CRSI **ANTI-CORROSION TIMES**

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

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In this issue

Page 2 .... Proven Performance

Page 3 .... Proven Performance

Page 4 .... 'Smart' Bridges

Page 5 . . . I-290/IL-53 Reconstruction

Page 6 .... Best Buy Garage

Page 6 . . 30 Year Milestone Brochure

Page 7 . . . Humphrey Parking Center

Page 7 .... Certification

Page 8 . . . I-290/IL-53 Reconstruction

Page 8 .... Acknowledgments

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 M. Prentice, Director of Marketing for CRSI.

Proven Performance for Your Reinforced Concrete Bridge Deck

By John M. Prentice

Preparing to check corrosion damage for this study.

Deicing salts, seawater, and harsh chemicals can wreak havoc on concrete structures. Reinforced concrete bridge decks constructed with unprotected steel reinforcement and exposed to deicing compounds can suffer premature deterioration. The corroding steel in the reinforcing bar can expand three to six times its original volume, which can lead to delamination and spalling of the concrete deck.

Recently completed, this study substantiates that epoxy-coated reinforcing bars extend the service life of bridge decks to over 60 years.

Deicing salts first began to be used on bridge decks in the late 1950s and corrosion of the reinforcing bars emerged as a problem in the 1960s. Shortly thereafter, epoxy-coated steel reinforcing bars were proposed as a solution to the problem of bridge deck deterioration from reinforcing steel corrosion.

The first bridge deck using epoxy-coated reinforcing steel was built in Philadelphia in 1973. Since then, millions of tons of steel

continued on next page

This article appeared in Better Roads Magazine, August 2003 edition. John Prentice is the Concrete Reinforcing Steel Institute's Director of Marketing. Contact him at jprentice@crsi.org for additional information about this study.

Proven Performance . . . continued from page 1

reinforcing bar have been epoxy-coated in North America. Virtually every department of transportation in regions of the U.S. and Canada with a corrosive environment has used epoxy coating corrosion protection in reinforced concrete bridges.

While widely accepted as anecdotal evidence that reinforced concrete bridge decks in corrosive environments built with epoxy-coated reinforcing bars will have a significantly longer service life than those built with uncoated black reinforcing bars, no long-term, "insitu" study had previously been done to substantiate this. However, a study sponsored by the Concrete Reinforcing Steel Institute now provides definitive proof that using epoxy-coated reinforcing bars adds many decades of life to a reinforced concrete bridge deck.

Small percentage of damage at railing barriers caused by corroded bars.

Workhorse Bridges

For the Phase I study, Wiss, Janney, Elstner Associates Inc. (WJE) performed extensive evaluations on 11 bridges in the U.S. that were built using epoxy-coated reinforcing bars in the **top mat only**: two in Minnesota, one in Wisconsin, two in New York, three in Virginia, one in Pennsylvania, and two in Ohio.

The oldest bridge of the group was built in 1973 and the youngest in 1981. These bridges have been exposed to deicing salts for over 19 years. Each bridge has exhibited excellent performance. Out of the 11 bridges inspected, the worst showed only a small percentage of damage from spalling and delamination, caused by corrosion of the reinforcing bars. But the visual and statistical analysis of field and laboratory tests tell a much more compelling story. Comparing the condition of these bridges against hypothetical identical bridges built with black reinforcing bars predicts a service life extension of between 11 years and greater than 90 years.

Core sample from bridge showing epoxy-coated rebar in perfect condition.

Survey and Analysis

After a detailed visual examination followed by a delamination survey, the present damage level of each bridge deck was estimated. Equi-potential contour maps were developed as an indication of areas of active corrosion versus areas with relatively little corrosion.

Seven or eight 3-inch-diameter concrete core samples were obtained from each bridge, for a total of 79 cores. Three or four cores were taken at cracked areas on each bridge deck. The cracked areas have the highest concentrations of chlorides, and therefore represent the "worst case" corrosive conditions. Previous studies have been based primarily on cores from uncracked areas.

Approximately 80 measurements per bridge deck of the depth of concrete cover over the transverse reinforcing bars were made using state of the art equipment.

In the laboratory, the field cores were analyzed to determine the chloride concentration profiles in the concrete and the chloride diffusion coefficients. The condition of the epoxy-coated reinforcing bars was also examined after the bars were extracted from the cores and examined for physical condition, coating

Concrete bridge pavement in excellent condition compared to blacktop road approach.

Proven Performance . . . *continued from page 2*

thickness, substrate condition, and knife adhesion strength.

Epoxy Coating

The epoxy-coated reinforcing bars have performed well, as demonstrated in Table 1.

The corrosion of reinforcing bars can be attributed to the presence of high chloride content at the top reinforcing steel layer level. The chloride content is higher in areas of a bridge deck that exhibit cracks in the concrete, because the cracks allowed the deicing compounds to infiltrate into the concrete more readily.

The chloride data from the concrete cores in this study suggest that the epoxy-coated reinforcing bars with poor ratings (1 or 2) were more likely to be found in very highly contaminated concrete. But the data also indicate that that the epoxy-coated reinforcing bars can remain corrosion-free in harsh high-chloride environments.

Deck Performance

The time for corrosion initiation is calculated based on Fick's Second Law. The time for corrosion propagation is typically assumed to be 3 to 6 years for uncoated "black" bar, while this amount of time is likely a very conservative assumption for epoxy-coated reinforcing bars.

In this study, it was assumed that a bridge deck would end its functional service life (for example, require major repair or resurfacing) when cumulative damage of the deck reached 10% of the total deck surface area. Using the service life prediction model developed for this study, it was determined that hypothetical bridge decks identical to the bridge decks in this study but constructed with black reinforcing bars on both mats would take 10.5 to 33 years to exhibit 10% damage.

This bridge maintained corrosion resistance at barrier.

The actual bridge decks constructed with epoxy-coated reinforcing bars **in the top mat only** would take 24 to more than 120 years for the same level of damage. The average service life extension offered by epoxy-coated reinforcing bars was more than 40 years.

The Phase II study is being conducted on six Iowa bridge decks containing epoxy-coated reinforcing bars in both mats (top and bottom). Preliminary field data indicate that greater service life extension can be achieved by the two-mat epoxy-coated reinforcing bar construction.

With definitive proof to demonstrate the proven performance of epoxy-coated reinforcing bars, it continues to be the major corrosion protection product for concrete bridge decks. ■

Table 1

REINFORCING BAR RATING	Percent of Epoxy-Coated Reinforcing Bar Samples
5 (no evidence of corrosion)	64%
4 (a number of small, countable corrosion spots) 3 (corrosion area less than 20 % of total reinforcing bar surface area)	13%

'Smart' bridges are educating engineers

By Vicki Smith, Associated Press Writer Published December 16, 2003

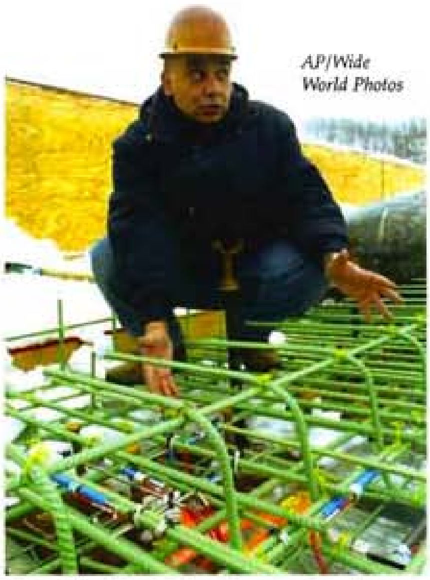
STAR CITY, WV — Samir Shoukry works his way from the belly of the bridge to the slippery green rebar of its snow-covered back, talking about the 1,000-foot span over the Monongahela River as if it were alive.

Though still unfinished, the Star City bridge is already loaded with 770 finely tuned sensors, 28 data-collection boxes and a central unit called the brain. Together, they make up what Shoukry says is the smartest bridge in the world. "Smart" bridges and roads that communicate with their makers through built-in sensors are becoming more common as engineers worldwide try to determine whether long-held construction assumptions are correct or whether there are better ways to build.

Several states have smart structures, and at least one span—Florida's Sunshine Skyway Bridge—may have more sensors than Star City. "But if we're talking about density," Shoukry says, "this would be the most. This is one of the most extensively instrumented bridges in the world." The sensors measure minuscule, visibly undetectable changes in steel girders and support structures, in piers and abutments, in concrete and rebar. If a crack is about to occur, the sensors should detect it. If settling shifts the inclination by as little as one-millionth of a degree, that will be recognized and recorded.

"Intelligent structures are like the human body. It's provided with millions of sensors that send signals to the brain when you're in pain," says Shoukry, an engineering professor at West Virginia University. "Basically, I want the structure to tell me where it hurts so I can make a quick response to the cry and come and repair it. We are providing the structure with the ability to have input," he says. "It's like looking into the flesh and bones."

West Virginia's Division of Highways is spending nearly $18 million



AP/Wide World Photos

West Virginia University engineering professor Samir Shoukey shows one of the 770 data sensors located in a new bridge in Star City, WV that will monitor the bridge for maintenance purposes.

on the bridge and decided to invest an additional $471,000 in Shoukry's project to learn more about what causes stress and deterioration of expensive infrastructure. The information may help the state make smaller, less costly repairs while

Scattered sensors can detect problems, help in design of better structures.

problems are still manageable, Deputy Commissioner Norman Roush says. "We wouldn't be surprised to see people coming from all over the world to see this and use it," he says. "I don't know of anybody worldwide who has done this much gauging and metering on a bridge."

Roads and bridges face different problems. Roads have solid support and mainly move up and down as the load on the surface changes. Roads also can shift near the edge of the pavement, and inadequate drainage can affect their performance. Bridges, meanwhile, are not rigid. "They bend, act and react under loads," Roush says. "Their actions are working with and against each other."

Already, West Virginia's demonstration projects have yielded results. On the Corridor H project, the state learned that concrete slabs 20 feet long are prone to crack, while those 15 feet are not. The state of Pennsylvania, which had problems with cracks on Interstate 81, is changing its slab length based on those results, Roush says.

Smart projects also may help engineers determine whether planning for worst-case scenarios has resulted in over designing. Perhaps some assumptions are wrong, Shoukry suggests. Maybe steel and concrete don't need to be quite as thick as the engineers think. If data were to prove that, designs could be more efficient and costs could be held down without sacrificing quality or safety.

Shoukry's team has set up a weather station and two small sheds as a field laboratory at the bridge, just a mile or so from the engineering school. They collect environmental data 24 hours a day and readings from the bridge sensors every 20 minutes. That makes for a unique lab, says David Martinelli, chairman of WVU's civil and environmental engineering department. Rather than read about devices in books, civil engineering students will be able to study real-world functioning on structures, Martinelli says.

Mechanical and aerospace students will learn how to install instruments and analyze data. Computer science students will be able to develop and test better types of sensors and design databases for sharing the findings. Smart structures are the way of the future, Shoukry says. The technology is there, and it only makes sense to use it. "The cost is like medical insurance," he says. "You pay whether you use it or not, but it pays off when you get sick." ■

I-290/IL-53 Reconstruction Project Completed Ahead of Schedule

The Chicago area debut of the Extended Life Pavement demonstration project is a four-mile section of the expressway in northwest suburban Chicago. The project started on March 1, 2003 and was finished on October 16, 2003 two weeks ahead of schedule. It was the largest Chicago area project IDOT worked on during the 2003 road construction season.

The $62.3 million reconstruction is slated to last until mid century before

major repairs are needed. This new design is intended to double the pavement's life expectancy from the current 20-year standard to at least 40 years. Innovative design and materials provide this extended life expectancy.

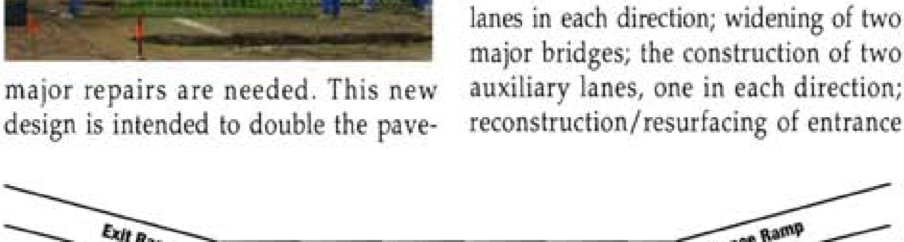
Opened in the early 1970's, this section of I-290/IL-53 still had the original pavement. Over the years, the highway has seen increased traffic volume, has suffered through three decades of harsh Chicago winters and undergone a variety of maintenance efforts. Dirk Fuqua, who oversees all state road construction for IDOT in the Chicago region stated, "It is now time to build a new roadway from the ground up and to do it with improved design standards."

Planned Improvements

The reconstruction project involved many improvements: complete pavement removal and reconstruction of four lanes in each direction; widening of two major bridges; the construction of two auxiliary lanes, one in each direction; reconstruction/resurfacing of entrance and exit ramps and resurfacing of additional express and local lanes north of the reconstructed lanes.

Another project innovation was the addition of an auxiliary lane in both directions. These lanes extend only from the entrance ramps at one interchange to the exit at the next interchange. They are not "through" or "travel" lanes, but rather a fifth lane that eases congestion by making it easier for vehicles to enter and exit the highway.

continued on page 8



Stages of I-290/IL-53 Reconstruction

Stage I — March to June 2003
Reconstruction of northbound lanes.
All traffic switched to southbound lanes.
Three entrance ramps reconstructed.
Two exit ramps reconstructed.

Stage II — June and July 2003
Northbound and southbound inside lanes reconstructed.

Stage III — July to October 2003
Reconstruction of southbound lanes.
All traffic switched to northbound lanes.
Four entrance ramps reconstructed.
Two exit ramps reconstructed.

Stage IV — October and November 2003
Construct median barrier wall. Install overhead electronic message signs along southbound lanes.

The Best Buy Corporate Parking Garage was designed with epoxy-coated rebar for a long service life.

The new Best Buy Corporate Headquarters located in Richfield, Minnesota near Interstate Highway I-494 and Penn Avenue South was built at an estimated cost of $160 million. The large complex is part of a Richfield redevelopment district that uses tax-increment financing, an important tool for attracting businesses in this day and age.

Included in the Best Buy Corporate complex is a four level parking garage. This cast-in-place reinforced concrete garage includes 5,000 parking stalls in the all above ground parking structure. More than 2,900 tons of epoxy-coated reinforcing bars were used in its construction. Cast-in-place reinforced concrete construction was used for structural elements and for the parking decks. It was chosen for its durability in this severe climate. With the use of epoxy-coated rebar for corrosion protection, maintenance is reduced, making it the most cost-effective solution for this new corporate complex. ■

The Project

Owner: Best Buy Corporation

Epoxy-Coater:
ABC Coating Company of Michigan and ABC Coating Company of Minnesota

Progress with Epoxy-Coated Rebar" in New '30 Year' Milestone Brochure

This new 12-page, full color brochure celebrates the 30th anniversary of epoxy-coated rebar. The first specified application for epoxy-coated steel reinforcing bars was in bridges. Here's an outline of the brochure:

- Early years and the players
- Fusion-Bonded Coaters join CRSI
- Plant Certification
- Research Findings over the years
- Epoxy-Coating Economics

For your copy of the '30 Year' Milestone brochure, contact:
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Humphrey Terminal Parking and Transit Center

The Humphrey Terminal at the Minneapolis — St. Paul International Airport in Bloomington, Minnesota was recently completed at a cost of $130 million. After the terminal was completed, the airport's continued growth and increased employment, the need to expand the airport's parking facilities was planned.

From July of 1999 to February of 2000, numerous studies and evaluations of site conditions, air traffic demand and automobile traffic projections were prepared. A total of ten functional design studies determined the most desirable size and configuration to meet the parking requirements.

After all evaluations were made, cast-in-place concrete was chosen for the structure because it offered reduced maintenance, its related cost and an extended service life. The new parking garage was to incorporate state-of-the-art construction features providing a user-friendly facility that will weather Minnesota winters. For corrosion protection, 5,300 tons of epoxy-coated rebar were required throughout the structure.

Because of the projected parking demand and the mandate that construction could not begin until the new Humphrey Terminal was completed, the parking garage construction was complex and required staging to meet completion.

Within 17 months, four stages of this new parking facility were completed. The facility consists of 8-levels, each 410 feet x 610 feet, totaling 1,220,000 square feet. It includes a climate-controlled skyway connecting the parking facility and Humphrey Terminal. The airport parking garage is tied into the Twin Cities first Light Rail Transit (LRT) facility that will serve the Greater Minneapolis — St. Paul area and the airport. In addition to the parking stalls and LRT station the new parking complex is a transit center serving shuttles, taxis and buses.The structure was built for immediate needs and future growth of the area. Both this facility and planned facilities will house over 12,000 vehicles. ■

The Project

Owner:	Metropolitan Airports Commission
Architect:	Miller-Duwiddie Architects
Contractor:	Knutson Construction Services
Epoxy-Coater:	ABC Coating Company of Michigan ABC Coating Company of Minnesota

New Jersey now requiring certified plants

CERTIFIED PLANT

New Jersey recently became the 17th state to require that epoxy-coated steel reinforcement come only from plants in the CRSI Epoxy Plant Certification Program.

Started in 1992, the program was instituted to fill the need for a more dependable, consistent epoxy-coating on reinforcing bars. For additional information about the Certification Program, contact Scott Humphreys, Certification Program Administrator at CRSI, or John M. Prentice, Director of Marketing at CRSI. ■

I-290/IL-53 . . . *continued from page 5*

The new Extended Life Pavement process aims to achieve longer service life by counteracting damage caused by the "freeze-thaw cycle" so typical of the harsh Chicago winter season. The design increases

the total road thickness from 14 inches to 44 inches in combination with higher quality materials. Materials include a new concrete mix, aggregate base and epoxy-coated steel reinforcement to resist the effects of corrosive deicing chemicals. In all, 6,000 tons of epoxy-coated #7 bar, 60 feet long were used in the highway to combat corrosion and increase its expected life. An additional 600 tons of epoxy-coated fabricated rebar were used for structures in the project. While Extended Life Pavement increases initial construction costs; its use is expected to save taxpayer dollars by extending replacement periods, greatly reducing future maintenance costs, which lessens traffic congestion and commuting time. With the public in mind, these are very important improvements for this highly congested area. ■

The Project

Owner: Illinois Department of Transportation

Contractor: Walsh Construction, Chicago, IL

Epoxy-Coater & Fabricator: Toltec Steel Services, Kankakee, IL

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