The Exploratory Advanced Research Program Fact Sheet

Nano-Enhanced Repair Materials

Pursuing a Superior Coating for Corrosion Prevention

Exploratory Advanced Research . . . Next Generation Transportation Solutions

Corrosion of highway bridges has been estimated to cost the Nation $8.29 billion annually.[1] A corrosion-inhibiting nanocomposite solution that can be used to repair, strengthen, and protect highway infrastructure is the goal of "Multifunctional Nanomaterials and Processes for Infrastructure Repair and Corrosion Inhibition," an Exploratory Advanced Research (EAR) Program project awarded to Florida State University by the Federal Highway Administration (FHWA).

Addressing A Compelling Need

Much of the Nation's infrastructure is reaching the end of its useful life at a time when resources for repair and replacement are severely constrained. With so many critical highway structures in need of rehabilitation, an urgent search for more effective repair methods and longer lasting repair materials to preserve them is underway. In this 2-year EAR Program project, researchers are developing a promising multifunctional repair material to protect and strengthen salt-contaminated, corroding bridges. The experimental material utilizes carbon nanotubes (CNTs), which offer superior strength and thermal conductivity. The aim is to harness these properties in a coating that will inhibit corrosion and add strength to structural members.

[1] M. Yunovich, N. G. Thompson, and Y. P. Virmani. Corrosion protection system for construction and rehabilitation of reinforced concrete bridges. *International Journal of Materials and Product Technology,* Vol. 23, Nos. 3–4, pp. 269–285, 2005.

Optimizing the Mixture Design

This project is distinctive in its pursuit of a self-curing, spray-on coating that can be easily applied at the repair site, lowering labor costs. High concentrations of nanoparticles, well-dispersed in a composite matrix, could provide a protective barrier against corrosion while strengthening the structure. The challenge to researchers has been to identify the optimal combination of matrix system, curing agent, and CNT concentration that will result in high strength, durability, and ease of application at a moderate cost.

Exploratory Challenges

Several aspects of the study's technical approach involve considerable risk:

- **Nanoparticle dispersion**—Nanoparticles tend to clump, and hence achieving a uniform coating layer is difficult. The research has pursued a sonication and other mixing technologies that can deliver both a high concentration and uniform distribution of the CNTs in an epoxy coating. The study has achieved well-dispersed concentrations of 4 percent CNTs, with higher concentrations expected.
- **Curing behavior**—CNTs have been shown to interfere with epoxy curing in ways that are not well understood, causing undercuring, which could result in premature failure due to poor adhesion, delamination, microcracking, and reduced tensile and flexural strength. The study is expanding the knowledge of these processes as it experiments with mix reformulations with different concentrations of CNTs and different curing conditions.
- **Adhesion**—The investigators have devised a process to spray the composite repair material in a liquid form that will adhere permanently to structures under repair, allowing in situ application, which reduces the time and costs required for repairs over conventional repair techniques. Scaling up the spray application technology is the next challenge.

U.S. Department of Transportation
Federal Highway Administration

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SprayWriter, for applying the repair material.

Durability and Physical Properties

To assess the composite coating's behavior and performance for reducing corrosion and repair of infrastructure, the following will be evaluated:

- Thermal mechanical characterization by dynamic and thermal analysis (dynamic mechanical rheological testing data can be used to predict long-term performance through analysis of the material's chemical makeup).
- Corrosion behavior with electrochemical impedance spectroscopy (useful for identifying possible limitations and defects in the protective coating during its exposure to corrosive environments).
- Adhesion strength by peeling/shearing test.

These tests will be carried out at ambient as well as at elevated temperatures and humidity levels.

Looking Ahead

The technical innovations developed by the research team could significantly advance multifunctional composite coating for corrosion control as well as strengthening and repair of infrastructure. At the conclusion of the project, FHWA will assess the feasibility of next steps, including field testing to test the corrosion-inhibition properties of the materials as well as their potential for strengthening bridges

"A multifunctional nanomaterial that is corrosion-resistant, durable, and cost effective could substantially reduce the life-cycle cost of bridges and other highway structures," says Paul Virmani of FHWA, "and would have potential applications beyond the highway industry, both to protect new structures and to extend the lives of older ones." Besides bridges, corrosion is a major problem in military applications, drinking water and sewer systems, gas and other transmission pipelines, hazardous materials storage, and many other areas that might benefit with improved service life.

EXPLORATORY ADVANCED **RESEARCH**

What Is the Exploratory Advanced Research Program?

FHWA's Exploratory Advanced Research (EAR) Program focuses on long-term, high-risk research with a high payoff potential. The program addresses underlying gaps faced by applied highway research programs, anticipates emerging issues with national implications, and reflects broad transportation industry goals and objectives.

To learn more about the EAR Program, visit the Exploratory Advanced Research Web site at www.fhwa.dot.gov/advancedresearch. The site features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events. For additional information, contact David Kuehn at FHWA, 202-493-3414 (email: david.kuehn@fhwa.dot.gov), or Terry Halkyard at FHWA, 202-493-3467 (email: terry.halkyard@fhwa.dot.gov).

Learn More

For more information on this EAR Program project, contact Paul Virmani, Ph.D., FHWA Office of Infrastructure Research and Development, at 202-493-3052 (email: paul.virmani@dot.gov).

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