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Modelling Service Life and Life-Cycle Cost of Steel-Reinforced Concrete

Report from the NIST/ACI/ASTM Workshop held in Gaithersburg, MD on November 9-10, 1998

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United States Department of Commerce
William M. Daley, *Secretary*
Technology Administration
Gary R. Bachula, *Acting Under Secretary for Technology*
National Institute of Standards and Technology
Ray Kammer, *Director*

2. SUMMARIES OF INVITED PRESENTATIONS

2.1 RILEM TECHNICAL COMMITTEE TMC, TESTING AND MODELLING CHLORIDE PENETRATION IN CONCRETE

Marta Castellote, Eduardo Torroja Institute of Construction Sciences, Spain

Concrete, was established in 1997. Its scope and objectives [1]* are similar to those of the present workshop. The committee was established because of the increasing need for internationally-accepted methods for evaluating the durability of concrete and the lack of performance tests the results of which could be used to predict the long-term behavior of concrete in chloride-containing environments. The lack of suitable test methods is attributable, at least in part, to uncertainties about factors controlling the ingress of chlorides into concrete.

The scope of the RILEM Committee includes: mechanisms of chloride ingress into concrete; definition of terms; identification of important parameters; and the significance of different "diffusion coefficients." Test methods used in different countries are to be identified and models for predicting chloride ingress by different mechanisms evaluated. Consensus will be sought on test methods appropriate for use in the design phase and those applicable to existing structures. While the models identified may have different levels of sophistication, understanding of each will be sought to enable evaluation of their usefulness for predictive purposes.

The Committee's work is expected to take about five years. It will begin with preparation of a state-of-the-art report, and this will be followed by a two-part program:

1. Tests

   1.1 Identification and comparison of existing methods and testing variables.

   1.2 Round robin tests on selected methods.

   1.3 If needed, production of RILEM Technical Recommendations.

2. Models

   2.1 *Analysis of the background of the different models, and of the initial and boundary conditions of the different solutions of Fick's law.

   2.2 Discussion on the limits of application of the models for predictive purposes; and round robin tests for comparative predictions.

   2.3 Optimum framework of a model.

   2.4 Simplified models for design purposes.

   2.5 A state-of-the-art report and, if possible, a RILEM Recommendation on the use of models.

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* Numbers in [ ] are for references listed in Section 5.

The test methods to be recommended in 1999 will address: sampling and profiling; modelling and calibration; and determination of the chloride threshold for initiation of corrosion. The goal to be achieved in 2002 is a recommended international approach to modelling chloride penetration into concrete which can take into account all climates and environmental conditions. The Committee's state-of-the-art reports should be of particular interest to academics and testing laboratories, while its recommendations should be important to testing laboratories, practicing engineers, and standards bodies.

On behalf of Committee Chairperson, Carmen Andrade, Dr. Castellote invited other interested persons to join the RILEM Committee. (For those who may need it, Dr. Andrade's e-mail address is: Andrade@fresno.csic.es .)

2.2 MODEL FOR A QUANTITATIVE CORROSION DAMAGE FUNCTION FOR A REINFORCED CONCRETE MARINE SUBSTRUCTURE

Alberto Sagüés, University of South Florida

A damage function approach has been applied in predicting the course of corrosion in (mostly) marine structures. It has been applied in two ways [2,3], one simple and one more sophisticated. In the first, knowledge of the distribution of the thickness of the concrete cover over the reinforcing steel and of the surface chloride concentrations is used in calculations for each of three ranges of elevation with respect to sea level – the tidal zone, the lower splash zone, and the upper zone. Diffusion is assumed to be the only transport mechanism, and it is also assumed that each elevation has its own threshold concentration of chloride to initiate corrosion. From the results, if the cost of repair per unit area is known, the repair cost can be calculated. This model blends uncertainty with variability.

The first approach was used in forecasting the extent of corrosion of the reinforcement in two 31 year-old, parallel concrete bridges in a marine environment in northern Florida. A preliminary inspection showed that the chloride concentration at the depth of the reinforcement in the cylindrical piling was approaching the level normally associated with the onset of corrosion. Future traffic projections required deciding between alternatives that included expanding the present structures or rebuilding. To select the most appropriate alternative, an investigation was conducted to develop an approximate forecast of future corrosion development. The investigation included assessing the present condition, and developing a quantitative corrosion deterioration model. The corrosion condition was assessed by visual observation, direct examination of reinforcement, and electrochemical corrosion measurements. Chloride-penetration profiles were obtained from extracted concrete cores. Reinforcement cover was measured by direct observation. The chloride profile data were analyzed to obtain apparent chloride ion diffusivities, surface concentrations and bulk concentrations. The deterioration model used the statistical distributions of concrete cover, diffusion coefficient and surface concentration to estimate the distribution of times for corrosion initiation and appearance of external damage on the bridge substructure. The output of the model was a damage function indicating the amount and location of repairs needed as a function of bridge age.