U.S. Department of Transportation
Federal Highway Administration

Improved Method for Measuring the Chloride Permeability of Concrete

Deterioration of concrete bridge decks is a visible result of corrosion of the reinforcing steel within the concrete. The corrosion is initiated by the presence of chloride ions, which diffuse through the concrete after applications of deicing salt to the decks each winter.

Currently, when new decks are constructed, engineers use either or both of two approaches to slow down the inevitable corrosion process: the steel is given a protective coating, typically an epoxy; or the permeability of the concrete is reduced. Low permeability can be achieved by using well-consolidated, low water—cement ratio portland cement concrete ("Iowa mixes"), or by replacing a portion of the portland cement in a concrete with materials such as latex, other polymers, granulated slag, or silica fume.

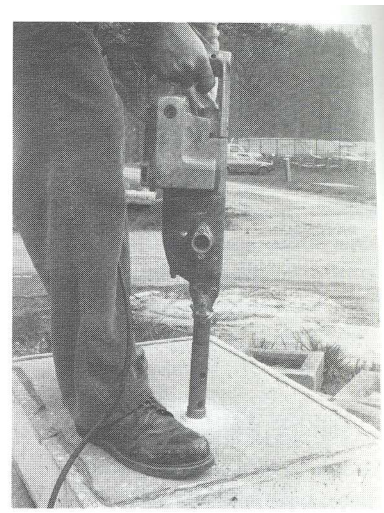
Problem

Highway agencies, materials producers, and construction contractors have a common need in the construction of low permeability bridge decks: how to measure the chloride permeability of concrete samples quickly. In the past these users have had to rely on ponding tests, such as American Association of State Highway and Transportation Officials (AASHTO) Standard Test T 259, for this determination. Such tests typically require ponding a 3 percent sodium chloride solution on the surface of a core or small slab for 90 days. The concrete is then sampled at various depths, and the chloride ion content of each depth increment is determined by laboratory chemical analysis. Because the overall test time, including the ponding and analysis periods, approaches 4 months, it is impractical for many purposes. Research conducted by the Construction Technology Laboratories, under a contract with the FHWA, produced a much faster and at least as accurate test method.

Solution

After considering a number of methods, researchers developed an electrical "applied voltage" technique into a rapid, straightforward laboratory test procedure. The new test is run on 2-inch thick slices of 4-inch diameter core or cast cylinder samples. The procedure involves the monitoring of the electrical current passing through the sample over a 6-hour period during which 60 volts d.c. are applied across its length. During the test the original top surface of the sample is maintained in a 3 percent sodium chloride solution; the chloride ions in the solution are forced to migrate into the concrete by the applied voltage.

The current is recorded every 30 minutes during the 6-hour test and plotted as a function of time. The area under this curve is the total charge passed, in coulombs, and was shown in the original research to correlate well with the results of 90-day ponding tests over a range of concrete types.



Chloride sampling after 90-day ponding test.

Because the moisture content of the sample at the beginning of the test affects the results, a vacuum saturation procedure is required to bring it to a standard moisture condition. This step requires a time period of 24 hours; thus the total test time is about 30 hours.

Most of the equipment for the test can be ordered from standard electronic and chemical catalogues; or a prepackaged, automated system can be purchased from commercial suppliers.

Application

To encourage use of the new method the FHWA distributed the original research report widely, published an abridgment in *Public Roads* magazine (December 1981), and made drawings and sample test cells available to prospective users. A number of state highway agencies began using the method immediately and the AASHTO Subcommittee on Materials adopted the procedure as a new standard test, T 277. In addition, adoption as an American Society for Testing and Materials (ASTM) standard is being sought; the FHWA has conducted an interlaboratory test program to develop a precision statement in support of the standardization effort.

Benefits

Recent information indicates that some two dozen laboratories in the United States and Canada are using this method. Users range from the state and provincial transportation agencies to specialized concrete manufacturers and corrosion consultants.

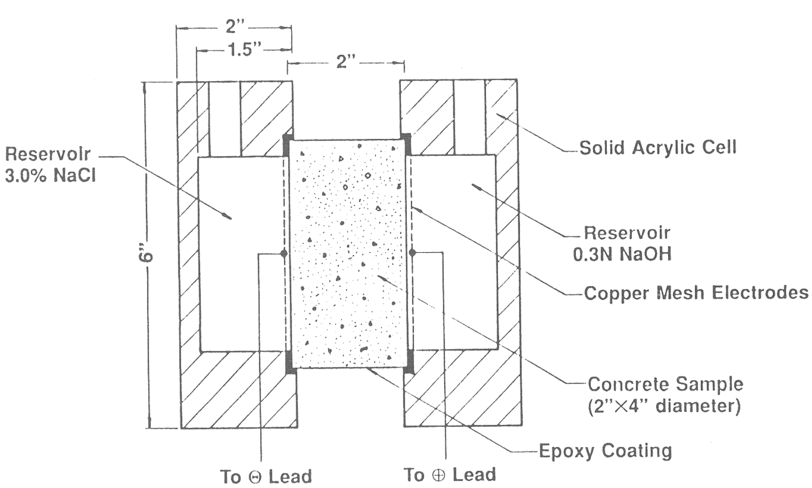
The applied voltage test is being used extensively as a product development and screening tool. The 4-month test period limited the usefulness of the ponding test for product evaluation; however, the new test is very effective for screening product formulations, curing procedures, and mix designs. As a result, the new test is playing an important role in the continuing development of latex-modified, granulated slag, and other specialized concretes. The rapidity of the test also makes it a useful diagnostic tool when problems crop up in field installations.

The applied voltage test is also extensively used as a research tool, which has added to the industry's basic knowledge about chloride permeability. For example, the new test readily shows how cure type and time, sample age, degree of consolidation, and surface cracking affect chloride permeability.

Additional basic research on the relationship of test results to bridge deck life and on the causes of high chloride permeability may, in the future, allow the test to be used in the acceptance of concrete. Research on other possible applications of the test is also continuing.

Direct cost savings could be quantified, but would not be a meaninful measure of benefits. Compared to the ponding method, the precision of the new test and the brief procedural steps involved have combined to significantly reduce the technician time necessary to evaluate a particular concrete. As is often the case, the ability to make a more rapid measurement than before has resulted in a sizable increase in the number of tests run. Laboratories running only a few 90-day ponding tests in the past now run hundreds of the rapid tests each year. The cost savings result from improvements in the quality of portland cement and specialized concrete in bridge decks, as well as from better diagnoses of field problems.

Repairing a concrete bridge deck damaged by corroding reinforcing steel.



Cross-sectional view of applied voltage test cells and concrete sample.

For further information, contact Terry Mitchell, HNR—30, Federal Highway Administration, 6300 Georgetown Pike, McLean, Virginia 22101 (703—285—2434). Copies of the abridgment in Public Roads, the AASHTO test procedure, and the interlaboratory test results are available from the FHWA; the original research report is available from the National Technical Information Service (PB# 82 140724).

Suggestions for "Research Pays Off" articles are welcome. Contact Nancy A. Ackerman, Editor, TR News, *Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418 (telephone 202—334—2972)*