stinger Welding Inc., Coolidge, Ariz.

BRIDGE DESCRIPTION: Four span, 635-ft-long, variable depth cast-in-place, post-tensioned concrete box girder bridge

STRUCTURAL COMPONENTS: Four spans up to 181 ft long varying from 6 ft 3 in. to 8 ft 6 in. deep supported on pairs of columns with a single cast-in-drilled-hole, 7-ft-diameter concrete pile under each column

BRIDGE CONSTRUCTION COST: $18,000,000

of a landscape architect for creating the images and architectural treatments that were used on the retaining walls.

Open barrier railings were used at the edges of the bridge deck to maximize the driver's view while travelling on the bridge.

Roya Golchoobian is senior bridge engineer and project manager with T.Y. Lin International, San Diego, Calif.

AESTHETICS COMMENTARY

by Frederick Gottemoeller

At first glance a project like the Pacific Street Bridge looks deceptively easy. After all, the spans are short, the bridge is low to the water, and it's not that big a body of water in the first place. Who is really going to care what the bridge looks like? Luckily, this designer cared, and realized that all of the residents in the condos around the bridge would care, too.

Using cast-in-place post-tensioned concrete allowed the superstructure to be relatively thin, and also allowed the wide overhangs that make it appear even thinner. The pier caps are invisible, hidden within the superstructure. Only two columns are required at each pier line. Most of the space between the water and the roadway is left open, and the natural reflectivity of the superstructure allows light to carry through the structure. Rather than creating a dark slit just above the water, visually cutting the lake in two, the bridge reveals the water surface beyond the bridge, keeping the lagoon visually intact. Finally, the superstructure seamlessly follows the geometry of the roadway, with no special brackets or offsets. The bridge seems to float effortlessly from shore to shore.

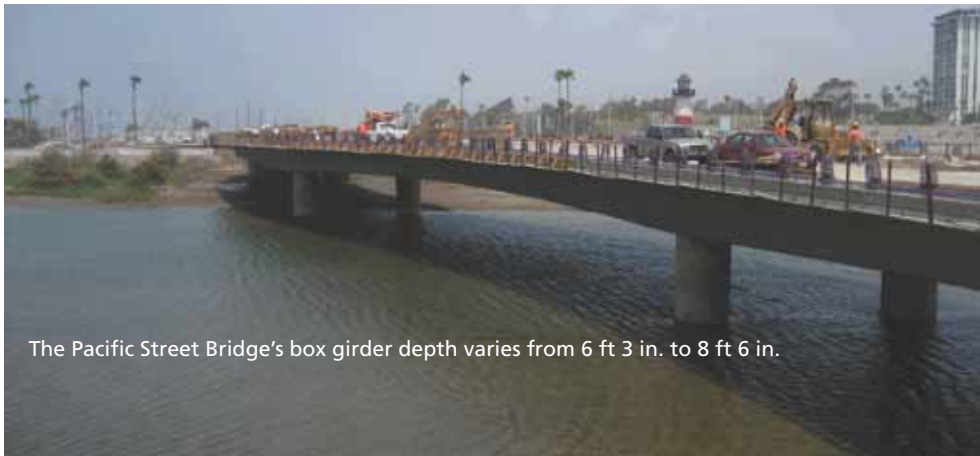
If the "bones" of a structure are as successful as this one, very little additional detail or ornamentation is needed. Knowing this, the designer has left the piers as simple cylinders, and made the railing transparent without adding complication. All in all, it's a very nice bridge to come home to.

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

The Pacific Street Bridge in Oceanside, Calif., incorporates a unique S-curve and open barrier rail.

The bridge is located in the seismically active area of Southern California.

Construction of the open barrier that permits views of the San Luis Rey River.



The Pacific Street Bridge's box girder depth varies from 6 ft 3 in. to 8 ft 6 in.

Photo courtesy of (U.S. Army Corps of Engineers)

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Silica Fume Association

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

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

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

- The publication of a *Silica Fume User's Manual*—the manual is a comprehensive guide for specifiers, ready mixed and precast concrete producers, and contractors that describes the best practice for the successful use of silica fume in the production of high performance concrete (HPC).
- The introduction of a Standard Reference Material (SRM)® 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

Auction Road Bridge Replacement

by Daniel A. Rogers, RETTEW Associates Inc.

Recreating an Historic Treasure

Lancaster County gave specific instructions . . . to develop a context-sensitive design that captures the architectural, historical, and structural features of the existing bridge.

Big Chickies No. 2 Bridge—more commonly known as Auction Road Bridge—is located between Rapho and Penn Townships over Chickies Creek in historic Lancaster County, Pa. It was designed in 1916 by prominent Lancaster County engineer Frank Shaw and put into service in 1922. The unique 58-ft-long, single-span, tied through-arch concrete bridge is believed to be one of only four of its kind in the commonwealth. Shaw modeled the bridge after the patented rainbow arch bridge design of James H. Marsh, only slightly changing the design by adding diagonal truss chords. Research indicates only a dozen or so of Marsh's bridges remain in the entire country.

Pennsylvania has a rich heritage of historic bridges. With 200 covered bridges, it boasts more covered bridges than any other state in the country. Lancaster County is home to 29 of Pennsylvania's covered bridges—second only to Parke County, Ind., for the most covered bridges of any county in the United States. Lancaster County has done a tremendous job of maintaining their covered bridges and, in an effort to preserve them, has been reluctant to put steel or prestressed concrete beams under the timber bridges. While Auction Road Bridge is not a covered bridge, the county adopted the same philosophy for this structure's replacement, requiring that the new bridge structurally mimic the original 1916 bridge.

In 2005, Lancaster County gave specific instructions early in the project to develop a context-sensitive design that captures the architectural, historical, and structural features of the National Register-eligible bridge. Context-sensitive design for this structure meant incorporating the same architectural and historical details of the original tied through-arch bridge. Similar to their covered bridge restorations, the county also opposed a design incorporating steel or prestressed concrete beams

A contributor to the project's success was effective coordination among the designer, the contractor, and the precaster.

The completed Auction Road Bridge over Chickies Creek features two lanes of traffic, sufficient sight distance, and current safety features. Photos: RETTEW.

profile

AUCTION ROAD BRIDGE / PENN AND RAPHO TOWNSHIPS, LANCASTER COUNTY, PENNSYLVANIA

BRIDGE DESIGN ENGINEER: RETTEW Associates Inc., Lancaster, Pa.

AWARDS: *2008-2009 Award for Outstanding New Short Span Bridge, Association for Bridge Construction and Design, Susquehanna Chapter; 25th Annual Road and Bridge Safety Improvement Award; 2010 Diamond Award Certificate, American Council of Engineering Companies of Pennsylvania; PCI 2009 Design Award for Best Bridge (Co-winner for Spans Less than 75 Ft)*

under the deck. Like the original, they required that the reinforced concrete arch and deck for the replacement structure function as load carrying structural members.

Design and Details

Auction Road Bridge needed to be replaced for several reasons. First and foremost, the structural concrete arch and deck exhibited severe deterioration, with cracked concrete members and exposed reinforcement. As a result of the structural deterioration, the bridge load rating was reduced to only 5 tons. The weight restriction was significant because Auction Road serves as a main thoroughfare for the Manheim Auto Auction—the largest auto auction in the United States and located within only a mile from the bridge.

In addition to the structural deterioration and weight restriction, the existing structure did not have a safety curb or barrier to protect against vehicular collision damage to the structural arch members. The original bridge was also limited to one lane with very steep approaches, which resulted in poor sight distances. Finally, the approach roadways frequently flooded.

Considering Form and Function

To address the poor sight distances, narrow cartway, and flooding problems, the profile grade was lowered by almost 2 ft at the approaches and the bridge expanded from a 58-ft-long span to a 70-ft span to maintain the required waterway opening. It was also widened from one lane to two 10-ft-wide lanes and two 4-ft-wide shoulders. Improving the steep roadway approaches greatly improved sight distance, and adding PA Type 10M bridge barrier and approach guiderail greatly improved safety. The guiderail meets current Pennsylvania Department of Transportation (PennDOT) standards and protects the arches' main structural members from vehicular collisions.

Finally, to achieve the county's goal of having a context-sensitive structure, the concrete arches were designed as precast concrete members with a compressive strength of 8000 psi. A cast-in-place concrete deck, with a compressive strength of 4000 psi, was designed to span between the two arches with a minimum thickness of 1 ft 6 in. at the edges and a maximum thickness of 1 ft 10½ in. at the crown. The final typical section of the bridge resulted in an out-to-out width of 34 ft 4 in. with two 1-ft 8-in-wide precast concrete arches. Although the arches spanned an additional 12 ft, it was possible to use the same number of panels and the same vertical height as the original reinforced concrete arches. The final design for the replacement bridge is one that behaves structurally identical to the original and replicates its aesthetic, architectural, and historic details.

Key Details of the Precast Arches

- Maximum height of 11 ft 7 ½ in.
- Top Chord: 1 ft 8 in. x 2 ft 0 in.
- Bottom Chord: 1 ft 8 in. x 2 ft 7 in.
- Vertical and Diagonals: 1 ft 0 in. x 1 ft 1 in.
- Weight: 47 tons/arch
- Reinforcement: 25,000 lb including temporary post-tensioning strands
- Post-tensioning used only for lifting and transportation; released after final erection
- Form tolerances set to 1/16 in. maximum using survey control equipment
- Modified concrete mix design with reduced large aggregate size to ensure concrete consolidation

The reconstructed Auction Road Bridge blends into the rural farmland landscape of Lancaster County.

SINGLE-SPAN, PRECAST CONCRETE TIED THROUGH-ARCH BRIDGE / LANCASTER COUNTY, PA., OWNER

PRECAST SPECIALTY ENGINEER: Pennoni Associates Inc., State College, Pa.

PRIME CONTRACTOR: Kinsley Construction, York, Pa.

PRECASTER: Newcrete Products, Collegeville, Pa., a PCI-certified producer

BRIDGE DESCRIPTION: A 70-ft-span precast concrete tied through-arch bridge with cast-in-place concrete deck

BRIDGE CONSTRUCTION COST: $966,000

The replacement bridge behaves structurally identical to the original and replicates its details.

Challenges

Numerous challenges needed to be addressed throughout the life of the project. First and foremost, meeting the project requirements meant it was necessary to ensure the final product was constructible and could be built within budget. From the beginning, discussions with contractors investigated erecting and pouring the cast-in-place deck and with fabricators to discuss issues such as formwork of the arches, reinforcing (clearances, bar bends, development lengths, etc.), and transporting the arches.

From a design perspective, a bridge of this nature required a unique approach. The arch and deck were modeled in STAAD and final design completed with spreadsheets that followed load and resistance factor design and PennDOT design requirements.

While each part of the design was important, two were critical. First, because of the continuous loading of the deck, the bottom chord was designed for both tension and flexure. Second, the connection of the deck to the arch was designed to properly account for both shear and torsion.

Finally, gaining approval for the final structure before moving on to construction was challenging. The Pennsylvania Historical and Museum Commission (PHMC) was involved from the very beginning of the project to ensure that the replacement structure matched the historical attributes of the original bridge. Since the design was context sensitive, obtaining PHMC's approval fared easier than originally anticipated. PHMC did, however, require inclusion of some of the nonstructural details, such as the unique architectural end treatments. A detailed historical recordation had already been completed for the existing bridge, but the owner and designer agreed to develop a website to detail the existing bridge and display photographs of the new bridge construction and completion.

Construction and Fabrication

In April 2008, the construction contract was awarded for a winning bid of $966,000. The county gave notice to proceed in May 2008 with a construction schedule of approximately 7 months.

Newcrete Products fabricated the two precast concrete arches in their Roaring Spring, Pa. plant while site work was ongoing and the abutments constructed. The precast specialty engineer provided services to Newcrete and coordinated with Newcrete and RETTEW Associates to address concerns and make several minor modifications to simplify fabrication and transportation of the arches. Modifications included adding post-tensioning to aid in lifting and transporting the arches, adjusting clearances and development lengths to work within the tight tolerances of the arch formwork, and adding mechanical couplers for the transverse deck bars protruding from the bottom chord of the arches.

On October 22, 2008, the arches were delivered to the site. The contractor worked overnight to erect them and set the deck formwork in place. The arches were set in place using a 500-ton crane and the deck formwork was hung directly from the bottom chord to avoid working in the creek water. By December 2008, Auction Road Bridge reopened to traffic.

Much of the credit for the success of this unique bridge goes to Lancaster County. Their desire to preserve the heritage of yet another historic bridge was impetus for designing a context-sensitive structure that so beautifully complements its rural surroundings. Another contributor to the project's success was effective coordination among the designer, the contractor, and the precaster. As a result of these three firms working together, Lancaster County now has a new bridge that will serve the community—both in form and function—for as many years as Frank Shaw's original 1916 structure.

Daniel A. Rogers is senior bridge engineer with RETTEW Associates Inc., Lancaster, Pa.

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

The original structure built in 1922 had one lane and limited sight distance. The original end treatment is replicated in the new bridge.

CONCRETE CONNECTIONS

Concrete Connections is an annotated list of websites where information is available about concrete bridges. Fast links to the websites are provided at www.aspirebridge.org.

IN THIS ISSUE

www.hooverdambypass.org
Visit this website for a history, more details, and the latest information about the Mike O'Callaghan-Pat Tillman Memorial Bridge at Hoover Dam described on page 16. A photo gallery and webcam are available.

www.oregon.gov/odot/hwy/bridge
More information about Oregon's bridges and Conde B. McCullough is provided at this Oregon bridge section website.

http://cms.transportation.org?siteid=34&pageid=1484
This website lists the preliminary versions of the balloted items from the AASHTO 2009 Subcommittee on Bridges and Structures Meeting. Balloted items in pdf format may be downloaded by scrolling to the bottom of the page.

Certification

More information about the industry certification programs described in the Safety and Serviceability article on page 52 is available at the following websites.

www.concrete.org/certification
American Concrete Institute

www.asbi-assoc.org/grouting
American Segmental Bridge Institute

www.crsi.org/corrosion/certification.cfm
Concrete Reinforcing Steel Institute

www.nrmca.org/certifications
National Ready Mixed Concrete Association

www.pci.org
Precast/Prestressed Concrete Institute.
Click on PCI Certification.

www.post-tensioning.org
Post-Tensioning Institute. Click on Certification.

Environmental

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

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

Bridge Technology

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

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

www.hpcbridgeviews.org
This website contains 59 issues of *HPC Bridge Views*, an electronic newsletter published jointly by the FHWA and the NCBC to provide relevant, reliable information on all aspects of high-performance concrete in bridges. Sign up at this website for a free subscription.

NEW www.tsp2.org/bridge
This website was developed to provide highway agencies and bridge preservation practitioners with online resources about bridge preservation, maintenance, and inspection.

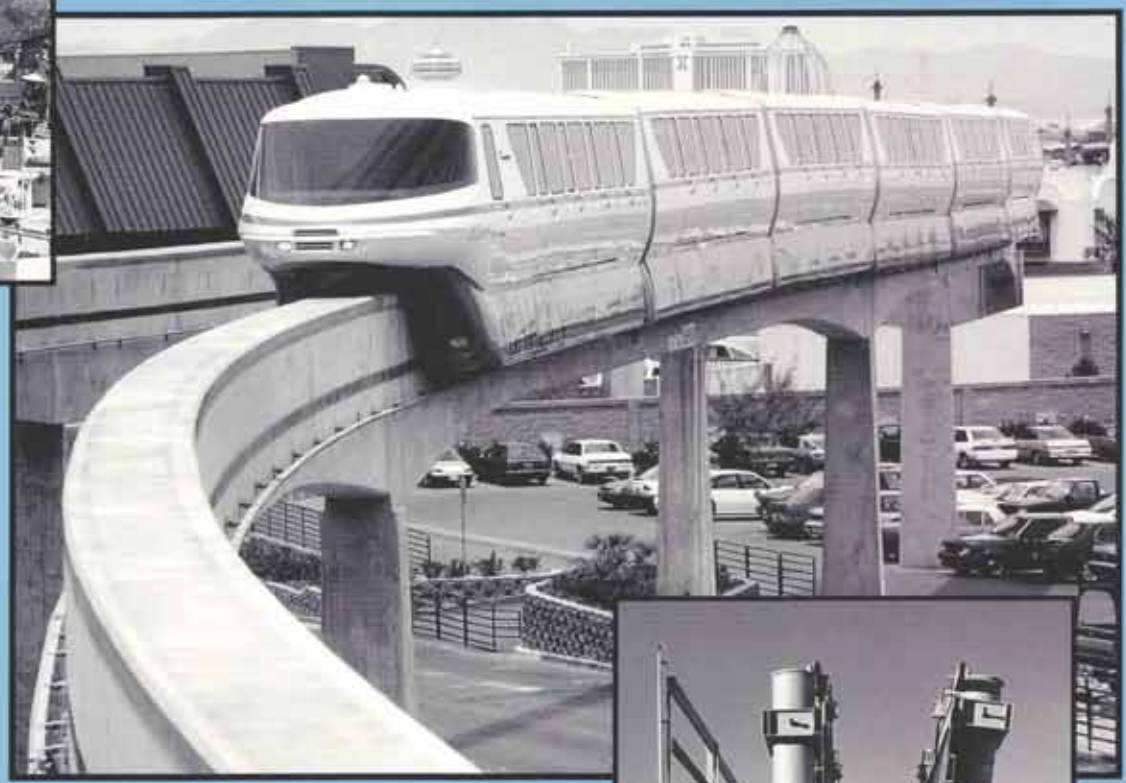
www.fhwa.dot.gov/pavement/concrete/asr.cfm
This online Alkali-Silica Reactivity Reference Center provides users with one-stop access to ASR-related information. The site features an overview of ASR, as well as research reports, specifications, guidance documents, case studies, and links to other useful websites. The FHWA report titled *Report on Determining Reactivity of Concrete Aggregate and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction* may be accessed and downloaded from this website. Click on Development of ASR Protocols.

http://www.wes.army.mil/SL/MTC/handbook/crd_c662.pdf
A new test method, CRD-C 662-09, titled *Test Method for Determining the Alkali-Silica Reactivity of Combinations of Cementitious Materials, Lithium Nitrate Admixture and Aggregate (Accelerated Mortar-Bar Method)* has been released by the U.S. Army Corps of Engineers and can be accessed at this website.

http://knowledge.fhwa.dot.gov/cops/ep.nsf/home
Come join the FHWA's online Information Exchange for Bridges at this website, which offers information on innovative products and processes for bridge construction. The report titled *Connection Details for Prefabricated Bridge Elements and Systems* is available.

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

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



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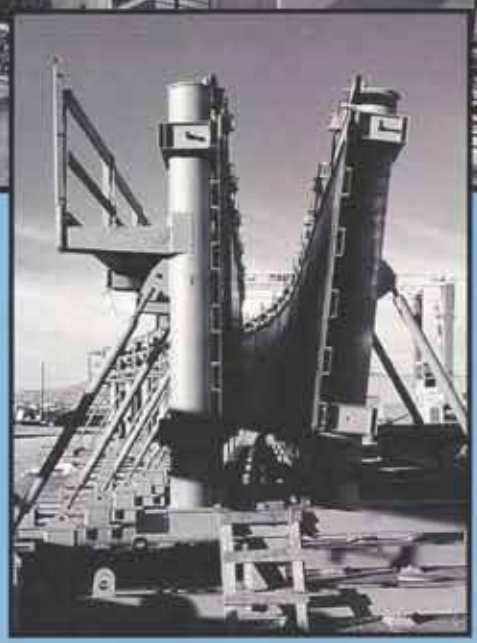

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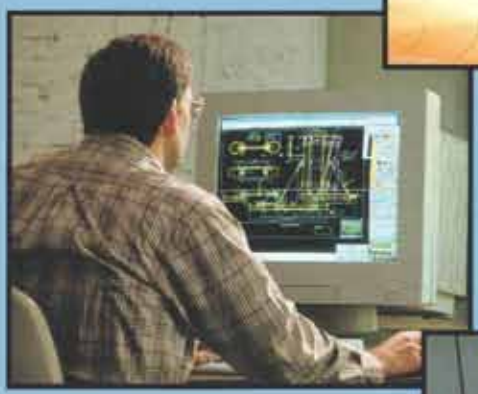

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ULTRA-HIGH-PERFORMANCE CONCRETE

A Bridge of the Future–A Solution Today

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

Ultra-high-performance concrete (UHPC) refers to a class of exceptionally durable and strong cementitious composites, usually containing fiber reinforcement and exhibiting self-consolidating properties. UHPC has been used in Europe and Asia in building vehicular bridges, pedestrian bridges, and other types of structures. In the United States, the Iowa, Virginia, and New York Departments of Transportation have used UHPC in building highway bridges. More applications of UHPC are expected in the years ahead.

The ongoing deterioration of highway bridges is an issue across the nation. This deterioration in combination with congestion related issues has created a situation where bridge owners need to repair, replace, and construct durable bridges. Those needs are greater than ever. Given the ever increasing demands on our bridge structures and resources, it is clear that conventional construction techniques of the 20th century are not in themselves sufficient to meet 21st century needs. There is a strong demand for new solutions to existing problems, whether the solutions emanate from materials or structural configurations or construction techniques. The advanced properties of UHPC open many new avenues toward these solutions.

The Federal Highway Administration's (FHWA) Bridge of the Future initiative seeks to develop new solutions to our existing highway bridge deterioration and congestion problems. The initiative has the following performance goals for highway bridges:

- 100-year service life with little or no maintenance
- Significantly reduced construction time
- Easily widened or adapted to new traffic demands
- Significantly reduced life-cycle-cost
- Significantly improved resistance to typical and extreme natural and man-made hazards including blast, flood, earthquake, fire, wind, fracture, corrosion, overload, and collision
- Integrated substructure and superstructure design and construction
- Reduction of vertical and lateral clearance problems

FHWA's UHPC efforts are a core component of the Bridge of the Future initiative. The efforts focus on engaging UHPC's exceptional durability and mechanical properties to create optimal structural systems capable of meeting current and future demands.

What is UHPC?

UHPC is a general classification that encompasses a range of advanced cementitious composite materials. Just as with conventional concretes, UHPC contains cement, aggregates, and water. Like many high-performance concretes, UHPC also contains supplementary cementitious materials and chemical admixtures to enhance specific presetting and post-setting behaviors. Unlike most concretes, UHPC generally contains no coarse aggregates, instead it includes a few percent by volume of short, discrete fibers.

Worldwide, UHPC-type materials are available from multiple suppliers. In the United States, one multinational firm has led the way in supplying UHPC for infrastructure-scale projects. Other entities are currently working to develop and deploy competing products in this market.

The performance attributes exhibited by these concretes may be up to an order of magnitude better than those exhibited by conventional and high-performance concretes. UHPC is sometimes thought of as 'extremely strong concrete'; however, a compressive strength seven or more times that of conventional concrete is only part of the story. UHPC exhibits sufficient sustained tensile capacity to allow for the reimagining of concrete structural design. Moreover, the durability properties of UHPC are so exceptional that they cannot be quantified with many standard concrete test methods. The table on page 47 presents some attributes of a widely available UHPC as independently measured by FHWA.

Applications

There are many potential applications for UHPC in the highway infrastructure; however, as is always the case with new technology, only some implementations will prove to be economically viable. The range of concepts being considered runs the gamut from conventional ideas such as bridge redecking systems and optimized prestressed girders,[1] to connection details such as field-cast spliced joints between precast modular elements,[2] to novel concepts such as energy dissipating seismic elements and cladding shells for bridge barriers.

Since its initiation in 2001, FHWA's UHPC program has been focused on developing practical UHPC applications that address pressing needs.

Ultra-high-performance concrete was used in the Cat Point Creek Bridge in Warsaw, Va.
Photos: Ben Graybeal, FHWA

The UHPC Pi Girder is a 33-in.-deep and 100-in.-wide decked bridge girder designed to span up to 87 ft and allows for rapid construction of an extremely durable superstructure.
Drawing: Ben Graybeal, FHWA.

This UHPC has been mixed in and is being discharged from a ready-mixed concrete truck.
Photo: Ben Graybeal, FHWA.

UHPC was used to connect these deck bulb tees in the Route 31 Bridge over Canandaigua Outlet in the Village of Lyons, N.Y. Tests showed that the No. 6 epoxy-coated reinforcement was fully developed with a 6-in. lap in the joint.[2] Photo: New York State Department of Transportation.

Initial efforts demonstrated that one-for-one replacement of conventional concrete with UHPC in standard prestressed concrete girder shapes was feasible and would produce results consistent with basic engineering mechanics principles. This work also demonstrated that the tensile capacity of UHPC is sufficient to reduce and even eliminate the secondary mild steel reinforcement in a girder, thus opening the door to reduced cover demands and lighter, optimized sections.

Subsequent efforts have focused on developing optimal solutions which engage the advanced mechanical and durability properties of the UHPC to create economically desirable components. One project of note has developed a deck bulb-double-tee girder that can span up to 87 ft using an 8-ft 4-in.-wide component that has structural depth of only 33 in. This 932-lb/ft girder is transportable, stable, and does not require any structural overlay.[3] A second project has developed a bridge redecking system, which uses the strengths of UHPC to reduce deck weight and simplify connection details. A third project has developed practical QA/QC methods for assessing UHPC properties in plant and field environments.

Conclusion

In coming years, the demand to rehabilitate, construct, or reconstruct highway bridges will only grow stronger. Construction techniques and structural materials implemented in the middle of the twentieth century have left us with structures nearing the end of their service lives at a time when highway mobility is increasingly important and budgets for maintenance and repair are strained. Advanced structural materials open doors to new structural systems and construction techniques. UHPC is the culmination of decades of research in concrete materials science. This class of concretes has already been demonstrated to allow for structural forms heretofore considered impossible with conventional concrete. Further development of optimal solutions is underway and existing knowledge has facilitated initial deployments of UHPC technology in bridges around the nation. Additional details on UHPC deployments and opportunities will be covered in the Summer issue of *ASPIRE*.™

UHPC Physical Properties

Property	Plant-Cast*	Field-Cast*
Compressive Strength	28 ksi	18.3 ksi
Modulus of Elasticity	7600 ksi	6200 ksi
Sustained Tensile Strength	~1.5 ksi	~0.9 ksi
Creep Coefficient	0.3	0.8
Scaling (ASTM C672)	None	None
Chloride Penetrability (AASHTO T 277)	20 coulombs	360 coulombs
Freeze/Thaw Resistance (AASHTO T 161)	RDM > 95%	RDM > 100%

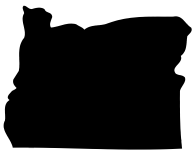
** Field-cast UHPC is cured through conventional means while plant-cast refers to UHPC that has had its properties enhanced through early-age steam treatment.*

References

1. "A Whole New Cast," *ASPIRE,*™ Summer 2007, pp. 26-29.
2. "UHPC Joint Provides New Solution," *ASPIRE*, Fall 2009, pp. 28-30.
3. "FHWA, Iowa Optimize Pi Girder," *ASPIRE*, Winter 2010, pp. 24-26.

EDITOR'S NOTE

More information on research and deployment of UHPC technology can be obtained by contacting Dr. Graybeal at bgraybeal@dot.gov or 202-493-3122.



CONCRETE BRIDGES *in Oregon*

by Ray Bottenberg, Oregon Department of Transportation

The earliest bridges in Oregon were made from readily available timber, but their useful life was limited due to decay in western Oregon's damp weather. A good example is provided by two of Portland's first three Willamette River bridges, built of timber in 1887 and 1891 with neither one lasting 20 years. Oregon surely needed longer-lasting bridge materials.

The Early Years

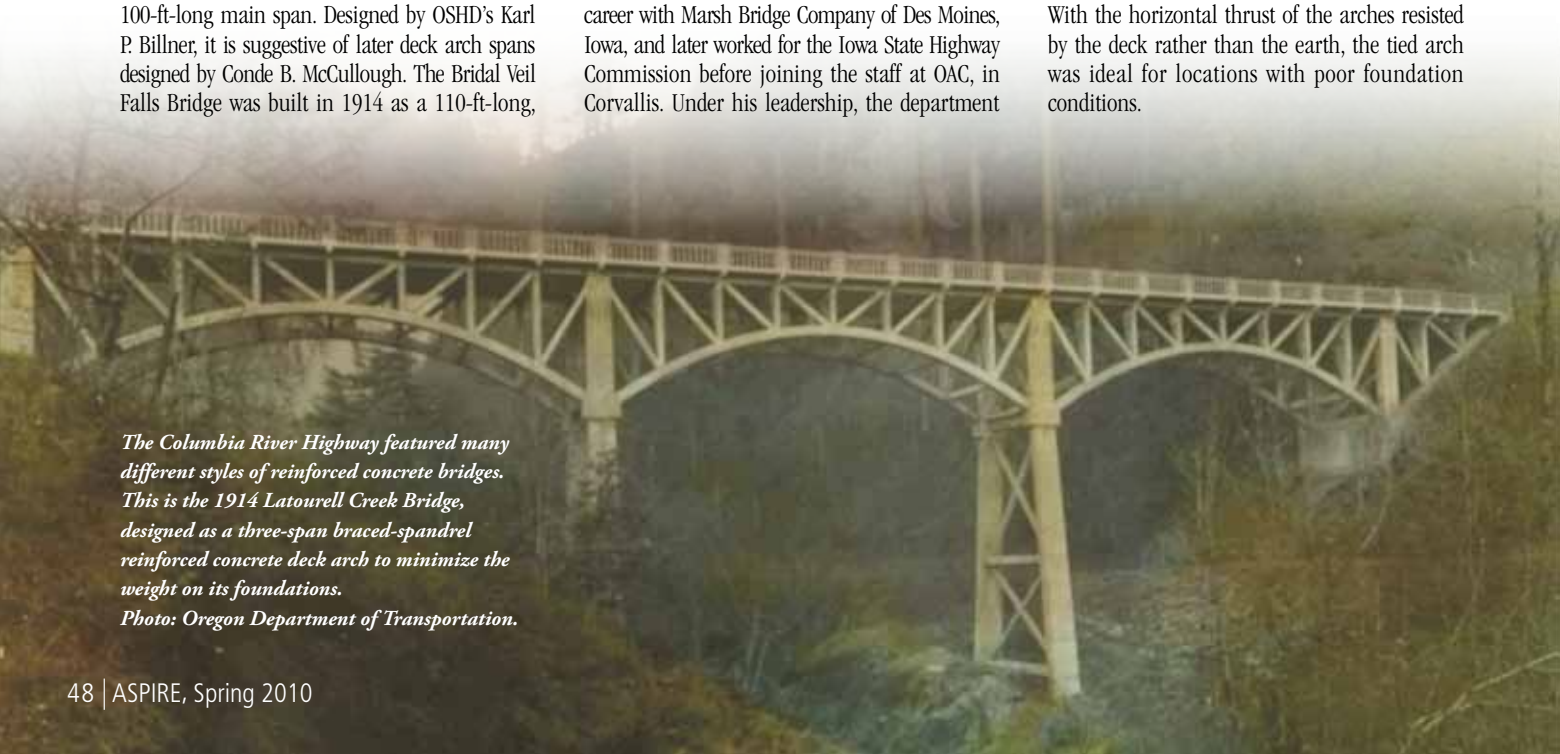
Reinforced concrete became widely recognized as a long-lasting bridge material after the first reinforced concrete bridge was built in the United States in 1889. There is some record of small reinforced concrete bridges and box culverts built in Oregon before 1900, with several still in use. The use of reinforced concrete was greatly accelerated by the 1913 formation of the Oregon State Highway Department (OSHD) by the Legislative Assembly. One of the OSHD's first major projects was the construction of the Columbia River Highway from 1913 to 1922. Championed by railroad executive Sam Hill from neighboring Washington, the rugged terrain of the new highway alignment, with its many waterfalls and streams, required numerous bridges. All of these structures were designed in reinforced concrete and most complement the stunning scenic beauty of their locations.

The Shepperd's Dell Bridge was built in 1914 as a 150-ft-long reinforced concrete deck arch with a 100-ft-long main span. Designed by OSHD's Karl P. Billner, it is suggestive of later deck arch spans designed by Conde B. McCullough. The Bridal Veil Falls Bridge was built in 1914 as a 110-ft-long, three-span reinforced concrete through-girder, designed by Billner. The need to span both the falls and a lumber flume require a design whereby the parapet rails were actually the stiffening girders and carried the loads. The Latourell Creek Bridge was built in 1914. It featured a 312-ft-long, braced-spandrel reinforced concrete deck arch with three 80-ft-long main spans and short approaches at each end. Billner followed the principles of French bridge expert Armand Considère. This resulted in a lightweight structure to accommodate poor foundation conditions. The Moffett Creek Bridge was built in 1915 as a 205-ft-long reinforced concrete deck arch with only 17 ft of rise in the 170-ft-long main span. Designed by OSHD's Lewis W. Metzger, it was the longest span, three-hinged, reinforced concrete arch in the United States at the time, with only one longer on record in Germany.

In 1917, a major initiative for "getting Oregon out of the mud" was started with legislative approval of a $6 million highway construction bond issue. In 1919, the lawmakers increased the bond amount by $10 million, instituted the nations' first gasoline tax of 1 cent per gallon dedicated to highway funding, and submitted a referendum to create a military highway along the Pacific coast. On April 9, 1919, OSHD hired the head of the Oregon Agricultural College (OAC) civil engineering program, Conde B. McCullough, to be the Oregon State Bridge Engineer. McCullough was an Iowa State College graduate, who had begun his career with Marsh Bridge Company of Des Moines, Iowa, and later worked for the Iowa State Highway Commission before joining the staff at OAC, in Corvallis. Under his leadership, the department constructed an impressive collection of reinforced concrete bridges throughout the state. His reinforced concrete deck arches and tied arches are well known for their elegant architectural qualities in harmony with their natural settings, and heavy load capacity. In addition, many reinforced concrete deck girder (RCDG) bridges were constructed for spans up to 50 ft. Reinforced concrete slab bridges and box culverts were used where suitable.

The 1920s

Beginning in the late 1920s, McCullough adopted several practices to control cracking in his arch bridge designs. One was to use the "Considère hinges" to reduce built-in bending stresses in the arch ribs. The hinges were hourglass-shaped articulation points that reduced built-in bending stresses in the arch ribs during construction. They were welded and encased in concrete once the dead load was applied to the arch. Another such practice involved the hangers that suspend the deck from the arch ribs on tied arches. The steel reinforcement of the hangers was placed, but the concrete was delayed until after the dead load was applied to the arch. By doing this, the concrete was not subject to tensile strain caused by the dead load. In bridges such as the Wilson River Bridge at Tillamook in 1931, these practices helped McCullough pioneer the use of reinforced concrete for tied arch structures. With the horizontal thrust of the arches resisted by the deck rather than the earth, the tied arch was ideal for locations with poor foundation conditions.



The Columbia River Highway featured many different styles of reinforced concrete bridges. This is the 1914 Latourell Creek Bridge, designed as a three-span braced-spandrel reinforced concrete deck arch to minimize the weight on its foundations.
Photo: Oregon Department of Transportation.

The 1930s

In 1931 and 1932, McCullough experimented with the principles of Eugène Freyssinet during construction of the Rogue River Bridge at Gold Beach, on the Oregon Coast Highway. In the Freyssinet method of concrete arch construction, a short section of the arch ribs was left open at the crown, then jacks placed in the openings were used to lift the halves of the arch ribs away from each other just enough to compensate for creep and shrinkage, dead load shortening, and temperature stresses. After jacking, the reinforcement from each arch halve was connected and the crown of the arch closed with a final concrete placement. The result was a slender arch design and the first U.S. application of the Freyssinet method, a precursor to modern prestressed and post-tensioned structures.

In 1934 through 1936, a massive Public Works Administration (PWA) project was undertaken to build five major bridges to replace ferries on coastal bay and river crossings. Structures were built across Yaquina Bay at Newport, the Siuslaw River at Florence, the Umpqua River at Reedsport, Coos Bay at North Bend, and Alsea Bay at Waldport. McCullough and his staff designed these structures in 6 months, working two shifts per day. Total cost was $5,400,000. The 3260-ft-long Yaquina Bay Bridge has three steel arch spans over the marine channel, five reinforced concrete deck arch spans south of the main spans, and RCDG approach spans. The 1568-ft-long Siuslaw River Bridge has a steel bascule movable span over the marine channel, one reinforced concrete tied arch span on each side of the main span, and RCDG approach spans. The 2206-ft-long Umpqua River Bridge has a steel swing movable span over the marine channel, two reinforced concrete tied arch spans on each side of the main span, and RCDG approach spans. The 5305-ft-long Coos Bay Bridge has a steel cantilever span over the marine channel, six reinforced concrete deck arch spans south of the main span, seven reinforced concrete deck arch spans north of the main span, and RCDG approach spans. The 3028-ft-long Alsea Bay Bridge had three reinforced concrete tied arch spans over the marine channel, three-reinforced concrete deck arch spans each side of the main spans, and RCDG approach spans. This bridge was replaced in 1991 as a result of extensive corrosion damage. Due to public outcry at the loss of the community's icon, a cathodic protection program was developed to protect the remaining structures.

After the McCullough era ended in 1936 and through the 1950s, most construction was RCDG and slab type bridges. The design philosophy of this time was to produce the most economical structure that met the design codes of the day, with less attention paid to aesthetics. While economical designs stretched construction funds, a long-term consequence was that these bridges typically were not serviceable enough when actual live loads began to increase. As a result, bridge inspectors began finding structural cracks wider than 0.025 in., which spurred the Oregon Legislature in 2001 and 2003 to fund the Oregon Transportation Investment Acts (OTIA I, OTIA II, and OTIA III), investing $3.132 billion in roads and bridges and replacing or repairing nearly 500 bridges. (See Winter 2008 issue of *ASPIRE*.™)

The 1950s and Beyond

In 1954, OSHD prestressed concrete beam designs were used to build Willow Creek Bridge with three 98-ft-long spans on the Columbia River Highway near Arlington and the 93-ft-long span Haines Road Undercrossing in Tigard. Using concrete compressive strengths of 5000 psi and prestressing strand of 7/16-in.-diameter prestressing strands with an ultimate tensile strength (UTS) of 200 ksi allowed considerably longer spans than with 40 ksi yield strength reinforcement. Also in 1954, a Bureau of Public Roads design for a 60-ft span precast concrete beam, post-tensioned before placement, was used to build Ten Mile Creek Bridge on the Oregon Coast Highway near Lakeside in Coos County.

The 1966 Columbia River Bridge at Astoria includes a 2.1-mile-long section of 80-ft-span AASHO Type III precast, prestressed concrete girder construction in the shallow middle of the river, shown here during construction. The south approach of the bridge also includes a 1095-ft-long section of AASHO Type II and Type III precast, prestressed concrete girder construction. The bridge was built jointly by the states of Oregon and Washington.

OSHD produced standard drawing designs when different types of sections reached common usage. These standards included American Association of State Highway Officials (AASHO) Type II, III, IV, and V precast girders by 1957, hollow precast slabs by 1962, bulb-tee girders in 1966, channel beams in 1967, and box beams in 1986. The bulb-tee girder design was updated in 1984 to provide optimized "tee" and "I" girders, which have largely replaced the AASHO sections. By 1959, 7/16-in.-diameter prestressing strand with 270 ksi UTS was common, and by 1966, ½-in.-diameter strand was in use. Currently, standard designs are available for girders that can span up to 183 ft, making use of 0.6-in.-diameter strand.

In 1970, OSHD built eight cast-in-place, post-tensioned concrete box girder bridges and one combination cast-in-place, post-tensioned box girder and spliced, post-tensioned precast girder beam bridge.

The 1982 Glenn L. Jackson Memorial Bridge over the Columbia River at Portland was designed partly by Sverdrup and Parcel and Associates and

The 1932 Rogue River Bridge at Gold Beach was the first U.S. application of the Freyssinet method of reinforced concrete arch bridge construction, which introduced stress into the partially cured arch ribs. It was a precursor to modern post-tensioned concrete construction.
Photo: Oregon Department of Transportation.

partly by OSHD, and funded jointly by the states of Oregon and Washington. It is partly a cast-in-place, post-tensioned, segmental concrete box girder and partly a precast, post-tensioned, segmental box girder bridge. The 11,750-ft-long structure boasted a 600-ft clear span over the navigation channel.

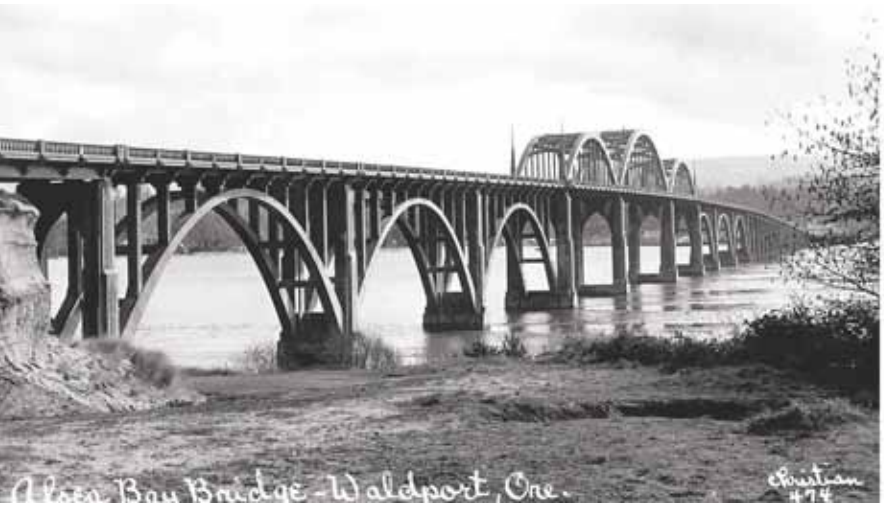
During the last decade, two precast concrete segmental post-tensioned deck arch bridges have been built along the Oregon Coast, Cook's Chasm Bridge near Yachats with a 126-ft-long main span and Spencer Creek Bridge near Newport with a 140-ft-long main span. (For more information on this project, see the Winter 2010 issue of *ASPIRE*.)

For a century, Oregon has played an active role in the evolution of concrete bridge design and construction. In 1913, construction of the scenic Columbia River Highway began, relying heavily on reinforced concrete structures to span the many streams, chasms, and mountainsides of the Columbia Gorge. From 1919 to 1936, the renowned concrete arch expert, Conde B. McCullough, headed the OSHD Bridge Section and produced many beautiful bridges that are still in service today. During the past decade, there was a tremendous amount of prestressed concrete girder construction as the state updated many major freeway structures. All of these things point to a future that makes extensive use of both reinforced and prestressed concrete and could include longer span concrete structures, incorporation of a larger variety of precast components, additional aesthetic solutions, and more preservation work so that future generations can enjoy Oregon's bridge heritage.

Ray Bottenberg is senior corrosion engineer with the Oregon Department of Transportation in Salem, Ore.

Seen from the north, the 1982 Glenn L. Jackson Memorial Bridge across the Columbia River at Portland was touted as the "first of a new generation of large segmental bridges."
Photo: Oregon Department of Transportation.

The Cape Creek Bridge on the Oregon Coast Highway is a 619-ft-long, two-tiered reinforced concrete arch inspired by the Roman aquaduct near Nimes, France. The bridge, completed in 1932, is still in use today.
Photo: Henry G. Russell.



The 1936 Alsea Bay Bridge, shown on left, at Waldport was one of five bridges built simultaneously under a large Public Works Administration project that eliminated five ferries along the Oregon Coast Highway. Designed by Conde B. McCullough and his staff to complement their natural settings, all five bridges included reinforced concrete arches. The Alsea Bay Bridge was replaced in 1991 with a new bridge, shown on right, that features post-tensioned concrete box-girder approaches.
Photos: Oregon Department of Transportation.

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Angeles Crest Bridge No. 1, Wrightwood, Calif.
Photo courtesy of Tindall

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Institutes Offer Reliable Certification

by Craig A. Shutt

Available certification programs have increased, as owners and designers seek to qualify individuals, suppliers, and contractors. But not all "certification" programs offer the same value. There are many reasons. Some lack experience or depth in the research and documentation to support their standards and procedures. Some auditors have limited experience and insufficient background with the industry. Specifying and adopting certification programs that are well tested and long used in the field provide the best results for owners, designers, contractors, and users.

The following certifying organizations provide consensus standards and procedures that have been tested over time and proven to provide owners and designers with the consistent results they desire:

American Concrete Institute

ACI offers 17 certification programs that create minimum competency standards for personnel in various areas of concrete production and application.

The programs focus on seven key areas: Aggregate Technician, Craftsman, Field Technician, Inspector, Laboratory Technician, Shotcrete Nozzleman, and Tilt-Up Supervisor and Technician. To learn more, visit www.concrete.org/certification.

American Segmental Bridge Institute

ASBI provides Grouting Certification training for supervisors and inspectors of grouting operations for post-tensioned structures. The training consists of a 2-day program generally conducted in Austin, Tex. ASBI certifies personnel for a period of 5 years before recertification is required.

A growing number of states require construction managers and contractors to employ an ASBI-qualified grouting technician to perform or inspect grouting procedures. The course also provides 12 hours of professional development hours for professional engineering registration requirements. For details, visit www.asbi-asssoc.org/grouting.

Concrete Reinforcing Steel Institute

CRSI through its Epoxy Interest Group offers voluntary certification for plants producing fusion-bonded, epoxy-coated reinforcement, dowels, and accessories for the fabrication of these products. The program's goals are to ensure that the certified plant and its employees are trained, equipped, and capable of producing high-quality, epoxy-coated products for use in concrete.

Inspections are performed unannounced at least once each year by a third-party testing agency. In addition, plants are selected at random to receive a second unannounced inspection. For details, visit www.crsi.org.

National Ready Mixed Concrete Association

NRMCA offers certifications for both ready mixed concrete industry facilities and personnel. Certifications provide customers and regulatory agencies that certified producers have an understanding of and support measures to provide the highest quality ready mixed concrete in the safest and most efficient ways possible.

In addition to Plant, Truck, and Environmental Certifications, NRMCA offers 10 personnel training and certification programs. More information is available at http://www.nrmca.org/certifications.

Precast/Prestressed Concrete Institute

PCI provides both Plant Certification and Personnel Certification related to prefabricated concrete components. Plant Certification ensures that fabricators have approved in-depth documentation of their quality system. Each plant must comply with rigorous national standards for quality control and production. Every plant undergoes not less than two unannounced audits each year conducted by accredited third-party engineers.

PCI's Plant Quality Personnel Certification Program provides instruction and evaluation for three levels of trained and certified quality-control personnel. PCI also trains Certified Field Auditors (CFAs) and Certified Company Auditors (CCAs) to inspect and certify precast concrete erectors. PCI Plant Certification requires certified personnel in each plant. For details, visit www.pci.org and click on PCI Certification.

Post-Tensioning Institute

PTI offers Plant and Field-Personnel Certification programs that ensure post-tensioning materials, products, and services meet a consensus standard of quality. PTI's programs are recognized and required throughout North America.

The programs include certification for plants producing unbonded post-tensioning materials, which comprise unbonded single-strand tendons and prestressed concrete strands. They also certify a variety of field personnel. For details, visit www.post-tensioning.org and click on Certification.

The programs of these organizations are accompanied by state-of-the-art training. They facilitate rigorous feed-back procedures to revise and refine standards that ensure that products and procedures meet the industry's evolving standards for quality. They complete the circle of continuous quality improvement.

The Bridge Replacement Program of Grant County, Washington

by Derek Pohle, Grant County, Ephrata, Wash.

Grant County is located in the center of Washington State in the upper Columbia River Basin. The county is dominated by irrigated and dry land agriculture, much of it served by the United States Bureau of Reclamation (USBR) Columbia Basin Reclamation Project. Most of Grant County's bridges were originally built by the USBR and subsequently turned over to the county. These bridges were typically timber superstructures supported by concrete substructures. Grant County owns over 250 bridges ranging in length from less than 20 ft to 313 ft. Some 145 of these bridges have concrete superstructures.

All of the original bridges that have been replaced used concrete bridge elements. The county typically uses single-span, prestressed concrete deck bulb tees or deck precast concrete units with multiple webs that are designed for asphalt overlays. "Deck" girders have a structural deck cast monolithically with the girder and require no additional deck casting in the field. Generally, Central Pre-Mix Prestress Inc., located in Spokane, Wash., supplies our girders. Grant County together with the Federal Bridge Replacement Program and local dollars fund the replacement bridges over 20 ft long. Replacements under 20 ft long use local funds. Grant County chooses concrete for ease of construction, extended service life, durability, and ease of maintenance and inspection.

During the 2007-2008 construction season, the county replaced the Crescent Bar Bridge, which is the only link to Crescent Bar Island on the Columbia River at Trinidad. The bridge had to be constructed during the Salmonid fish window of November through February. The bridge was replaced in halves to allow traffic to be maintained to the island. The old steel beam and wood deck structure was replaced by a 130-ft-long, single-span, prestressed concrete deck bulb-tee bridge. Using concrete allowed the unique timing and construction constraints of this project to be met.

In 2008, the county replaced Br. No. 118 where Road F-NE crosses the USBR Main Canal. Road F-NE serves a remote area in the north-central portion of the county. The original structure was a surplus U.S. Army steel Bailey bridge that the county over time needed to restrict to a 5-ton capacity. The Bailey bridge was replaced with a 148-ft-long, single-span, prestressed concrete deck bulb-tee bridge. The span length and the clear span requirement over the canal made concrete an ideal choice.

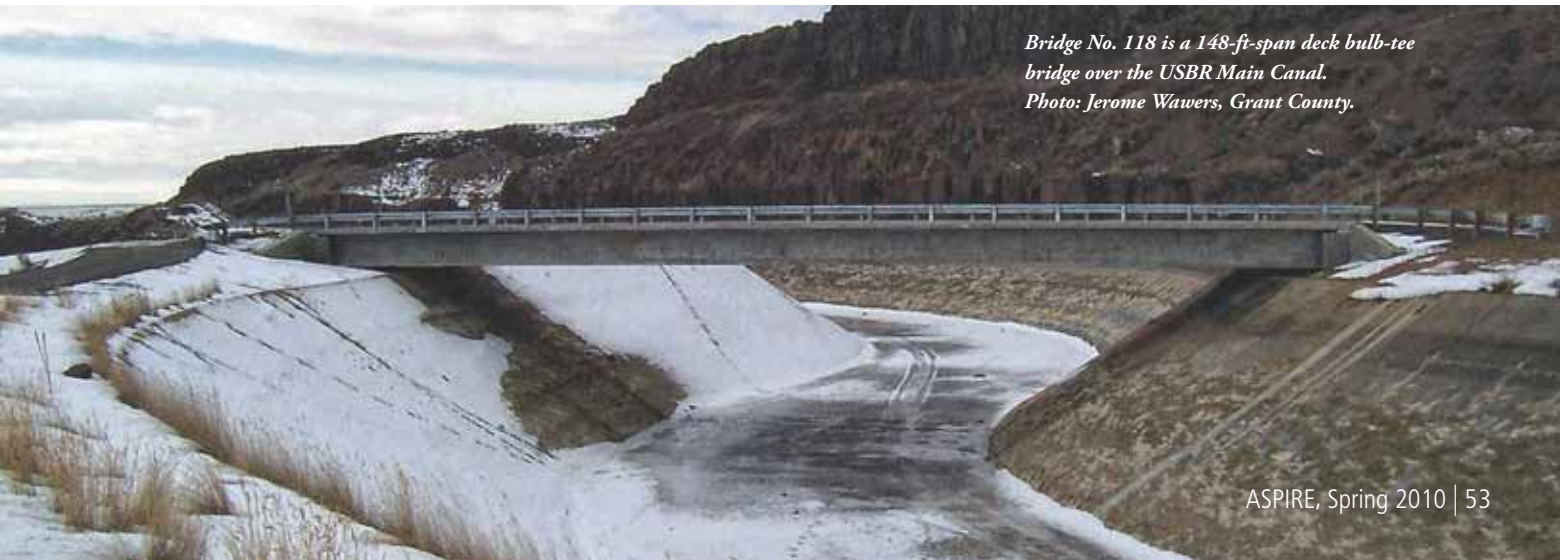
During 2009 and 2010, the county replaced Br No. 244 where Road 3-NE crosses the USBR East Low Canal. Road 3-NE (Wheeler Road) serves the Wheeler corridor; the most commercially and industrially developed area of Grant County, just east of Moses Lake. The existing five-span structure experienced deterioration and was selected for replacement. The study also determined a single-span concrete structure was the most economical and easiest to construct. The county was resigned to replace the bridge using its own funds and had started the design when funding became available from the American Recovery and Reinvestment Act (ARRA). The bridge was replaced with a 165-ft-long, skewed, single-span, prestressed concrete deck bulb-tee bridge. These girders are believed to be the longest single-cast girders of this type in Washington State.

Grant County formed a dedicated bridge maintenance crew in 2002. Due to their inspired hard work, the condition of our bridges has improved significantly, especially our remaining timber bridges. This has caused us some unexpected consternation as now only one of our bridges qualifies for replacement funding. We look forward however to continuing replacement of our timber system with concrete. Concrete offers us the best value for our investment.

The Crescent Bar Bridge over the Columbia River is a 130-ft-long, single-span, prestressed concrete deck bulb-tee bridge shown here during girder placement. Photo: Jeff Tincher, Grant County.

The Wheeler Road Bridge No. 244 was a five span structure replaced in February 2010 with a 165-ft-long single-span deck bulb-tee girder. Photo: Larry Maine, Grant County.

Derek Pohle is director of public works/ county road engineer, Grant County Public Works, Ephrata, Wash.



Bridge No. 118 is a 148-ft-span deck bulb-tee bridge over the USBR Main Canal. Photo: Jerome Wawers, Grant County.

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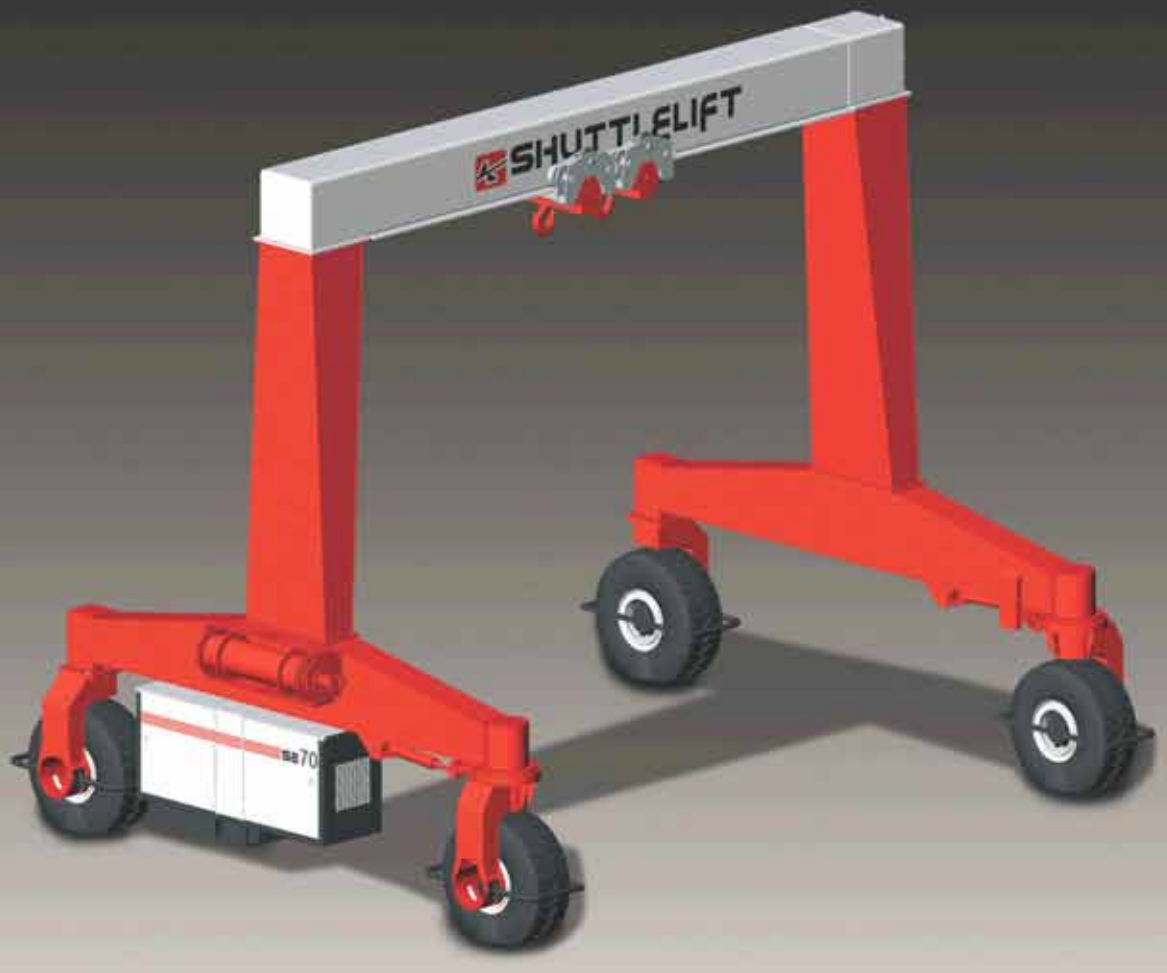

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2010 Interim Revisions Related to Concrete Structures Part 1

by Dr. Dennis R. Mertz

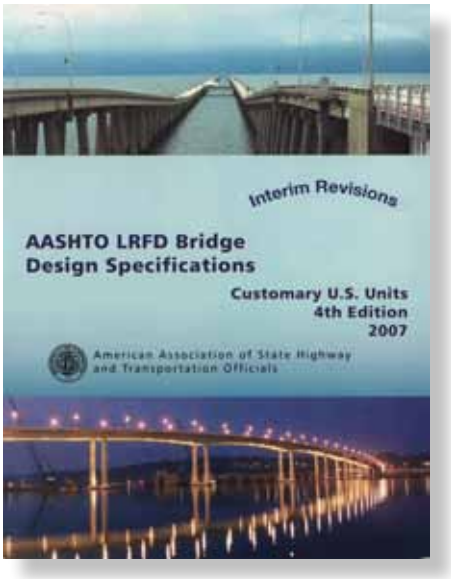
At their annual meeting in New Orleans, La., in July 2009, the American Association of State Highway and Transportation Officials (AASHTO) Subcommittee on Bridges and Structures (SCOBS) considered and adopted five agenda items specifically related to concrete structures. Technical Committee T-10, Concrete Design, developed Agenda Items 9, 10, 12, 14, and 15 over the past several years and moved them to the subcommittee ballot for consideration in New Orleans. The agenda items represent revisions and additions to the AASHTO *LRFD Bridge Design Specifications*. These agenda items along with the complete list of items for the recent SCOBS meeting can be found on the AASHTO website at http://cms.transportation.org/?siteid=34&pageid=1484. This article and the article in the next issue will review the 2009 concrete-structures agenda items, which will become the 2010 interim revisions.

Agenda Item 9 makes revisions and additions to Article 5.14.2 for segmental construction. Segmental construction equipment loads were previously defined by the two-letter abbreviation, CE. This was in conflict with the use of CE as the abbreviation for centrifugal loads in Section 3, Loads and Load Factors. For clarity, segmental construction equipment loads are now defined by the three-letter abbreviation, CEQ, in Article 5.14.2.3.2.

Reference to Types A and B joints has been removed from Article 5.14.2.3.3. These references are no longer needed since dry joints (Type B) were eliminated from the specifications. In addition, clarification is provided for Table 5.14.2.3.3-1 indicating that the table applies to vertically post-tensioned substructures, not to cast-in-place substructures supporting segmental superstructures.

The load combinations required at the strength limit state during construction are clarified through revisions to Article 5.14.2.3.4. Wind loads, WS, critical to the design of columns especially prior to span closure, were not explicitly required in Article 5.14.2.3.4. This revision explicitly requires the general load combinations of Table 3.4.1-1 including wind loads be used for design of substructures of post-tensioned segmental bridges. Finally, the proper provisions for the design of segmental bridge substructures and nonsegmentally constructed substructures are cited.

Agenda Item 10. In the 2005 interim revisions to the *LRFD Specifications*, Article 5.8.2.6 was revised to be consistent with the AASHTO *Standard Specifications for Highway Bridges* with regard to the use of longitudinal bent bars as transverse reinforcement. The revisions did not include all the associated provisions from the *Standard Specifications* governing bent-up bars. Agenda Item 10 includes those provisions required to complete the revision.



Agenda Item 12 revises Article 5.9.5.3 relating to the approximate estimate of time-dependent losses in prestressed concrete members. Table 5.9.5.3-1 has been deleted from the specifications. This action was taken because the approximate estimate of time-dependent losses shown in the table did not conform to the ones calculated using the newer refined estimate of time-dependent losses of Article 5.9.5.4. In addition, clarification is provided as to when the application of the equations of Article 5.9.5.3, the approximate estimate, is appropriate and when the refined estimates of Article 5.9.5.4 are required.

The additions and revisions represented by Agenda Items 14 and 15 will be reviewed and discussed in the next issue of *ASPIRE*.™