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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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To facilitate its use, the model provides default values for quantities for which actual data may not be available. As can be seen from the plots in Figure 1, the model appears to provide a good fit to data for OPC concrete. Comparable results have been obtained for concretes containing blast furnace slag and fly ash.

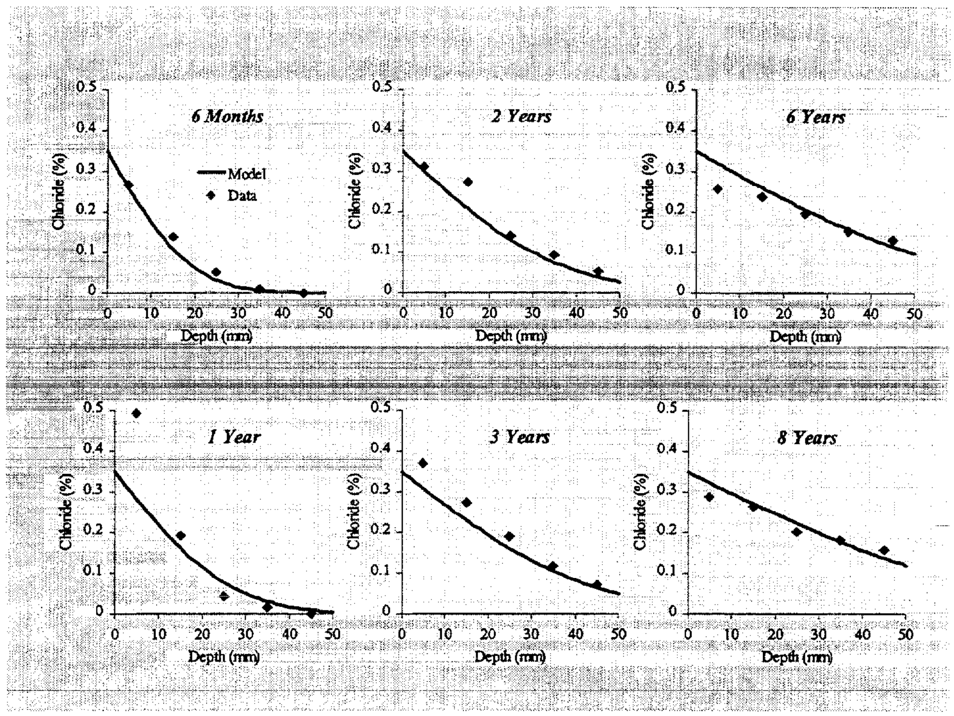

Figure 1. Comparison between U of T Model outputs and experimental data

2.6 MODELING ION TRANSPORT IN CEMENT-BASED MATERIALS

Jacques Marchand, Laval University, Canada (with E. Samson and Y. Maltais)

Over the past few years, the mechanisms of ionic transport in cement systems have been the subject of a great deal of attention. Most of the reports published on the topic have clearly emphasized the intricate nature of the problem. Given the number of parameters involved, the process of ionic transport cannot be described by analytical models, and numerical modeling is required.

The main features of a numerical model that predicts the mechanisms of ionic transport in reactive porous media were described in the presentation. An important original feature of the model is that it accounts for the electrical coupling (diffusion potential) between the various species in solution.

The model is divided into four parts: ionic diffusion, moisture transport, chemical reactions, and chemical damage. The transport of ions by diffusion is modeled by solving the extended

Nernst-Planck / Poisson set of equations. The diffusion of all ionic species present in the system can be accounted for by the model. It also accounts for chemical activity effects.

The transport of water by capillary suction is described by a diffusion-type equation, and the variation of the water diffusion coefficient is described by an exponential equation. The water content of the solid serves as the state variable for this part of the model.

Chemical reactions are modeled through a series of sink and source terms. The non-linear nature of each chemical reaction process is accounted for by a number of interaction isotherms. The influence of on-going chemical reactions on the material transport properties is accounted for. The effects of the chemically-induced alterations are described in terms of porosity variations.

To solve such a complex system of non-linear equations, a numerical algorithm must be used. All the equations are solved simultaneously. The spatial discretization of this coupled system is performed through the finite element method using the standard Galerkin procedure. An Euler implicit scheme is used to discretize the transient part of the model. The non-linear set of equations is solved with the Newton-Raphson algorithm. The second order algorithm gives a good convergence rate and is robust enough to handle the electrical coupling between the ionic flux and the water movement.

The model can be used to follow any changes in the concrete pore solution chemistry to obtain a precise description of the materials solid phase distribution. The model has been successfully applied to cases of degradation by sulfates and by chlorides.

2.7 THE DURAMODEL® FOR THE DESIGN OF COST-EFFECTIVE CONCRETE STRUCTURES

Paul Tourney, W.R. Grace Company

Systems for the corrosion protection of reinforcing steel in concrete have three possible effects: 1) reduction of the ingress of chloride, 2) increase of the chloride level at which corrosion initiates; and 3) reduction of the corrosion rate once corrosion initiates. The performance of a protection system needs to be evaluated in light of these effects. Once these are documented, one can determine the initial costs of the protection system and then project the time to corrosion for first and subsequent repairs. The future repair costs are converted to present day costs using a net present value analysis. Examples have shown that eliminating corrosion protection at the design stage is an expensive long-term option.

The Grace model [19] describes each of the three possible effects mathematically. The model is WINDOWS-based and the inputs include the type of structure and application, and the exposure conditions – temperature, surface chloride, thickness, chloride build up/year, and the corrosion threshold. Outputs include the service life with repair and the costs for various protective systems. Evaluation of the performance of a protection system as related to the three effects requires data from accelerated and long-term field and laboratory tests, and the evaluation requires an understanding of corrosion mechanisms as well as protection mechanisms; the same accelerated testing techniques cannot be used for all methods.