

TURNING RESEARCH INVESTMENTS INTO INNOVATIONS AND COST SAVINGS

VIRGINIA TRANSPORTATION RESEARCH COUNCIL

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The Virginia Transportation Research Council, the research arm of the Virginia Department of Transportation, was established in 1948 under a joint agreement between VDOT and the University of Virginia. The council's mission is to promote excellence in transportation through research and technical services. Primary objectives include developing innovations, producing cost savings, and improving practices at VDOT and helping the University of Virginia to carry out its teaching and research mission.

The council is presently focusing its research program on five strategic areas: advancing new technology, managing the infrastructure, enhancing safety, promoting the efficient movement of people and goods, and improving financial and investment decisions. Highlighted below are several projects that have brought about significant innovations and cost savings to the council's sponsors. These projects fall primarily in the areas of advancing new technology, managing the infrastructure, and enhancing safety.

HIGH PERFORMANCE CONCRETE

Structural concrete is subject to four major types of environmental stress: rebar corrosion, alkali-aggregate reactivity, freeze-thaw damage, and sulfate attack. This stress can be initiated or accelerated when water and other liquids penetrate concrete. To make cement less permeable, pozzolans and slag are added, and the water-to-cementitious material ratio (W/CM) is kept below 0.45. Pozzolanic material and slag generally improve the ultimate strengths of conventional portland cement concrete. To attain the particularly high strengths required for certain structures, such as prestressed beams, the W/CM is reduced to a minimum of 0.30.

VDOT specifies a minimum compressive strength of 35 megapascals (5,000 pounds per square inch) at 28 days for regular prestressed concrete. The department asked the council to develop concrete of higher strengths and lower permeability for a four-span bridge constructed in 1995. In preliminary studies, AASHTO Type II beams with 15-millimeter (0.6-inch) prestressing strands were tested at the Turner-Fairbank Research Center's Structures Laboratory. Two beams with composite slabs were then tested. The beams contained high-strength, low-permeability concrete, which proved to have excellent bond strength and satisfactory development length with the large strands.

The studies led to three findings. First, high-performance concrete can be produced with a W/CM close to or below 0.30. Achieving such a low W/CM requires trial batching, large amounts of cementitious material made of portland cement and pozzolans, proper selection of aggregates, and high dosages of a high-range, water-reducing admixture. Second, to achieve high strengths within 20 hours, the proper temperature must be maintained. The optimal temperature for high-early and ultimate strengths can be determined by trial batching and testing. Third, achieving 83 megapascals (12,000 pounds per square inch) at 28 days with air-entrained concrete using locally available materials may be difficult, but the desired strength may be achieved with a longer cure time.

In bridge construction, the potential benefits of high-strength concretes include longer girder lengths, increased rigidity, and lower prestress losses, reducing overall cost. Even with the requirement for low-permeability concrete, the construction unit cost per square foot (0.09 square meters) for the 4-span bridge was \$49, less

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than the 1994 average of \$58 for 34 bridges in the federal-aid highway system in Virginia. The initial cost savings are estimated to be \$30,000, approximately 4 percent of the total bridge cost. Additional savings are expected over the life of the bridge as a result of increased service life and low maintenance requirements, especially as a result of potentially reduced rebar corrosion.

ELECTROCHEMICAL CHLORIDE EXTRACTION FROM CONCRETE BRIDGE DECKS AND PIERS

Salt intrusion requires replacement of vast amounts of concrete, some of it still structurally sound. This approach to rehabilitation can be wasteful and expensive, especially when load-bearing concrete piers are involved. A more effective way to prevent or halt corrosion is electrochemical treatment. Cathodic protection systems permanently halt rebar corrosion in salt-contaminated structures. Unfortunately, the need for frequent maintenance of these systems has discouraged many transportation agencies from using them.

Electrochemical chloride extraction (ECE) may be the long-lasting, no-maintenance procedure needed to solve the problem of salt intrusion. An electrical current is run through the concrete between the rebar and a temporary anode on the surface. The more mobile chloride ions migrate toward the oppositely charged anode, which moves the damaging chloride away from the rebar. One treatment takes from 10 to 50 days.

In pilot studies on actual bridges, the Virginia Transportation Research Council used temporary anode systems to apply low levels of electricity to full-sized, salt-contaminated bridge elements for several weeks. Most of the chloride was extracted from the deck and pier concrete with no damage to structural integrity.

The anode in a bridge deck ECE treatment is actually a titanium mesh placed between two layers of felt and wetted with an electrolyte solution (Figure 1). Titanium ribbons are welded to the mesh and connected to a rectifier. The rectifier is operated in constant-voltage mode, with the DC output set as high as possible, but not higher than 40 volts and 1 ampere per square meter of concrete. The anode must be kept wet with electrolyte solution during the entire process. The electrolyte solution can be retained by wooden dams and recirculated.

In the council's tests of ECE treatment of piers, the titanium mesh was layered between sprayed-on cellulose fibers, and a more complex system of baffles was used to recirculate the electrolyte solu-

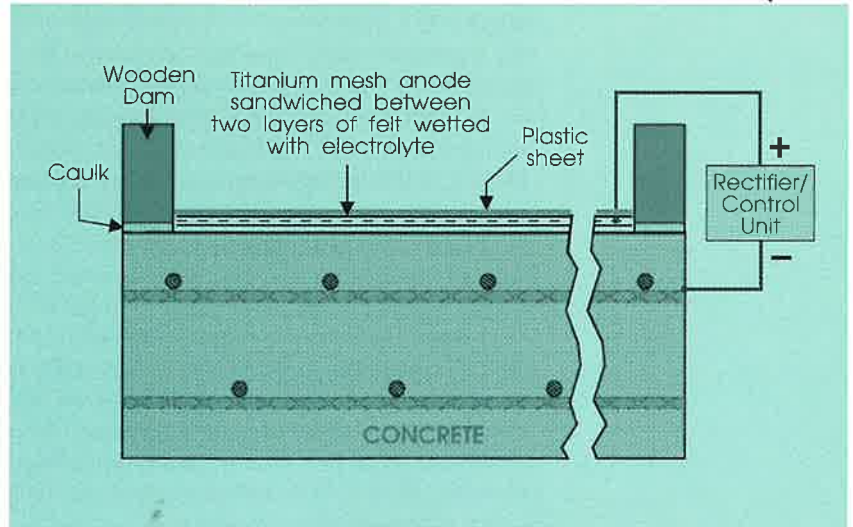


FIGURE 1 Cross section of bridge deck with electrochemical chloride extraction (ECE) treatment.

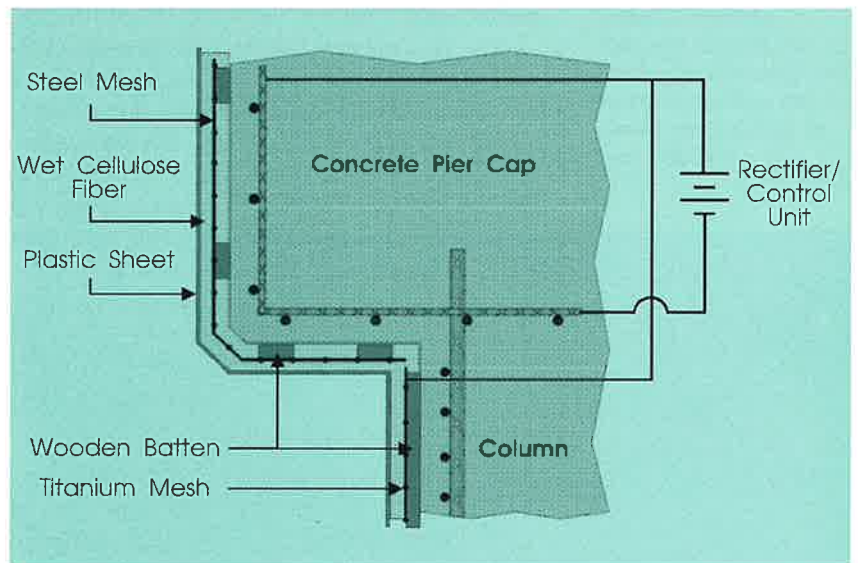


FIGURE 2 Cross section of pier with ECE treatment.

tion (Figure 2). (Around the pier cap, using steel mesh is more practical than using titanium.) After treatment only 20 to 33 percent of the sample rebars continued to exceed the corrosion threshold. However, researchers concluded that corrosion will be delayed in these rebars.

The beneficial effects of ECE treatment are projected to last for a period of at least 12 years. The total cost of the pilot treatment was \$128.35 per square meter for decks and \$131.01 per square meter for piers, making the treatment less expensive than concrete replacement. Ultimately, a cost of \$86 per square meter is expected.

BLOT SEALS

On secondary roads, chip seal treatments have proven to be less than totally effective. Traffic on newly treated surfaces can dislodge stones if the aggregate layer does not adhere to the asphalt under it. Windshields are broken, and the exposed asphalt causes friction problems. Flushing and spalling are common. Finally, uncontrollable factors, such as weather and material properties, can reduce the effectiveness of standard chip seals.

A multicourse surface treatment that minimizes such problems has been widely used in North Carolina. A layer of asphalt is placed, followed by a layer of cover aggregate, a second layer of asphalt, and a blot coat of sand or screenings. The council placed 60 test sections of this blot seal in 1986 and 1987 and evaluated them for several years.

After 3 years in service, 56 of the sections retained a rating of "good," and 22 of these sections were rated "excellent." Only one section was rated "poor."

The performance of blot seals is superior to that of conventional surface treatments. Although treatment with a blot seal costs more than conventional treatment, it lasts longer: 5½ years compared with 4 years. Given the extended service life, the life-cycle cost for a blot seal is 20 percent less than for conventional treatment, saving VDOT approximately \$1 million annually. Lower maintenance costs make the treatment even more cost-effective. Reducing the number of broken windshields also produces savings.

SURVEY OF NONARCHED HISTORIC CONCRETE BRIDGES

Under the National Historic Preservation Act of 1966, the cultural significance of bridges affected by highway maintenance or construction must be evaluated to avoid the unnecessary destruction of historic structures. Action that serves and protects the highway user, while complying with the National Historic Preservation Act, can be efficiently and effectively implemented if an early warning procedure were devised for including historic bridges in a bridge-management system plan.

The historical evaluation requirement for older bridges has long posed a logistical problem for highway agencies. The evaluations are usually done by outside consultants, an expensive and time-consuming method that complicates the planning process and sometimes delays construction. Because the evaluations are made on a case-by-case basis, they yield information only about

particular bridges, not comparative or contextual data about a class of bridges.

The council created an inventory of the more than 1,400 pre-1950 nonarched concrete bridges still in service and ranked them for historic significance. The inventory was compiled from VDOT bridge files and field reviews and sorted first by construction district and then by county within each district. A historic structures task group consisting of a historian, an archaeologist, an architectural historian, and representatives of state and federal transportation agencies and the Virginia Department of Historic Resources determined that the following information was needed for each bridge: geographic location; engineering profile, including designer (if known), builder (if known), date of construction, date of reconstruction, design and technological data, physical description, and photographic documentation; and historic context, including photographs of associated buildings and surroundings and documentation of historic relevance.

Each bridge on the inventory list was surveyed. The data were used to place each bridge into one of three categories: bridges with one or more unusual features, bridges of a common type and having no significant features, and bridges in poor condition or largely or totally rebuilt and having no significant features.

These preliminary results were presented to the task group, which then developed criteria and a rating sheet by which the bridges were evaluated. The criteria were the level of significance (local, regional, state, national), with four levels of rating (5, 7, 10, 15); visual prominence as a landmark, rated from 0 to 2; rarity of bridge type, rated from 0 to 3; rarity of design elements (including unique or special features), rated from 0 to 3; technological significance (first of its kind), rated from 0 to 3; integrity of bridge (condition and degree of modifications), rated from 0 to 4; contextual integrity, rated from 0 to 2 on general surroundings and 0 to 2 on immediate and associated transportation resources; and historic significance and associative value (including the builder), rated from 0 to 4.

The maximum score with a determination of national significance is 38; of statewide significance, 33; of regional significance, 30; and of local significance, 28. A score of 18 or above signifies that the bridge is eligible for the National Register of Historic Places. The results of the survey and evaluation were presented to the Virginia Department of Historic Resources, which concurred with the task group's determination that 11 of the bridges were eligible for the register.

This study established procedures for meeting state and federal requirements for the inventory of historic structures. The major benefit to VDOT is the avoidance of construction delays. The benefit to the state and the nation is that historic structures will be identified, evaluated, and cataloged so that questions of mitigation, replacement, and preservation can be addressed systematically.

This council's survey cleared more than 1,400 bridges for necessary maintenance and upgrade. VDOT has already saved an estimated \$500,000 plus eliminated the delay for each project. Savings over the next 10 years are conservatively estimated at \$2.5 million. They will continue to accrue as more maintenance and replacement projects are begun on these bridges.

SIGN MATERIALS AND CONFIGURATIONS FOR RAILROAD CROSSINGS

The public's demand for improved safety at railroad crossings has been a recurring theme at recent transportation safety forums. Several states have increased the visibility and safety of these crossings by using retroreflective materials on the support posts and the backs of the crossbucks. This approach is efficient and inexpensive. However, the configuration of the materials varies among states, and the configurations used are not equally effective.

The council developed five marking systems for evaluation at passive, at-grade railroad crossings, which do not have train-activated warnings. The systems, which vary with regard to location and amount of retroreflective materials, were installed at five grade crossings along the Virginia Southern Railroad line. The crossings were selected on the basis of four criteria: visibility of the crossing from the roadway; absence of external light sources, such as home security lights or street lights; relatively flat approach grades; and an approximately 90-degree angle at which the railroad tracks and roadway intersect.

Photographs of each approach to the crossings were taken using only the low and high beams from a vehicle's headlights for illumination. In addition, videotapes were shot at night to show a vehicle driving through each crossing, once with low beams and once with high beams, and to show a train traveling through each crossing, using only high beams.

Personnel from VDOT's Traffic Engineering Division, the Virginia Department of Rail and Public Transportation, and the council viewed the

photographs and videotapes and filled out a questionnaire about each crossing treatment. The respondents rated the visibility of various components of each crossing using a five-point scale and then ranked the crossings. Their responses were used to calculate a final rating for each system and a final overall ranking of all five systems.

In the lowest-ranked system, retroreflective material installed only on the crossbucks or on less than the full length of the posts causes the crossbucks to appear to float in the sky, preventing motorists from accurately determining where the tracks cross the roadway. The highest-ranked system featured double-sided crossbucks, with VIP® reflective sheeting, mounted 2.74 meters (9 feet) from ground level; aluminum strips 1 millimeter (0.040 inches) thick, 7.5 centimeters (3 inches) wide, and 2.74 meters (9 feet) long and attached to the front and back of the support posts; and strips of VIP® retroreflective tape 5.08 centimeters (2 inches) wide and 2.74 meters (9 feet) long and applied to the aluminum strips on both sides of the support posts (Figure 3).

The materials cost of the highest-ranked system is approximately \$215 per crossing. (Punched aluminum sign blanks, instead of retroreflective

FIGURE 3 Of systems tested by Virginia Research Council for marking passive, at-grade railroad-crossings, this system was found to be most effective.

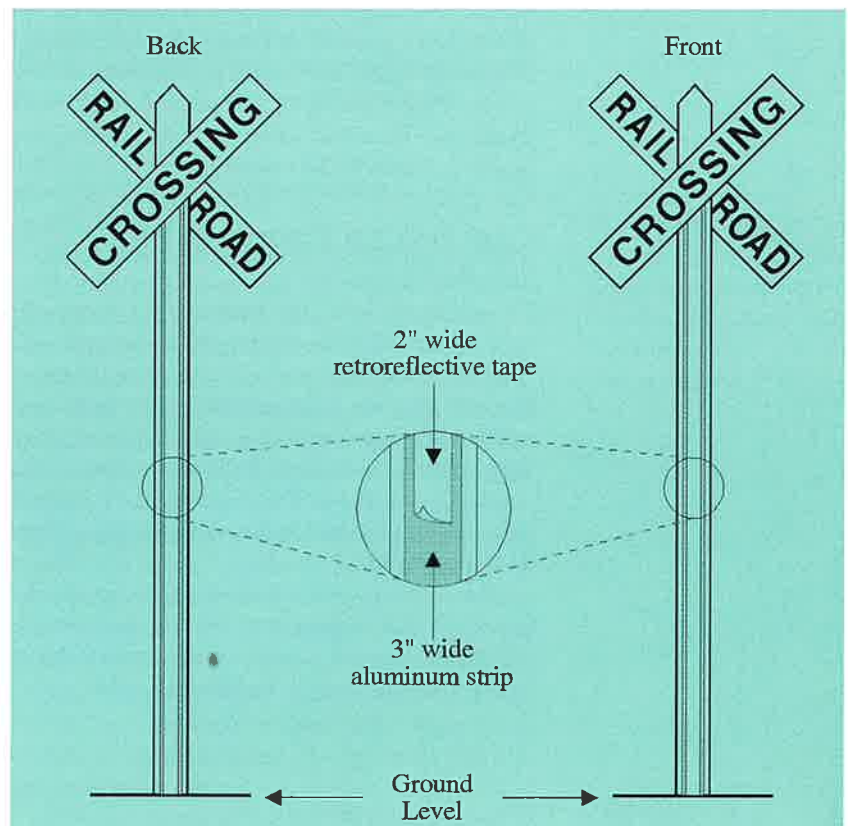


FIGURE 4 Marking system implemented at Virginia's passive, at-grade railroad crossings was found to increase ability of motorists to perceive the actual location of crossings.



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materials, account for most of this cost.) By the end of 1997, this system will be in place at all 967 of Virginia's passive, at-grade railroad crossings (Figure 4). Use of the system will increase the visibility of the crossing as well as motorists' ability to perceive the actual location of the crossing and to detect a train in the crossing.

CONTINUED COMMITMENT TO RESEARCH

For nearly 50 years, the partnership between the council and VDOT's central office divisions and field units has supported a strong, comprehensive research program. Commitment to innovation and technology improvement is maintained through daily interaction between those at the council who conduct research and the members of 12 research advisory committees from the Virginia Department of Transportation.

The council's goal is to return \$2 in benefits for every \$1 the department invests in research. VDOT's continued support of the council is evidence that this research is paying off.