Mass Transfer Model for Predicting Water Uptake in Coated Concrete

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Abstract

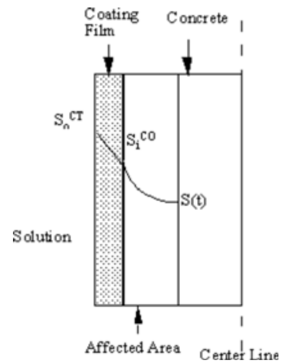
A mass transfer model was developed to predict the weight increase in coated concrete in a non-reactive solution. The model was verified using epoxy coated concrete specimens. The mass transfer model parameters for water-coating combinations were obtained from controlled experiments.

Introduction

When cement concrete specimens are submerged in liquids for testing, the weight change of the concrete is a key factor that indicates the change in concrete. Mebarkia and Vipulanandan (1995)[1] developed a cylindrical model to predict weight increase in polymer concrete when submerged in water. For coated concrete, because of the porous nature of the substrate, the penetration of coating into the concrete is a very important factor and the interface properties may have affected the penetration of liquids; therefore, it was necessary to incorporate the interface properties related to coating-concrete in modeling the coated concrete behavior.

Modeling

When coated concrete comes into contact with water, it will penetrate the coating film into the concrete. The Physical model for coated concrete when immersed in water is shown in Fig.1.



Where S_o^{CT} ultimate degree of saturation in coating film, g water/cm^3 solid;

S_i^{CO} degree of saturation on the interface of coating film and concrete substrate, g water/cm^3 solid;

S(t) Degree of saturation distribution of liquid inside corroded zone of concrete cylinder, g water/cm^3 solid.

Figure 1 Physical Model of Coated Concrete in Water

For mass transport in cylindrical specimens, if the degree of saturation is a function of radius and time only, the second order differential equation is:

$$\frac{\partial S}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}\left(rD_{co}\frac{\partial S}{\partial r}\right), \qquad (1)$$

where D_{CO} is the mass transfer coefficient of the substrate and r is the radius of cylinder.

For liquid transport in a coated concrete cylinder without chemical reaction, the degree of saturation on the concrete surface changes with time. If the degree of saturation at the concrete surface is $\phi(t)$, assuming $\phi(t) = S_0^{CO}\{1-\exp(-\bar{\beta}t)\}$, the sorption-time curve is given by Crank (1975)

$$\frac{W_t^{co}}{\pi R^2 h S_0^{co}} = 1 - \frac{2J_1\{(\bar{\beta}r^2/D_{co})^{1/2}\}\exp(-\bar{\beta}t)}{(\bar{\beta}R^2/D_{co})^{1/2}J_0\{(\bar{\beta}R^2/D_{co})^{1/2}\}} + \frac{4}{R^2}\sum_{n=1}^{\infty}\frac{\exp(-D_{co}\alpha_n^2 t)}{\alpha_n^2\{\alpha_n^2/(\bar{\beta}/D_{co})-1\}}. \qquad (2)$$

From Fig. 2, the solution uptake is determined by the parameter $\bar{\beta}R^2/D_{co}$ which represents the effects of the coating material properties and the parameter $(D_{co}t/R^2)^{1/2}$ (x-axis) which represents the time effect. Let $\lambda_{co} = \bar{\beta}R^2/D_{co}$.

Approximating Eq. (3) and considering an exponential function of the form

$$\frac{W_t^{CO}}{\pi R^2 h S_0^{CO}} = \left\{1-\exp\left[-\lambda_{co}\left(\frac{D_{co}t}{R^2}\right)^m\right]\right\} \qquad (3)$$

where m is a constant.

The Eq. (3) is best fitted to the standard curves in Fig. 2 for different l_{CO} values by using the least-square method. The value of m varied from 0.98 to 1.26 when the value of l was in the range of 0.01 to 5.

The approximate solution for Eq. (3) is in good agreement with the solution suggested by Crank (1975) (Fig. 2). The solid curves are the standard curves (Eq. (3)) as given by Crank (1975) while the dotted lines are the approximate solution from Eq. (3).

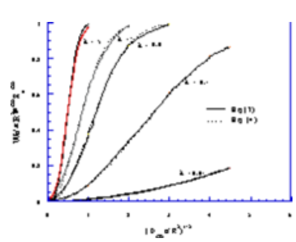


Figure 3. Comparison of the experimental Data with Model Predictions in D. I. Water

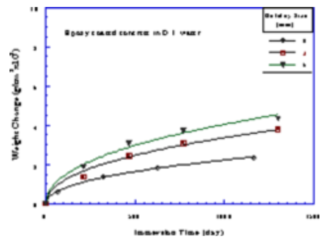


Figure 2.�� Comparing Exact (Solid Line) Solution to the Approximate Solutions

The mass transfer coefficients of concrete (D_{CO}) can be obtained by fitting the cylindrical model (Mebarkia, 1995[1]) to experimental data of uncoated concrete specimens. The values of mass transfer coefficients was 2.55 �10^{-10} m^2/s in D. I. water. Using Eq. (3) and experimental data, the parameters n, l, and $\bar{\beta}$�can be obtained for different coatings. The comparisons of model prediction (Eq. (4)) to experiment data are shown in Fig. 3.

Conclusions

����������� A model was developed to predict the weight increase of coated concrete in water. Parameters in the model can be obtained from controlled experiments. The model prediction was in� agreement with the test results.

Acknowledgement

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�Reference:

1. Mebarkia, S. and Vipulanandan, C. (1995). Journal of Engr. Mech., Vol. 121, No. 12, 1359-1365.
2. Crank, J. (1975). The mathematics of diffusion**,** Oxford University Press, 2^{nd}, New York, N.Y.