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THE CONCRETE BRIDGE MAGAZINE

Fall 2009

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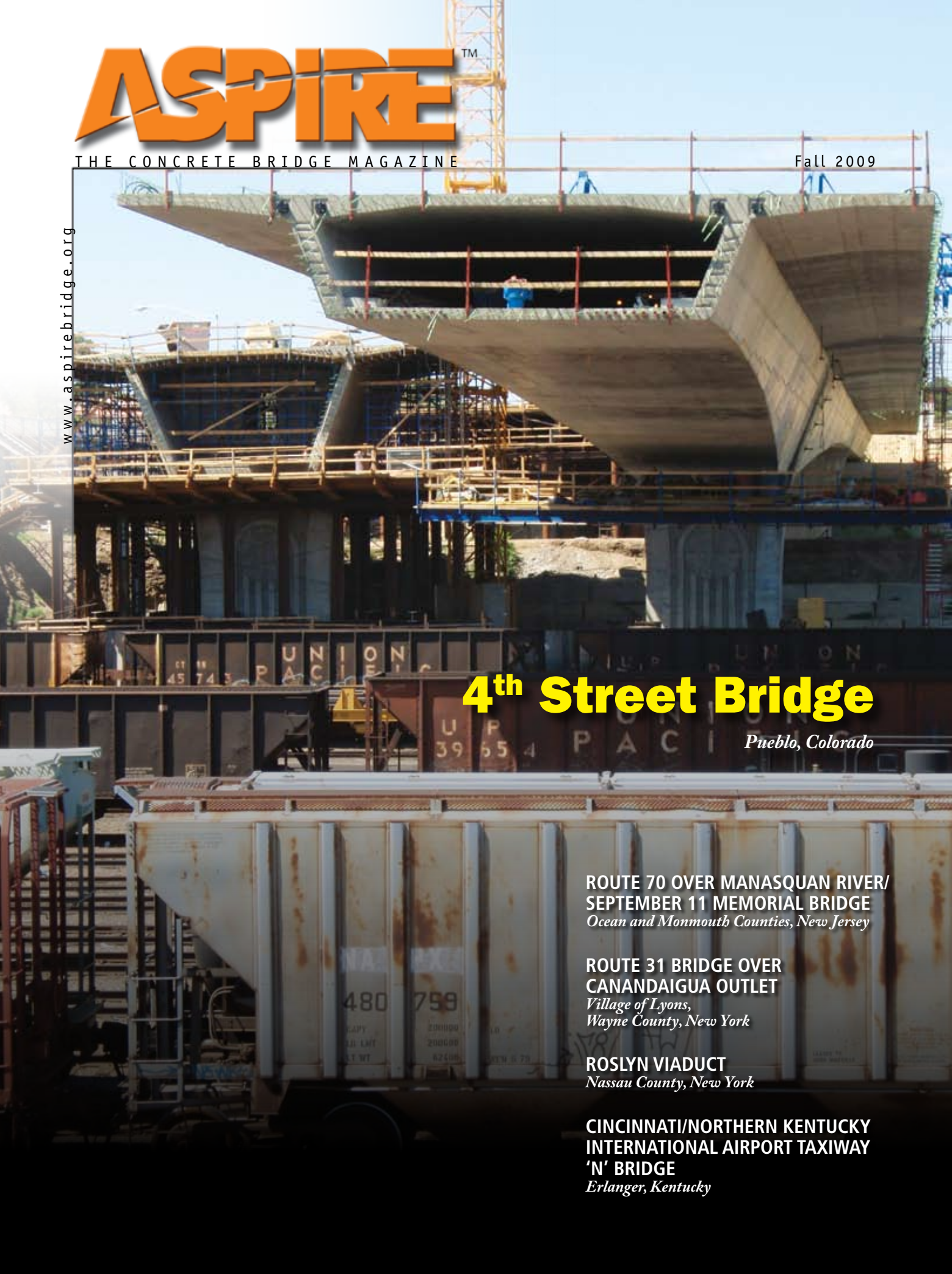

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Pueblo, Colorado

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Ocean and Monmouth Counties, New Jersey

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INSTITUTE CERTIFICATION since 1967

CERTIFICATION RELIES ON A BODY OF KNOWLEDGE AND CONTINUOUS IMPROVEMENT

AASHTO resolution endorses certification programs by technical institutes to ensure that products meet specifications and remain on cutting edge of improvements

By William N. Nickas, P.E., and Dean A. Frank, P.E., Precast/Prestressed Concrete Institute

The American Association of State Highway and Transportation Officials (AASHTO) has released a resolution supporting the specification of components for bridge construction that have been fabricated using certified quality-control and production procedures. The resolution additionally recognizes that a national technical institute is uniquely qualified to develop and deliver certification programs for its specific industry.

The resolution, endorsed by the AASHTO Subcommittee on Bridges & Structures during its recent 2009 general meeting, calls for recognition of "national industry certification programs for personnel, production, and quality control related to fabricated structural bridge components and processes." It cites a number of reasons that technical institutes are the best option to ensure that standards and certification procedures fully engage current research results and state-of-the-art techniques. This body of knowledge, which is constantly evolving, is the foundation of the technical institute and the institute remains its guardian.

The resolution was crafted to address the recent proliferation of "certification" programs, which has caused confusion in the marketplace. Private commercial concerns and groups from other industries have developed inspection programs—often based on standards published by technical institutes—that are touted as certification programs. They have led some specifiers to believe that their certification programs offer procedures and results compatible with certification by the industry technical institute.

The Federal Office of Management and Budget has stated that government agencies are encouraged to reference nonprofit, consensus-based standards and participate with these institutes, rather than create their own requirements. Programs that lack the foundations of strong research, the organization of technical committees to gather consensus, or the ongoing commitment to a continuous improvement process, will fail to meet the standards-development requirements of the American National Standards Institute.

Also, adoption of certification programs outside an industry's nationally recognized technical institute effectively fragments the industry's quality-assurance machinery and isolates groups of fabricators from immediate access to the industry's official, continuously evolving body of knowledge. More than that, new certification programs may create confusion by establishing parallel but inconsistent procedures, references, and benchmarks. An industry must be attuned to one national standard.

As the AASHTO resolution makes clear, technical institutes offer significant benefits that other certifying entities cannot provide (to read the complete resolution, see the sidebar on the following page). Using a certification program is important, it notes, because state departments of transportation above all else must ensure the safety of the construction team and structure users. The resolution further states that the best way to provide such assurance is through "consistency of results and quality"

Certification
Much more than a checklist

Certification programs are much more than checklists used to conduct inspections. Effective, credible certification programs are based on an industry's body of knowledge, from which all related industry standards and state-of-the-art procedures are derived. This body of knowledge tells us what the industry can do with a particular material, product, or system and explains how it can be done reliably. The primary purpose of a certification program is to help ensure that products are manufactured in accordance with specifications and customer expectations. It is therefore critical that certification programs be continuously linked as closely as possible to the source of the industry's body of knowledge: the national technical institute.

Top Photo: Modern prestressed concrete manufacturing facilities require sophisticated industrial engineering capability. (Photo: Northeast Prestressed Products LLC, Cressona, Pa.)

American Association of State Highway and Transportation Officials
The Voice of Transportation
A Resolution of the AASHTO Subcommittee on Bridges and Structures

Whereas, the State Departments of Transportation (DOTs) recognize that it is in the public interest to ensure that fabricated structural components made for highway, transit and pedestrian bridges are manufactured to the high standards to ensure safety through consistency of results and quality; and,

Whereas, the State Departments of Transportation rely on proven certification programs in accepting fabricated structural components, and such certification programs have as their goals: training and evaluation of personnel, evaluation of production and quality control procedures as measured against national industry standards and agency specification requirements; and,

Whereas, it is accepted that nationally recognized technical institutes are comprised of membership representing all segments of bridge stakeholders and develop consensus standards for their industries; sponsor relevant research; draw upon and energize established technical committees; publish technical training, design, and standards manuals; have staff positions held by engineers and subject experts; and qualify and monitor their third-party independent auditors who are trained to provide critical assessment and bring consistency to their work; and,

Whereas, such certification programs have as additional goals, continuous quality improvement, the identification of best practices, the discovery of potential problems and issues and the dissemination of these topics to the entire industry; and,

Whereas, AASHTO bridge design and rating specifications are developed and calibrated to levels of safety provided by the quality inherent to such industry certification programs; and

Whereas, reductions in DOT staff and the wider use of performance-based construction specifications will lead to increased effort to evaluate and assess quality; and,

Now, therefore, be it resolved on the occasion of the 2009 General Meeting of the AASHTO Subcommittee on Bridges and Structures, the members in attendance express their support for and endorse national industry certification programs for personnel, production and quality control related to fabricated structural bridge components and processes.

produced by using procedures and personnel certified by a technical institute.

PRECAST CONCRETE WELL POSITIONED FOR QUALITY

The precast concrete structures industry, in particular, benefits from having a strong, nationally recognized technical institute with a long-standing quality assurance program. The Precast/Prestressed Concrete Institute (PCI) continuously supports, monitors, and incorporates improvements in design methods, materials, mixtures, fabrication techniques, environmental impact, and other factors into its ongoing programs. The PCI Certification program, far from standing alone, is part of a broad quality system that derives from the industry's most comprehensive, up-to-date body of knowledge. This system utilizes the tools of publication, education, and communication to convey this knowledge within the industry. Quite simply, it has no match within the industry it serves.

A worker adjusts reinforcement in a complex 120-in.-deep girder for the Illinois Toll Highway Authority.
(Photo: Prestress Engineering Corporation, Prairie Grove, Ill.)

As the AASHTO resolution makes clear, technical institutes offer significant benefits that other programs cannot provide.

WHITE PAPER OUTLINES ESSENTIAL COMPONENTS

PCI has joined with the American Institute of Steel Construction (AISC) to produce a joint white paper on the clear advantages of a certification program operated by an industry's technical institute, elaborating on and adding to the points specified in AASHTO's resolution. Twelve elements were outlined in the white paper as critical to a successful certification program.

1. **Industry Standing.** Technical institutes serve as the principal body of knowledge within their industries. They facilitate the exchange and encouragement of new ideas and test those concepts across the full spectrum of stakeholders. Their programs are based on decades of experience. As the collaboration between PCI and AISC indicates, they can also join together to assess noncompetitive issues that aid their industries, thanks to the all-encompassing scope of their membership and responsibilities.

2. **Clearly Stated Purpose.** Certification programs run by not-for-profit technical institutes state their purpose and foundation transparently. There is no hidden agenda in their direction, and no individual person or company stands to profit from their programs.

3. **Broad Professional Involvement.** A technical institute's membership and committee participation reflect a diverse mix of industry professionals, including engineers, producers, and academicians, whereas a trade association is generally dominated by a single interest. This diversity ensures that every perspective is considered and best practices are identified. Documents and other knowledge products created by the organization are subject to review by committees representing all interested parties.

4. **Governance & Consensus.** Technical institutes are governed by boards with elected officers and members having no ownership interest. They have formal, consistently applied procedures for making decisions and achieving consensus. This formalized process al-

lows a technical institute to create and apply a comprehensive quality system in a fair and balanced manner that reflects a true consensus of the industry and its professions.

5. **Research.** Technical institutes base their programs on a body of knowledge that includes formal and informal research activities that address current industry challenges, emerging technologies, and innovative practices. These activities are ongoing, and new and improved knowledge is directly applied to the institute's quality programs, in many cases well before being incorporated into published codes and standards. Institutes also monitor and disseminate results from the global independent-research community, keeping the industry up to date on all types of data. The institute's research credibility is evidenced by its ability to attract funding and collaborative assistance from outside sources, including corporations, universities, and other associations. These vetted efforts further expand the available knowledge base and improve the effectiveness of the institute's certification and quality programs.

6. **Validation.** Certification programs developed by technical institutes provide a rigorous review process that includes oversight committees and review panels of experts and stakeholders. Every element is examined and documented to ensure that it helps meet the goal of achieving high quality.

7. **Dissemination.** Technical institutes have access to a wide range of communication media that can immediately alert the industry to concerns, best practices, regulatory issues, and technical matters. They also offer educational programs with qualified instructors to spread new information and explain new developments.

PCI joined with AISC to create a white paper delineating the benefits produced by a certification program operated by a technical institute.

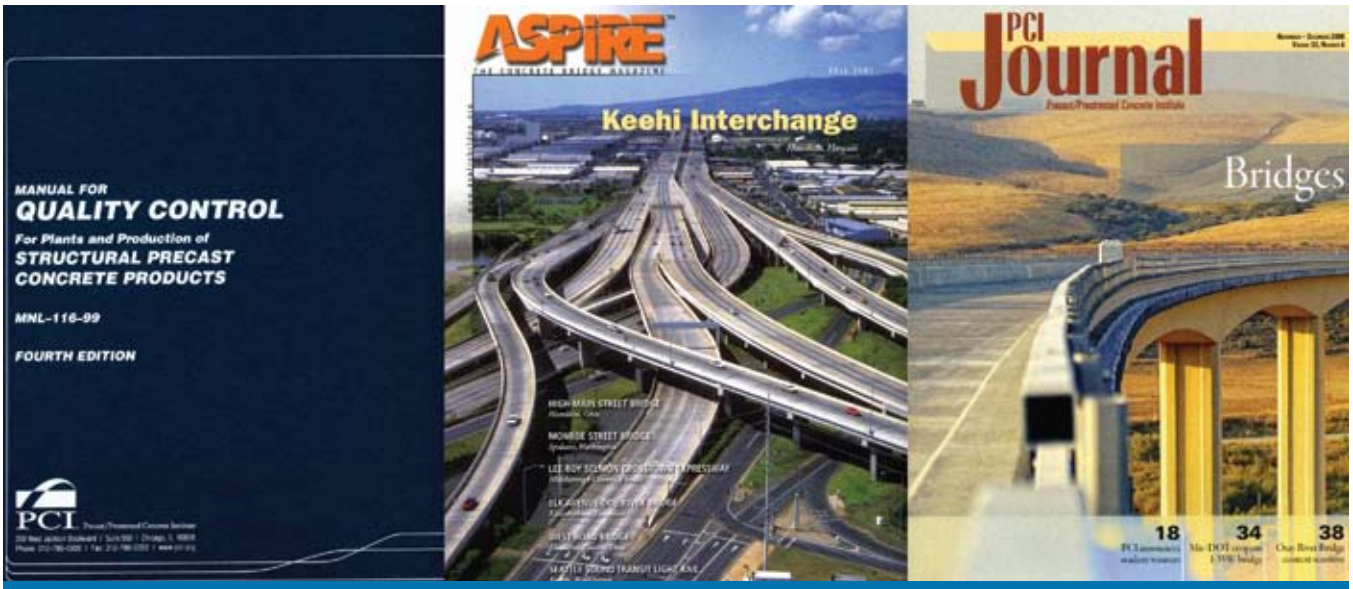
8. **Certification of Personnel.** A comprehensive quality system must validate the competence of the personnel involved with quality control and other key activities. Quality is not an end point but a continuous examination of best practices that improve quality performance consistently over time. A technical institute ensures that both plant personnel and auditors have the capabilities to review project requirements, audit records, interview personnel, and observe practices and equipment to ensure that procedures reinforce the quality mission.

9. **Certification of Fabrication Process.** The primary focus of a manufacturing certification program is to ensure fabrication of high-quality components that meet specifications on a consistent basis. Technical institutes base their inspections on their own promulgated standards, procedures, and research, creating a foundation for inspectors and fabricators to understand the reasoning behind the requirements.

As precast products evolve into more-complex systems, the demands for quality assurance increase accordingly.
(Photo: Summit Engineering Group Inc., Littleton, Colo.)

10. **Independent Audits.** PCI's certification program requires periodic on-site audits by independent, technically qualified, and professionally accredited personnel who have no financial or employment interest in the institute or the fabricators being audited. Auditor-qualification programs verify the quality and effectiveness of the individual auditors themselves, and include periodic training to remain current with evolving quality standards.

11. **Feedback & Recourse.** Technical institutes can take advantage of their



An institute's publications and periodicals are an effective means to provide current information and technology to stakeholders.

Research, Documentation Underlie Best Programs

Research produced and openly disseminated by long-standing technical institutes, which fund and monitor ongoing studies and programs of all types, often serve as the basis for the creation of alternative, static, low-cost, checklist-based programs run by trade associations and for-profit organizations.

This is why code organizations turn to technical institutes when developing their own standards, as the institutes are the source of the critical research that underlies the procedures. For instance, the codification and calibration of the AASHTO LRFD Bridge Design, Construction, and Rating Specifications for fabricated bridge elements relied upon the standards, publications, practices, and personnel certifications noted below, all promulgated by technical institutes:

- American Iron and Steel Institute (AISI) plate standards;
- AISC for best practices and plant certification;
- American Segmental Bridge Institute (ASBI) for best practices and grouting-personnel certification;
- American Concrete Institute (ACI) for best practices and personnel certification;
- ASTM International for materials and test standards;
- American Welding Society (AWS) structural welding code, after-welding distortion tolerances, best practices, and personnel certification;
- Concrete Reinforcing Steel Institute (CRSI) reinforcement dimensions, bending and placement standards, and epoxy coating plant certification;
- PCI for best practices, plant certification, and personnel certification; and
- Post-Tensioning Institute (PTI) for best practices, hardware standards, and personnel certification.

various communication media—including publications, technical conferences, educational programs, and auditor feedback—to gather and immediately apply enhancements to the audit process. A proper certification program includes formal procedures establishing consistent rules under which fabricators must address and/or can dispute identified nonconformances. The goal is to raise the bar on quality on a consistent, continuous basis and ensure that fabricators are accountable for quality, not to grade programs and declare a "winner."

12. **Continuing Commitment.** A vast array of stakeholders provide the foundation for technical institutes, which have provided long-term service to their industries and are supported through a variety of funding sources. This history provides a stable basis for certification programs and ensures that they will remain in place as consistent, continuously improving systems for assessing quality processes.

All of these certification benefits are provided at no expense to the owner and contractor, while creating efficiencies that can save the project time and money. Cost savings for no increase in price produces a return on investment that cannot be matched.

SUMMARY

A reliable certification program cannot stand alone and successfully perform the important function of ensuring quality fabrication of components. It must be part of a comprehensive, continuously improving quality system specific to the engineered components being addressed and directly linked to the body of knowledge.

Commercial firms and other organizations can provide audit services, including preparation of checklists derived from published standards and requirements. Only a technical institute, however, can provide all of the essential components of a comprehensive quality system, intimately connected to the evolving body of knowledge for the industry it serves.

Industry stakeholders and project decision makers must recognize these distinctions and insist that they take advantage of the highest levels of quality assurance and quality control available to them. With their vision and support, technical institutes can build on their strong base and provide the market with consistent, continuously improving programs that ensure that best practices are used throughout the industry. Such systems are the only ones that ensure the highest levels of reliability and ultimate client satisfaction.

William N. Nickas is managing director of transportation systems and Dean A. Frank is director of quality programs at the Precast/Prestressed Concrete Institute, Chicago, Ill.

Certification must be part of a comprehensive, continuously improving quality system specific to the engineered components being addressed.

MORE INFORMATION

To view the AASHTO resolution or the PCI-AISC white paper online, visit www.pci.org and click on the "Quality Systems" icon on the homepage. The resolution and white paper are also available at www.steelbridges.org.

To learn more about PCI quality-assurance programs and certification, visit www.pci.org or contact Dean Frank, PCI director of quality programs, at (312) 583-6770 or dfrank@pci.org. For information regarding AISC certification, contact Brian Raff at (312) 670-7527 or raff@aisc.org.

For general information about precast concrete bridges, contact William Nickas, managing director of transportation systems, at (312) 583-6776 or wnickas@pci.org.

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EDITORIAL

Photo: Ted Lacey Photography.

Performance of Concrete and Market Share

John S. Dick, *Executive Editor*

As *ASPIRE*™ concludes its second year of exploring sustainable solutions, this issue's PERSPECTIVE by Clifford L. Freyermuth offers a challenge to the nation's bridge officials. In it, he addresses the growing durability of bridges and suggests that the American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) begin work to require from 100- to 150-year service lives for highway bridges. Such a goal is noteworthy—and achievable.

Cliff's career has spanned nearly 55 years. His direct involvement in bridges began with the Arizona State Highway Department in 1958. From there on, it was all concrete when, in 1964, he joined the Portland Cement Association. Then, in 1971, he directed post-tensioning activities for the Prestressed Concrete Institute before founding and managing the Post-Tensioning Institute in 1976. In 1989, he helped establish and then managed the American Segmental Bridge Institute through 2008.

He has been instrumental in dealing with many durability and constructability issues that have challenged the prestressed concrete industry since the 1960s. With his unique background, he proposes ways to extend the service life of bridges and advocates the incorporation of minimum service life provisions in the LRFD Specifications. His perspective begins on page 12.

Concrete bridges have an enviable performance record. In the United States, statistics on the condition of bridges are kept in the National Bridge Inventory (NBI) maintained by the FHWA. Generally, high-performance concrete for bridges has been widely adopted over the past two decades. As a result, concrete bridges will perform increasingly well in all likelihood, surpassing expectations. Past performance and suggestions for the future are presented in the Perspective feature mentioned above. Another way to measure performance is through the confidence shown by those designing bridges in the materials they select. The percentage of bridges being built of concrete continues to increase.

Each year, the FHWA compiles data from the NBI (http://www.fhwa.dot.gov/bridge/nbi/matreport2008.cfm). They publish the quantity and deck areas of all bridges built in a given year, by the material of their superstructures. The data are broken down also by federal and non-federal aid highways and are reported by state. Since it takes nearly 2 years for the NBI to receive data for all new bridges built, the latest complete data released this July was for 2006. The data of interest here are for new and replaced bridges. Rehabilitated bridges are not considered.

For the three most recent years, 2004, 2005, and 2006, the percentages of the nation's bridges built using concrete, based on the numbers of projects was 75.8, 76.2, and 75.4, respectively. The balance, of course, is of other materials.

Although the percentage of bridges has remained relatively constant, it appears the size of bridge projects using concrete is growing larger, based on the deck areas of bridges built. For concrete, the percentages for the same years are 67.5, 65.5, and 69.3; a dip then significant growth.

One may also look at the share of bridges built of prestressed concrete. This includes precast, prestressed concrete and all means of prestressing concrete on site such as cast-in-place post-tensioned concrete and all types of segmental concrete construction. The percentages of prestressed concrete bridges built in the past 3 years are by numbers of projects—39.4, 42.5, and 42.9; and by the areas of bridges built—54.8, 55.0, and 60.2. At the same time, in 2006, the number of mildly reinforced concrete bridges exceeded 32% of the total built.

These numbers also likely are understated. A bridge's material in the NBI is determined by the material of the main span. A considerable number of bridges are built with a main span of steel and concrete approach spans. Accounting for these additional areas of concrete construction would most certainly add share for concrete.

Each day, innovative new solutions are being implemented. In this issue, five such projects are featured; each one employs sustainable design concepts. Each project offers ideas to meet a range of challenges. Consider the 24,000 psi compressive strength concrete

(Continued on page 4)

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Publisher:
Precast/Prestressed Concrete Institute,
James G. Toscas, President

POSTMASTER: Send address changes to *ASPIRE*, 209 W. Jackson Blvd., Suite 500, Chicago, IL 60606. Standard postage paid at Chicago, IL, and additional mailing offices.

ASPIRE (Vol. 3, No. 4), ISSN 1935-2093 is published quarterly by the Precast/Prestressed Concrete Institute, 209 W. Jackson Blvd., Suite 500, Chicago, IL 60606.

If you have a project to be considered for *ASPIRE*, send information to *ASPIRE*,
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Cover:
4th Street Bridge, Pueblo, Colorado
Photo: ©FIGG.

Colorado's Longest Concrete Bridge Span

4th Street Bridge, Pueblo, Colorado

OWNER: COLORADO DEPARTMENT OF TRANSPORTATION
DESIGNER: FIGG **CONTRACTOR:** FLATIRON

Construction of Colorado's longest concrete highway span at 378' with twin 1,137' long bridges is scheduled for completion in Spring 2011.

This sustainable, environmentally friendly bridge is being built in concrete segmental, balanced cantilever construction over 28 active rail tracks in the Pueblo Rail Yard and the Arkansas River. The canal wall of the Arkansas River is the world's longest painted mural featuring local artistic expression.

Aesthetics were developed through the FIGG Bridge Design Charette™ process with community members selecting features of the bridge. Participants selected bridge features that blend the timeless lines of Contemporary Sculpture with the Natural River Environment and the stylistic aspects of Pueblo Heritage.

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READER RESPONSE

Editor,
I wanted to share with you a comment I received from our client, Bob Friedenwald, senior advisor, The Confluence Project, regarding the article on the Vancouver Land Bridge [see ASPIRE™ Summer 2009, p. 26]: "Excellent article in ASPIRE on the Land Bridge. Congratulations! You provide a very interesting technical insight that clearly shows the uniqueness of this structure."

I especially enjoyed the Aesthetics Commentary on the Vancouver Land Bridge. I am an admirer of the work that Frank Lloyd Wright completed during his lifetime, and being mentioned in the same paragraph as he, even as a passing reference is a great honor!

Tim Shell
KPFF Consulting Engineers
Portland, Ore.

[Editor's Note: We appreciate Tim's note. Also, we extend to him, his colleagues, and client, a heartfelt apology because we printed the wrong headline on the second page of the project profile (p.27). The correct headline should have read, "CAST-IN-PLACE REINFORCED CONCRETE PEDESTRIAN BRIDGE / CITY OF VANCOUVER, OWNER"]

Editor,
[We received] three copies [of the Summer 2009 issue as requested], just to have enough to go around the office. I ask because [three of us] were in picking up plans from the Arizona Department of Transportation and saw your magazine on a table. We were drawn to the advertisement on the lower half of page 21 in reference to the QuikDeck™ Suspended Access System. We were looking for such a system on a recent project we bid for ADOT.

Ryan Withrow
DBA Construction Inc.
Phoenix, Ariz.

Editor,
I received today the Summer 2009 issue of ASPIRE. I immediately glanced through it. Great issue. The quality and value of the magazine is outstanding. You find new ways to improve upon perfection. Congratulations to [the ASPIRE] team.

I enjoyed thoroughly reading several of the articles. Because of my interest in the condition of the nation's bridges, I paid particular attention to the Perspective article by Andrew Herrmann. When I reached the end of the second page I could not find the continuation of the sentence on the next page! What am I missing?

Basile Rabbat
Portland Cement Association
Skokie, Ill.

[Editor's Note: Dr. Rabbat was not the only one to spot our error. During layout, the final four words of the article were hidden under the graphic that follows the last sentence. Those words were "in the long run," so the last sentence provides wise advice and should have read, "However, if we do not invest now, we will end up paying more in the long run." Our sincere apologizes to author Andrew Herrmann!]

(EDITORIAL continued from page 2)

used in longitudinal joints between deck bulb-tee girders on a small bridge in the Village of Lyons in New York State. Within the joints, No. 6 epoxy-coated bars are developed with a 6-in. lap length and No. 4 epoxy-coated bars are developed with a 4-in. lap length. In laboratory tests, this joint sustained 9 million load cycles without water leakage through the joint. The article begins on page 28. How can such technology be used with adjacent box beams or with precast, full-depth bridge deck panels?

Each owner and designer associated with this issue's articles is acknowledged as a leader in the industry, making wise investments on behalf of the public they serve. These projects are but a small slice of those being built throughout the country, and we will endeavor to continue to bring you the best and most innovative in every issue of *ASPIRE*! We hope you enjoy and benefit from their presentation.

CONTRIBUTING AUTHORS

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. 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.

Clifford L. Freyermuth is principal, Clifford L. Freyermuth Inc. In a career spanning nearly 55 years, he helped found then managed the American Segmental Bridge Institute. Before that, he established and directed the Post-Tensioning Institute. Earlier, he held engineering positions at the Precast/Prestressed Concrete Institute, the Portland Cement Association, and the Arizona Highway Department.

Robert Bini is program coordinator with the FHWA Office of Planning, Environment, and Realty.

MANAGING TECHNICAL EDITOR

Photo: Ted Lacey Photography.

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.

CONCRETE CALENDAR 2009/2010

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

October 25-27, 2009
2009 ASBI 21st Annual Convention
The Hilton Minneapolis Hotel, Minneapolis, Minn.

November 8-12, 2009
ACI Fall Convention
Marriott New Orleans, New Orleans, La.

November 12-13, 2009
Developing a Research Agenda for Transportation Infrastructure Preservation and Renewal
Keck Center of the National Academies, Washington, D.C.

December 14-19, 2009
PCI Quality Control & Assurance Schools, Levels I, II & III
Sheraton Music City Hotel, Nashville, Tenn.

January 10-14, 2010
Transportation Research Board Annual Meeting
Marriott Wardman Park, Omni Shoreham, and Hilton Washington, Washington, D.C.

February 24-26, 2010
NCBC Concrete Bridge Conference
Hyatt Regency, Phoenix, Ariz.

March 21-25, 2010
ACI Spring Convention
Sheraton Hotel, Chicago, Ill.

May 23-27, 2010
AASHTO Subcommittee on Bridges and Structures Annual Meeting
Sacramento, Calif.

May 29 – June 2, 2010
Third International CEB-fib Congress and Exhibition
PCI Annual Convention
PCI-FHWA National Bridge Conference
Gaylord National Resort & Convention Center, National Harbor, Md.

June 6-9, 2010
International Bridge Conference
David L. Lawrence Convention Center, Pittsburgh, Pa.

July 11-15, 2010
5th International Conference on Bridge Maintenance, Safety and Management
International Association for Bridge Maintenance and Safety (IABMAS)
Loews Philadelphia Hotel, Philadelphia, Pa.

September 23-26, 2010
PCI Committee Days
Chicago, Ill.

October 24-28, 2010
ACI Fall Convention
The Westin Convention Center, Pittsburgh, Pa.

Michael Baker Jr. Inc.

ADDS VALUE TO BRIDGE BUDGETS

by Craig A. Shutt

Range of services, including design, inspections, training, and software development, offers perspectives that aid tight budgets

Photo: Shutterstock.

Photo: Michael Baker Jr. Inc.

The recessionary economy has caused bridge owners to tighten their belts and ensure every budget dollar is well spent. That creates challenges for designers and contractors, but Michael Baker Jr. Inc. has positioned itself to overcome those obstacles and give clients a range of options for achieving their goals.

"The bridge environment was considerably different a few years ago," says John Dietrick, bridge technical services manager in Baker's Cleveland, Ohio, office. "State departments of transportation (DOTs) are facing difficult financial challenges, and their interest in other factors, such as sustainability, has, at times, had to be prioritized versus simply getting projects going with a level of financial responsibility. Their goal is to do as much as possible with dwindling resources."

Baker's diverse expertise and services allows it to aid clients in reaching goals while tightening budgets, he says. Its services include not only bridge design, but also inspection and maintenance work, software development, and cost-control initiatives.

"The range of services we offer reflects the diversity of our expertise, and that diversity gives us a good perspective from which to help clients make tough decisions," explains Chris White, a senior bridge engineer in Baker's Houston, Tex., office. "Often, financial realities force agencies to rehabilitate a bridge rather than replace it

'The range of services we offer reflects the diversity of our expertise, and that diversity gives us a good perspective from which to help clients make tough decisions.'

The bridge on Riverdale Road over I-84 in Riverdale, Utah, features a variety of prefabricated components to speed construction, including precast concrete blocks used for abutments, precast concrete columns, bent caps, end diaphragms, noncomposite deck panels, and approach slabs. Photos: Michael Baker Jr. Inc.

and to do so as economically as possible. They all are looking for how they can get more value out of their budgets."

Speed Versus Cost

Continued attention to the deteriorating state of bridges and highways, coupled with money from the stimulus bill for shovel-ready projects, is focusing officials on upgrading their infrastructure in the most cost-effective way possible. "The states want answers to how they can get their most critical structures off the list of structurally deficient bridges as quickly as possible," Dietrick says. "And they want to know what the cost implications of doing it will be."

The cost benefits of rehabilitation are apparent, but the risk of repairing a bridge that will deteriorate in other areas and create more costs concerns owners, Dietrick notes. "To make these difficult decisions, owners need to bring the best ability, knowledge, and tools to bear, especially for complex bridges, such as post-tensioned concrete structures. Baker strives to provide owners with the best possible analysis and modeling skills to be able to analyze bridge designs at every stage of construction, not just at the beginning."

An example of this modeling is the Fulton Road Bridge replacement project in Cleveland, Ohio, (featured in the Spring 2009 *ASPIRE*™). Baker provided preliminary and final design-engineering services for replacing the landmark concrete-arch bridge that spanned Cleveland's MetroParks Zoo. The new bridge features six 210-ft-long reinforced concrete open-spandrel deck arch spans, with concrete approach spans. The design team followed a context-sensitive design process and worked closely with key stakeholders and local community groups.

"The unique use of precast concrete arches presented numerous design challenges, but it worked perfectly to reduce construction time and impact on the zoo," says Dietrick. The arches were cast in three pieces, consisting of two end segments and a crown segment. Temporary towers were constructed, with each tower supporting a precast concrete leg until all three pieces could be post-tensioned.

Cost control also manifests itself in a focus on speed of construction, notes Jim Deschenes, operations manager and senior bridge engineer in Baker's Salt Lake City office. "Accelerated bridge construction is the driver for a lot of our design approach today, and a lot of those designs are using concrete," he says.

An example is the company's design for the bridge on Riverdale Road over I-84 in Riverdale, Utah, which required replacement in conjunction with roadway widening and upgrading the interchange from a diamond to a single-point urban interchange (SPUI). To reduce construction impact to this high-density retail area, the Utah Department of Transportation used several innovative solutions, including multiple prefabricated abutments, columns, bent caps, end diaphragms, noncomposite, full-depth precast concrete deck panels, and approach slabs.

"The SPUI bridge was constructed in phases using almost all prefabricated elements," says Deschenes. The deck panels were placed on neoprene foam strips on the outside of the top flanges of the girders. "This feature greatly accelerated the installation of the deck

The Fulton Road Bridge replacement project required cultural sensitivity to ensure minimal impact to the Cleveland MetroParks Zoo over which it spanned. The design featured six 210-ft-long reinforced concrete open-spandrel deck arches cast in three pieces and assembled on temporary supports.

The Route 52 Causeway project in New Jersey will incorporate precast, prestressed and post-tensioned concrete I-girder spans over each main channel of the 2.8-mile-long continuous bridge.

panels, since shear studs did not have to be installed and grout pockets did not have to be filled," Deschenes explains.

Focus on Constructability

This work also exemplifies Baker's focus on constructability, which can significantly reduce costs, especially the most important one: the final cost after all changes are totaled up. "We commit our senior people to our complex projects to ensure we are looking at the project from the contractor's perspective," says Dietrick. The Fulton Road Bridge involved many constructability factors, including how the arches could be transported within the zoo, how they could be lifted, what crane access existed, and how the construction would impact zoo accessibility.

"You need people who have been through the battles and can see the contractor's needs before a set of plans hits the street," Dietrick says. "If these factors aren't thought through, significant change orders and claims can result, as the contractor adapts to field conditions that weren't considered."

Also aiding their value-engineering approach are software programs they have created, as well as their inspection processes. Baker, in fact, provides training for state inspectors across the country under contract with the Federal Highway Administration and offers design courses in load and resistance factor design to state DOTs through the National Highway Institute. "Being on the ground floor with these programs allows us to better understand our clients' perspective and needs, which ultimately enhances our ability to help them in making decisions," Dietrick says.

These support services can be seen in projects such as the Pomeroy-Mason Bridge connecting Ohio and West Virginia, a cast-in-place concrete cable-stayed bridge that replaced an existing

Aesthetic Impact and Sustainability

Aesthetic considerations are growing in importance as owners receive more feedback from users, John Dietrick of Michael Baker Jr. Inc. notes. "In the past, agencies' decisions were not as influenced by public outreach as they are today. Now, there is much more involvement from the public side, and it creates real challenges to balance all of the needs." It also brings new skills into the mix, he adds. "As engineers, we weren't trained to sell project benefits to the public, but we now have to think in those terms and make presentations that explain the project from the public's perspective."

The public's growing interest in the ramifications of bridges on the community also is generating more interest in minimizing the environmental impact of projects and maximizing sustainable design concepts. "Clients still want sustainability in their projects, but they want it at a reasonable cost," adds White. "With the information we glean from our experience around the country, we can give them the information they need to decide which way to go."

The impact that aesthetics can have can be seen in a design by Baker for the Pennsylvania Department of Transportation for the Hickory Street Bridge in Warren, Pa. The new 500-ft-long crossing of the Allegheny River replicates and replaces an existing concrete-spandrel arch structure. The replacement bridge, consisting of four 129-ft-long prestressed concrete box-girder spans, features aesthetic lighting, architectural railings, and façade panels. It also includes ornamental concrete balustrades and scenic observation alcoves in anticipation of significant pedestrian use. "The aesthetic features of this structure were added at a minimal additional cost to the overall project," says Dietrick.

The Hickory Street Bridge in Warren, Pa., replaced an older concrete spandrel arch bridge with four prestressed box-girder spans that replicated the original look and included period lighting, architectural railings, and façade panels.

'Accelerated bridge construction is the driver for a lot of our design approach today, and a lot of those designs are using concrete.'

steel bridge (for more on this project, see the Summer 2008 *ASPIRE*). The firm's contributions included inspection and documentation, expertise with cable-stayed designs, problem solving during construction, falsework design, schedule monitoring, submittal review, and project closeout. "Partnering techniques and good communication between all the construction team participants allowed us to mitigate and expedite practical solutions to the daily challenges," says Jorge Suarez, technical manager in the Pittsburgh, Pa., office.

To reinforce its commitment to cost-effectiveness, Baker created a program 2 years ago to refine its techniques for cost estimating. Directed by Earl Neiderhiser, a former PennDOT district executive, the initiative is aimed at ensuring cost estimates are as accurate as possible. "We're keeping an eye on cost trends and following data closely to ensure our estimators have the best information available," says Dietrick. "These data are critical to owners, and we don't want to overestimate or underestimate it." The company already is seeing some fruits from that work, he adds, with bids and final costs coming close to original estimates.

Concrete construction has benefited from states' focus on cost control, he notes. "The volatility of pricing, especially with steel, has often directed us more to concrete designs. We have to take a long-term look at costs 3 years from now, when bridges go to bid. Concrete's cost has risen along with everything else, but it has typically been more predictable, and clients need that control."

Lightweight concrete also is being used more often in Utah, particularly because an aggregate supplier is nearby, Deschenes notes. "There's no premium on transportation that other states might have, and we take advantage of it." Texas also has been using lightweight concrete for components, including girders and abutments, notes White. "It goes hand-in-hand with the economic benefits that states are searching for."

Fast Collaboration a Must

Baker's wide expertise and multiple offices ensure there is a range of experience to tap for such complex permitting and design challenges, and that is enhanced with fast communication. "There's a global trend to be more nimble and flexible in today's market," Dietrick notes. "We target key people to collaborate on projects even if they're not in the project's backyard."

This experience aids with many complex projects, such as the proposed Route 52 Causeway between Somers Point and Ocean City, N.J. The project, which evaluated a broad range of alternatives including precast concrete segmental box girders, is approximately 2.8 miles long and replaces four concrete bridges comprising the causeway over Great Egg Harbor Bay. The segmental concrete alternative that was evaluated used span-by-span construction with a 160-ft-long main span over each of the main channels and 140-ft-long spans in other areas. The alternative selected, which is currently under construction, consists of post-tensioned concrete I-girders supported on single-shaft piers or two-column bents with large-diameter piles and suspended footings.

Rather than incorporate bascule bridges into the design, as in the original structure due to low clearance, designers used the shallow profile of the precast components to provide 55-ft underclearance to alleviate this need. The project also includes a two-story visitors' center with a scenic overlook and multiple fishing piers with decorative lighting along their length.

The American Recovery & Reinvestment Act (ARRA) is helping projects that had been shelved receive new consideration, as well as ensuring "shovel-ready" projects get out the door, Dietrick notes. The Utah office is designing three projects that were started as a result of ARRA funds, including two replacement projects that feature cast-in-place designs with lightweight concrete and one using precast concrete full-depth deck panels.

Likewise, the $400-million Central Viaduct project in Cleveland, Ohio, has gotten underway due to stimulus funding. "ARRA has been a real blessing to the state in that regard, because officials have wanted to move forward with this new bridge for a long time," says Dietrick. It's now on track to be advertised in 2010 as a design-build project, with Baker assisting the Ohio Department of Transportation to prepare the design-build package to meet the stimulus-funding deadlines. Ohio has completed other design-build projects, but never this big, he notes.

Other states also are expanding their use of design-build concepts, as they become more open to concepts that will provide fast, economical bridges. "States are taking new concrete concepts more seriously today," says Deschenes. "Before, we'd suggest using spliced-girder technology to stretch the spans, and the DOTs weren't interested—they preferred to build what they knew. Now, the thinking is that if we can save them money, they're open to listening."

"Design-build concepts in particular are opening doors to innovation," says White. "Contractors and designers are looking for an edge and proposing creative ideas that make sense. In a conservative design-bid-build environment, states were reluctant to consider anything but what they had done before. Now, it's more open. And concrete materials offer a lot that can be done to meet these new needs."

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

The I-35W Bridge Replacement in Minneapolis uses a fixed, anti-icing spray technology (FAST) system. The bridge has been designed for a 100-year service life. Photo: FIGG.

by Cliff Freyermuth,
CLF Inc.

Service Life and Sustainability of Concrete Bridges

Some notable concrete bridges have been constructed in the United States in recent years using criteria developed to ensure service life of 100 to 150 years. However, these examples have been limited to a relatively small number of large and exceptional projects. Limited consideration of extended service life in the United States may partially be a result of the lack of an AASHTO specification on this subject. The AASHTO LRFD Specifications[1] provides these definitions:

Service Life—"The period of time that the bridge is expected to be in operation."

Design Life—"Period of time on which the statistical derivation of transient loads is based: 75 years for these Specifications."

Since service life involves consideration of many environmental, design, materials, and construction factors, the LRFD definition of design life obviously does not represent a basis for service life. Accordingly, the AASHTO LRFD Specifications does not recommend any specific time period for service life.

On an international basis, British Standards have required a minimum service life design of 120 years since 1988.[2] This requirement has also been implemented in other parts of the world where British Standards are used. The range of service life criteria internationally is indicated by the 300-year target service life of the Second Gateway Bridge now under construction in Brisbane, Australia, with an 850 ft-long, cast-in-place concrete, balanced cantilever main span. Special serviceability limit state specifications as well as special concrete specifications were developed for the Confederation Bridge between New Brunswick and Prince Edward Island to ensure a minimum service life of 100 years. Service life of 100 years has been used for major bridge and tunnel projects in Europe since the early 1990s.[3] The Oresund Fixed Link between Denmark and Sweden, opened to traffic on July 1, 2000, utilized concrete specifications developed to ensure a service life of 100 years.[4] In 1994, the owner and the consultants for the Oresund Fixed Link established the following as the basis for the concrete specification requirements: "The requirements will be based on well-known technology, and will secure a service life of 100 years with proper maintenance but without any major repair work." For purposes of this discussion, the service life period will be considered to be the time period to be achieved "with proper maintenance but without any major repair work." This would preclude, for example, complete removal and replacement of the bridge deck.

The United Nations defined sustainable development as "meeting the needs of people today without destroying the resources that will be needed by future generations." Increasing the service life of major bridges from 75 to 120 or 150 years "without major repair work" would obviously greatly reduce the resources required for a given installation on an annual basis. From this

The San Francisco-Oakland East Bay Skyway Bridge was designed for a 150-year service life. Photo: Caltrans.

While this article deals primarily with major concrete bridges, extended service life is considered necessary for all bridges to achieve a sustainable bridge infrastructure.

perspective, sustainable development and service life are clearly interrelated.

This article includes discussion of sustainability of concrete bridges in comparison to alternative materials; service life, including comments on life-cycle costs; and concludes with discussion of design options that have been used or have become available recently that might be considered to achieve a service life of 120 to 150 years for major concrete bridges.

While this article deals primarily with major concrete bridges, extended service life is considered necessary for all bridges to achieve a sustainable bridge infrastructure. Different service life levels might be appropriate in an eventual AASHTO specification depending on factors such as initial cost, importance, location, and average daily traffic.

Sustainability

As is the case with all industries in the United States, and in most of the industrialized world, major efforts have been underway for a number of years by the cement and concrete industries to improve the sustainability of concrete construction and concrete products. There have been positive results from this work to date, and the efforts are continuing. From the standpoints of energy consumption and CO_2 emissions, a 1978 study comparing the embodied energy of 5-m-long beams designed to provide equal load capacity[5] provided the following results:

Prestressed Concrete: 2100 kWhth 100%

Reinforced Concrete: 2750 kWhth 130%

Structural Steel: 5460 kWhth 260%

Where kWhth is the thermal energy in kilowatt hours

These results were essentially confirmed by a 2007 life-cycle study.[6] Notwithstanding the significant energy consumption and CO_2 emissions related to concrete bridge construction, these studies indicate that concrete alternatives compare favorably to the primary competitive material on the basis of these important sustainability criteria.

As noted in the introductory comments, the resources required for a given installation are substantially reduced on an annual basis by extending the service life, provided that the service life is achieved without major repairs, or large unexpected maintenance costs.

Service Life

The lack of AASHTO specification provisions concerning the length of service life is an obvious obstacle to the implementation of extended service life for bridge projects in the United States. Development of specific service life recommendations for bridges would probably involve an effort by the AASHTO Subcommittee on Bridges and Structures and the Federal Highway Administration extending over a number of years. On the basis of international practice discussed earlier, service life of 100 to 150 years is considered to be achievable, and has been implemented in the United States on an ad hoc basis by owners of major bridge projects. From the perspective of sustainability of the national bridge infrastructure, continued ad hoc implementation of 100- to 150-year service life for major bridges seems appropriate until AASHTO specifications are developed.

The technology related to factors and mechanisms governing the performance of structures throughout their service lives continues to evolve rapidly.[7,8] The Great Belt Link,[3] developed to provide a service life of 100 years, has been re-evaluated using the technology presented in Reference 8, published in 1999. On this basis, it appears that 150-year service life can be expected.[7]

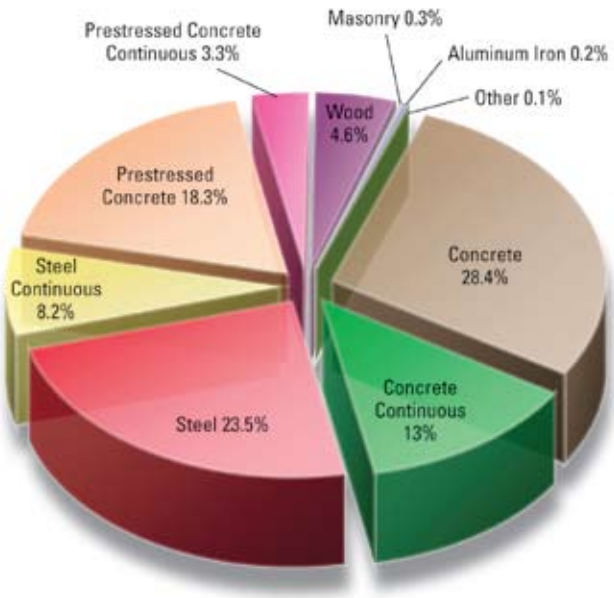

FIGURE 1 - Percentage of bridges in the 2006 National Bridge Inventory by material type. Figure: Brett Pielstick, Eisman & Russo Inc.

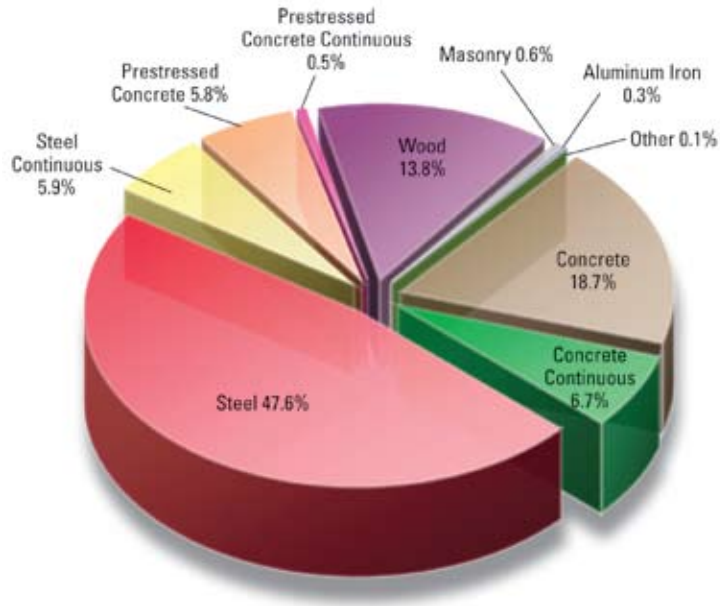

FIGURE 2 - Percentage of structurally deficient bridges in the 2006 National Bridge Inventory by material type. Figure: Brett Pielstick, Eisman & Russo Inc.

Life-Cycle Costs

The four components of life-cycle costs are:

Construction (Owner's cost)

Maintenance (Owner's cost)

Traffic Management (Owner's cost)

Traffic delay costs (Users' costs)

The August 1, 2007, failure of the I-35W Bridge in Minneapolis, Minn., provides an important example of user costs that may be associated with replacement or repair of a major urban bridge, or an important bridge on a "lifeline" highway. In this case, the Minnesota Department of Transportation (DOT) established a user cost related to this failure of $400,000 per day. For the 413-day period that the I-35W Bridge was out of service, the user costs become $165,200,000. The user costs were held at this level in this case only because of the unprecedented achievement of replacing the bridge in an 11-month period. From this perspective, small marginal cost increases that may be associated with design and construction of such bridges to ensure an essentially uninterrupted service life of 150 years are clearly warranted.

The 2006 National Bridge Inventory (NBI) data lists 73,798 bridges (12.35%) as structurally deficient.[9] The 2006 NBI data by material type, and the 2006 structurally deficient bridges by material type are shown in Figs. 1 and 2, respectively.[9] These data are considered to provide an approximate index of maintenance, traffic management, and traffic delay costs for bridges of different material types. The figures indicate that the structural deficiency rate for steel bridges is substantially greater than for concrete bridges. In numerical terms, the structural deficiency rate for steel bridges reflected by the 2006 NBI data is 5.8 times that of prestressed concrete bridges, and 2.7 times that of conventionally reinforced concrete bridges. The most problematic component of life-cycle calculations may be maintenance costs. Nearly all states experience chronic deficiencies in funding available for maintenance. The lack of adequate maintenance funding may be a significant factor contributing to the structural deficiency of bridges. Proper maintenance is essential to achieving extended service life, as well as a sustainable bridge infrastructure. It would be futile to implement procedures intended to achieve 100- to 150-year service life without a related commitment to provide the funding necessary to ensure proper maintenance.

Design Options for Achieving Extended Service Life

Design options that have been used to extend service life include:

1. High-performance concrete (HPC) to reduce permeability.
2. Pretensioning and/or post-tensioning to control or eliminate cracking.
3. Minimizing use of expansion joints and bearings (integral bridges where feasible).
4. Integral deck overlays on precast concrete segmental bridges in aggressive environments.

There are two additional design options that might be considered to further enhance service life and sustainability. These are:

1. Selective use of stainless steel reinforcing (SSR). Several States have used SSR in trial applications, including Oregon, Michigan, Missouri, and New Jersey. Most recently, 100 tons of SSR were used in the decks of the fixed and moveable bascule spans of the Woodrow Wilson Memorial Bridge Replacement by Maryland and Virginia. The bid prices for this application ranged from $2.00/lb to $3.50/lb. The price submitted by the successful bidder was $2.50/lb, a premium of $1.65/lb over the cost of

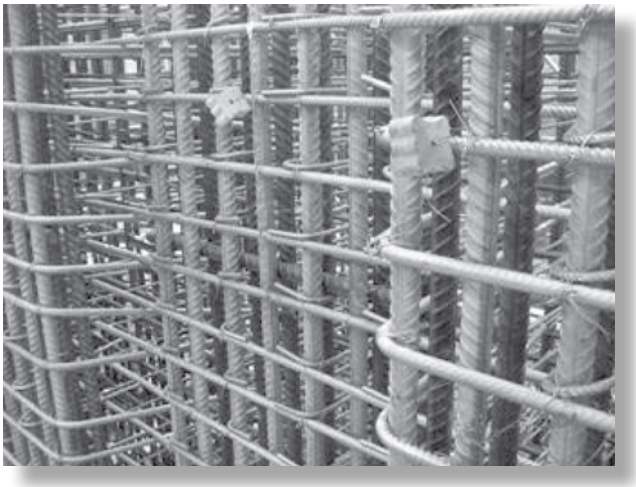

FIGURE 3 - Selective use of stainless steel reinforcement in the pylons in the Stonecutter's Bridge, Hong Kong. Photo: Steen Rostam, COWI, A/S, Denmark.

epoxy-coated bars on the project. Figure 3 illustrates the selective use of SSR in the outer layer of reinforcement of the pylons of the Stonecutters Bridge in Hong Kong.[7]

Selective use of SSR is discussed extensively in Reference 7, which notes that SSR can be used with black steel without causing galvanic corrosion. The use of SSR in the top mat of bridge decks in aggressive environments is considered to be a reasonable expenditure to ensure corrosion-free extended service life of major bridges.[7,10,11]

2. Non-Corrosive de-icing chemicals and fixed anti-icing spray technology (FAST) systems.[12,13]

As of 2005, Reference 12 indicates that FAST systems had been supplied to 11 state DOTs, as well as the Ontario Ministry of Transportation. Minnesota has 10 installations. The most recent application of the FAST system in Minnesota is on the St. Anthony Falls Bridge (I-35W). The deicer on I-35W is potassium acetate, which is understood to be not corrosive to steel, but will attack galvanized coatings. The computer controlled system comprises spray discs spaced every 25 ft in a staggered pattern on the bridge decks and approaches. The Minnesota DOT cautioned,[13] "The long-term effect of FAST systems on bridges may not be known" and, "Potassium acetate can be detrimental to concrete mixes that are susceptible to alkali-silica reaction." Notwithstanding the relatively limited time history of FAST systems on bridges, the possibility of de-icing major bridges with a non-corrosive spray is considered to be very attractive from the standpoint of eliminating the primary factor responsible for generating corrosion of bridge deck reinforcement. Potassium acetate could also be used with truck-mounted delivery systems.

Conclusion

It appears that a paradigm shift is necessary in United States practice to achieve the goals of extended service life and a sustainable bridge infrastructure. Reaching these goals involves incorporating details in the design process necessary for extended service life, as well as providing consistent funding necessary for bridge maintenance. Probabilistic, performance-based durability design of concrete structures is now available.[8] Extended service life of major bridges is recommended even if some marginal increase in initial cost is required. Service life of 150 years is recommended for major urban bridges or bridges on critical highways. Eventually, extended service life is recommended for application to all bridges. Development of an AASHTO specification with specific service life periods would be beneficial to bridge infrastructure sustainability in the United States.

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PROJECT

PUEBLO'S NEW 4TH STREET BRIDGE

Bridge aesthetics selected by the Pueblo community complement the bridge theme, which blends contemporary sculpture, natural environment, and Pueblo heritage. Rendering: © FIGG.

by Karen Rowe, Colorado Department of Transportation, and John Dvorak and Steve Fultz, FIGG

A record-setting concrete segmental bridge for Colorado focused on efficient construction and community involvement

The Colorado Department of Transportation's (CDOT) new 4th Street Bridge in Pueblo, Colo., features twin concrete segmental bridges built utilizing balanced cantilever construction over 28 active rail tracks and the Arkansas River. Bridge construction began in December 2007 and is scheduled to be completed in early 2011.

The existing seven-span 4th Street Bridge opened in 1958 and carries two lanes of traffic in each direction, linking historic downtown with the western residential neighborhoods of Pueblo. The existing bridge consists of a non-composite reinforced concrete deck on steel plate girders, which are supported on concrete multicolumn pier bents. Options to replace and repair the existing bridge were evaluated prior to design, but the condition of the aging substructure drove the decision to replace the existing bridge.

After evaluating several structure types, a concrete segmental solution with long, open spans and a minimal footprint proved to be the best option. Tight yard constraints and closely spaced railroad tracks eliminated conventional structure types, which required expensive track closures and potential track realignments to meet current railroad clearance requirements. According to Dean Sandoval, CDOT project manager for the 4th Street Bridge replacement, "Balanced cantilever construction provided the least impact to the railroads and was the most cost effective."

Using the existing track layout, a 378-ft-long main span over 23 Union Pacific Railroad (UPRR) tracks was developed, which is a record for the longest highway bridge span in the state of Colorado. Once the main-span lengths for the twin bridges were established, the side-spans were proportioned to

profile

4TH STREET BRIDGE / PUEBLO, COLORADO

BRIDGE DESIGN ENGINEER: FIGG, Denver, Colo.
PRIME CONTRACTOR: Flatiron Constructors Inc.—Intermountain Division, Longmont, Colo.
POST-TENSIONING CONTRACTOR: VSL, Grand Prairie, Tex.
CONCRETE SUPPLIER: Transit Mix Inc., Pueblo, Colo.
PIER TABLE AND TRAVELER FORMWORK: DOKA, Los Angeles, Calif.
PIER FORMWORK: EFCO, Phoenix, Ariz.
STEEL REINFORCEMENT: Banner Rebar, Denver, Colo.
POT BEARINGS: DS Brown, North Baltimore, Ohio
MODULAR EXPANSION JOINTS: Watson Bowman Acme, Amherst, N.Y.
POST-TENSIONING GROUT: Sika, Lyndhurst, N.J.

balance the superstructure loads and maintain adequate clearance above the Burlington Northern Santa Fe Railway Company (BNSF) tracks to the east and the Arkansas River to the west. End spans were designed to be cast-in-place concrete on falsework, since ground access is readily available in these locations.

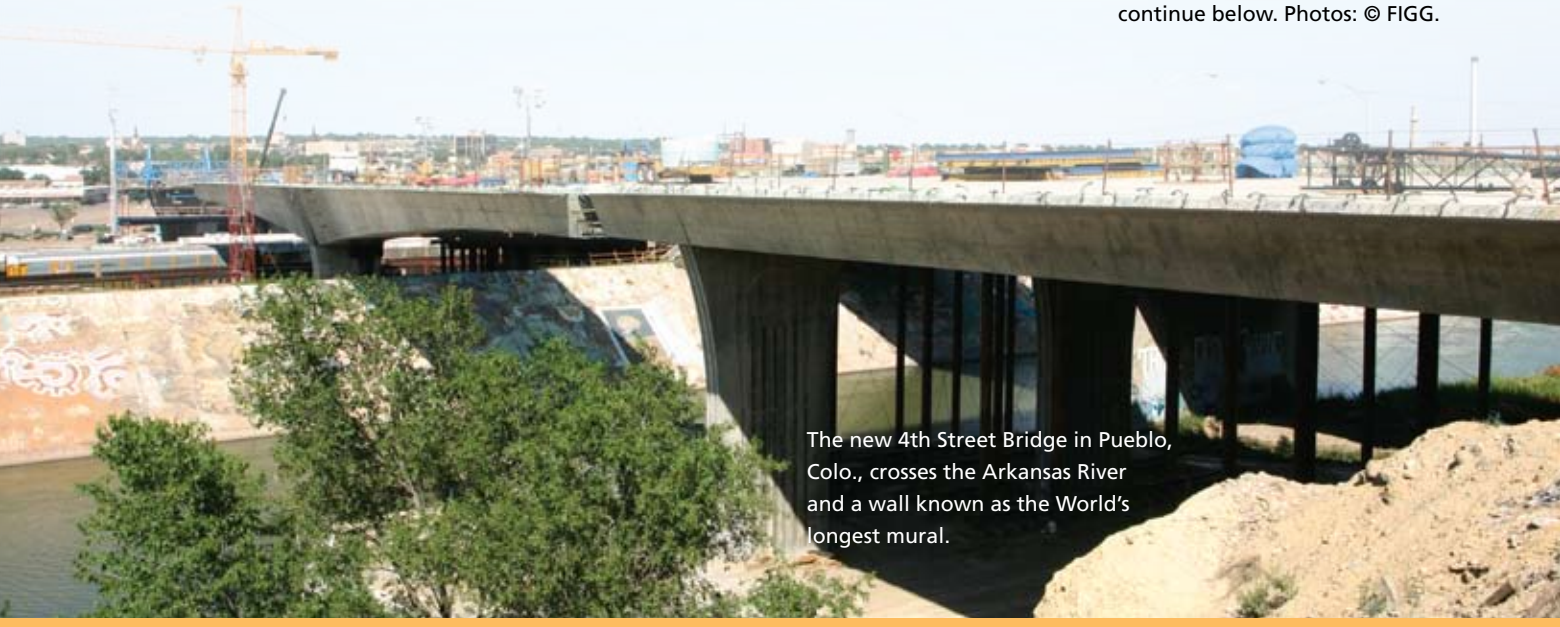
The New Bridge

The new bridge consists of two 1137-ft-long, five-span, single cell, parallel structures for eastbound and westbound traffic with a 6-ft-wide gap between bridges for future access and inspection. The 53-ft-wide variable-depth box girder accommodates two lanes of traffic with 6-ft-wide inside shoulders, 10-ft-wide outside shoulders, and a 10-ft-wide multiuse path for pedestrians and cyclists, with the option for future expansion to three traffic lanes.

The new bridges are parallel to the existing bridge and outside the current alignment, with the exception of the easternmost span of the new eastbound bridge. To keep traffic moving, the westbound bridge is being completed first and all four lanes of traffic will be transferred on to this structure temporarily. Following demolition of the eastern spans of the existing bridge, the new eastbound structure will be completed and traffic reconfigured to the final two lanes per structure.

The cantilevers are 18 ft deep at the main-span piers and decrease to the typical section depth of 8 ft at the end spans, as well as at the center of the main-span. Traveling forms are used to construct the cantilevers in the balanced cantilever construction method from above, allowing for continuous railroad operations. Two cantilevers for each

Form traveler removal begins by back launching to the pier, while railroad operations in the Pueblo Rail Yard continue below. Photos: © FIGG.



The new 4th Street Bridge in Pueblo, Colo., crosses the Arkansas River and a wall known as the World's longest mural.

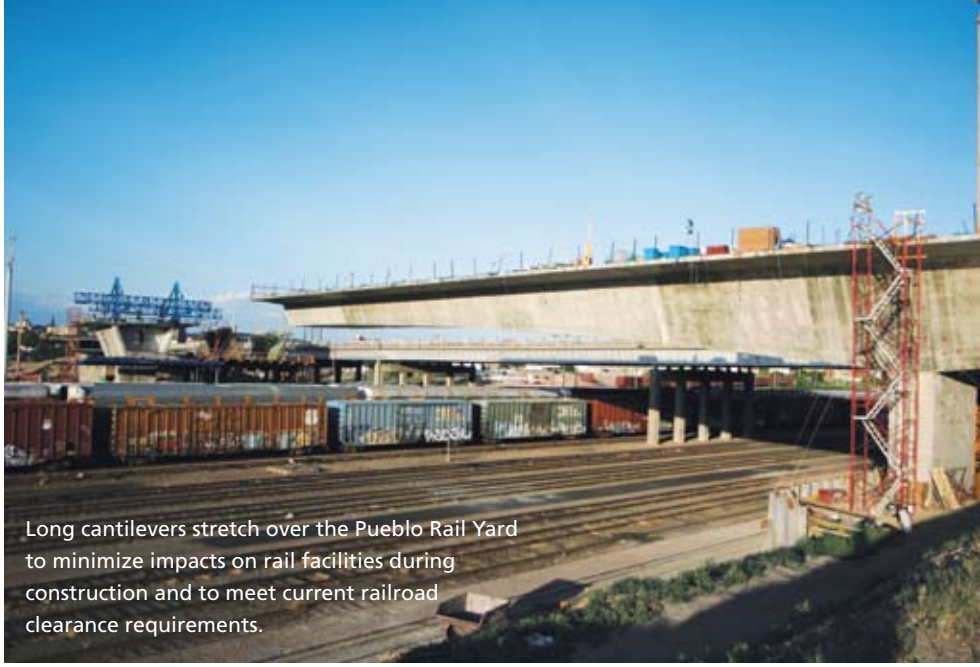
CAST-IN-PLACE, POST-TENSIONED, SEGMENTAL BOX GIRDER BRIDGES / COLORADO DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Twin, 1137-ft-long, concrete segmental box girder bridges built from above in balanced cantilever, with 378-ft-long main spans over the Arkansas River and 23 Union Pacific and 5 Burlington Northern Santa Fe railroad tracks.

STRUCTURAL COMPONENTS: Cast-in-place drilled shafts, footings, columns, and superstructure segments

BRIDGE CONSTRUCTION COST: $20.3 million

Building from above using concrete segmental balanced cantilever construction accommodates unique site constraints and allows rail traffic to keep moving.



Long cantilevers stretch over the Pueblo Rail Yard to minimize impacts on rail facilities during construction and to meet current railroad clearance requirements.

structure result in two side spans of approximately 230 ft and a main span of 378 ft. The 150-ft-long end spans cantilever approximately 30 ft into the side spans and connect to the main-span cantilevers with 8-ft-long closure joints.

With the extensive level of deterioration of the existing bridge's substructure, CDOT was interested in long-term durability. Several levels of protection are provided, including a 3-in.-thick sacrificial asphalt wearing surface with an elastomeric waterproofing membrane, epoxy-coated superstructure reinforcement, and integral piers. Expansion joints are located only at the abutments. With these levels of protection, along with bidirectional compression of the superstructure deck from the application of post-tensioning, the concrete segmental solution provides a low maintenance, durable, and sustainable structure.

Unique Site Conditions

The Pueblo Railroad Yard is jointly operated by the UPRR and the BNSF and is a major switching yard and hub for western railroad operations. Coal and freight moving along the front range of the Rocky Mountains is stacked and redirected from this point. One BNSF and two UPRR mainlines are among the 28 continuously operating tracks at the crossing. Because of the constant activity, neither closure nor track removal was feasible during construction or as a long-term solution.

The existing bridge does not meet current railroad clearance envelopes, with piers as close as 8 ft 3 in. to adjacent tracks. The new bridge accommodates current railroad design requirements, including temporary and permanent clearance envelopes. In addition, the bridge solution had to minimize temporary and permanent impacts to tracks, yard roads, utilities, railroad operations, and facilities.

Previous bridges at this location followed an alignment parallel to and north of the existing bridge. Following this same alignment, the new bridge minimizes right-of-way acquisition requirements, satisfies maintenance of traffic demands, and provides the best opportunity for geometric improvements.

Construction Schedule

The 4th Street Bridge contract was awarded in October 2007. The $27.7 million bid for the segmental alternate saved CDOT approximately $5 million against the steel alternate and was less than the engineer's estimate. Construction is progressing on schedule with the completion of the first cantilever in mid-June 2009 and casting of the second cantilever now underway.

Construction is currently proceeding across both the rail yard and Arkansas River. The majority of substructure work was completed as of September 30, 2008, and once the existing bridge is removed, the remaining substructure for the eastbound bridge will be completed by June 2010. During construction of the first main span cantilevers the contractor was able to achieve a production rate of approximately two segments per week. Once the first pair of cantilevers was complete, operations moved to the adjacent cantilevers to complete the new westbound bridge. Following this, travelers will be relocated for construction of the eastbound bridge.

Environmental Challenge

Restoring Natural Environment

The City of Pueblo and Corps of Engineers recently completed the Arkansas River Restoration Project with the goal of restoring the natural riverine environment in this region. Among other features, this included construction of a white water kayak park just downstream of the bridge. Maintaining recreation through the project site both during and after construction was an important consideration. Building from above and utilizing long open spans supported by slender piers—a minimal bridge footprint—created many benefits for this recreational area.

Substructure Design and Construction

All piers are supported on two drilled shafts, providing the necessary flexibility, minimizing the bridge's footprint, and greatly reducing the number of construction operations. This is especially advantageous in the railroad yard. Abutments and end span piers utilize 4-ft- and 5-ft-diameter drilled shafts, respectively, while main-span piers are supported on 8-ft-diameter shafts. Shafts are drilled through an alluvial sand layer and socketed 25 to 43 ft into hard rock. Overexposure of the shale bedrock layers found along Colorado's Front Range can lead to a loss in capacity over time. To minimize this potential, the contractor chose to drill the larger 8-ft-diameter shafts in stages, first drilling smaller pilot holes followed by the final required diameter. Tip elevation was not drilled until the contractor was satisfied that concrete could be placed within the required CDOT timeframe.

Footing and column construction followed completion of drilled shafts at each pier location. Careful design and close coordination with the railroads during construction ensured efficient movement of materials, forming, and concrete placement. At Pier 4, adjacent to both the UPRR and BNSF mainline tracks, substructure construction occurred without any track closures.

Superstructure Design and Construction

The end spans are cast-in-place on ground-based falsework. To speed construction and minimize materials, falsework is removed once the spans are completed and all post-tensioning stressed. Once the adjacent cast-in-place cantilevers are complete, they are joined to the end spans with closure placements.

Pier tables on top of the main span piers are cast-in-place on temporary falsework that has been designed to maintain the required railroad clearances. Tracks remain open while pier table construction occurs overhead.

Another challenge from the rail yard constraints was overcoming the large out-of-balance forces induced from the balanced cantilever construction. Typical twin wall pier construction could not be used because of the large footings required and the need to remove tracks from service. Therefore, a temporary support prop is used during cantilever construction. This prop shares construction loads with the permanent pier and provides added rigidity for better geometry control. This allows the bridge piers to maintain a slender shape and minimal footprint.

Concrete segmental balanced cantilever construction has proven to be an efficient and economical option for the new 4th Street Bridge in Pueblo, Colo.—allowing vehicular and rail traffic to remain operational while delivering an aesthetically pleasing design for the community.

Karen Rowe is resident engineer, Colorado Department of Transportation, Pueblo, Colo. Steve Fultz is assistant regional director for FIGG, Denver, Colo., and John Dvorak is the resident engineer/lead inspector for FIGG, Pueblo, Colo.

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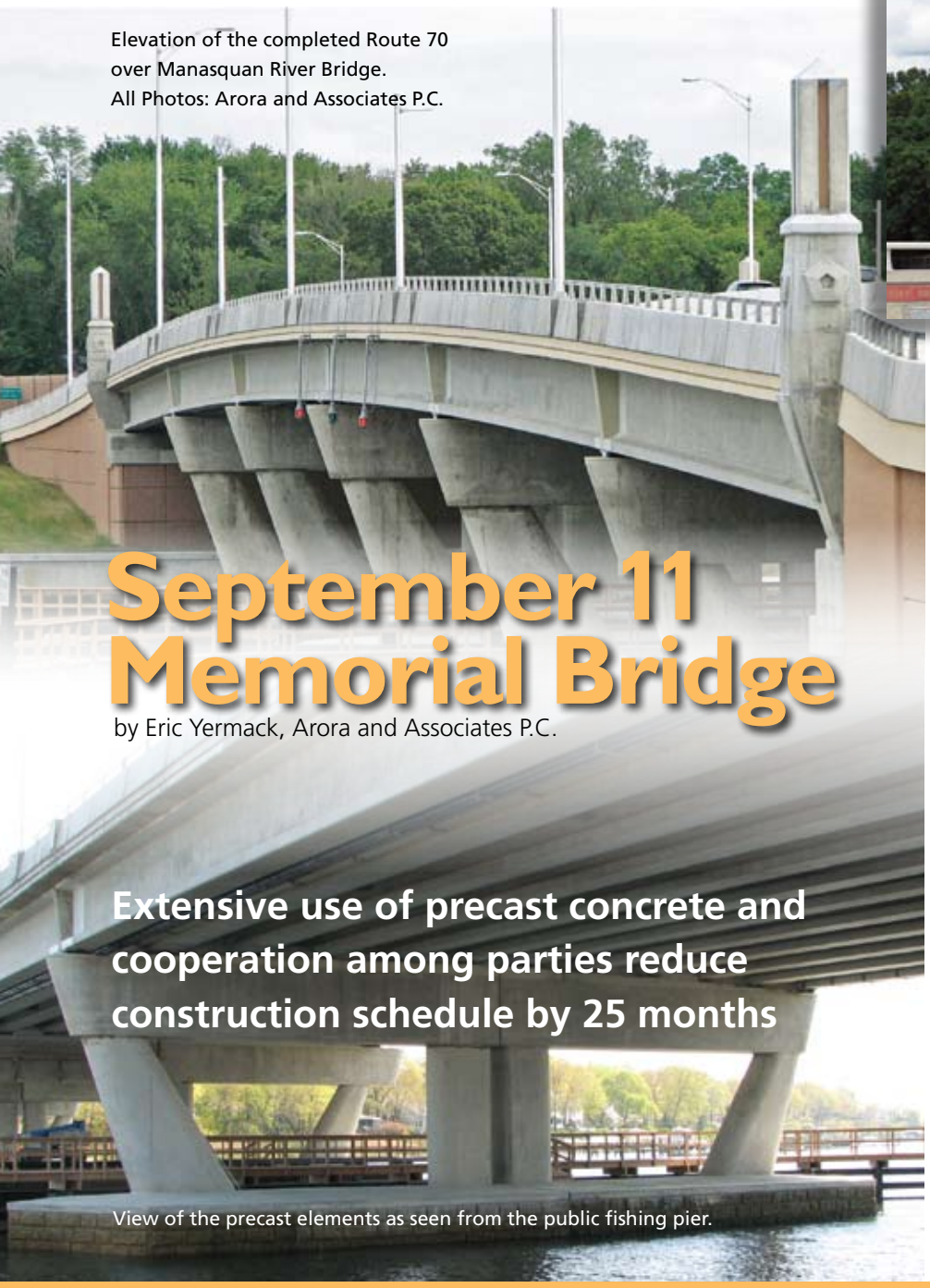

Elevation of the completed Route 70 over Manasquan River Bridge.
All Photos: Arora and Associates P.C.

September 11 Memorial Bridge

by Eric Yermack, Arora and Associates P.C.

Extensive use of precast concrete and cooperation among parties reduce construction schedule by 25 months

View of the precast elements as seen from the public fishing pier.

One of the September 11 Memorial Bridge monuments.

With the replacement of the Route 70 over Manasquan River Bridge, the New Jersey Department of Transportation (NJDOT) planned to create a gateway structure to Monmouth and Ocean Counties in the coastal region of the state. The NJDOT also sought to provide a memorial structure for the 170 local residents who died in the September 11, 2001, terrorist attacks. In September 2004, the bridge was formally dedicated as the "September 11 Memorial Bridge."

The $53 million project replaced a structurally deficient and functionally obsolete single-leaf, bascule bridge constructed in 1936 with a pair of modern, high-level, fixed precast concrete bridges. Each 724-ft-long structure has two, three-span continuous superstructure units (119 ft, 120.25 ft, and 120.25 ft long) comprised of bulb-tee girders at 8-ft center-to-center spacing. The superstructures are supported on two abutments and five architecturally treated in-water piers with pile foundations. To accommodate the needs of marine traffic, the bridge underclearance was increased to 25 ft and the navigation channel was widened from 50 ft to 75 ft.

profile

ROUTE 70 OVER MANASQUAN RIVER, SEPTEMBER 11 MEMORIAL BRIDGE / OCEAN AND MONMOUTH COUNTIES, NEW JERSEY

BRIDGE DESIGN ENGINEER: Arora and Associates P.C., Lawrenceville, N.J.

BRIDGE ARCHITECT: H2L2 Architects/Planners LLP, New York, N.Y.

PRIME CONTRACTOR: George Harms Construction Co. Inc., Howell, N.J.

CONCRETE SUPPLIER: Ralph Clayton & Sons, Lakewood, N.J.

PRECASTERS: Pier Cofferdams, Columns, Cap Beams and Bulb-Tee Girders: Northeast Prestressed Products LLC, Cressona, Pa., (formerly Schuylkill Products Inc.) a PCI-certified producer

AWARDS: *Best Bridge With Spans Between 75 and 150 Feet, 2009 Precast/Prestressed Concrete Institute Design Awards; 2009 Grand Award, American Concrete Institute, New Jersey Chapter; 2009 Project of the Year, American Society of Highway Engineers, North-Central & Southern New Jersey Sections (Projects over $5 million)*

NJDOT then challenged the design team to utilize precast concrete to simplify the architectural concept and minimize the duration of in-water construction.

In addition to completing the NJDOT master plan for the widening of the Route 70 corridor, the project also included the following: a fiber-reinforced polymer bridge fender system, an Americans with Disabilities Act compliant public fishing pier, retaining walls, noise walls, bulkheads, ramps, traffic signals, storm water management structures, highway lighting, intelligent transportation systems (ITS) improvements, and utility relocations.

The Precast Pier Solution

Architectural recommendations were developed with the architect and the NJDOT Bureau of Landscape and Urban Design. The preferred alternative was to use V-shaped piers, with eased edges, punctured by symmetrical, sloped geometric voids. The NJDOT then challenged the design team to utilize precast concrete to simplify the architectural concept and minimize the duration of in-water construction. The process resulted in an architectural pier design with each pier being supported at the waterline on a simulated masonry faced plinth. Each pier would have a pair of prismatic vertical columns near the centerline of the bridge and inclined tapered columns sloping outward towards the bridge fascias. The pier structural system consisted of precast concrete cofferdam shells, columns, and cap beams connected with post-tensioning. The precast bridge elements used 8000 psi high-performance concrete for added strength and durability. The parapets, sidewalks, retaining walls, and noise walls also received architectural treatments.

The foundations utilized 24-in.-diameter concrete-filled steel pipe piles driven to an average pile tip elevation of -110 ft. Groups of 37 piles were used at the fixed piers, 26 piles were used at the continuity piers, and 32 piles were used at the expansion piers. The contractor drove pilot piles with a template around the perimeter of each pile group so that a temporary system could be installed to support the precast cofferdam sections. The remaining piles were then driven through openings in the floor slab of the cofferdam shell. A vibratory hammer was used to advance the piles the first 60 ft through the upper riverbed muck layer, and an impact hammer was used to drive the piles to the estimated tip elevation. After a 7-day setup period, each test pile was restruck to verify attainment of the minimum 800 kip ultimate resistance. Utilizing the setup characteristics of the sandy subsurface layers allowed the pile capacities to be developed without driving to a lower stratum.

The size of the cofferdam footing for each pier half was standardized at 30 ft wide by 49.5 ft long allowing for efficient precast production. The cofferdam shells offered several advantages over traditional cofferdams. These included: providing driving templates, serving as architecturally detailed formwork, constructing the footings at the waterline, and minimizing disturbance of the riverbed. The contract documents allowed the contractor to select the method of support and introduce joints to facilitate casting, shipping, and erection, which resulted in section lengths varying from 7.2 ft to 14.5 ft. The sections could then be easily hoisted into place from barge platforms and connected with couplers consisting of 1¼-in.-diameter anchor bolts, 4-in.-diameter structural tubing, and 1-in.-diameter threaded rods. The cofferdams were faced with a random cut stone pattern and a clear epoxy waterproofing seal coat giving the appearance of wet granite masonry at the waterline.

The piers were constructed using 16-ft-long hollow precast concrete column units with 9-in.-thick walls and 7-ft-deep by 5-ft-wide hollow prestressed concrete cap beams. These precast components were connected by post-tensioning extending from anchorages in the footings to connection points in the cap beams. The post-tensioning design was based on ½-in.-diameter, ASTM A416, Grade 270, low-relaxation strands. However, to facilitate the erection and post-tensioning in the sloped outer columns, the contractor substituted an equivalent system of 1¾-in.-diameter, epoxy-coated, Grade 150 bars (ASTM A775).

Superstructure Innovations

The bridge was designed to accommodate either Prestressed Concrete

TWIN 724-FT-LONG, SIX-SPAN, PRECAST CONCRETE BULB-TEE GIRDER BRIDGES WITH PRECAST PIERS / NEW JERSEY DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Twin, parallel bridges built in phases to appear as one structure, 724 ft long and 94 ft 8 in. wide, using PCEF 71-in.-deep bulb-tees spaced at 8-ft centers; precast concrete piers with a pair of precast plumb columns and a pair of precast voided, inclined columns; a precast cap beam; precast cofferdam shells; precast sound walls; and MSE walls

NOISE WALLS: Jersey Precast Corp., North Brunswick, N.J., a PCI-certified producer

MSE WALLS: Wyoming Concrete Industries, Camden Wyoming, Del.

BEARINGS AND JOINTS SUPPLIER: The D.S. Brown Company, North Baltimore, Ohio

BRIDGE CONSTRUCTION COST: $28 million as part of a $53 million construction project

(Left Photo) Placing reinforcement in a form for the inclined precast concrete column.

(Right Photo) Inclined, voided, precast concrete column being handled in the casting yard.

Economic Fabrication (PCEF) Bulb-Tee girders or New England Bulb-Tee girders. The contract plans were detailed using the PCEF XB 71 47 section, a 71-in.-deep bulb-tee girder, which was the section ultimately supplied by the contractor. The existing bridge was used as a working platform during Stage 1 to set the girders for the eastbound structure. During Stage 2 the newly constructed eastbound structure was used to set the girders for the westbound structure. Galvanized steel intermediate diaphragms were used to quickly secure the girders at the time of erection.

The bulb-tee girders were designed to be simply supported for dead load and continuous for live load. To improve the performance of the continuity diaphragms, NJDOT requested that a better detail be developed for this project. Borrowing ideas from the Pennsylvania DOT and Illinois DOT, the prestressing strands were extended and bent upwards for continuity and 90 lb roofing felt was introduced on the sides of the girder ends to serve as a bond breaker.

Keys to Accelerated Construction

The construction contract was awarded in December 2005 with a construction start date of February 6, 2006. Since in-water construction operations were prohibited from January 1 through June 30, every effort had to be made to maximize each in-water construction season. Cold weather concrete provisions would pose an added difficulty if the pier construction extended into the winter months. The preconstruction baseline schedule was predicated on the pier construction being impacted by these restrictions, so an extended construction schedule of 56 months was anticipated.

To make a significant improvement on the overall project duration, the contractor had to complete the substructures and superstructure of the first half of the bridge as quickly as possible so that traffic could be shifted onto the new structure and the in-water construction activities could begin at the start of the following in-water construction season.

To achieve this, the contractor operated on a 6-day workweek and employed multiple crews, which moved from one pier location to the next, performing the same tasks for each pier in sequence. In this way the contractor was able to achieve a production rate of 19 working days per pier on each half of the bridge. The project was substantially complete on September 8, 2008, 25 months ahead of schedule.

Lessons Learned

The Route 70 over Manasquan River Bridge Replacement Project provided a sustainable, signature bridge design that met the project requirements. A precast concrete substructure solution achieved the architectural and environmental goals while contributing to accelerated bridge construction.

Of the many important lessons learned on this project, cooperation between the owner, engineer, and contractor stands out. By providing flexibility and alternate provisions in the contract documents and allowing reasonable substitutions, engineers and owners can empower contractors and fabricators to provide lower cost, high-quality projects constructed at a faster pace.

The project also demonstrated the feasibility of precast pier systems for medium-span, in-water bridges. As engineers and contractors continue to gain experience with precast substructure construction, it is expected that precast substructures will be adopted for more conventional spans and even greater efficiencies will be realized with lower project costs in the future.

Working within the Environment

Route 70 is a coastal evacuation route and a heavily traveled regional corridor with a two-way average daily traffic in 2005 of 32,300 vehicles. Therefore, NJDOT required that staged construction be utilized and traffic maintained. Following a partial demolition to remove an auxiliary bridge operator's house, the eastbound bridge structure was constructed approximately 3 ft from the south fascia of the existing bridge. The span arrangement allowed the proposed pier foundations to be constructed adjacent to the existing bridge with minor adjustments to clear existing piles. After construction of a temporary pedestrian walkway and transfer of traffic onto the newly constructed eastbound structure, the existing structure was demolished and the westbound bridge constructed.

Environmental permit considerations were important. To protect fish during migration and spawning runs, an in-water work restriction period was imposed from January 1 to June 30 by the United States Army Corps of Engineers and New Jersey Department of Environmental Protection. It was also desirable to minimize the bridge footprint in the riverbed to avoid excavation of salt laden soils and contaminated riverbed sediments.

Eric Yermack is manager, structural engineering with Arora and Associates P.C., Lawrenceville, N.J.

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The bridge over the Canandaigua Outlet in New York replaces a steel bridge with a precast concrete single-span bridge that used ultra-high-performance concrete to connect beams longitudinally and to speed construction. Photos: New York State DOT.

UHPC JOINT PROVIDES NEW SOLUTION

New York State's first application of deck bulb-tee girders results from new joint design

by Craig A. Shutt

The bridge consists of eight precast concrete deck bulb-tee girders that were erected to close tolerances despite a variety of logistical needs.

To complete a bridge superstructure replacement project on a tight deadline, officials at the New York State Department of Transportation (NYSDOT) decided to take a new design approach: precast concrete deck bulb-tee girders. To overcome durability concerns that had kept them from using deck bulb-tee girders in the past, they customized the bulb tees to create joints between the girders that would be filled with ultra-high-performance concrete (UHPC), optimizing the system. The result was a satisfactory design with a significantly shorter construction time and will be used in additional applications.

"This was the first time any of us—designers, contractors, or precasters—had used this approach in New York State," explains Mathew Royce, an engineer in the Structures Division at NYSDOT. Royce had attended sessions at bridge conventions discussing the technique. Bill Adams, vice president and project manager for the general contractor, also had researched the technique prior to bidding, talking with Washington DOT officials and contractors who had experience with constructing such bridges.

The goal was to replace the superstructure on a former steel jack-arch bridge that spans the Canandaigua Outlet creek while retaining most of the cast-in-place abutments. The new bridge consists of a single-span, 87 ft 5 in. long and 42 ft 9 in. wide, comprising eight precast concrete deck bulb-tee girders that are 41 in. deep. The interior girders have a top flange 4 ft 10 in. wide while the width of the exterior girders' top flange is 5 ft 1 in. The flange is 6 in. deep at the edges. This top flange and the joint design represented the innovative aspect of this bridge technique for the project, Royce explains.

"We were familiar with the deck bulb tee, but we were concerned about the longitudinal joint and its ability to stand up over a long time period with heavy traffic," he says. "We had seen it used in low-traffic applications, but this bridge already has fairly high usage, and we wanted to prepare for the future when the usage increases further. We didn't

profile

ROUTE 31 BRIDGE OVER CANANDAIGUA OUTLET / VILLAGE OF LYONS, WAYNE COUNTY, NEW YORK

ENGINEER: New York State Department of Transportation, Albany, N.Y.

PRIME CONTRACTOR: Ramsey Construction Inc., Lakeville, N.Y.

CONTRACTOR'S ENGINEERING CONSULTANT: Erdman Anthony and Associates Inc., Rochester, N.Y.

PRECASTER: Northeast Prestressed Products LLC, Cressona, Pa., (formally Schuylkill Products Inc.) a PCI-certified producer

ULTRA-HIGH-PERFORMANCE CONCRETE SUPPLIER: Lafarge North America, Calgary, AB, Canada

The 6-in. wide joints were created by extending epoxy-coated reinforcing bars 4 in. or 6 in. from the edge of each flange, offset longitudinally so they would not meet each other, and filling the joints with ultra-high-performance concrete.

After the beams were set, a jacking system was used to even out the camber between the beams, so they were as level as possible for the waterproofing membrane and overlay.

want to have to worry about increasing inspection or maintenance costs to avoid worries about leaks or corrosion."

This concern was exacerbated by the short period of time available for the closure, he notes. A maximum of 3 months was available, due to scheduling of an annual fall festival, for which the bridge had to be accessible to handle the heavy traffic of additional visitors to the area.

Test Beams Fabricated

Prior to beginning construction, the designers and contractor worked with the precaster to test several designs in the precaster's yard to ensure a proper joint fit, according to Troy M. Jenkins, the precaster's chief engineer. "We decided to pre-erect the beams in our yard to ensure everything would fit correctly." "In addition, the field installation has been instrumented with strain gauges," Royce notes. "They will give us more valuable information about the material's performance under different conditions.

The girders are set with a 6-in.-wide joint between the top flanges. The joint tapers to 9 in. wide at mid-depth. Two layers of epoxy-coated reinforcement extend from each girder flange and lap within the joint. No. 6 bars just above mid-depth lap 6 in. and No. 4 bars just below mid-depth lap 4 in. That's more than adequate to ensure the bars are fully developed in the ultra-high-performance concrete, Royce explains. The UHPC concrete, manufactured by LaFarge North America, allowed the joint to be narrowed and also sped up the curing process, he notes.

"It's a very high-end concrete with very high-strength capabilities, and it will resist scaling, freeze-thaw deterioration, and cracking due to the high steel fiber content," Royce says. "But the key for us was not the added strength the UHPC could provide but the speed with which we could complete the closure. The shorter length of reinforcing bar that we could use let us create a narrower joint that could be completed in less time."

The precaster's prior tests had showed that, with heat curing, the UHPC concrete could achieve a compressive strength of 33 ksi. In the field, without heat curing, it could reach 22 to 24 ksi, with an initial strength of 14 ksi after 4 days. "The girder concrete provides 10 ksi, so the joint will be stronger than the concrete beam," Royce notes.

Stability of the beams during construction was provided by bolting the beams down to the abutments. The upper part of the beam-end tie downs consist of an approximately 1-ft-square steel plate with a no. 6 all-thread bar protruding down on a slight angle. It connects through the beam flange to an anchor below in the end abutment.

'The key for us was not the added strength the UHPC could provide but the speed with which we could complete the closure.'

SINGLE-SPAN PRECAST CONCRETE DECK BULB-TEE BRIDGE / NEW YORK STATE DEPARTMENT OF TRANSPORTATION, OWNER

BRIDGE DESCRIPTION: Single span, precast concrete deck bulb-tee bridge consisting of eight girders 87 ft 5 in. long, 41 in. deep with a 58-in.- or 61-in.-wide top flange. Joints between the flanges contain a short lap length that was filled with ultra-high-performance concrete.

BRIDGE CONSTRUCTION COST: $1.3 million

The joints were overfilled to account for some settling in the UHPC mix. The excess was ground off later.

Ground area between beams 4 and 5.

The designers worked with the precaster to create a staggered plan so the bars protruding from adjacent flanges didn't meet in the middle, Royce says. "Each side was adjusted accordingly so the bars land between two bars from the other side." Epoxy-coated reinforcement for the concrete vehicle barrier was cast into one of the fascia beams at the plant. A bolted steel rail was used for the other barrier.

Camber Adjustment Required

A detailed erection plan was prepared by the contractor's engineering firm to show the specified crane locations, beam tie-downs at end abutments, top-flange blocking, and transverse stabilization during construction.

A key challenge came from the need for the contractor, engineer, and precaster to recalculate and adjust pedestal elevations and process this information to field crews so they could place pedestal concrete 3 days before beam erection. "This schedule left no time or margin for error," says Adams. To ensure accuracy, the team followed specific measures to control camber growth while the beams were in storage, as that time delay could affect the tolerances in the specifications.

The beams were preloaded with concrete weights at the fabricator's plant. The precaster shot camber elevations just before the beams were loaded with weights to determine a base line. Three days prior to shipping and erecting the beams, the concrete weights were removed and camber elevations were shot again. These data showed that all of the pedestal elevations had to be adjusted.

"We had to place the pedestal high-early strength concrete by noon that day to achieve the needed strength in the 72-hour curing time before the beams arrived," Adams explains. The process went like clockwork, and the beams were hoisted into place on schedule. "It was nerve racking to await the concrete cylinder breaks on the pedestal concrete," he says. "But we had confidence the concrete would achieve strength because test-batching the previous week had delivered the required strength."

Once all eight girders were in place, their camber was adjusted to keep them level at midspan so a thin spray-applied waterproofing membrane and wearing overlay could be provided later without adding depth to the profile. "It required some adjustment, and we didn't have a lot of room to play with since the overlay was very thin—2 in. at midspan," Royce explains.

The contractor's Adams agreed. "Designing the camber leveling beam and jacking system so the girders could be aligned to the required tolerance was the most challenging part of the entire project," he says. The contractor worked closely with their engineering consultant to create the camber-beam jacking system." The crew used this beam to lift or push each girder into vertical alignment within 3 mm (1/8 in.) tolerance. Then the diaphragms were cast with high-performance concrete and the beam tie downs and top-flange blocking were removed.

The joints were overfilled by a few millimeters to ensure they would be level when settling was completed, Royce notes. Once the material settled, any remainder was ground off. "It required some grinding, but took less than a day to complete" Adams says.

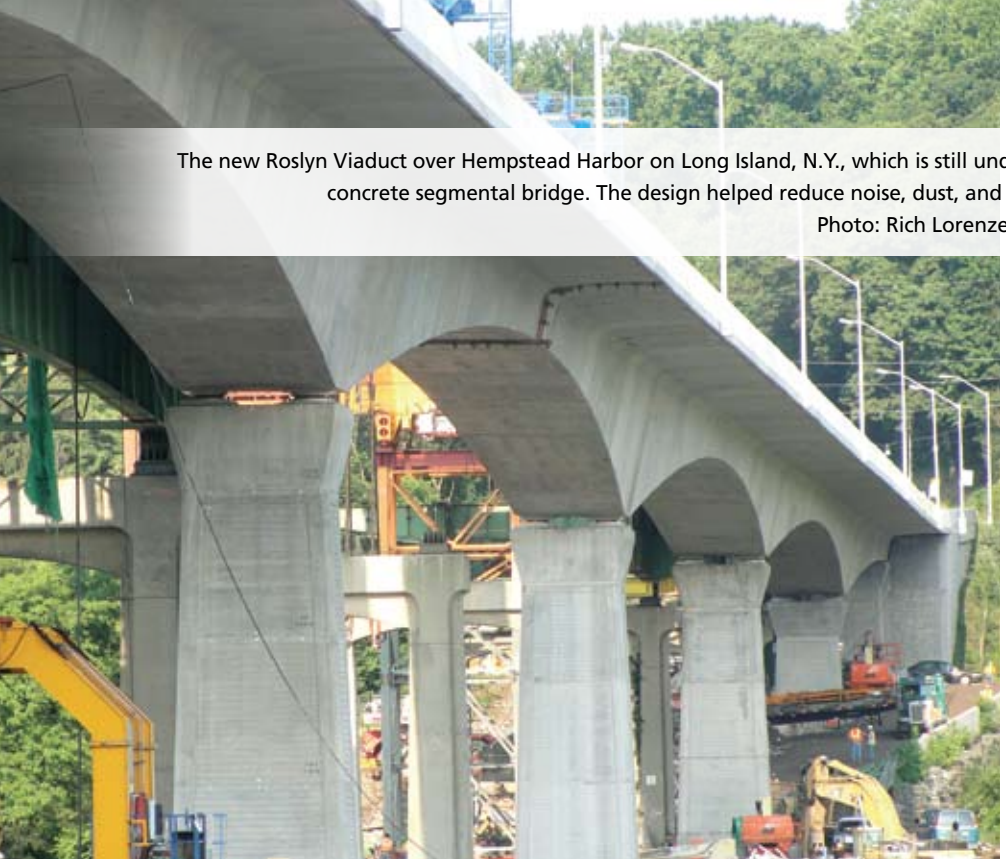
The project was completed on budget and a few days ahead of schedule, Royce reports. "Everyone was very happy with the results. The design and the overall application of the concrete joints worked very well." As a result of this success—and the on-going tests being conducted on load conditions, Royce expects the design will be used more often in the state.

"In the near future, I can see it being used for specialty applications such as this one, certainly," he says. "And as more opportunities arise, especially where the need is very high for rapid construction, I expect we'll be using it more often overall, because of its effectiveness. This approach eliminates any concerns about joint conditions, while giving us the speed of construction that we needed. That gives us the potential to use it in more situations like this."

As a first-time use, he notes, costs were somewhat higher as expected, due to the learning curve associated with the new techniques. "The steep learning curve will be reduced as we become more familiar with it and contractors learn about it," he says. "Plus, we eliminate the costs associated with later inspections and maintenance, which become significant, so the long-term value is higher."

Adams agrees that more projects would benefit. "I can see it being used in applications with the right conditions, because it does expedite projects," he says. Already, the state has begun work on another project in which these bulb-tee girders and UHPC joints are being considered, Royce adds. "It's a slight variation from this first project, but it's similar, and we think this approach will work very well."

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



The new Roslyn Viaduct over Hempstead Harbor on Long Island, N.Y., which is still under construction, features the area's first precast concrete segmental bridge. The design helped reduce noise, dust, and vibration while providing an aesthetic solution. Photo: Rich Lorenzen. Rendering (below): Hardesty & Hanover LLP.

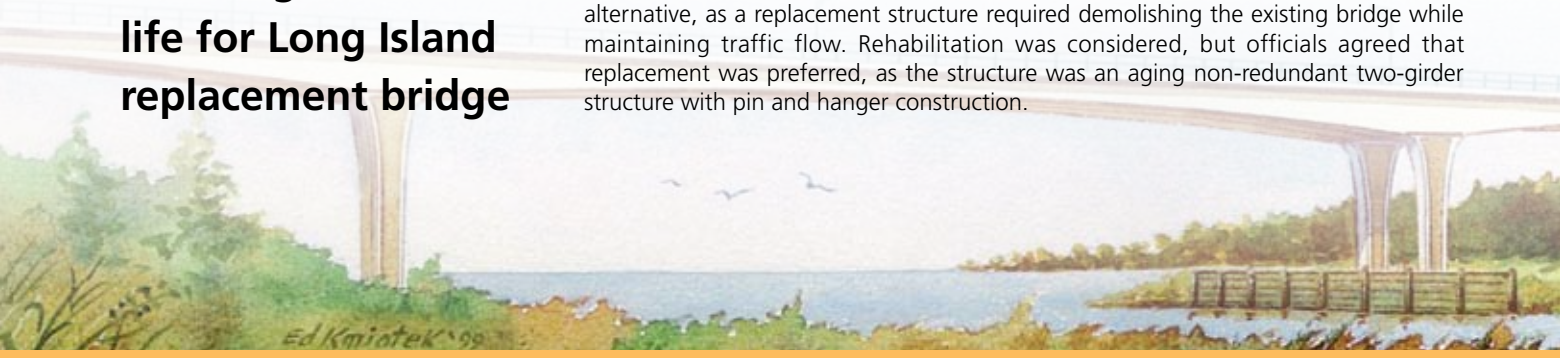
BUILDING A BRIDGE IN TIGHT QUARTERS

by Eileen Peters, New York State Department of Transporation

Haunched box girders made with high-performance concrete provides strong aesthetics and long service life for Long Island replacement bridge

The new Roslyn Viaduct Bridge on Route 25A over Hempstead Harbor, Long Island, N.Y., provides a wider, aesthetically pleasing and effective design that replaces a deteriorating 1949 steel bridge that could not handle the growing traffic volume. The new segmental precast concrete structure, featuring haunched box girders, provides a 75-year service life, minimizes impact to the public and its surroundings, and complements the area's many historical structures and characteristics. It also represents the first bridge of this type on Long Island.

The $127-million project is a key east-west roadway in Nassau County, carrying 38,000 vehicles each day. Significant challenges arose in designing the best alternative, as a replacement structure required demolishing the existing bridge while maintaining traffic flow. Rehabilitation was considered, but officials agreed that replacement was preferred, as the structure was an aging non-redundant two-girder structure with pin and hanger construction.



profile

ROSLYN VIADUCT / N.Y. ROUTE 25A OVER HEMPSTEAD HARBOR, NASSAU COUNTY, NEW YORK

ENGINEER: Hardesty & Hanover LLP, New York, N.Y.

CONSTRUCTION INSPECTION: STV Inc. / PB Americas Inc. Joint Venture, New York, N.Y.

PRIME CONTRACTOR: Tully Construction Co., Flushing, N.Y.

CONTRACTOR CONSTRUCTION ENGINEER: Weidlinger Associates Inc., Mountain Lakes, N.J., and HDR Inc., Newark, N.J.

CONSTRUCTABILITY REVIEWS: FIGG Bridge Engineers Inc., Exton, Pa.

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

AWARDS: *Named among "Top 10 Bridges in North America" in 2007 by* Roads & Bridges *magazine*

Self-consolidating, high-performance, 10,200 psi concrete was used for girders and abutments to ensure a 75-year service life.

Community Involved

As part of the development process, the New York State Department of Transportation (NYSDOT) undertook a partnering initiative with the community to ensure that the bridge was constructed in context with its surroundings and in keeping with the local vision for future needs. To ensure the process moved smoothly, a Bridge Task Force (BTF) was created, comprising public officials and their appointed representatives. Designers presented several concepts, including a cable-stayed design, a deck-arch bridge, a multigirder structure (of either steel or concrete), a box-girder bridge (of either steel or concrete), and a tunnel.

After considering the options and receiving local input, the BTF chose a segmental concrete bridge with haunched box girders, which could be designed to resemble the contours of the existing bridge. Key considerations were that this approach would limit dust and noise at the site, with most superstructure and column components fabricated off-site, as well as reduce construction time; thereby minimizing the amount of traffic impacted by the construction.

The nine-span bridge is 78.2 ft wide with two 11.8-ft-wide travel lanes and 7.9-ft-wide shoulders in each direction with a concrete median barrier. The bridge provides a pedestrian walkway on one side and widens to 84.2 ft at the east end to provide transitions for entrance and exit ramps. The nine spans vary in length, becoming shorter as they approach the ends to leave the center of the bridge more open. The lengths of the spans from west to east are 152.6, 252.6, 272.3, 292.0, 272.3, 272.3, 265.7, 215.4, and 120.9 ft. The cross section of the bridge consists of two single-cell box girders.

The bridge contains no horizontal curvature and only a slight vertical curve to the east end with gradient increases from east to west. It was designed to meet the existing approach roadways with an increase in elevation at the west end. Since the approaches could be raised only marginally to meet existing grades, the haunched box girders provided a workable solution.

Designers also chose 10,200 psi (70 MPa) high-performance, self-consolidating concrete for the girders and abutments to ensure a 75-year service life for the structure. The abutments were designed to contain interior hollow sections to store equipment needed to maintain the bridge and provide access to the interior for inspection and maintenance activities. Each abutment also includes two hydraulic dampers to address seismic concerns.

To protect the waterway near the site, precast concrete segments were barged from the precaster's plant in Cape Charles, Va., to a location several miles from the project and then hauled by specialized trailers to the site. Photo: Will Brown.

Design Addresses Key Challenges

A key challenge focused on the soil conditions at the site, which were of varying compositions, with layers of organic material at some strata levels. There also is high groundwater that had to be considered in the design. Drilled and grouted micropiles were used to transfer the high dead loads into the ground. Drilling the piles rather than driving them also minimized vibration to nearby historic buildings and structures and to several 100-year-old wells in close proximity. Vibration monitoring was provided throughout the site.

PRECAST CONCRETE HAUNCHED BOX-GIRDER BRIDGE / NEW YORK STATE DEPARTMENT OF TRANSPORTATION, OWNER

POST-TENSIONING CONTRACTOR: Freyssinet LLC, Sterling, Va.

GANTRY CRANE SUPPLIER: DEAL, Italy

TENDON GROUT SUPPLIER: Sika Corporation, Lyndhurst, N.J.

BRIDGE DESCRIPTION: Nine-span haunched segmental box-girder bridge with precast segments for the superstructure and columns

BRIDGE CONSTRUCTION COST: $127.4 million

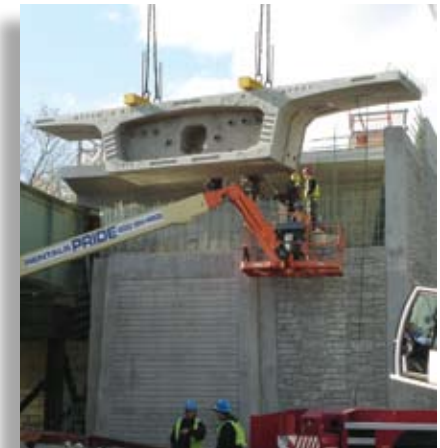
Ironworkers align the couplers for the post tensioning bars as they set the precast concrete column cap segment at pier 7. Photo: Renata Magoc.

Another significant challenge arose with transporting the precast concrete segments to the site. The largest segments weighed close to 100 tons. Initially, the construction team planned to use the channel waterway, but the NYS Department of Environmental Conservation was concerned about protecting the aquatic natural habitat. Instead, the segments were barged from the precaster's plant in Cape Charles, Va., to a location several miles from the project and then hauled by specialized trailers to the site via ground-surface transportation routes. This approach required numerous contacts and discussions with local public agencies, residents and other stakeholders. The contractor obtained permits to use special multi-axle trailers to transport many of the bridge segments over the existing viaduct bridge.

Demolition of the existing bridge and construction of the new structure were coordinated to minimize traffic disruptions and required construction in two stages. Demolition of the northern third of the bridge came first. Then, new pier-column segments were installed and girder segments for the portion of the bridge east of the waterway erected. The column segments and many of the girder segments for the portion west of the waterway were transported over the existing viaduct during nighttime operations while the bridge was closed to traffic.

After the northern portion of the original bridge was demolished, NYSDOT used three travel lanes on the remaining southern portion, with the center lane accommodating traffic in peak periods by alternating flow direction. The traffic switches took place three times per day using three sets of lane-use signals. Two westbound lanes were used in the morning and early afternoon. Two eastbound lanes were used in the late afternoon and evening. One lane in each direction was used overnight. To prevent traffic backups, a manned tow truck was available at all times, and the bridge was monitored remotely with multiple cameras.

The majority of the precast concrete girder segments for the northern portion of the bridge were installed using a 700-ft-long gantry built on the site away from locations where it would impact travel. The northern approach roadways were completed first, in the fall of 2008. Once the northern half of the new bridge was finished, traffic switched to this new structure and the gantry shifted to the south to facilitate demolition of the southern portion of the existing structure. Construction on that portion then commenced. Self-consolidating concrete was used for cast-in-place closure placements, using a similar concrete mix to the one used for the column and girder segments.



The end segment is positioned on the west abutment bearings. Access to the inside of the structure will be from a stairway inside the abutment and the opening in the center of the segment. Photo: Rich Lorenzen.

Durability and Corrosion Protection

The post-tensioning tendons were provided with multiple layers of protection in accordance with AASHTO design standards. Provisions for future post-tensioning continuity tendons were provided within the bridge. In addition, epoxy-coated reinforcing bars were used in the cast-in-place pile caps and abutments throughout the project.

The designed combination of HPC with a 2-in.-thick silica fume concrete overlay will produce a highly durable bridge able to withstand 75 years of New York weather and de-icing salts. Several components were further designed to withstand the test of time with the use of stainless steel reinforcing bars. These components included light-pole pilasters, barrier walls, and closure placements. Stainless steel also was used for anchors and supports for the bridge's electrical components, as well as for the access doors, ladders, and platforms within the bridge columns.

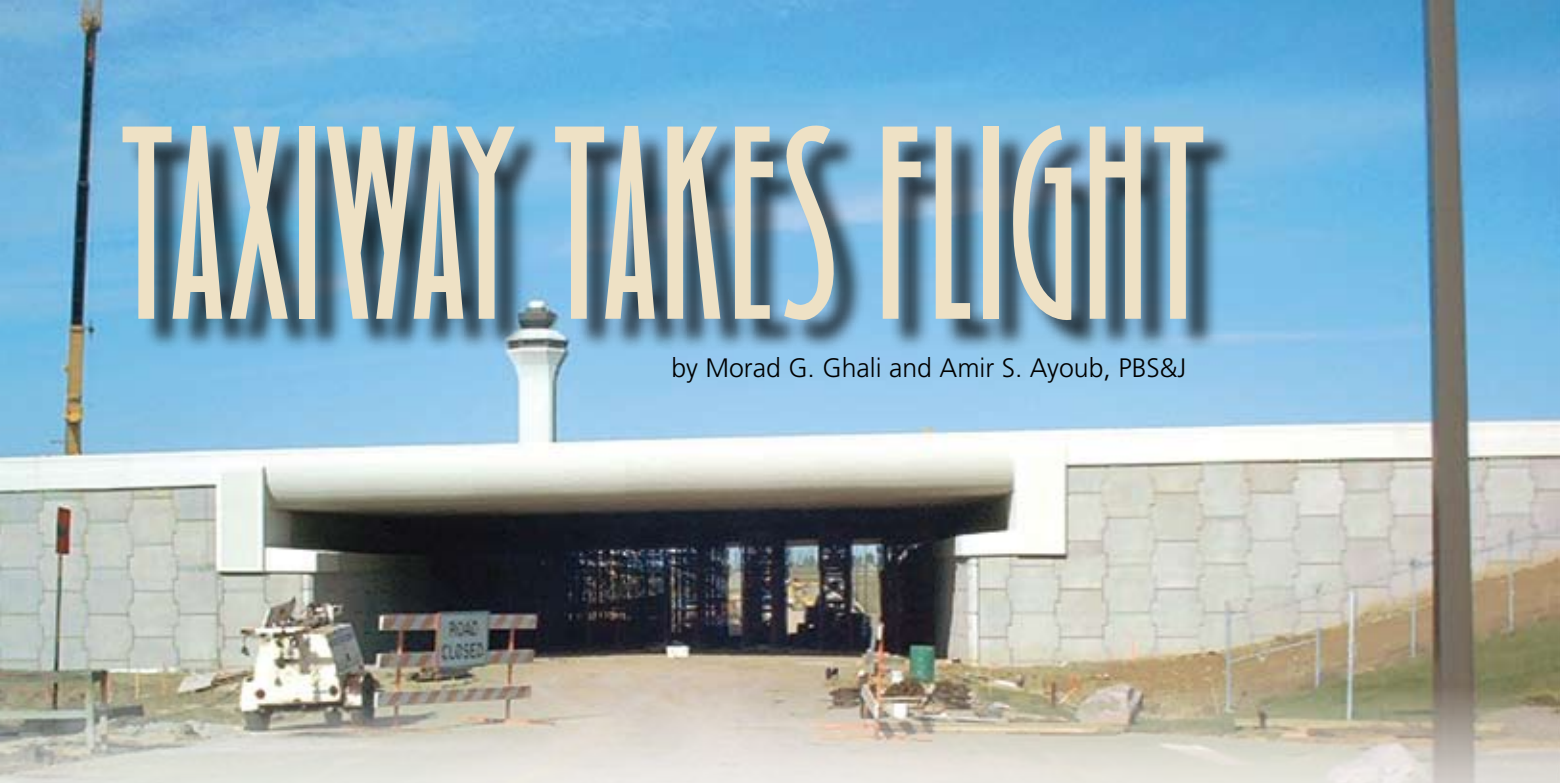
The resulting bridge will provide a strong addition to the community. The haunched superstructure and long spans provide local residents and businesses with a more open view of the harbor, with the total number of piers reduced from 13 to 8. To blend into the surroundings, pier columns and faux columns at the abutments feature a ship-lap pattern in the concrete, while a New England dry-stack form liner along with the ship-lap pattern were used for the abutments and wing walls. This attention to detail ensures that residents will find their new bridge to be both functional and aesthetically pleasing for many decades to come.

The information in this article was compiled by Eileen Peters, the public information officer for the New York State Department of Transportation, Region 10 in Long Island, N.Y., and was supplied by NYSDOT construction and design personnel who worked on the project.

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

TAXIWAY TAKES FLIGHT

by Morad G. Ghali and Amir S. Ayoub, PBS&J



The new taxiway at the Cincinnati/Northern Kentucky International Airport features a single post-tensioned, cast-in-place span to support the required loading and maximize clearance above the roadway. Photos: PBS&J.

Severe depth limitations, heavy loads, and a short timetable created design challenges for this cast-in-place, post-tensioned concrete bridge

Designing the new aircraft-support bridge at the Cincinnati/Northern Kentucky International Airport required a novel approach due to severe loading and the structural depth requirements. With a clearance of only 16 ft 11 in. over the roadway, a careful design had to be developed that could support the heavy weight of the aircraft and emergency vehicles using this bridge.

After careful consideration of the options, a single 87-ft 2-in.-long, post-tensioned, cast-in-place bridge without any transverse joints was created. It was designed and detailed as a simple-span structure to carry the aircraft loading. To meet the variety of challenges, the 217-ft-wide bridge comprises three segments: two 72-ft 4-in.-wide outer segments and an inner segment that is 72 ft 2 in. wide.

The segments are separated by longitudinal expansion joints made of an expandable, watertight foam sealant and a strip-seal system at the roadway level. Dividing the width into three segments allowed the contractor to erect the falsework and cast the slab for each segment individually.

The post-tensioned voided deck is supported by plain elastomeric bearing pads that in turn are supported by 6-ft-deep by 4-ft 6-in.-wide end bents. Each bent is supported by thirteen 48-in.-diameter concrete drilled shafts. This approach was used due to the presence of limestone close to the soil surface throughout the entire project.

The 30-ft-long approach slabs on each side of the bridge consist of 24-in.-thick cast-in-place reinforced concrete slabs supported on one end by a bracket protruding from the post-tensioned slabs and on the other end by a 6-ft-wide reinforced concrete transverse sleeper pad. The approach slabs were designed as structural members on elastic foundations to carry the wheel load of the aircraft. The retaining walls for the approach backfill are made of

profile

CINCINNATI/NORTHERN KENTUCKY INTERNATIONAL AIRPORT TAXIWAY 'N' BRIDGE / ERLANGER, KENTUCKY

ENGINEER: PBS&J, Tampa, Fla.

PRIME CONTRACTOR: The Harper Co., Hebron, Ky.

POST-TENSIONING CONTRACTOR: DSI America, Bolingbrook, Ill.

GROUT SUPPLIER: Sika Corporation, Lyndhurst, N.J.

STRAND SUPPLIER: Sumiden Wire Products Corporation, Stockton, Calif.

The design team considered a variety of alternatives before selecting the structural system capable of carrying the heavy loading while providing necessary clearance below the bridge.

mechanically stabilized earth (MSE) walls designed to support lateral earth-pressure equivalent to that produced from the weight of the aircraft.

Driven by Aircraft Loading

This bridge design was driven by several key factors, particularly the requirements for aircraft loading and limited clearance below the bridge. The design followed the FAA's advisory circular 150/5370-10 in addition to *AASHTO Standard Specifications for Highway Bridges*. The FAA circular required a 1.6-million-lb, Group VI airport loading, following the required gear-configuration types, plus 83,000 lb for emergency vehicles.

The impact load was 30% for the superstructure elements, with maximum longitudinal breaking force set at 35% of the live load without impact. Earthquake loads were considered in accordance with AASHTO Specifications, division 1A, seismic design for seismic performance category A with a ground acceleration of 0.06g. Wind load on the structure and on the aircraft were based on a wind velocity of 100 mph.

The design team considered a variety of alternatives before deciding on the solution that would best create the structural system capable of carrying the heavy loading while providing necessary clearance below the bridge. AASHTO precast, prestressed concrete girders were considered but eliminated because the high load requirements would necessitate a deep beam profile. Likewise, post-tensioned concrete box girders were found to require deeper webs and a special design for the lateral bending of the top slab, necessitating a thicker top slab to resist the aircraft load.

The team then investigated the possibility of using a voided, post-tensioned, cast-in-place slab, with the design optimized by varying the size and location of the void within the slabs. After several trial designs, the voided, post-tensioned, cast-in-place slab option was found to provide the most cost-effective solution while complying with all project requirements and resolving the unique geometrical and strength requirements.

Multilayered anchor protection will prevent water recharge around anchorages that could result in tendon corrosion. All anchorages had a minimum of four levels of protection.

Voids within the post-tensioned cast-in-place slab consist of fourteen 30-in.-diameter precoated, galvanized, corrugated metal pipes capped at each end and spliced to prevent leaks.

CAST-IN-PLACE CONCRETE, TWO-WAY POST-TENSIONED VOIDED-SLAB AND CAST-IN-PLACE STRUCTURAL APPROACH SLABS / KENTON COUNTY AIRPORT BOARD, OWNER

BRIDGE DESCRIPTION: Simple span, cast-in-place concrete, two-way post-tensioned voided-slab, 4 ft 6 in. thick, 87 ft long and 217 ft wide, and 24-in.-thick cast-in-place structural approach slabs designed for aircraft loading

BRIDGE CONSTRUCTION COST: $10.2 million (including approaches)

The designer used post-tensioning specifications developed by the State of Florida to increase the durability and performance level of the bridge.

New post-tensioning specifications were used to increase the durability and performance level of the bridge.

The concrete slab, which is 4 ft 6 in. thick, was post-tensioned both longitudinally and transversely. The voids were formed using 14 corrugated metal pipes, 30-in. in diameter, in each segment, spaced at 4 ft 6 in. on center. The pipes were precoated and galvanized in accordance with Kentucky state standards. They were capped at each end and spliced to ensure they were free of leaks. The centers of the corrugated pipes are offset from the center of the slab toward the bottom, to reduce the dead load while providing greater resistance on the compression face.

The longitudinal post-tensioning of each slab segment consists of 30 tendons. Each is composed of twenty-seven 0.6-in.-diameter strands. Two additional ducts were provided and capped for future use. The transverse post-tensioning features four 0.6-in.-diameter strands at 11⅜ in. from the top of the slab. All post-tensioning strands are seven-wire strands conforming to ASTM A416 270 ksi low-relaxation steel.

New Post-Tensioning Specifications Used

The post-tensioning specifications developed by the State of Florida were used as a guide to increase the durability and performance level of the bridge. The specifications consisted of five key elements: an enhanced post-tensioning system, fully grouted tendons, multilayered anchor protection, watertight bridges, and multiple tendon paths.

The enhanced post-tensioning system was designed to ensure the grout inlets/outlets were suitable for inspection from either the top or front of the anchorage. Three levels of protection for the tendons were provided within the concrete element. These consisted of ensuring sufficient concrete cover, using plastic ducts, and completely filling the annular space between duct and strands with grout. All anchorages for the post-tensioning system had permanent grout caps made from fiber-reinforced plastic and were sealed with neoprene O rings. Additional recommendations such as spacings and inspections were followed as well.

The contractor was required to submit a detailed grouting plan to ensure the tendons would be completely grouted. Shop drawings were required to include all details of the post-tensioning system and grouting plan. Grout pumping rates and pressures were required to reach the rate of 16 linear ft to 50 linear ft of duct per minute with the pressure not to exceed 145 psi at the grout inlet. A fluidity test of the grout from the discharge end was performed using a flow cone to test the efflux time. Inspections were performed using probes or endoscopes, and the grout inlets and outlets were sealed with threaded plugs.

Multilayered anchor protection was used to avoid water recharge around anchorages that could result in tendon corrosion. All anchorages had a minimum of four levels of protection, comprising grout, a permanent grout cap, encapsulating epoxy grout, and a seal coat.

Water tightness was ensured by providing 2-in.-diameter drain holes at each end of the 30-in.-diameter pipes that formed the voids. The bottom edges of the post-tensioned slab were curved to prevent water from accumulating and dripping.

The final element, providing multiple tendon paths, was achieved with 30 longitudinal tendons of twenty-seven 0.6-in.-diameter strands in each slab segment. Multiple tendon paths will provide more structural strength in the event a tendon is lost. Provisions were made for any future strengthening through the addition of two conduits provided in the slab.

Construction Sequence

Construction proceeded smoothly. After driving and casting the drilled shafts, the end bents were formed and cast, and the MSE walls constructed. The falsework for the cast-in-place slab was put in place, and the reinforcing steel, 30-in.-diameter void pipes and post-tensioning ducts were set in place. The concrete was cast and longitudinal and transverse post-tensioning of the slab was completed. Construction of the approach slab and sleeper pad did not begin until the fill within the limits of the MSE walls had been completely compacted.

The result of this attention to detail and key concerns is a bridge that will support heavy aircraft loads for many decades of service to come. Performance was improved by using post-tensioning enhancement strategies that will help reduce inspection and maintenance needs over its entire service life. The project provides an attractive, functional design that was completed on schedule and within budget.

Morad G. Ghali is the chief structural engineer and Amir S. Ayoub is the senior engineer at PBS&J, Tampa, Fla.

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

CONCRETE CONNECTIONS

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

IN THIS ISSUE

www.stainless-rebar.org/public.htm
This website contains an English language summary of the paper by Hunkeler referenced on page 15.

www.fhwa.dot.gov/economicrecovery/index.htm
Visit this FHWA website for more information on the American Recovery and Reinvesting Act, including funding distributions and requirements, answers to frequently asked questions, presentations and guidance materials, and training mentioned on page 43.

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

www.fhwa.dot.gov/pavement/concrete/asr.cfm
This new 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.

www.fhwa.dot.gov/bridge/prefab/if09010
Visit this website to download a copy of *Connection Details for Prefabricated Bridge Elements and Systems*. This document represents the State-of-the-Practice with respect to connections between prefabricated elements in accelerated bridge construction projects. Connection details for superstructure, substructure, and foundation elements are included.

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 I-70 Overpass Beam Failure, New Technologies in Driven Piles, and Use of Self-Propelled Modular Transporters.

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

Bridge Research

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

http://www.trb.org/news/blurb_detail.asp?id=8718
NCHRP Report 609, *Recommended Construction Specifications and Process Control Manual for Repair and Retrofit of Concrete Structures Using Bonded FRP Composites* explores recommended construction specifications to facilitate highway agencies' use of bonded fiber-reinforced polymer (FRP) composites for the repair and retrofit of concrete structures. The specifications cover the construction of FRP systems used as externally bonded or near surface-mounted reinforcement to enhance axial, shear, or flexural strength of a concrete member.

http://www.trb.org/news/blurb_detail.asp?id=10217
NCHRP Synthesis 393, *Adjacent Precast Concrete Box Beam Bridges: Connection Details* explores current design and construction practices that are reported to reduce the likelihood of longitudinal cracking in box beam bridges.

http://www.trb.org/news/blurb_detail.asp?id=9627
NCHRP Report 628, *Self-Consolidating Concrete for Precast, Prestressed Concrete Bridge Elements* explores recommended guidelines for the use of self-consolidating concrete (SCC) in precast, prestressed concrete bridge elements. The report examines the selection of constituent materials, proportioning of concrete mixtures, testing methods, fresh and hardened concrete properties, production, quality control issues, and other aspects of SCC.

The American Recovery and Reinvestment Act of 2009 – the First 120 Days

by Robert Bini and M. Myint Lwin, Federal Highway Administration

The American Recovery and Reinvestment Act of 2009 (Recovery Act) was enacted by the 111th United States Congress and signed into law by President Obama on February 17, 2009. The purposes of the Recovery Act are to:

- Preserve and create jobs and promote economic recovery;
- Assist those most impacted by the recession;
- Provide investments needed to increase economic efficiency by spurring technological advances in science and health;
- Invest in transportation, environmental protection, and other infrastructure that will provide long-term economic benefits; and
- Stabilize state and local government budgets, in order to minimize and avoid reductions in essential services and counterproductive state and local tax increases.

The Recovery Act contains a total of $787 billion in investments, of which $48.12 billion is for modernizing the nation's transportation infrastructure. The distributions of the transportation investments are shown in Fig. 1.

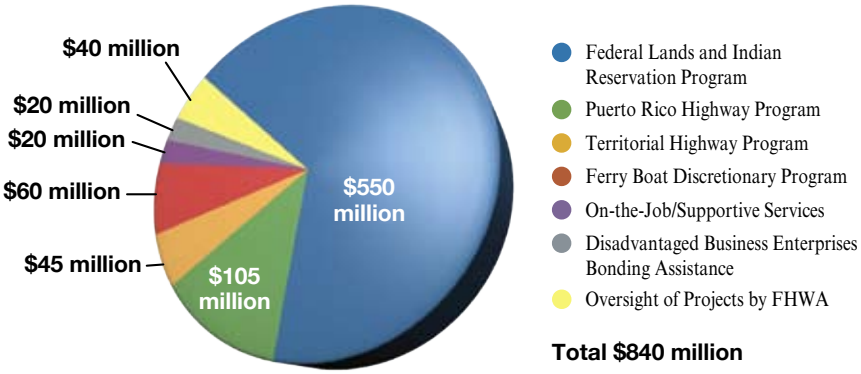


FIGURE 2 - The established Recovery Act set-asides.

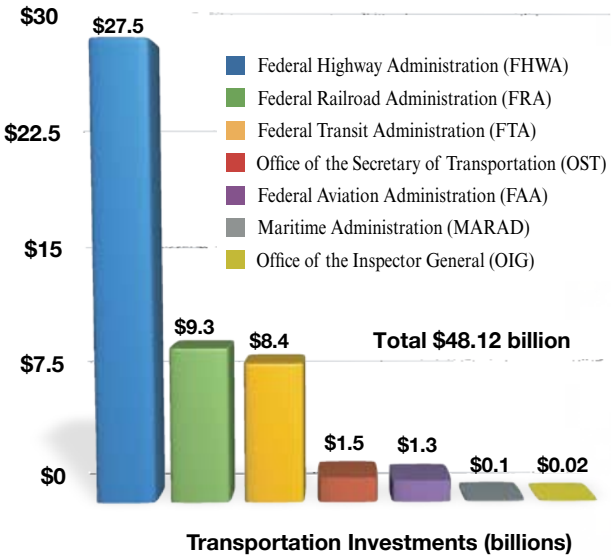
Rebuilding America's Highway Infrastructure

In his inauguration day address on January 20, 2009, President Obama said, "For everywhere we look, there is work to be done. The state of the economy calls for action, bold and swift, and we will act—not only to create new jobs, but to lay a new foundation for growth. We will build the **roads and bridges**, the electric grids, and digital lines that feed our commerce and bind us together…All this we can do. All this we will do."

The Recovery Act appropriates a total of $27.5 billion in Highway Infrastructure Investment funds for restoration, repair, construction, and other improvement activities for roads and bridges under the Surface Transportation Program (STP). The Recovery Act establishes the set-asides shown in Fig. 2.

The remaining $26.66 billion ($27.5 billion less set-asides of $0.84 billion) of the Highway Infrastructure Investment funds is to be distributed in accordance with provisions in the Recovery Act. The Recovery Act requires that 3% of the funds be dedicated to transportation enhancements, 30% be dedicated and distributed according to urban areas with a population greater than 200,000, to

FIGURE 1 - Distributions of the Transportation Investments.



suburban areas with a population equal to or less than 200,000, and to rural areas with a population less than 5,000 and the remaining 67% be used by the states in any areas. Accordingly, the distribution of the Highway Infrastructure Investment funds is as shown in Fig. 3.

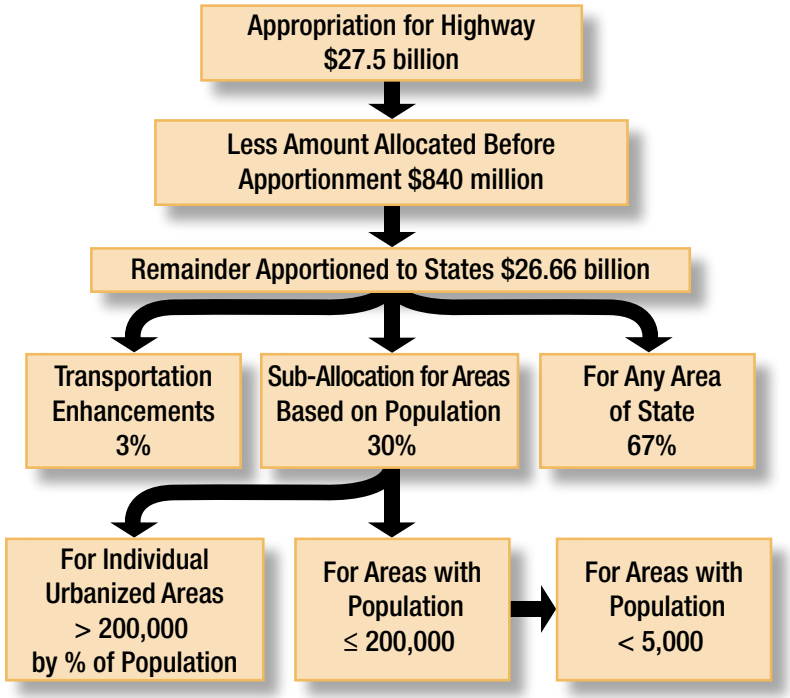


FIGURE 3 *- Distributions of the Highway Infrastructure Investment funds.*

The First 120 Days

The Recovery Act further provides that after 120 days following the date of apportionment of funds, the Secretary of Transportation shall withdraw from each state an amount equal to 50% of the funds awarded to that state (excluding funds suballocated within the state) less the amount of funding obligated (excluding funds suballocated within the state). This means that only the funds for Transportation Enhancements (3%) and For Any Area of State (67%) are subject to the 120-day provisions.

During the weeks and months following the enactment of the Recovery Act, FHWA has worked diligently with state partners and stakeholders to meet the purposes and provisions of the Recovery Act; to be ready to put Americans back to work by making needed investments in the nation's infrastructure.

On March 3, 2009, President Obama and Vice President Biden came to the U.S. Department of Transportation to join Secretary LaHood in announcing that nearly $26.7 billion was available to the states for investment in roads and bridges. Within hours of the President's announcement, the states began approving projects in full compliance with the federal laws and regulations.

On April 13, 2009, the President and Vice President returned to the U.S. Department of Transportation to celebrate the 2000th transportation project approved for Recovery Act funding—reconstruction of a $68 million interchange on I-94 in Portage, Mich., to improve safety, reduce congestion, and create 900 jobs. Of the first 2000 transportation projects approved for funding, 1860 were FHWA-funded projects. On August 3, 2009, the $44.5 million highway project near Phoenix, Ariz., became the 6000th project funded by the Recovery Act.

FHWA continues to work together with the states as successful partners in approving, authorizing, and contracting Recovery Act projects to put America to work for a quick economic recovery. The 120-day deadline for having 50% of the Highway Infrastructure Investment funds apportioned to the states was June 29, 2009. By June 22, the FHWA Division Offices have already authorized 4836 projects in all 50 States, the District of Columbia, Puerto Rico, and the territories for a total of $15.4 billion obligated. That was 58% of total funds available and beat the deadline by many days! FHWA is working diligently with the states to ensure that the funds for the Recovery Act projects continue to be distributed quickly, responsibly, and with unprecedented transparency and accountability. Figure 4 shows the progress of the projects.

Closing Remarks

Recovery Act dollars are creating jobs and promoting economic recovery. The funds are directed toward needed investments in people and in the transportation infrastructure. Every new project FHWA obligates is a signal for states to advertise construction contracts, and for contractors to begin hiring workers and ordering construction materials, such as concrete, steel, and asphalt. The nation is making investments in projects that will save lives; to help the highway system operate more efficiently and effectively, while moving the people and goods needed to regain a healthy economy.

The FHWA website, http://www.fhwa.dot.gov/economicrecovery/index.htm, contains comprehensive information about FHWA efforts on the Recovery Act. The White House website, http://www.recovery.gov/, provides reports on the activities relating to the Recovery Act.

Robert Bini is program coordinator with the FHWA Office of Planning, Environment, and Realty and M. Myint Lwin is director, Office of Bridge Technology, Federal Highway Administration, Washington, D.C.

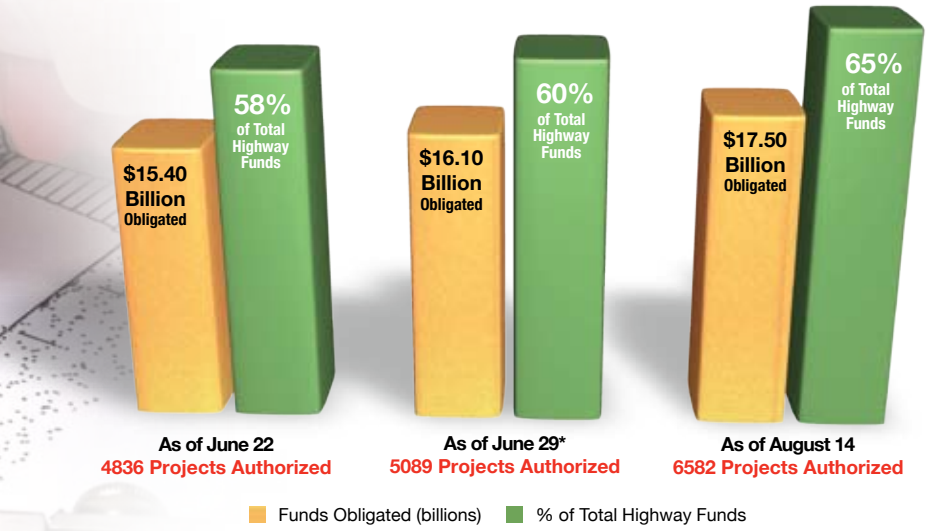


FIGURE 4 *- Progress of the Projects.*

**The 120-Day Deadline*

U.S. Department of Transportation
Federal Highway Administration

Expanded Shale, Clay, and Slate Institute

The Expanded Shale, Clay & Slate Institute (ESCSI) is the international trade association for manufacturers of expanded shale, clay, and slate (ESCS) aggregates produced using a rotary kiln. The institute is proud to sponsor *ASPIRE*™ magazine.

Sustainable concrete bridges must be durable bridges. Durable concrete must have both low permeability and few or no cracks. Lightweight aggregate concrete has been shown to have enhanced properties in both of these issues. The enhanced performance of lightweight concrete has been attributed to a number of factors including:

- Internal curing provided by premoistened lightweight aggregate;
- Elastic matching of the lightweight aggregate and hardened paste;
- Excellent bond between the lightweight aggregate and paste; and
- Lower modulus of elasticity and higher strain capacity.

The enhanced durability of lightweight concrete, combined with the obvious benefits of reduced density, results in structures that will last longer. Such structures conserve valuable natural resources as well as scarce funds for bridge construction and rehabilitation.

For more information on lightweight concrete, including references discussing the factors mentioned above, please visit www.escsi.org. The members of ESCSI look forward to assisting owners, designers, and concrete producers in using lightweight concrete for bridges.

A Brief History of Concrete Bridge Construction in Tennessee

by Edward P. Wasserman, Tennessee Department of Transportation

The Elk Avenue Bridge in Elizabethton, Tenn., completed in1926, is a Luten Bridge Company reinforced concrete arch, restored in 2003 by TDOT. Photos: Tennessee DOT.

The beginnings of concrete bridge construction in Tennessee can be traced to approximately 1910. At the time, there were no formal bridge construction programs. Cities and counties usually funded individual projects. Prior to about 1910, bridges, depending on span lengths, were constructed of all timber, iron, or steel trusses with wooden decks, masonry filled arches, or masonry substructures with wooden beams and decks.

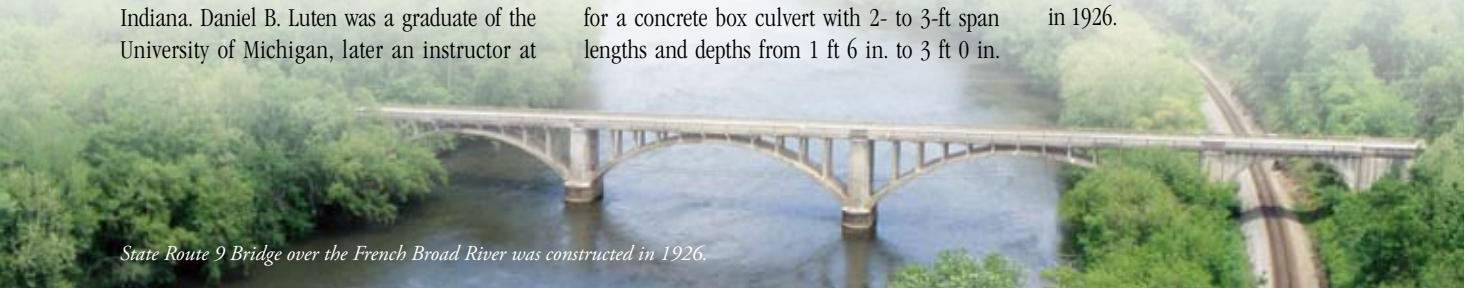
The impetus for the initiation of concrete construction was two-fold. First, counties perceived that a new structural system utilizing concrete spandrel arches—both filled and open—while not less expensive than the other systems mentioned, offered the potential for less maintenance, even "a 100-year life." The second driving force was the establishment of several firms, many located in Knoxville that aggressively marketed concrete arch construction. The most notable of the companies was the Luten Bridge Company, based in Indiana. Daniel B. Luten was a graduate of the University of Michigan, later an instructor at Purdue University, and an entrepreneur who was a pioneer in the design and construction of reinforced concrete. An example of his work in Tennessee is the Elk Avenue Bridge over the Doe River in Elizabethton, constructed in 1926. The bridge was recently rehabilitated by the Tennessee Department of Transportation (TDOT) and was described in *ASPIRE*™, Fall 2007.

The Tennessee Highway Department was established by the Legislature in 1915. The Legislature anticipated favorable action by the United States Congress on a pending bill that would provide federal aid for road construction. The federal law had a provision that each state was required to have a highway department suitably organized and equipped to discharge its responsibilities. The bill became law in 1916.

From those beginnings, reinforced concrete played an integral and dominant part in bridges designed and constructed by the new Highway Department staff. The first standard drawing, D-0-1, dated February 15, 1917, was for a concrete box culvert with 2- to 3-ft span lengths and depths from 1 ft 6 in. to 3 ft 0 in. for a 20-ft-wide roadway. Other standards that bear a similar date included the first slab bridge for span lengths of 12 ft 0 in. to 24 ft 0 in. and the first concrete deck girder bridge with a 32-ft length for a 16-ft 0-in.-wide roadway.

The era of reinforced concrete had begun. It was followed by the development of standard wingwalls, abutments, piers, and bents to support the superstructures of bridges of all types of construction. In addition, there was a seemingly endless variety of concrete box and slab bridges, and concrete deck girder spans of varying lengths, skews, and roadway widths.

The vast majority of concrete deck girders were standard simple spans assembled in series to form a bridge of needed length. However, by as early as 1928, certain bridges were constructed utilizing multiple-span, continuous tee-beam units with integral intermediate substructures. There were also more monumental designs, such as the State Route 9 Bridge over the French Broad River, an open spandrel arch bridge built in 1926.



State Route 9 Bridge over the French Broad River was constructed in 1926.

A Change in Direction

The use of reinforced concrete continued into the late 1950s and the beginning of the interstate highway construction era. Several events at the time converged to redirect structural concrete systems in Tennessee.

As the Highway Department (Department) staffed up to design the Interstate System, new young engineers with fresh eyes and ideas joined the Department. The first fully continuous tee-beam bridge to be constructed in many years appeared in 1956 and became, for a while, the dominant type of construction for Tennessee.

A continuous tee-beam bridge typical of Tennessee construction from the late 1950s through the early 1970s.

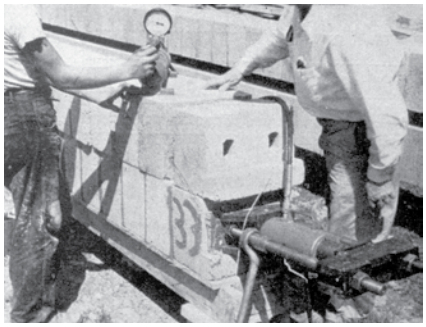
It was recognized that continuity provided redundancy, structural efficiency, and reduced maintenance requirements. For spans greater than 70 to 80 ft, the concrete structural system of choice was the cast-in-place concrete hollow box girder, the first of which was the two-level Hope's Gap Interchange near Knoxville.

The first cast-in-place concrete, mildly reinforced, integral, hollow box girder bridge, Hope's Gap, near Knoxville, constructed circa 1960.

An event in the fall of 1950 started a chain of events that would blossom into the predominant concrete structural system in Tennessee today. To quote an editorial in the January 18, 1951, issue of the *Engineering News Record*, "The first prestressed bridge in the United States was completed last October. But it wasn't the Walnut Lane Bridge in Philadelphia—the one nearly everybody expected to be the first. It was a highway bridge in Madison County, Tennessee." The subject bridge, Christmasville Road over Duffy's Creek, was opened to traffic on October 20, 1950, less than 2 weeks after erection started.

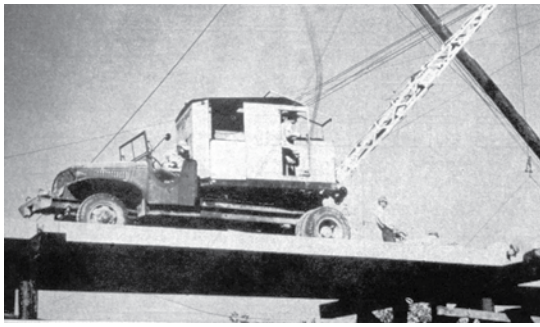
While consisting of only three spans, the largest of which was 28 ft 9¼ in., it was dwarfed by the Walnut Lane Bridge. However, besides being the first open to traffic, the Christmasville Road Bridge is significant in several other respects important to the precast, prestressed concrete industry. In the Walnut Lane Bridge, located in Fairmont Park in Philadelphia, Pa., the girders were prestressed by tendons composed of from 24 to 64 wires with a diameter of 0.276 in. Only two of these wires were tensioned at a time. The beams in Walnut Lane were prestressed utilizing a specialty contractor hired for the work. On the other hand, the Christmasville Road beams utilized seven-wire strands, equipped with special fittings, all supplied by the John A. Roebling and Sons Company. These are the same seven-wire strands that are still the industry standard today.

The beams for Christmasville Road were fabricated from nominal 16-in. by 12-in. by 8-in. concrete blocks pressed from a mold and manufactured by Nashville's Breeko Block and Tile Company. Blocks were laid on a smooth concrete slab and strung on the seven-wire cables individually with butting surfaces mortared. Special 4-in.-long deviation blocks were inserted at the one-third points to establish strand deflection. Solid sections were placed at each end to accommodate anchor plates for jacking. Stressing was accomplished with a hydraulic monostrand jack. The strands were not grouted. Technically, this was the first bridge in the United States utilizing span-by-span, post-tensioned segmental construction! Unlike the Walnut Lane Bridge, this bridge remains in service today.



Tensioning both strands during fabrication of the prestressed concrete block beam for the bridge carrying Christmasville Road over Duffy's Creek, Madison County, Tenn.

Completed beams were transported to the site and erected side-by-side on the substructures. Concrete was placed to fill the voids between adjacent beams, to form the support diaphragms and provide a nominal 3-in.-thick riding surface. Transverse rods were fitted through the beams and torqued to complete the bridge.



Christmasville Road Bridge, Madison County, Tenn., nearing completion.

Based on this early exposure, the Department became interested in prestressed concrete. Several more bridges of the block beam variety were constructed by the state. These were designed by the firm of Bryan and Dozier, Nashville, designers of the Christmasville Road Bridge.

By 1957, the Department was in high gear. Plans were underway for a large number of precast, prestressed concrete bridges using simple-span I-beams with composite decks and side-by-side box beams with asphalt overlays. Between the newly instituted Interstate Highway System and the state's road building program, structures were being turned out at a rapid rate.

In the early years, prestressed concrete beams were not particularly the most cost effective solution to bridge construction, especially when bid without alternatives. As more prestressed concrete manufacturing plants sprang up and as the Department began to offer competing alternate designs pitting precast, prestressed concrete against cast-in-place concrete with mild reinforcement, precast concrete beam prices began to become truly competitive.

By the early 1960s, the Department's Structures Division was wholeheartedly committed to the proposition that continuity in superstructure design was the future. Leakage through the joints of simple span bridges was recognized as the Achilles Heel for bridges, even before the advent of using large quantities of salt. Given time, this leakage would attack the pier caps, columns and beam ends, causing serious deterioration of the concrete and corrosion of the steel.

The I-26 Bridges over the Holston River in Kingsport are 2700-ft-long continuous bridges with no intermediate expansion joints.

At that time, the logical materials for continuous structures were cast-in-place concrete and structural steel beams because they readily adapted themselves to continuity. Consequently, more and more of the Department's designs utilized steel and cast-in-place concrete to accomplish the goal of total continuity. This created a problem. One of the most economical materials, precast, prestressed concrete, was not being used as often.

The Department didn't want to ignore a proven economical building material simply because it could not, at that time, meet the framing criteria. They set about to address the challenge of bringing precast, prestressed concrete into the continuity fold.

Taking a cue from the Illinois Toll Highway Department, where prestressed concrete beams had been designed as simple spans but were fitted with continuous decks, the wheels began to turn. While the decks and end diaphragms between beams on the Illinois Toll Road beams experienced cracking, it was felt that prestressed concrete beams could be designed as continuous for live load and composite for dead load if the correct connection between the ends of abutting beams could be made. Several solutions were evaluated without success. Then, in 1963, the Department received several Portland Cement Association (PCA) bulletins that discussed recent test results on continuous prestressed concrete structures recently constructed. The PCA reports indicated a very simple connection was practical to achieve. The connection consisted of reinforcing bars, developed into the beam ends and projecting, with hooked ends, and lapped with bars from beams in the adjacent span.

I-40 Bridge over Big Sandy River was the first bridge in the United States using simple spans for dead loads and continuous spans for composite live load.

The first design in Tennessee of a continuous-for-live-load prestressed concrete bridge utilizing the PCA details was completed in 1963 and constructed in 1964. This trial design was for dual, 11-span bridges, 703 ft long and 36 ft wide, constructed to carry I-40 over the Big Sandy River. These bridges were subsequently widened to 42 ft in 1990. Except for deck repairs, no deterioration of diaphragms, beams, or substructure was observed. The longest precast, prestressed continuous bridges in Tennessee are dual roadways in Kingsport, constructed in 1980. The bridges are 2700 ft long with joints at the abutments only. All bents incorporate fixed neoprene bearings in a pinned connection.

As continuous designs with prestressed concrete bridges matured, there was a corresponding decline in the use of cast-in-place, reinforced concrete bridges. Several factors drove this transition. Prestressed concrete bridges became cost competitive, offered faster construction with less labor, and the Department had established a policy of no falsework construction over streams or active rail and road traffic. As the construction of the Interstate System came to a close, the opportunity to use cast-in-place concrete construction diminished and new, longer prestressed concrete beam sections became available to negate the need for longer cast-in-place concrete hollow box girder spans.

Jointless Construction

By the mid-1960s, having achieved the goal of continuous bridge design, the Department began to seek total elimination of bridge joints by constructing bridges with integral abutments. The first such bridge was a ramp in Chattanooga, constructed in 1960. This continuous, haunched, three-span bridge was 168 ft long. Since those years, based on trial and error, the Department has extended jointless construction so that 800-ft-long bridges are the norm. Over 85% of the new designs are jointless. Two jointless bridges with lengths of 1157 ft and 1175 ft have been constructed and have proved successful.

The Tennessee Department of Transportation is proud of its role in the development of concrete bridge design and trusts that many of its pioneering efforts have made contributions to the design community.

Edward P. Wasserman is civil engineering director, Structures Division, Tennessee Department of Transportation, Nashville, Tenn.

For more information on Tennessee's bridges, visit www.tdot.state.tn.us.

The State Route 50 Bridge over Happy Hollow Creek is 1175-ft-long and jointless with integral abutments.

photo courtesy of PCI and Mid-States Concrete Industries

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GEMS OF THE CITY: THE BRIDGES OF DAYTON, OHIO

by Stephen J. Finke, John D. Gower, Joseph R. Weinel, and Keith G. Steeber, City of Dayton, Ohio.

Construction on the six-lane, seven-span Stewart Street Bridge over the Great Miami River began in June of 2008 and its completion is expected in December of 2009. It uses spread, precast, prestressed concrete box beams on V-shaped piers.

Dayton, Ohio, located in the Miami River Valley, sits at the confluence of four waterways: the Great Miami River, the Mad River, the Stillwater River, and Wolf Creek. The City of Dayton owns and maintains 10 roadway bridges over these watercourses, with the original bridges being built between 1907 and 1927. Of those, one was built as a steel truss bridge, two as concrete-encased steel plate girder bridges, and seven as concrete arch bridges. Dayton's bridges of the 1800s were primarily steel bridges. However, with the development of street cars, it was determined that steel bridges could not support the extra weight, and in the early 1900s the decision was made to require concrete to be the main material for the construction of future bridges.

All bridges in Dayton are inspected annually. Recognizing a need to perform a more thorough evaluation of these bridges, the city hired a consultant in 1999 to inspect them, assess their condition and structural integrity, and provide recommendations (with costs) for any necessary rehabilitation or replacement. What was found was alarming: eight of the 10 bridges would need reconstruction or replacement within the next 15 years. So far, with the help of the Ohio Department of Transportation, the Ohio Public Works Commission, and the U. S. Department of Housing and Urban Development, the city has been able to fund the replacement of seven of these bridges.

One of the first tasks undertaken by the Engineering and Planning staff was to develop a philosophy for the aesthetics of the new bridges. Although most of the bridges were arches, the thinking was that it wasn't necessary that new bridges had to be arches. The philosophy that was crafted envisioned a series of high-style bridges that would strengthen unique characters of their locations. What has resulted is a design spectrum that incorporates the best of public works design traditions of Dayton's past into contemporary design approaches that represent a fresh and forward look for the city. At least three alternate bridge types were evaluated for each project, and the community was engaged in the decision making for the bridge selected. Precast, prestressed concrete beams—box beams, I-beams, and U-beams—have been used on all the bridges. Concrete's availability, durability, and low maintenance made its choice a sensible one. Features such as lighting, railing, and fascia panels have been incorporated into final designs, enhancing existing features prevalent in the surrounding neighborhoods.

Two bridges presently under construction will function as new public works landmarks on Dayton's panoramic landscape. The Stewart Street Bridge over the Great Miami River provides the significant east-west connection through southern Dayton. The six-lane, seven-span precast, prestressed concrete box beam bridge, supported on cast-in-place concrete V-shaped piers, will be the city's largest. It will feature colored, patterned concrete plazas at each corner, galvanized, painted steel railing, and decorative under-bridge lighting. The Edwin C. Moses Boulevard Bridge over Wolf Creek will be the city's most visible bridge for western downtown residents and businesses and for travelers on Interstate 75. The new two-span structure will consist of a concrete deck on prestressed concrete U-beam girders, supported by wall-type piers. The west sidewalk will present a cable-stay appearance, with a 55-ft-tall tower and 10 cable tendons. Each cable will be individually lit, and flood lighting will be provided for the tower.

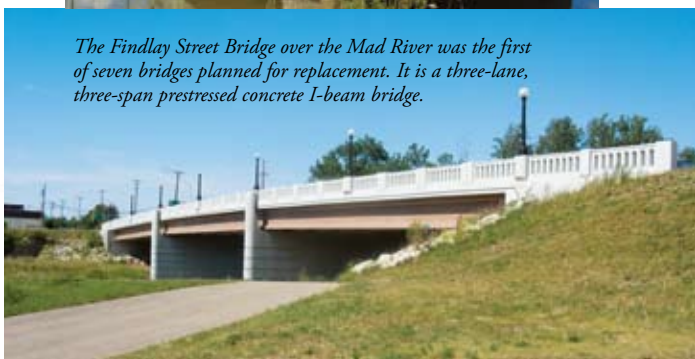
It will be the aesthetic look and innovative concrete structure design that will define the next century of the city of Dayton's bridges. They will truly be the 'Gems' of the Gem City.

Stephen J. Finke is assistant director, Department of Public Works, John D. Gower is director, Department of Planning and Community Development, Joseph R. Weinel is senior engineer II, Department of Public Works, and Keith G. Steeber is chief engineer, Department of Public Works, all with the City of Dayton, Ohio.

The Washington Street Bridge over the Great Miami River is a three-lane, seven-span, precast, prestressed concrete box beam bridge with precast concrete arch segments and cast-in-place concrete wall piers. It has 10-ft-wide sidewalks with decorative lighting above and below the bridge.

The Paul Laurence Dunbar Street Bridge spans Wolf Creek as a two-lane, three-span bridge using prestressed concrete box beams and reinforced concrete wall piers. It has ornamental lighting and plazas at all four corners.

This is a rendering of the Edwin C. Moses Boulevard Bridge over Wolf Creek. It will be a five-lane, two-span bridge with U-girders.



The Findlay Street Bridge over the Mad River was the first of seven bridges planned for replacement. It is a three-lane, three-span prestressed concrete I-beam bridge.

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.

The HL-93 Notional Live Load Model: What Nature of Truck Does It Represent

by Dr. Dennis R. Mertz

In the Summer 2009 issue of *ASPIRE,*™ Part 1 of the discussion of the HL-93 notional live load model discussed the reason for developing the new model and compared HL-93 with the HS20-44 live load model of the *AASHTO Standard Specifications for Highway Bridges*. In Part 2, the nature of the truck it represents is defined.

The HL-93 notional live-load model, in which HL stands for "highway load" and 93 designates the year of its development of the *AASHTO LRFD Bridge Design Specifications* is the superposition of a vehicle and a lane load. The vehicle is either the traditional HS20-44 truck, now termed the design truck, or a design tandem consisting of two 25-kip axles 4 ft apart, similar to the traditional interstate or alternative military load; whichever produces the greater force effect. The design lane load is the traditional HS20-44 lane load, but without the supplementary concentrated loads associated with it. Thus, traditional load components are combined to produce the HL-93 load.

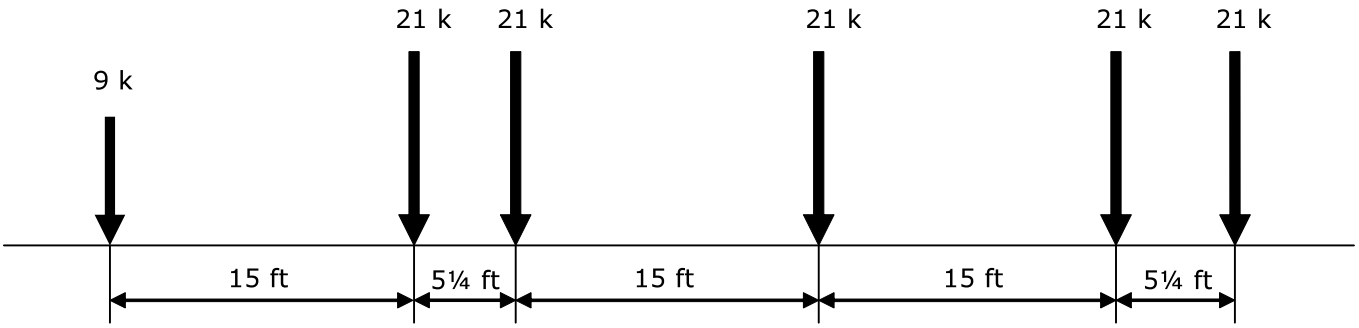
For long-span bridges, the *design lane* load becomes the predominant load component with the vehicle becoming more and more insignificant with increasing span lengths. For short- and medium-length spans, the design tandem or design truck loads are the predominant load components with the design lane serving to amplify the vehicle loads to loads of greater magnitude. Thus, for these span lengths, the force effects of the vehicles, which have a gross vehicle weight less than the legal loads, are magnified to super-legal load levels for design. Therefore, highway bridges are implicitly designed for loads above the legal limits without explicitly specifying individual super-legal vehicle loads in the specifications.

The three components of the HL-93 notional live load model—the design tandem, the design truck, and the design lane—can be used to define short-, medium- and long-span bridges. Bridges for which the design tandem is the predominant load component can be thought of as short-span bridges; those for which the design truck is predominant, as medium-span bridges; and those for which the design lane is predominant as long-span bridges.

To understand the magnitudes of the force effects of the HL-93 notional live-load model, an explanation of its origins is useful. Originally, a live-load model similar to that of the original *Ontario Highway Bridge Design Code* was envisioned for the *LRFD Specifications*. As such, a single 55½-ft-long, 57-ton design truck (without any coincident lane load) was developed to produce the desirable uniform bias across all span lengths, as discussed in the previous issue of *ASPIRE*. This design truck was to be termed the HTL-57 (HTL stands for "highway truck load" and 57 designates 57 tons gross vehicle weight). A schematic drawing of the HTL-57 design truck that was proposed is shown below in Fig. 1.

The specification writers realized the potential political ramifications of specifying a super-legal design load, the HTL-57 design truck, in the *LRFD Specifications*. They decided instead to use the superposition of sub-legal loads, the HL-93 notional live-load model, to produce super-legal load effects. The moments and shears due to the HL-93 notional live-load model and the HTL-57 design truck are comparable for all span lengths. Thus, the moments and shears due to the superposition of the load components of the HL-93 notional live-load model are those of a relatively long, 114-kip, 6-axle truck.

Figure 1 – The HTL-57 Design Truck.



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The 47th annual Design Awards Competition sponsored by PCI drew projects from across the industry, showcasing the ways that precast concrete has become an indispensible option in the quest to build exceptional structures across America. The award winners comprise an array of complex projects, including several bridges soaring over high-traffic interchanges and environmentally delicate waterways.

Seven projects won awards in a variety of categories. The judges also conferred the Harry H. Edwards Industry Advancement Award.

The following pages showcase the bridge projects selected by the bridges and special awards juries. The honors will be presented to representatives of each project during PCI's 55th Annual Convention and Exhibition and National Bridge Conference September 12–15, 2009, in San Antonio, Tex., at the Marriott Rivercenter and Henry B. Gonzalez Convention Center.

Courtesy of Paul Grigonis.

Bridges jury (from left)

Jim Guarre, P.E.
Senior Vice President
BergerABAM Inc.
Federal Way, Wash.

Myint Lwin, P.E., S.E.
Director of the Office of Bridge Technology
Federal Highway Administration
Washington, D.C.

Mark Richardson, P.E.
Bridge Design Bureau Administrator
New Hampshire Department of Transportation
Concord, N.H.

Courtesy of Paul Grigonis.

Special awards jury (from left)

Roger Becker, P.E., S.E.
Precast Division Vice President
The Spancrete Group, Inc.
Waukesha, Wisc.

Doug Widener, LEED AP
Chicago Chapter Executive Director
U.S. Green Building Council (USGBC)
Chicago, Ill.

David P. Nasser, P.E.
Texas Office Vice President
The Consulting Engineers Group, Inc.
San Antonio, Tex.

Owner
Colorado Department of Transportation, Denver, Colo.

Bridge Engineer of Record
Summit Engineering Group Inc., Littleton, Colo.

Project Engineer of Record
CH2M Hill, Englewood, Colo.

Contractor
Ames Construction Inc., Aurora, Colo.

Precaster
Encon Bridge Co. LLC, Denver

Design Check
Max Condiotti, Longmont, Colo.

Harry H. Edwards Industry Advancement Award

SH 58, Ramp A Flyover Bridge

Golden, Colo.

"This project represents the latest state of the art in the use of curved precast bridge girders on a … public transportation project."

—Gregg Reese, engineer

The sweeping 2115-ft-(645 m)-long Ramp A Flyover Bridge on Interstate 70 (I-70) in Golden, Colo., showcases the beauty, functionality, and economy of using precast concrete for complex, long-span bridges. The $30 million project was the fifth bridge in Colorado to use curved, precast concrete girder construction and has the longest span using constant-depth, precast concrete U-girder construction in the state.

"This project represents the latest state of the art in the use of curved precast bridge girders on a … public transportation project," says engineer Gregg Reese of Summit Engineering Group Inc. in Littleton, Colo. "The bridge utilizes a number of innovations that demonstrate the flexibility inherent in the use of precast U-girders."

The new structure uses a constant, 38-ft-wide (12 m) cross section comprising one lane and two large shoulders along its length. The layout includes a four-span unit to cross over I-70 and two three-span units to bring the roadway back to grade. Bridge spans vary from 147 ft to 235 ft (45 m to 72 m) in length.

The bridge begins in a spiral curve with an 809 ft (247 m) horizontal curve at the center of the bridge deck. All curved girders were plant manufactured, and curved formwork was designed with discreet panels with break points at each end that could be adjusted to provide the necessary curvature. The curved girders were manufactured with conventional reinforcment and small quantities of monostrand post-tensioning to control stresses when the girders were removed from the casting beds.

The girders were erected in three phases and were braced during erection with double angles that were field welded to the falsework to prevent rolling. Conventional hydraulic and crawler cranes were used to set the girders.

"This project clearly demonstrates the advantages of using commercially [available] precast concrete products to construct cost-effective, complex long-span structures in high-profile applications where aesthetics and urban geometrics are significant design considerations," Reese says.

Photo courtesy of Summit Engineering Group Inc.

HHE

JUDGES' COMMENTS

This project was a unique application of precast, prestressed bridge elements to a flyover ramp where the U-shaped sections were curved, and in fact this is a terrific direction that precast concrete ought to be going to challenge the steel people in the marketplace: a marketplace where precast concrete hasn't been before. The thing that really caught my eye on this project was the fact that the girders were curved and all of the potential issues with curved elements were resolved, that the structure could be constructed economically, and that it became a very viable solution in precast, prestressed concrete.

Best Bridge with Spans Less than 75 ft, Co-winner
The Jakway Park Bridge
Buchanan County, Iowa

Owner
Buchanan County Secondary Roads, Buchanan County, Iowa

Engineer of Record
Iowa Department of Transportation, Ames, Iowa

Contractor
Taylor Construction Inc., New Vienna, Iowa

Precaster
Lafarge North America, Winnipeg, MB, Canada

Project Cost
$600,000

Because shear stresses were taken up by the UHPC, which contained steel fibers, no conventional steel reinforcing bars were required.

Photo courtesy of Iowa Department of Transportation.

The Jakway Park Bridge in Buchanan County, Iowa, is the first highway bridge in North America to be built with a new generation of ultra-high performance concrete (UHPC) pi girders, as well as being the first to incorporate UHPC batching in ready-mix trucks, establishing it as a model for bridge designs around the world.

UHPC provides compressive strengths up to 30,000 psi (210 MPa) and flexural strengths up to 6000 psi (42 MPa), as well as ductility, durability, and a range of aesthetic design possibilities.

The bridge is 112 ft long × 25 ft wide (34 m × 7.6 m) and was built using cast-in-place concrete slabs for the end spans and a center span consisting of three precast concrete pi-shaped girders. Because shear stresses were taken up by the UHPC, which contained steel fibers, no conventional steel reinforcing bars were required. The material's low permeability also makes the structure resistant to deicing salts and harsh environmental conditions.

The center span is 51 ft long (16 m) from center to center of the pier caps, and the girders are pretensioned longitudinally and tied together transversely with mild-steel reinforcement and steel diaphragms. A concrete bucket, which was almost as wide as the pi-shaped forms, was used to place the material in a way that would allow it to flow and properly align the fibers at the same time.

TA

Once the pi girders were in place at the bridge site, cast-in-place concrete end diaphragms were used to encase the beam ends and tie the girders together at the pier. Total cost for the project was $600,000.

"This important, collaborative project provided the opportunity to gain additional experience in the designing, testing, mixing, and casting of UHPC in this first-ever use of the material in the FHWA-developed pi girder," says Norm McDonald, bridge engineer for the Iowa Department of Transportation in Ames, Iowa.

JUDGES' COMMENTS

This ultra-high-performance concrete project is a good demonstration of the use of an emerging technology for expanding the application of precast, prestressed concrete to improve durability, reduce weight, and increase speed in construction. This project pushes the envelope of design by utilizing an ultra-high-performance concrete member that provides a very economical section for the project and has a variety of applications for future projects.

Owner
County of Lancaster, Lancaster, Pa.

Engineer of Record
RETTEW Associates Inc., Lancaster

Contractor
Kinsley Construction Inc., York, Pa.

Precaster
Newcrete Products, Roaring Spring, Pa.

Precaster Specialty Engineer
Pennoni Associates, State College, Pa.

Best Bridge with Spans Less than 75 ft, Co-winner
Big Chickies No. 2 Bridge over Chiques Creek
Lancaster, Pa.

No temporary formwork or scaffolding was placed in the creek during the construction of the new bridge, which saved the contractor time and money.

Photo courtesy of Kinsley Construction.

The engineers who designed the replacement for the two-lane Big Chickies No. 2 Bridge over Big Chiques Creek, in Lancaster, Pa., chose a precast concrete solution to mimic the distinctive architectural features of the original 1920s design, but with a more durable structure that could sustain greater loads, minimize flooding, and increase sight lines for safety.

The new bridge, which opened December 2008, features precast concrete tied-through arches and a cast-in-place concrete deck that replicates the graceful appearance of the original. The engineer lengthened the bridge to a 70 ft (20 m) span to facilitate hydraulic improvements and to minimize the frequency of floodwater overtopping the road.

The massive arches were cast in the manufacturer's plant and were then erected in a single-night operation in the field.

During fabrication of the arches, the team used 1/16 in. (2 mm) form tolerances measured with a transit so that the enormous amount of reinforcement and post-tensioning steel would fit in the forms and meet clearance and cover requirements. The fabricator used additional reinforcement and temporary post-tensioning in the arches to accommodate handling forces, which permitted the arches to be safely transported from their plant to the jobsite. No temporary formwork or scaffolding was placed in the creek during the construction of the new bridge, which saved the contractor time and money. A 22-in.-thick (560 mm) deck spanning the distance between arches eliminated the need for embedded steel floor beams.

"While the design team faced numerous design challenges with the bridge replacement project, the team's efforts resulted in a bridge that pays homage to the original structure and the historic setting in which it is located," says senior bridge engineer Dan Rogers.

JUDGES' COMMENTS

Precast concrete provides an excellent solution for the replacement of a historic bridge.

Best Bridge with Spans between 75 and 150 feet

Route 70 over Manasquan River, September 11 Memorial Bridge

Ocean and Monmouth Counties, N.J.

Photo courtesy of Eric Yermack, P.E.

The bridge was designated a memorial to the 170 people from Monmouth and Ocean counties who died in the September 11 terrorist attacks.

Owner
New Jersey Department of Transportation
Trenton, N.J.

Architect
HZLZ LLP
New York, N.Y.

Engineer of Record
Arora and Associates PC
Lawrenceville, N.J.

Contractor
George Harms Construction Co. Inc.
Farmingdale, N.J.

Precaster
Northeast Prestressed Products LLC
Cressona, N.J.

Project Cost
$65 million

Developers of the $65 million project to replace a structurally deficient 70-year-old movable bridge over the Manasquan River in New Jersey faced many aesthetic, structural, and environmental challenges.

Along with creating a gateway to Monmouth and Ocean counties, the bridge was designated a memorial to the 170 people from those counties who died in the September 11, 2001 terrorist attacks, which meant careful attention had to be paid to every architectural detail. Developers were also required to work around migrating and spawning fish runs, which limited in-water construction to six months out of the year.

Choosing a precast concrete design enabled the project team to overcome many of these challenges while creating a beautiful and functional bridge that meets the needs of the community and the environment.

The 724-ft-long (221 m) bridge features twin structures, each with two three-span continuous superstructure units comprising 120-ft-long (37 m) bulb-tee girders spaced at 8 ft (2.4 m) on center.

TB

The original bridge's substandard 15 ft (4.6 m) vertical underclearance was raised to 25 ft (7.6 m), and the navigation channel was widened from 50 ft to 75 ft (15 m to 23 m). The resulting span arrangement and geometry allowed the first half of the bridge to be constructed next to the existing bridge foundations without any traffic disruption.

The superstructure is supported on stub abutments behind mechanically stabilized earth walls and five in-water piers with deep foundations. The architecturally treated pier columns and caps were constructed using precast concrete components connected through post-tensioning. The pier foundations were constructed at the waterline within precast concrete cofferdam shells, which offered significant cost and schedule advantages over traditional cofferdams.

"Using precast [concrete] eliminated the need for traditional cofferdams, minimized riverbed disturbances, and facilitated the construction of a high-quality signature bridge 25 months ahead of schedule," says project manager Eric Yermack of Arora and Associates in Lawrenceville, N. J.

JUDGES' COMMENTS

The thing that caught our eye on this project was really the extensive use of precast concrete in the cofferdams, in the piers, the caps, and the bridge superstructure. The use of precast concrete shortened the construction time by 25 months. Another thing was the use of an innovative diaphragm between superstructure elements, which really was borrowed from other states.

Best Bridge with Spans More than 150 ft
Angeles Crest Bridge No. 1
Wrightwood, Calif.

Owner
California Department of Transportation
Sacramento, Calif.

Engineer of Record
California Department of Transportation
Sacramento

Contractor
Griffith Co.
Brea, Calif.

Precaster
Pomeroy
Perris, Calif.

"The modular nature of the precast girders proved to be key to the success of this project." —Jose Higareda, project engineer

After a landslide closed the main highway linking a resort town near Wrightwood, Calif., to the major metropolitan area, the California Department of Transportation (Caltrans) wrestled with various solutions to reopen the pass. The side of the mountain continued to slump more than 500 ft (150 m) to the valley floor, and the landslide was active. Efforts to stabilize the mass of rock were ineffective, which made it necessary to place abutments on stable soil comfortably outside the slide limits. This decision meant that the bridge span would reach more than 200 ft (60 m).

A cast-in-place (CIP) concrete option was eliminated because falsework could not be placed on the sliding mass, and steel was not used because of its cost and six-month delivery schedule. After careful consideration, an 8-ft-deep (2.4 m) and 4-ft-wide (1.2m), spliced, precast concrete bulb-tee-girder design was selected.

Due to the narrow mountain roads, the girder had to be fabricated in pieces short enough to maneuver the two-lane road that leads to the site. The 208-ft-long (63 m) girder was divided into three pieces: two 56-ft-long (17 m) end sections that house the post-tensioning anchorages, and one 92-ft-long (28 m) center section with a 2-ft-long (0.6 m) CIP concrete closure pour between the segments.

Because girders of this size can become laterally unstable when subjected to cross slopes that place the center of mass of the girder offset from the support, special hauling rigs equipped with hydraulics were used to adjust for the superelevation and maintain the girder in a vertical position.

Special bearing seats were built into the ends of the girders to accommodate the 5.3% profile grade and reduce the bearing-pad thickness.

"The modular nature of the precast girders proved to be key to the success of this project," says Jose Higareda, project engineer for Caltrans.

JUDGES' COMMENTS

Precast concrete was used to create a bridge that was almost truly invisible in this beautiful landscape. Three large precast concrete segments were transported to the site up a very steep mountainous road, assembled into a continuous 208-ft-long girder, and then erected over this landslide. It was the mission of this bridge.

Photo courtesy of Pomeroy.

Best Non-highway Bridge, Co-winner
David Kreitzer Lake Hodges Bicycle/Pedestrian Bridge
San Diego, Calif.

TE

Owner
San Dieguito River Park
Escondido, Calif.

Engineer of Record
T. Y. Lin International
San Diego, Calif.

Contractor
Flatiron Construction Corp.
San Marcos, Calif.

Precaster
U.S. Concrete Inc.
San Diego

Additional Team Members
Safdie Rabines Architects
San Diego

"Without precast prestressed concrete, this bridge would not have been possible."
—Anthony Sánchez, senior bridge engineer

Photo courtesy of Mark Defeo.

The 1000-ft-long (300 m) David Kreitzer Lake Hodges Bicycle/Pedestrian Bridge in San Diego, Calif., is the world's longest stress-ribbon bridge. The stress-ribbon style, which is a suspension bridge with cables embedded in an ultrathin concrete deck, was chosen because it causes minimal disruption to the local ecology and blends naturally into the surroundings, all thanks to the strength and versatility of precast concrete.

"The choice to use an innovative stress-ribbon design was only possible by means of precast, prestressed concrete technology," says senior bridge engineer Anthony Sánchez of T. Y. Lin International in San Diego, Calif.

Erecting the bridge also had its challenges. The design required complex analytical methods to capture the nonlinear behavior of the cable system and the time-dependent effects from concrete creep and shrinkage, as well as staged construction analysis to capture the stresses that are locked in as the bridge is constructed.

Due to its location in an environmentally sensitive area, access to the construction site was only allowed during winter months.

The use of precast concrete enabled the project team to accommodate the limited construction schedule and minimize environmental impacts. Because the superstructure was constructed of precast concrete panels suspended on cables, it was erected quickly with no need for falsework.

Post-tensioning of the precast concrete deck panels closed the transverse joints and gave the bridge its required stiffness for live loads. The visual impact was minimized through the use of a slender 16-in.-thick (410 mm) deck and 330-ft-long (100 m) spans and only two piers.

"By using this specialized form of precast, prestressed concrete, [we] were able to design a bridge that could span the required distance with an amazingly thin deck and only two supports in the lake," Sánchez says. "Without precast prestressed concrete, this bridge would not have been possible."

JUDGES' COMMENTS

Its use of precast concrete panels in this stress-ribbon bridge provided a very slender, elegant structure. The solution used resulted in minimal harm to the environment.

Best Non-highway Bridge, Co-winner

Seattle Sound Transit Tukwila Segment Light Rail

Seattle, Wash.

TE

Owner
Sound Transit Authority
Seattle, Wash.

Project Engineer of Record
Hatch Mott McDonald
Millburn, N.J.

Bridge Engineer of Record
International Bridge Technologies Inc.
San Diego, Calif.

Contractor
PCL Construction Services
Bellevue, Wash.

Contractor's Specialty Engineer
T.Y. Lin Intenational
Olympia, Wash.

Precaster
Bethlehem Construction Inc.
Cashmere, Wash.

The Seattle Sound Transit Tukwila Segment is a 4.9-mi-long (8 km) light-rail bridge in Seattle, Wash., that provides the final link in a 20-mi-long (32 km) mass-transit system known as the Sound Transit Central Link Light Rail.

The project was the last phase in an effort to connect the southern limit of the city to the Sea-Tac airport, but the project faced significant challenges to completion, including limited access to the project site, long-span crossings over major thoroughfares, environmental concerns, and seismic activity.

"Using precast concrete offered solutions to all of these challenges," says Christopher Hall, guideway engineer for International Bridge Technologies Inc. in San Diego, Calif.

The use of precast concrete with a design compressive strength of 6500 psi (45 MPa) allowed the dimensions of the box girder to be streamlined, delivering a lighter guideway and reducing seismic loads. External diaphragms at the ends of the span provided a wider bearing spacing to add stability, and the bottom face of the diaphragm was adjustable and set to the proper grade and cross-fall in the precast concrete manufacturer's yard so that only minor adjustments were needed when the span seated on the bearings.

This precast concrete segmental box-girder design resulted in a $20 million savings on the project and accelerated the original construction schedule by six months.

Space and scheduling challenges were further addressed by limiting span lengths to increments of individual precast concrete segments and by using a standard curved vertical profile on long-span structures.

Precasting of superstructure segments took place in parallel with foundation and pier construction operations, and a single erection gantry was used to place most of the superstructure segments at a rapid pace, including periods where three spans were constructed within a week.

"Erecting from the top also eliminated many access issues associated with ground-based cranes or falsework and minimized impact to traffic and the environment," Hall says.

JUDGES' COMMENTS

The application of precast concrete sections demonstrates the versatility of this type of construction in meeting the needs of many projects. The segmental construction allows the aesthetics of the project to be easily demonstrated with a slender structure that meets the horizontal and vertical alignment constraints of the project.

Photo courtesy of International Bridge Technologies Inc.

This precast concrete segmental box-girder design resulted in a $20 million savings on the project and accelerated the original construction schedule by six months.

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PHOTO OF ROUTE 70 OVER MANASQUAN RIVER IN NEW JERSEY (PHOTO COURTESY ARORA ASSOCIATES).
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1042 North Thirty Eighth Street • Allentown, PA 18104
Telephone: (610) 395-2338

The new 4th Street Bridge in Pueblo, Colo., spans 28 active rail tracks in the Pueblo Rail Yard. Rendering courtesy of FIGG.

Access is limited in the Pueblo Rail Yard, but balanced cantilever construction easily solves this with overhead construction. Photo: FIGG.

Community Selects Bridge Aesthetics

Community members in Pueblo, Colo., had a hand in selecting the aesthetic features for the new bridge. In the FIGG Bridge Design Charette™ process, they first selected a theme that blends the clean simple and timeless lines of contemporary sculpture with the natural environment and stylistic aspects of Pueblo heritage.

Earth tone staining was selected for the bridge color to blend the bridge into its environment along the river. Specific features of aesthetic treatments will honor Pueblo's history, heritage, and artistic focus. Artistic pier medallions and tile work on the barriers and monument will include the theme at a pedestrian level. CDOT will advertise a request for proposals for the final details for the medallions and tile work.

Other elements selected by the community include vertical monuments to mark the ends of the bridge, overlooks on the bridge deck at the river piers, a plaza overlook on the southwest approach, and open pedestrian railings. Aesthetic light poles were also selected to reflect the bridge theme and provide roadway and sidewalk illumination.

Placing reinforcement and setting forms for a precast concrete cofferdam.

The precast concrete cofferdam shells offered several advantages over traditional cofferdams.

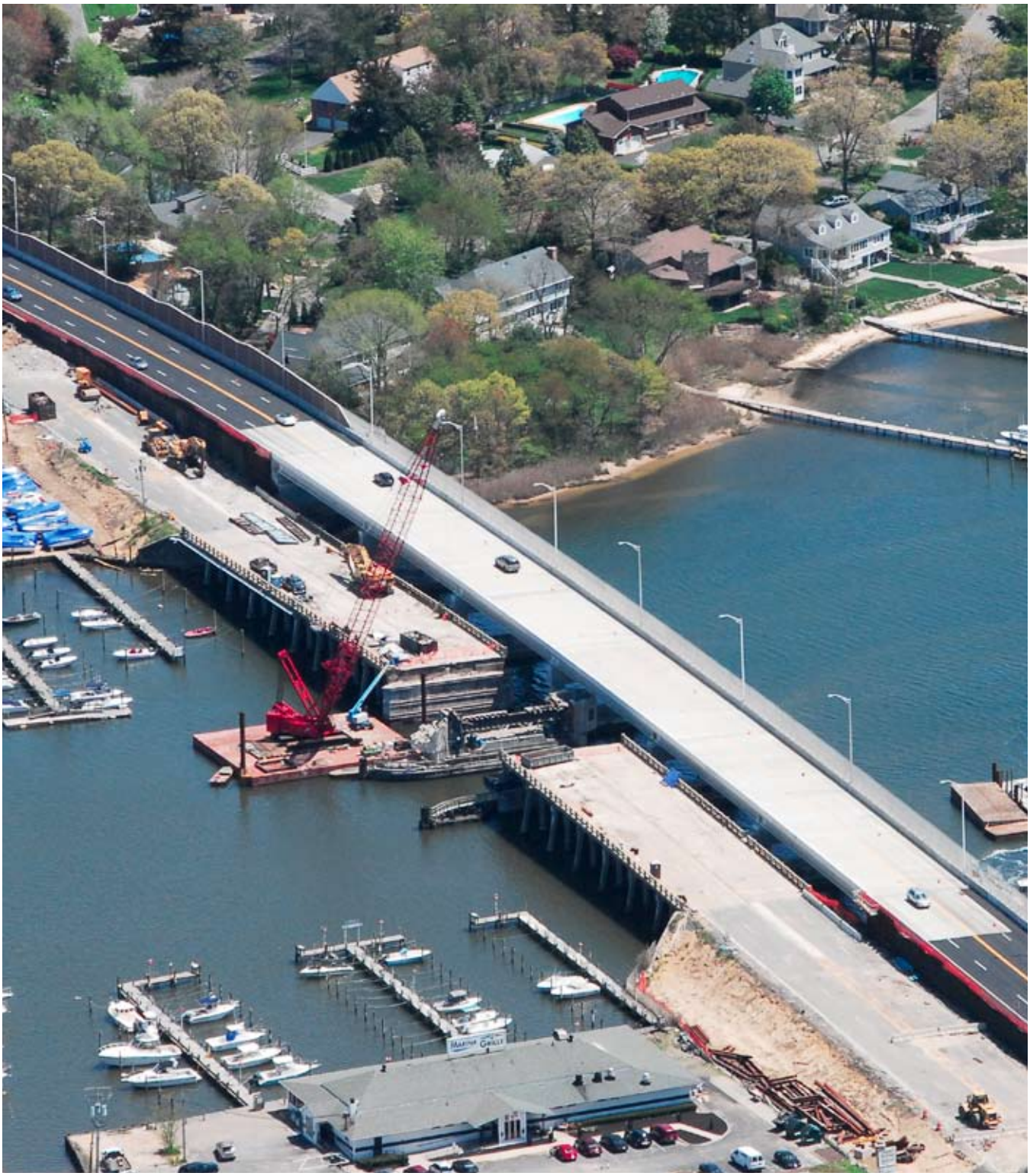
Precast cofferdam section being lowered into place.

All Photos: Arora and Associates P.C.

ROUTE 70 OVER MANASQUAN RIVER, SEPTEMBER 11 MEMORIAL BRIDGE /
OCEAN AND MONMOUTH COUNTIES, NEW JERSEY

A precast concrete substructure solution achieved the architectural and environmental goals while contributing to accelerated bridge construction.

Demolition of the existing bridge during Stage 2 construction. Four lanes of traffic were maintained and located on the new eastbound structure.



All Photos: Arora and Associates P.C.

Westbound piers during Stage 2 construction.

All Photos: Arora and Associates P.C.

ROUTE 70 OVER MANASQUAN RIVER, SEPTEMBER 11 MEMORIAL BRIDGE /
OCEAN AND MONMOUTH COUNTIES, NEW JERSEY

The Stage 1 eastbound structure under construction.

View of the precast elements and the underside of the bulb-tee girders.

All Photos: Arora and Associates P.C.

A completed cantilever section over pier 5. In the foreground, a straddlecarrier moves segments into position on the ground. Photo: Rich Lorenzen.

The Roslyn Viaduct was designed and built as a balanced cantilever bridge. The gantry crane moves segments 4 east and 4 west into position followed by stressing platforms at each end, which allow the workers to accomplish the post-tensioning. Photo: Rich Lorenzen.

After the north side of the bridge was constructed, the gantry crane was shifted to the south to remove the steel frame of the existing bridge. Photo: Rich Lorenzen.

The majority of the precast concrete girder segments for the northern portion of the bridge were installed using a 700-ft-long gantry.

Tapered pier columns create a new visual appeal for the Roslyn Viaduct. The near end will tie into the east abutment. Photo: Rich Lorenzen.

Concrete is placed at the closure pour at pier 7 using a crane and bucket while the gantry is positioned at piers 6 and 7. In the foreground are the pier 8 pier table and the east abutment. Photo: Rich Lorenzen.

Falsework for the cast-in-place slab was put in place after completing the end bents and MSE walls.

The final lift of concrete for the voided slab is consolidated and screeded.

CINCINNATI /NORTHERN KENTUCKY INTERNATIONAL AIRPORT TAXIWAY 'N' BRIDGE /
ERLANGER, KENTUCKY