Note on Research in Progress

CHLORIDE DIFFUSION AND CORROSION INITIATION OF STEEL REINFORCEMENT IN FLY-ASH CONCRETES

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(Communicated by G.M. Idorn)
(Received June 26, 1986)

Pergamon Journals

New York • Oxford • Beijing • Frankfurt • São Paulo • Sydney • Tokyo • Toronto

CEMENT and CONCRETE RESEARCH. Vol. 16, pp. 782-784, 1986. Printed in the USA.
0008-8846/86 $3.00+00.

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1. Introduction

The influence of fly ash cement blends on diffusion of chlorides in concrete is being investigated by means of an electrical half-cell potential method. Preliminary results are presented. Further investigations are underway using other cements, fly ashes, and concrete mix proportions.

2. Theory

It is known that penetration of chloride ions into uncracked and water saturated concrete can be calculated according to Fick's Second Law. Departing from Fick's law, Collepardi, Marcialis, and Turriziani (1) found Equation 1 from which the diffusion coefficient of chloride ions in concrete D may be calculated

$$D = \frac{0.0625\ d^2}{t} \qquad \text{Equation 1}$$

where D = diffusion coefficient of chloride ions in concrete, in cm^2/sec
d = depth of concrete cover over reinforcement, in cm
t = length of time from the moment of first chloride exposure of concrete specimens, to the moment of onset of steel corrosion, in sec

3. Experimental

Steel rods in samples of fly-ash concrete specimens of various mix proportions were immersed in a salt water bath as shown in Figure 1 and subjected to a small impressed anodic potential of 200 mV. For a non-corroding steel the resulting current is of the order of 0.1-0.3 μA only, and initially the current is constant with time. The experimental procedure is described in detail by Hansson (2) and Hansson, Frølund, and Markussen (3).

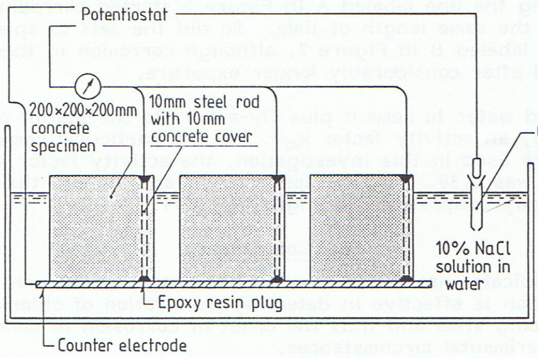

Figure 1. Experimental arrangement for detecting the onset of corrosion of steel in concrete.

The current in the circuit was monitored daily until a significant increase was noticed. Such increase occurs within a few hours and indicates first penetration of chloride ions to the steel rods and onset of steel corrosion in concrete.

The time from the moment of first chloride exposure of concrete specimens to the moment of corrosion initiation was recorded for each set of three specimens (Nos. 1 through 10 in Figure 2), and corresponding coefficients of chloride ion diffusion were calculated.

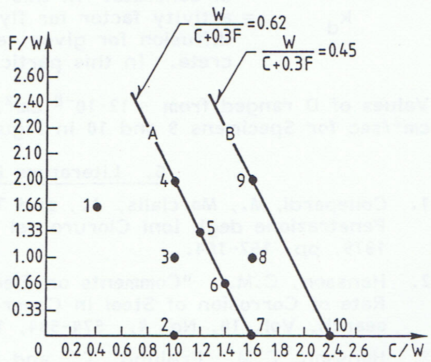

Figure 2.
Fly ash-water and cement-water ratios of concretes studied.

4. Results

Figure 2 shows the fly ash-water ratios and the cement-water ratios of the various 8 mm maximum size aggregate concretes which were studied.

All concretes which were produced with the same modified water to cement plus fly-ash ratio as shown in Figure 2 started corroding after approximately the same time of exposure to chlorides. Thus the sets of specimens along the line labeled A in Figure 2 started corroding after approximately the same length of time. So did the sets of specimens along the line labeled B in Figure 2, although corrosion in these specimens started after considerably longer exposure.

In the modified water to cement plus fly-ash ratio the weight of fly ash is multiplied by an activity factor k_d. For the particular cement and fly ash which were used in this investigation, the activity factor k_d for chloride diffusion was 0.30. For the same cement and fly ash the activity factor for 28-day compressive strength was 0.17.

5. Conclusion

The results indicate that the electrochemical method which was used in this investigation is effective in detecting penetration of chloride ions to the reinforcing steel and thus the onset of corrosion in concrete under the given experimental circumstances.

For concretes made with the particular Portland cement and fly ash which were used in this investigation it appears that the coefficient of chloride ion diffusion is governed by a modified water-cement ratio rule as shown in Equation 2.

$$D = \alpha \, 10^{-\frac{C + k_d F}{W} + \rho} \qquad \text{Equation 2}$$

where D = coefficient of chloride ion diffusion, in cm^2/sec
C = cement content of concrete, in kg/m^3
W = water content of concrete, in kg/m^3
F = fly-ash content of concrete, in kg/m^3
α and ρ = constants for given cement, fly ash, and curing time of concrete. In this particular case $\alpha \sim 1.7$ and $\rho \sim 7$
k_d = activity factor for fly ash with respect to chloride diffusion for given cement and curing time of concrete. In this particular case $k_d \sim 0.30$

Values of D ranged from $\sim 12 \cdot 10^{-8}$ cm^2/sec for Specimens 1 to $\sim 0.6 \cdot 10^{-8}$ cm^2/sec for Specimens 9 and 10 in Figure 2.

6. Literature References

1. Collepardi, M., Marcialis, A., and Turriziani, R.: "La Cinetica di Penetrazione degli Ioni Cloruro nel Calcestruzzo", Il Cemento 67, 1979, pp. 157-164.

2. Hansson, C.M.: "Comments on Electrochemical Measurements of the Rate of Corrosion of Steel in Concrete", Cement and Concrete Research, Vol. 14, No. 4, 574-584, 1984.

3. Hansson, C.M., Frølund, T., and Markussen, J.B.: "The Effect of Chloride Cation Type on the Corrosion of Steel in Concrete by Chloride Salts", Cement and Concrete Research, Vol. 15, No. 1, 1985, pp. 65-73.