



# Creating Environmentally Sound Specifications for Culvert Rehabilitation

## *Virginia Applies Findings for Cured-in-Place Pipe Repair*

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A CIPP repair project during the steam cure.

**R**epair or replacement of damaged or worn culverts and pipes is a major maintenance concern for U.S. transportation agencies. Cured-in-place pipe (CIPP) rehabilitation allows users to repair underground pipes in place, instead of unearthing and replacing damaged pipe sections.

### Problem

CIPP repair has become a common way to preserve transportation infrastructure efficiently and at a reasonable cost. Typically, a liner saturated with a styrene-based thermosetting resin is inserted into the damaged pipe and polymerized—or cured—through the introduction of steam or heated water.

Although styrene can be toxic to aquatic species and is classified as a potential carcinogen by the Environmental Protection Agency (EPA), the potential environmental impacts of CIPP repair have been little investigated. Of particular concern are the potential impacts of the release of the styrene-

contaminated water or steam condensate and the leaching effects of styrene from the cured pipe.

### Research

The Virginia Department of Transportation (DOT) tasked the Virginia Transportation Research Council (VTRC) to evaluate the impacts of styrene-based CIPP repair on water quality. During the 1-year study, VTRC evaluated seven steam-cured CIPP installations in Virginia by three different companies.

Researchers collected water samples from each project site before, during, and after installations and analyzed the samples for styrene. The results were evaluated against established regulatory standards and toxicity criteria for several aquatic indicator species found in freshwater habitats throughout the United States.

### Observations

At two of the installations, researchers observed that effluent—steam condensate—from the curing process was discharged directly downstream. At three installations, uncured resin residue waste extruded during the lining process and either washed downstream or remained on the dry stream bed immediately outside the pipe outlet or inlet. At three sites, algal blooms—which can indicate pollution—were apparent within 1 week after installation and remained visible for up to 3 months.

### Water and Waste Samples

Water sampling results were compared with EPA's maximum contaminant level (MCL) of 0.1 parts per million (ppm) for styrene in drinking water and with the lethal concentrations of styrene for five different species that indicate water quality—water flea, fat-head minnow, rainbow trout, amphipod, and fresh-



Photo: VTRC



PHOTO: VTRC

An uncured extruded resin with algal blooms 1 week after CIPP installation.

water green algae—which range from 0.7 ppm to 10.0 ppm.

Water sampling results were as follows:

- ◆ Styrene was detected in water samples from six of the seven sites and up to 88 days after CIPP installation.

- ◆ The highest concentration of styrene, 77 ppm, was found in water samples taken during the downstream release of effluent from the curing process.

- ◆ Although the sites were not directly linked to sources of drinking water, styrene concentrations reached up to two orders of magnitude—more than 700 times—greater than the MCL for drinking water. Styrene concentrations at five of the seven sites exceeded the MCL for drinking water for 5 to 71 days after the CIPP installation.

- ◆ Styrene concentrations at five sites exceeded the toxicity criteria for aquatic species for up to 24 days after the installation.

In addition to the water samples, a sample of the uncured resin waste in a stream bed was collected 1 day after installation and had a styrene concentration of 580 ppm.

### Study Implications

The findings suggest that the elevated styrene levels

could have resulted from any one or more of the following: (a) installation practices that did not capture effluent containing styrene; (b) uncured resin that escaped from the liner during installation; (c) insufficient curing—that is, incomplete polymerization—of the resin; and (d) some degree of permeability in the liner material. In addition, if the curing was incomplete in the finished product, the maximum structural strength likely was not achieved, although destructive testing was not performed to confirm this. The research report is available online.<sup>1</sup>

### Application

The research findings led Virginia DOT to place a stop-work order on all contracts for styrene-based CIPP repair. Virginia DOT formed a task group, led by staff in the Environmental Division, to evaluate further the use of the technology and to provide recommendations about continuing use. The task group asked the state environmental quality agency for input; performed additional testing at CIPP sites; solicited input from CIPP industry representatives; and developed new construction specifications to minimize environmental risks and ensure maximum structural performance of the finished product.

With the release of the new specifications, Virginia DOT reinstated CIPP installations.<sup>2</sup> The specifications require the following:

- ◆ Both an inner and an outer impervious film to envelop the resin-liner system and promote complete polymerization, prevent resin loss, and prevent styrene contamination of the interior portion of the finished pipe;

- ◆ Use of a semirigid plastic slip sheet over significant voids and pipe intrusions that could damage the liner during insertion;

- ◆ Installation oversight by a trained inspector;

- ◆ Time-temperature monitoring, with data logging, at points throughout the length of the pipe for the curing of the lining material;

- ◆ Thorough rinsing of the finished product;

- ◆ Proper containment and disposal of effluent cure water and rinseate;

- ◆ Water and soil testing for styrene before and after installation; and

- ◆ Corrective actions to remediate the accidental release of styrene.

Further research by VTRC will determine if the

<sup>1</sup> [www.virginiadot.org/vtrc/main/online\\_reports/pdf/08-r16.pdf](http://www.virginiadot.org/vtrc/main/online_reports/pdf/08-r16.pdf).

<sup>2</sup> The complete list of specifications is posted at [www.virginiadot.org/business/resources/const/cdmemo-0811.pdf](http://www.virginiadot.org/business/resources/const/cdmemo-0811.pdf).

application of these specifications ensures strict control of styrene at new installations.

## Benefits

The research confirmed that discharges of styrene into the environment were occurring during styrene-based CIPP installations. The findings highlighted the need for more stringent controls of the installation process to prevent impacts to aquatic species and associated violations of water quality. The research findings also served as a foundation for candid discussions with industry representatives in the search for achievable process modifications that would satisfy environmental requirements.

Follow-up research revealed that lack of control over cure variables increased the chances of inadequate liner cure, potentially jeopardizing the structural strength and durability of the finished product. The research and the actions taken by Virginia DOT have generated attention from other states with similar concerns about styrene-based CIPP and other pipe repair technologies and have prompted several transportation agencies to review their pipe repair specifications more closely.

As pipes that convey stormwater and streams age, deteriorate, and require repair, new products are developed to provide quick and affordable rehabili-

tation. Although the literature on the performance and durability of a variety of pipe repair products is readily available, research into the environmental implications during and after installation is lacking.

Many transportation agencies are facing budget restrictions, making the affordability of maintenance technologies more important than ever before. The Virginia DOT-VTRC investigation underscores the importance of maintaining a commitment to environmental protection by testing these products for potential environmental impacts during and after installation in the field.

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EDITOR'S NOTE: Appreciation is expressed to Waseem Dekelbab and G. P. Jayaprakash, Transportation Research Board, for their efforts in developing this article.

Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2952; gjayaprakash@nas.edu).



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