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PCEF FOCUSES ON HPC PRESTRESSED BRIDGE MEMBERS

Louis N. Triandafilou, Federal Highway Administration

Since the fall of 1997, the Mid-Atlantic States Prestressed Concrete Committee for Economic Fabrication (PCEF) has been meeting twice a year to carry out its mission: ***"To encourage and promote economy, quality, and uniformity in the design, manufacture, and construction of high performance, prestressed concrete bridge members."*** The reference to high performance concrete (HPC) in the mission statement emphasizes the direction that the FHWA, state DOTs, and industry are taking to ensure improved durability, permeability, and strength in concrete bridges.

The PCEF consists of FHWA bridge engineers, industry representatives, and DOT bridge designers and materials engineers from Delaware, the District of Columbia, Maryland, Pennsylvania, Virginia, and West Virginia. Recent meetings have also included representatives from the DOTs in New Jersey, New York, and North Carolina, and the FHWA Eastern Federal Lands Highway Division. The precast, prestressed concrete suppliers that provide bridge members to these states are an integral part of the group. The PCEF is structured with subcommittees on standardization, design parameters, materials and quality control/quality assurance, construction/production, and contracting practices.

The first critical actions taken by the PCEF to promote uniformity, quality, and economy were to adopt two recommendations. Recommendation No. 1 was that, "HPC with a 28-day compressive strength of 8,000 psi (55 MPa) shall be used in prestressed concrete whenever it is economical. Prestressed concretes with strengths from 8,000 to 10,000 psi (55 to 70 MPa) may be used with approval of the State Bridge Engineer." Recommendation No. 2 deals with corrosion protection: "Concrete for piles, beams, and slabs shall contain 3.5 gal of calcium nitrite per cu yd of concrete, conforming to… unless granulated iron blast-furnace slag (minimum 40 percent by weight of cement) or silica fume (minimum 7 percent by weight of cement) conforming to… is used. Concrete for structures over tidal water, beams and slabs within 15 ft of mean high water, and all exposed piles shall contain either 5.4 gal of calcium nitrite per cu yd concrete, conforming to… or 2.0 gal of calcium nitrite per cu yd of concrete with granulated iron blast-furnace slag (minimum 40 percent by weight of cement) or silica fume (minimum 7 percent by weight of cement) conforming to…"

The PCEF has adopted a family of bulb-tee shapes that are interchangeable with the recently developed New England bulb-tees. The proposed sections are very versatile with nine girder depths, three web thicknesses, three top flange widths, and two bottom flange thicknesses providing a total of 162 possible shapes. The needs of every state and precaster should be satisfied within this framework that uses one set of form pieces to produce any of the girder shapes.

In summary, the Mid-Atlantic States PCEF is a dedicated group of professionals working hard toward the ultimate goal of enhancing the economy of prestressed concrete bridges through standardization and uniformity of design and fabrication practices. The group is an excellent example of the FHWA, state and local DOTs, and industry working together to adopt quality and economical measures through a consensus process. Positive effects have been achieved by tying the group's mission to the national emphasis on HPC. At each PCEF meeting, the states identify more and more activities on the implementation of HPC.

Further Information

More information about PCEF meetings, subcommittees, and the full committee roster can be found at the FHWA website www.fhwa.dot.gov/resourcecenters/eastern/infrastr/hipma.htm. Or, contact the author at lou.triandafilou@fhwa.dot.gov or 410-962-3648.

THE RAPID MIGRATION TEST—AN ALTERNATIVE TO AASHTO T 277

Kyle Stanish, R. Doug Hooton, and Michael D. A. Thomas, University of Toronto

The chloride penetration resistance of concrete is often a critical parameter in determining the long-term performance of concrete structures. However, there is a great deal of discussion regarding the best method to measure this property. From September 1997 to June 2000, the authors evaluated alternative rapid test procedures to determine the chloride penetration resistance of concrete under FHWA Contract DTFH61-97-C-00022 entitled "Prediction of Chloride Penetration into Concrete." The most promising test procedure, called the Rapid Migration Test (RMT), is based on a test developed at Chalmers University in Sweden. This test is now standardized as a Nordtest* procedure (NT Build 492) and has proven to give more consistent results than other methods currently available.

The RMT Procedure

Several alternative testing procedures were evaluated within the framework of the basic test methodology proposed by Tang and Nilsson.[1] Similar to the AASHTO T 277 test procedure, the RMT consists of subjecting a saturated concrete test specimen to an electrical field. A chloride-bearing solution is placed on one side of the concrete and a chloride-free solution on the other, such that the chlorides are driven into the concrete. A schematic of the test setup is shown in Fig. 1. The test is run for a specified time period. The concrete specimen is then split open and sprayed with a silver nitrate solution. After a few minutes, concrete penetrated by the chlorides turns white because silver chloride is formed. The chloride-free portion turns dark brown. The concrete can then be rated based on the observed depth of the chloride penetration.

In the FHWA study, the effect of several different voltages and test durations were evaluated. Based on the results, a fixed test duration of 18 hours was selected. The voltage to be applied in the test depends on the current measured initially using 60 volts. In most cases, 60 volts is appropriate for the test. However, 30 volts or 10 volts may be needed for more permeable concrete. The voltage is selected to attain an easily measurable depth of chloride penetration without the chloride penetrating the entire sample thickness. Sample preparation is much simpler than in the AASHTO T 277 test, as the sides of the concrete specimen do not need to be sealed.

RMT Results and Chloride Penetration Resistance

The relationship of the RMT results to the long-term chloride penetration resistance of concrete was evaluated using different concretes covering a wide range of concrete qualities and mix components. The RMT and AASHTO T 277 test were performed at different ages on these concretes. In addition, two long-term tests were performed – the AASHTO T 259 90-day salt ponding test and a bulk diffusion test (NT Build 443), which is currently being balloted as a new standard by ASTM Subcommittee C09.66. The results of the two rapid tests were then compared to the results of the two long-term tests. One comparison is shown in Fig. 2. More comparisons are given in Reference 2. In all cases, the correlations between the RMT and the long-term tests were equal or slightly better than those achieved by the AASHTO T 277 test. More importantly, the RMT was applicable to a wider range of concretes than the AASHTO T 277 test.

The suitability of the RMT for use with all concrete types was determined by examining the test results to detect any component that was evaluated improperly. With the exception of samples with embedded steel, the RMT was successful in predicting the chloride penetration resistance of all the concrete types tested. This included concretes containing calcium nitrite corrosion inhibitor (CNI). To further illustrate the independence of the RMT results to the presence of CNI, the results of two nominally identical concrete mixtures, one containing CNI and one without, were compared. For the non-CNI concrete, the NT Build 443 bulk diffusion test produced a diffusion value of 2.82×10^{-11} m^2/s and AASHTO T 259 test resulted in a chloride concentration of 0.19 percent of the concrete mass at a depth of 1/2 in. (12.5 mm). The CNI concrete had a diffusion coefficient of 1.27×10^{-11} m^2/s and a chloride concentration of 0.21 percent of the concrete mass at the same depth. Thus, the long-

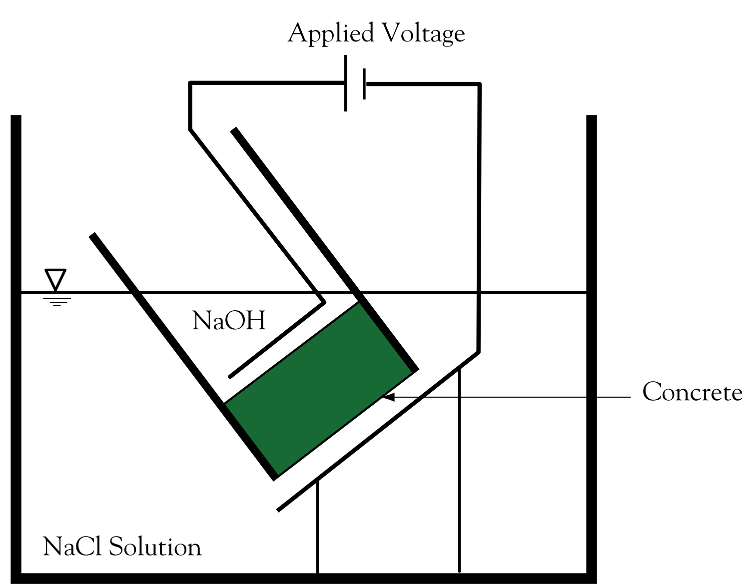


Fig. 1. Schematic of RMT test setup.

* *Nordtest is an organization for test methods in the Nordic countries.*

term tests confirmed that the two concretes had a similar resistance to chloride penetration when compared to the complete range of diffusion coefficients shown in Fig. 2. However, the AASHTO T 277 test gave a much higher result for the CNI concrete (9874 vs. 5557 coulombs) due to the greater conductivity of the nitrite ion in the pore solution. The results of the RMT were close together for both concretes—0.0403 and 0.0539 mm/volt-hr for the CNI concrete and non-CNI concrete, respectively.

In the samples containing reinforcing steel bars, when the chloride ions reach the steel, the ions cease to penetrate further and react with the steel to cause corrosion. Consequently, the test results are not valid. If the embedded steel is deep enough and the chloride ions do not reach the steel, then the test gives valid results.

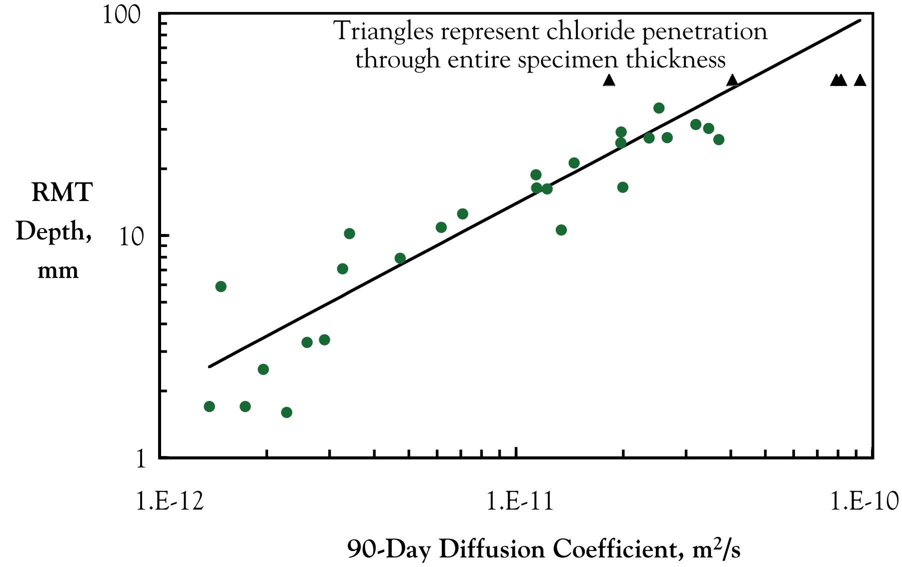


Fig. 2. RMT chloride depths versus 90-day diffusion coefficients.

Additional Evaluation

An inter-laboratory evaluation of the RMT was run on two different concretes with the assistance of four additional testing agencies. The AASHTO T 277 test was also run for comparative purposes. For both concretes, the coefficient of variation was lower for the RMT than for AASHTO T 277 test (approximately 16 percent versus 26 percent), despite the greater familiarity of the laboratories with the AASHTO T 277 test.

In addition, a rating system for concrete was developed that could be included in the framework developed by Goodspeed, Vanikar, and Cook.[3] In this paper, three performance grades for resistance of concrete to chloride penetration were presented. The grades were based on the AASHTO T 277 test. The original performance grades and the ratings based upon the RMT are shown in Table 1. In this table, the RMT is rated by the millimeters of penetration per volt-hour of testing time.

Conclusions

The RMT appears to be a viable alternative for evaluating the chloride penetration resistance of concrete. It overcomes some of the drawbacks of the AASHTO T 277 test and outperforms it in some areas. The results of the research will soon be published by FHWA. In the meantime, a literature review, which serves as a general introduction to the evaluation of chloride penetration resistance of concrete, is available at www.tfhrc.gov. Click on Library and scroll down to the titles under the letter "T."

Standard Test Method	FHWA HPC Performance Grade 1	2	3
AASHTO T 277 (x = coulombs)	3000 ≥ x > 2000	2000 ≥ x > 800	800 ≥ x
RMT (y = rate of penetration in mm/volt-hour)	0.034 ≥ y > 0.024	0.024 ≥ y > 0.012	0.012 ≥ y

Table 1. HPC Chloride Penetration Resistance Performance Grades

References

1. Tang, L. and Nilsson, L. "Rapid Determination of the Chloride Diffusivity in Concrete by Applying an Electrical Field," ACI Materials Journal, Vol. 89, No. 1, January-February 1992, pp. 49-53.

2. Stanish, K. D., Hooton, R. D., and Thomas, M. D. A., "A Rapid Migration Test for Evaluation of the Chloride Penetration Resistance of High Performance Concrete," Symposium Proceedings, PCI/FHWA/FIB International Symposium on High Perfor-mance Concrete, Orlando, FL, Precast/ Prestressed Concrete Institute, Chicago, IL, 2000, pp. 358-367.

3. Goodspeed, C. H., Vanikar, S., and Cook, R., "High Performance Concrete Defined for Highway Structures," Concrete International, Vol. 18, No. 2, February 1996, pp. 62-67.

Editor's Note

HPC Bridge Views Issue No. 6, November/ December 1999, contained a discussion about the pros and cons of the rapid chloride permeability test – AASHTO T 277. This initiated a letter from R. Doug Hooton that appeared in Issue No. 9, May/June 2000. This, in turn, prompted the Editorial Committee to ask three experts about various aspects of the AASHTO T 277 test. Their responses were published in the last issue of *HPC Bridge Views*. Further thoughts on this topic and the reasons that the FHWA initiated research for an alternative method are available on the FHWA Eastern Resource Center web site at www.fhwa.dot.gov/resourcecenters/ eastern/infrastr/rpdcl.htm.

Q&A

Many questions arise about HPC and its applications. If you have a question that you would like answered in HPC Bridge Views, please submit it to the Editor.

http://hpc.fhwa.dot.gov

Question:

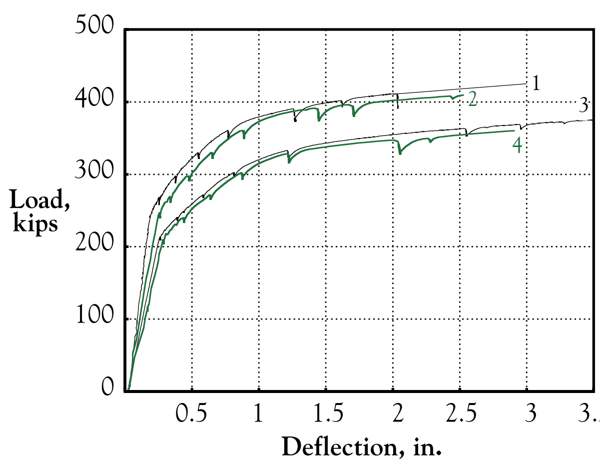
With a cast-in-place concrete deck placed on precast, prestressed concrete deck panels that are supported on precast, prestressed concrete beams, can I assume full composite action between the deck, panels, and beams in calculations of service load stresses and strengths?

Answer:

The answer to this question can be illustrated by the results of recent tests on four specimens, conducted at the Ferguson Structural Engineering Laboratory at The University of Texas at Austin. Each test specimen consisted of a Type I AASHTO girder with a depth of 28 in. (711 mm) and a composite deck with a thickness of 8 in. (203 mm) and a width of 78 in. (1.98 m). Two specimens used a full 8-in. (203-mm) thick cast-in-place, normal weight concrete deck. The other two specimens used 4-in. (101-mm) thick precast, lightweight concrete panels with a 4-in (101-mm) thick cast-in-place, normal weight concrete deck. The panels were placed immediately adjoining each other with no special treatment of the joint. The specimens were tested in flexure with a span of 24 ft (7.3 m).

The load-deflection curves for two pairs of test specimens are shown in the figure. Specimens 1 and 3 had a full-thickness, cast-in-place deck. Specimens 2 and 4 had precast panels with a half-thickness, cast-in-place deck. Specimens 1 and 2 were tested with a shorter shear span than Specimens 3 and 4. Consequently, Specimens 1 and 2 had less deflection for the same load and a higher load capacity.

The load-deflection curves and strengths for each pair of specimens are almost identical. Strain gages placed across the width of the slab showed that the full width of the slab was effective for both the full-thickness, cast-in-place deck and the composite, precast panel deck. Failure was identical for both cross sections with the strain at the top of the deck exceeding 0.003 before surface spalling and concrete crushing occurred at the maximum load. The measured flexural strengths exceeded values calculated either using the provisions of the AASHTO specifications or by strain compatibility analysis.



In terms of analysis at the section where the precast panels abut each other with no special treatment of the joint, the test results show that no special analysis is needed. Based on the test results, full composite action, with or without the use of precast, prestressed concrete panels, can be assumed for both service load and strength calculations.

Answer contributed by Ned H. Burns of the University of Texas at Austin. He may be contacted at nedburns@mail.utexas.edu or 512-471-1619 for further information.

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