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AUTHOR'S REPLY TO DISCUSSION OF PAPER "CHLORIDE THRESHOLDS IN MARINE CONCRETE" BY DAVID B. MCDONALD

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The author thanks Dr. McDonald for his comments. I agree that further work is required to elucidate the relationship between cement composition and the chloride threshold required to initiate steel reinforcement corrosion in portland cement concrete. However, I believe that the threshold value will be influenced by a number of factors in addition to the alkali content of the cement. The purpose of this study was to determine whether fly ash (Class F) had any significant influence on the chloride threshold value.

Dr. McDonald suggests that the lower threshold value in fly ash concrete may lead to a reduction in the time to initiate corrosion. This would be true if the ash had no impact on the diffusivity of the concrete. That this is not the case has been shown by numerous investigators and is further corroborated by results from this study. Chloride concentration profiles established for these concretes after various periods of marine exposure demonstrate that the use of fly ash increases the resistance of concrete to chloride ion penetration, the effect increasing with the level of replacement throughout the range studied, i.e. up to 50% (1, 2). Furthermore, differences between fly ash and portland cement concrete become more marked with time owing to the continued long-term hydration of fly ash. Fitting the 4-year data for 45 MPa concrete to Fick's second law yields the following diffusion coefficients (2):

Fly Ash (%)	Diffusion Coefficient, D_a (x 10^{-13} m^2/s)
0	64
15	13
30	5.8
50	8.5

Following on from the example given by Dr. McDonald, i.e. assuming ingress follows Fick's Law, the initiation period can be predicted for different levels of concrete cover. Figure 1 shows the relationship between initiation period and cover for portland cement

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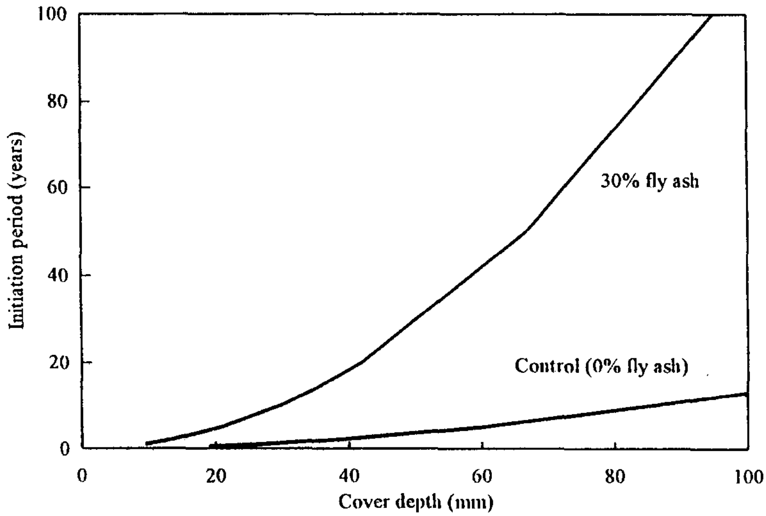

FIG. 1.
Time to corrosion initiation as a function of cover depth and fly ash content (45 mpa concrete).

concrete and concrete of the same strength grade with 30% fly ash. This analysis used the threshold values given in the paper (0.7% for portland cement and 0.5% for 30% fly ash), the diffusion coefficients given above and an assumed surface concentration of C_s = 4% chloride by mass of cementitious material. The results show that the lower threshold value in fly ash concrete is more than compensated for by the reduction in diffusion coefficient. Indeed, for concrete with 60mm cover (i.e. the minimum specified for Class 1 exposure in Canada) the time to corrosion initiation is approximately 5 years for portland cement concrete and 43 years in concrete with 30% fly ash.

Using this approach is somewhat overlysimplistic as it does not account for (i) transport by other mechanisms (e.g. initial sorption by capillary suction into unsaturated concrete), (ii) changing surface concentration with time (i.e. $C_s = f(t)$), (iii) changing diffusivity with time (i.e. $D_a = f(t)$), and (iv) chloride binding. More complex analysis using numerical methods has been attempted using this data set (3). The results indicate that the differences between portland cement and fly ash concrete become more marked when these effects are accounted for, particularly since fly ash concrete exhibits a significant reduction in diffusivity with time.

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