CRSI

ANTI-CORROSION TIMES

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REPORTING ON INDUSTRY NEWS, NOTEWORTHY APPLICATIONS & NEW DEVELOPMENTS ON FUSION BONDED EPOXY COATINGS FOR CORROSION PROTECTION OF REINFORCING STEEL

In this issue

Anti-Corrosion Times is a publication of the Concrete Reinforcing Steel Institute, a not-for-profit trade association providing valuable resources for the design and construction of quality cast-in-place reinforced concrete. Published biannually, the *Anti-Corrosion Times* is produced to help specifiers, engineers, architects, fabricators and end-users receive the most recent information about how and where epoxy-coated reinforcing steel is used, recent technical changes and information resources. Send any questions or comments regarding the *Anti-Corrosion Times* to John T. Prentice, Director of Marketing.

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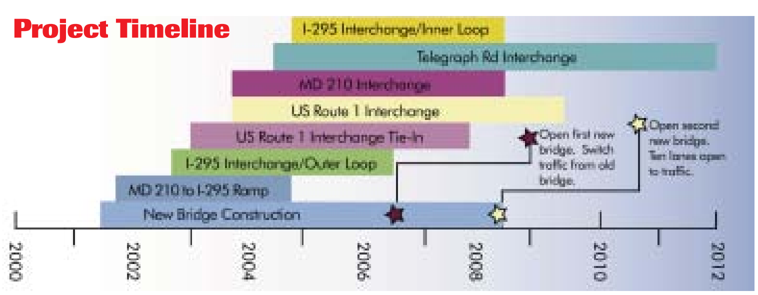
Building the New $820 Million Woodrow Wilson Bridge

Artist's rendering of Woodrow Wilson Bridge with bridge deck open

As the only Potomac River crossing in the southern half of the Washington, D.C. area, the Woodrow Wilson Bridge (WWB) is essential to the region's road and marine transportation. The WWB, integral to regional commerce, is located approximately at the mid-point of Interstate 95 and has to be efficient and safe. Replacing the existing WWB has long been a top transportation priority.

In the fall of 2000, the first phase of construction began with the dredging of the channel in the environmentally sensitive Potomac River. Some 340,000 cubic yards of mud were excavated for this initial contract — setting the stage for work on the new WWB, as well as the adjoining beltway, supporting ramps and bridges.

While the WWB will cost $820 million, the total project is $2.44 billion and is 7.5 miles long. Currently the project is on track to provide safer and more efficient travel for some 70 million bridge travel-



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ers each year. Careful and coordinated management by Virginia, Maryland, District of Columbia and U.S. Departments of Transportation, complemented by the good work of a large cast of contractors, is paying off, with a project that is on schedule and under budget. Over the life of this massive project, 45 contracts will be generated.

Coordinating between the various agencies has been essential because of the number of contracts that have been let. Many contractors were required to work concurrently to meet key milestones to enable the opening of the new bridge to traffic at the earliest possible date. The schedule calls for the first six lanes (southern span) to open by mid 2006, at which time traffic will be three lanes in each direction. The old WWB will then be demolished. Two years later, the second six lanes (northern span) is slated for opening. In addition to the new WWB, new interchanges at I-295 and Maryland 210 are scheduled to be completed in 2008. The bulk of the revamped U.S. Route 1 Interchange is scheduled for completion in 2009. The entire 7.5-mile project is scheduled for completion in 2011. The Telegraph Road Inter-change, along with a host of community and aesthetic improve-

The new Woodrow Wilson Bridge will have 12 lanes

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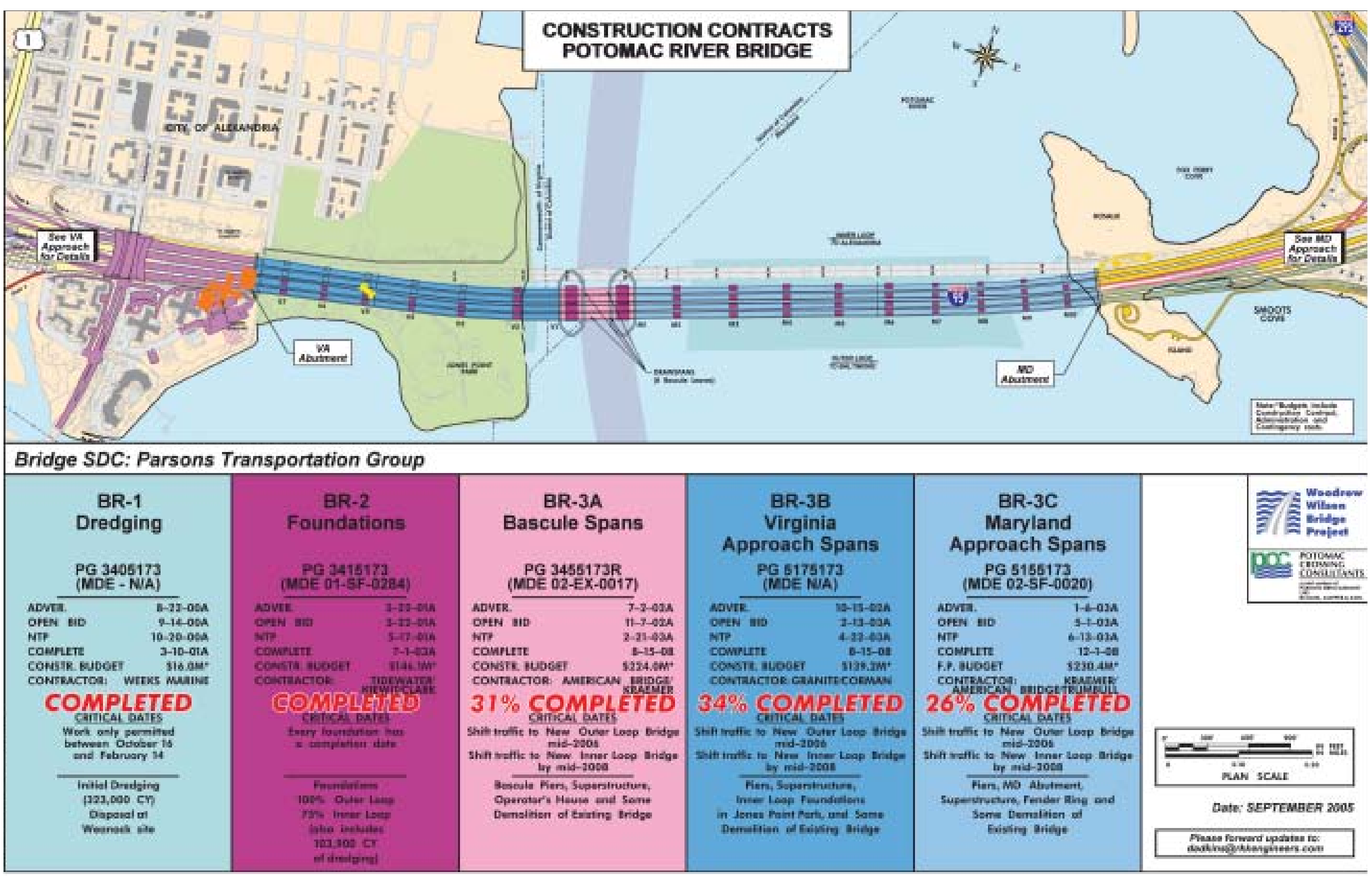

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Photo courtesy of
Trevor Wrayton, VDOT

ments, will be the last to be completed.

Old Woodrow Wilson Bridge

The existing six lane Woodrow Wilson Bridge, designed for 75,000 vehicles per day, now carries nearly three times the traffic. Daily backups occur in both Virginia and Maryland where the eight-lane Capital Beltway narrows down to the six-lane bottleneck. Congestion, usually many miles long, is made worse by the large volume of traffic entering from adjacent interchanges. Compounding the daily congestion is an accident rate that is twice as high as Virginia and Maryland averages, which stems from inadequate capacity, abrupt merge areas and a lack of shoulders. Today's 195,000 daily trips are projected to grow to 300,000 in 2020. A decade of study and planning culminated in a decision to:

- *Replace the old bridge with twin side-by-side bascule bridges, having higher clearance over the river, reducing bridge openings by an estimated 75 percent.*
- *Build for flexibility and expansion, ultimately offering twelve lanes: eight lanes to match the eight-lane Capital Beltway, two lanes to facilitate merging/exiting and two lanes for future rail transit, bus service or high-occupancy vehicles.*
- *Rebuild connecting interchanges to enable smoother and safer merges and exits.*
- *Reconstruct the Capital Beltway with a separate local/express lane for more efficient and safer traffic flow.*
- *Provide a bike/pedestrian path across the bridge and build several landside paths plus other community enhancements.*

New Woodrow Wilson Bridge

Construction of the actual structure for the new WWB began in spring 2001, with the building of pyramid-like foundation footings to support the bridge's V-shaped piers. In the river, 629 steel pipe piles were driven for the bridge foundations and 410 concrete piles were driven on land. Underway since early 2003, the draw span (or bascule) features eight opening leaves constructed of more than 14 million pounds of steel girders. Enormous form work, reaching beyond 70 feet in height, is used to form the cast-in-place concrete piers for the draw span. To increase the service life of the bridge and reduce maintenance caused by corrosion, 23,296,156 pounds of epoxy-coated rebar were used in the superstructure. An additional 1,932,528 pounds of stainless steel rebar were used in the draw spans decks. Construction of the approaches to the draw spans began in spring 2003. The Virginia approach, which begins at the Virginia abutment and connects to the draw span, is primarily over land, while the Maryland approach, from the Maryland shoreline to the draw span, involves mainly marine construction.

Special thanks to the Woodrow Wilson Bridge Project Staff for their help with information and photos for this article.

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CRCP Research . . . Use of Epoxy-Coated Steel Reinforcing Bars Substantiated Thinner Pavement

CRCP Review

Unlike plain jointed pavement or doweled jointed pavements, Continuously Reinforced Concrete Pavement (CRCP) is constructed without formed transverse joints. CRCP utilizes continuous, lapped longitudinal reinforcing bars as shown in Figure 1. Transverse cracks then develop as the concrete shrinks during curing. The steel reinforcing, in turn, provides restraint and holds the cracks tightly together. See Figure 2.

Figure 2

Depending on the many design, material, and construction variables, variations in temperature, as well as moisture conditions, transverse cracking will form at a uniform spacing of 3 to 10 feet on center. These variations are inevitable since the pavement is continuously exposed to the environment.

When CRCP is designed and constructed properly, the steel reinforcing bars hold the transverse cracks tightly together. As a vehicle's wheel passes from one pavement section to the next, the wheel load is resisted by both aggregate interlock at the crack and dowel action of the steel reinforcing bar. For this to occur efficiently and with the desired performance, the relatively tight crack width is critical. In contrast, pavement with cracks that are too wide are not able to efficiently transfer the wheel loads and consequently pavement punch-outs and subgrade deformations are likely to occur.

Figure 1

CRCP Research

Currently, the standard design practice for CRCP is reflected in the American Association of State Highway Transportation Organization (AASHTO) Guide for Design of Pavement Structures in which the steel reinforcing bar's contribution to pavement strength is assumed to be zero and recommends the same pavement thickness for doweled pavement as for CRCP.

However, based on a recently completed, indepth CRCP investigation conducted at Illinois Center for Transportation, it is anticipated that this design practice will be able to be changed now. The goal of this extensive investigation was to characterize the critical parameters that affect crack width of CRCP. The investigation included the construction of ten heavily instrumented sections of CRCP followed by loading of pavement. Based on these results, a new analytical model for cracks was developed and verified against the recorded measurements.

Focus– *To characterize critical parameters that affect the crack width of CRCP, while loading the pavement to failure.*

Parameters included:

1. *Percentage of reinforcing steel*
2. *Slab thickness*
3. *Concrete cover*
4. *The effect of uniformly induced crack spacing on performance*
5. *The affect of utilizing two layers of reinforcing steel*

In addition, to the new analytical model for crack width work was done to accurately predict crack width under diverse temperature conditions. The model, previously used to predict crack width at the steel depth, was adapted to predict crack width at any depth. Continuous surveying of the test pavement for more than two years and the

Figure 3

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Epoxy-coated rebar ready to pour

Machine finishing

Hand finishing

Heavily traveled I-290 Extension in suburban Chicago

sequential application of a large number of rolling-wheel loads at high load levels made possible the observation of responses and failure mechanisms. See Figure 3, CRCP test pavement showing the "testing to failure." CRCP is especially applicable for cases of intense heavy traffic and where the delays associated with repairs and rehabilitation have to be minimized.

For example, the first generation of interstate highway construction in the 1960s utilized pavements designed for 0.4 million ESAL (equivalent single axle loading) per design lane. Today, 2.5 million ESAL/design lane are anticipated. The Illinois Department of Transportation (IDOT) extended-life concrete pavement program anticipates and requires a design life of 30 to 40 years. This design has been used on the I-290 Extension (Route 53) in Schaumburg, Illinois, I-80/I-94, Chicago's Dan Ryan Expressway (I-90/I-94)and I-70 in downstate Illinois.

Conclusions — One of the most significant conclusions on crack width was the importance of temperature, average temperature of the pavement and temperature differential between the top and bottom of the pavement. Also noteworthy, cracks are the widest at the top of the pavement and narrowest at reinforcing steel depth or the bottom of the pavement. It was found that the reinforcing steel adds significant strength to the pavement and may allow for less concrete depth in future specifications without loss of benefits. ■

This research revealed rebar, which was epoxy-coated, adds significant strength to the pavement

Acknowledgements:

Steel Supplier: Nucor Steel (formerly Birmingham Steel) Kankakee, Illinois

Epoxy Coater: Toltec Steel Services, Inc., Kankakee, Illinois

The research referred to in this article is based upon the work supported by Illinois Department of Transportation (IDOT) under the Illinois Cooperative Highways and Transportation Research Program No. IHR-R32 and was conducted by Mr. Erwin Kohler, PhD, Project Scientist of the University of California Davis and Mr. Jeff R. Roesler, Assistant Professor, University of Illinois at Champaign-Urbana.

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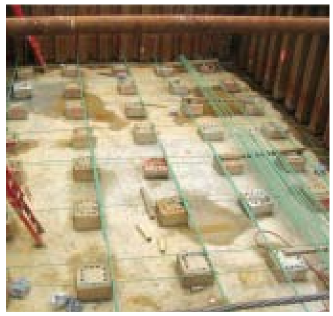
Budget Snapshot

Total Project Budget = $2.449 Billion
$ Virginia responsible for $1.062 Billion
$ Maryland Responsible for $1.371 Billion
$ D.C. Responsible for $16 Million

<u>Phase Budget</u>

River Crossing (BR)	$820M
I-295 Interchange (MA)	$275M
MD210 Interchange (MB)	$194M
Maryland Projectwide	$24M
US1 Interchange (VA)	$621M
Telegraph Road Int. (VB)	$316M
Virginia Projectwide	$184M
District of Columbia I-295	$16M



Project Team:

Owners:	States of Virginia & Maryland
Design & Construction:	State of Maryland
Sponsoring Agencies:	Federal Highway Administration, Maryland State Highway Administration, Virginia Department of Transportation, District Department of Transportation

Bridge Contracts:

Bridge Contract 1 - Initial Dredging Contractor:
Tidewater Construction Corporation/Kiewit Construction Company/Clark Construction Group
Virginia Beach, VA
Actual $14.5M
Completed February 2001

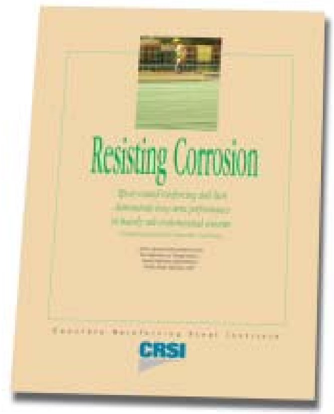
Bridge Contract 2 - Foundation contract Excludes VA and MD abutment.Contractor:
American Bridge/Edward Kraemer and Sons, Coraopolis, PA
Actual $125M
Completed June 2003

Bridge Contract 3A - Bascule Spans, Bascule Piers, portion of Superstructure and Operator's Tower
Actual $185.9M
Under Construction 66+

Bridge Contract 3B - Virginia approach spans.
Actual $115.5M
Under Construction 64+

Bridge Contract 3C - Maryland approach spans.
Actual $191.1M
Under Construction 61+

"Resisting Corrosion" article reprint from Public Roads Magazine, a must read.



Authors—Seung-Kyoung Lee, Paul D. Krauss, Y. Paul Virmani

Originally appearing in the May/June issue of Public Roads, this 6-page article was recently made available. The article is an easy to understand discussion of various types of concrete steel reinforcing bar and their ability to resist corrosion. The basis of the article is two FHWA corrosion research projects, in which all of the authors participated and, in which a variety of reinforcing materials were tested. Also included in the article are several charts that provide a side-by-side comparison of uncoated (black) steel reinforcing, epoxy-coated steel reinforcing and non-magnetic stainless steel reinforcing.

For your FREE copy of the 'Resisting Corrosion' article reprint, contact:

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Website: www.crsi.org

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Implementation of High Performance Concrete

Introduction

Despite the best efforts of many, there remain questions regarding the optimal materials to construct reinforced concrete structures, providing longest service life at the least cost. One of the relatively recent newcomers to this effort is High Performance Concrete (HPC). Like many new materials used in construction there is much to be learned regarding the effectiveness and cost of HPC. A recently released report from Federal Highway Administration (FHWA), *"High Performance Concrete Structural Designers' Guide,"* summarizes the effort of the High Performance Concrete Technology Delivery Team. The Team assists state transportation agencies in the use of HPC.

What is HPC?

Even the term HPC is somewhat controversial. The definition of concrete that is HPC versus that which is not HPC or conventional concrete has not been widely settled. The American Concrete Institute's document for Cement and Concrete Terminology, ACI 116R, defines HPC as:

> "*concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing and curing practices*."

In contrast, the FHWA report indicates that the term HPC should be used to describe concrete that is made with carefully selected high quality ingredients, optimized mixture designs, and then batched, mixed, placed, consolidated and cured to the highest industry standards. Often HPC has a water-cement ratio (w/cm) of 0.4 or less. In practice, to use these low w/cm ratios necessitates the use of admixtures to make a workable mix.

However, besides resisting chlorides, other characteristics of HPC are utilized to meet the requirements of a particular application. These criteria are:

Strength	Modulus of Elasticity	Abrasion Resistance
Durability	Scaling Resistance	Creep Coefficient
Compressive strength	Shrinkage	Chloride Permeability
Freeze-thaw durability		

Why HPC?

It has long been recognized that the first step in building durable cast-in-place reinforced concrete structures is the use of good quality concrete. After all, with the exception of cracks, concrete is first in the line of defense against the primary agent of deterioration—chlorides. Corrosion from chloride penetration is most commonly seen in bridge decks and closely related substructures. Similarly, it is also recognized that the use of epoxy-coated reinforcing is essential in assuring the structure will have a long service life.

Under normal circumstances, concrete by itself provides steel reinforcing excellent protection from corrosion. This protection is due to the alkaline environment of concrete which allows the steel to form a very thin film that passivates the steel. However, this harmony between concrete and steel, or passivity, is not always maintained. Corrosion occurs. The primary cause is the penetration of deicing chemicals (chlorides). Therefore, besides providing more corrosion resistant reinforcing steel, providing a greater thickness of concrete over steel (i.e., cover) and concrete that is less permeable are two methods that are commonly used to increase the service life of reinforced concrete structures.

Cast-in-Place HPC

For cast-in-place HPC, the FHWA report states that for substructure applica-

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tions of HPC the placing and curing operations are the same as for conventional concrete. However for bridge decks additional care is required for the HPC to exhibit the durability characteristics and performance that is possible.

The HPC mix for bridge decks is intended to exhibit less permeability and cracking, as the overall goal for a bridge deck is durability. The FHWA report details requirements for pre-placement meetings, which discuss necessary equipment, workforce, concrete characteristics, curing, and placing during cold and hot weather.

Mixture design and development include issues such as mix duration because pozzolans such as silica fume need to be properly dispersed throughout the mix. In addition, the cast-in place mix needs to be easy to handle, place and finish. In order to assure an optimal mix, trial batches and handling simulations are recommended. To prepare for placement of HPC on bridge decks, perform a dry run. Check the finishing equipment to assure proper operation including the set up of the machine.

Upper Wacker Drive HPC placement was scheduled for the evening hours. (Photos courtesy WJE)

HPC Cost

As either of the definitions for HPC indicate, HPC can be made from a wide range of constituent materials and admixtures, as well as percentages of materials. Determining the general material cost for HPC versus concrete is nearly impossible. Until recently it had been widely accepted that HPC for a bridge deck should cost less than conventional concrete because it is formulated by replacing cement with a less costly combination of fly ash, silica fume or ground slag. However, these materials are now reported to be similar in cost to cement. The other area that causes a cost differential is in placing and finishing operations. Some placing operations for HPC might be more costly than conventional concrete placement. In the FHWA report, HPC deck costs from six state departments of transportation agencies ranged from \$8.38/ft^2 to \$12.60/ft^2. Conventional concrete bridge deck concrete prices were not provided. ■

For more information, see FHWA's report on High Performance Concrete Structural Designer's Guide at http://knowledge.fhwa.dot.gov

New York State DOT Now Requires Epoxy-Coated Rebar From CRSI Certified Plants

The New York State Department of Transportation is the 20th transportation agency to require that epoxy-coated steel reinforcing bar be produced by certified plants under the CRSI Epoxy Plant Certification Program. The program is administered by CRSI. A third party performs independent inspections.

Included in a NYSDOT Engineering Bulletin, Materials Procedure No: 05-02, August 2005, is a specification about the CRSI Epoxy Plant Certification Program for epoxy-coated steel reinforcing bars used in NYSDOT projects. This requirement is effective January 12, 2006. In Appendix C, Facility and Quality Control Requirements C1.2, it is stated that, "Epoxy-coated bar reinforcement applicators must be certified by the Concrete Reinforcing Steel Institute (CRSI) Epoxy Plant Certification Program. Prequalification samples will not be required by the Department prior to Approved List addition."

In addition it is also specified that the steel reinforcing bars and coating material used must be the same as on the Department's approved list.

The report continues with an explanation of the implementation of the program and documentation required for this quality assurance procedure. Included are annual copies of the following documents to the Department:

- Quality Control plan prepared for CRSI Fusion Bonded Epoxy Coating Applicator Plant Certification Program.
- Current CRSI Plant Certification.
- CRSI plant inspection report.

At present, approximately 90% of all North American plants that produce fusion-bonded epoxy-coated steel reinforcing bars are participants in the program. Eighteen state transportation agencies in the United States and two provinces in Canada require that all epoxy-coated reinforcing come from plants certified by the CRSI program. ■