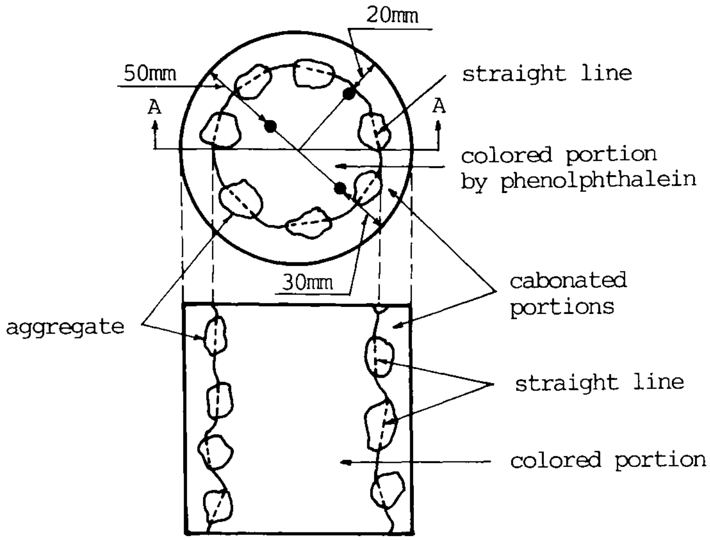

Figure 1 Specimen for Carbonation Test

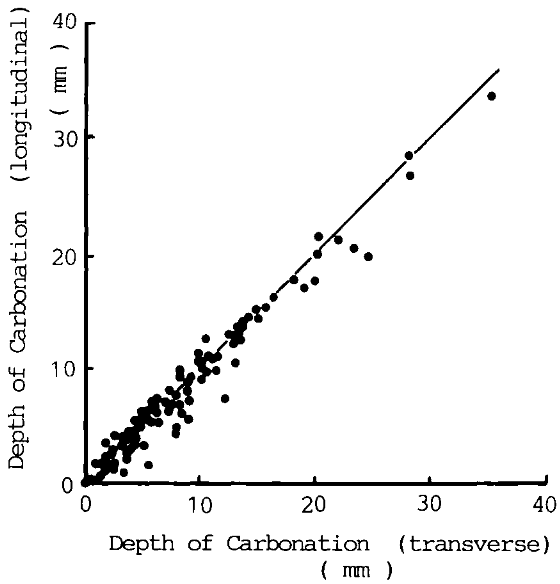

Figure 2 Relation between Average Depth of Carbonation in Transverse and in Longitudinal Cross Section

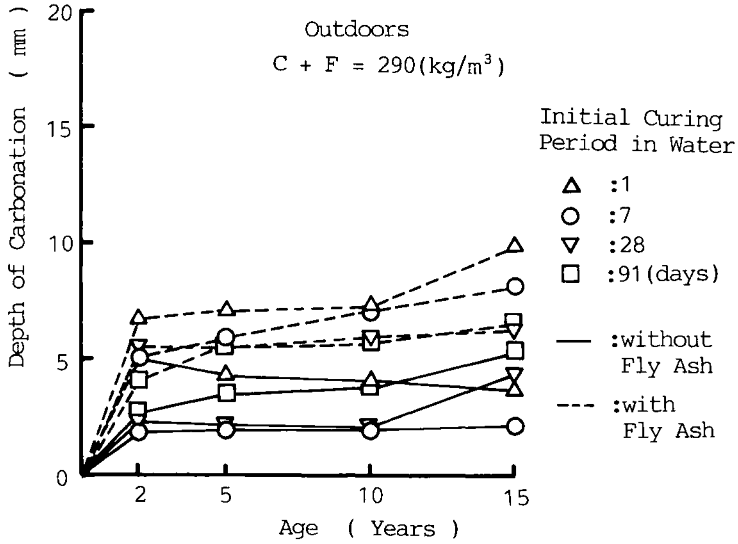

Figure 3 Relation between Age and Depth of Carbonation of Concrete (outdoors)

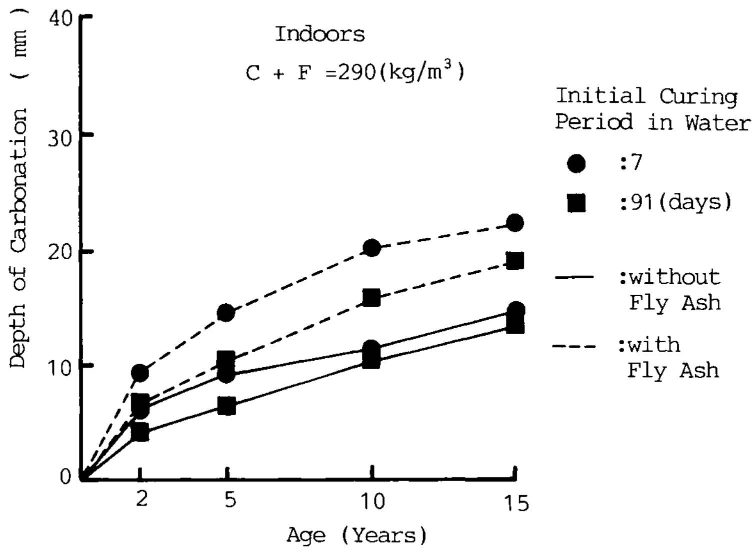

Figure 4 Relation between Age and Depth of Carbonation of Concrete (indoors)

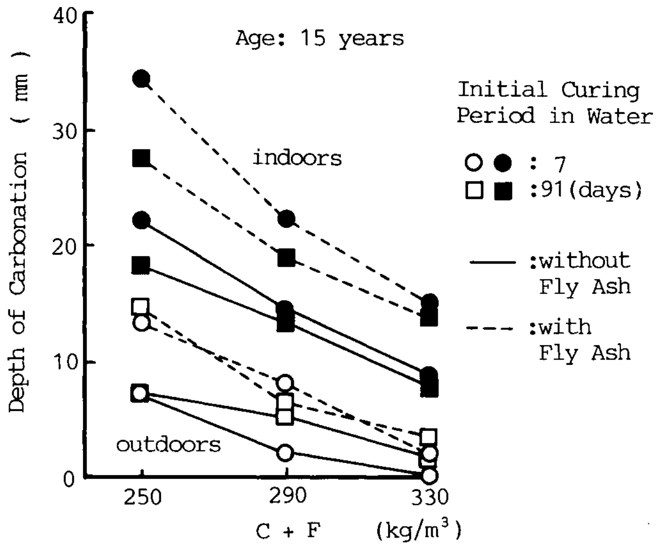

Figure 5 Influence of binder Content on Depth of Carbonation

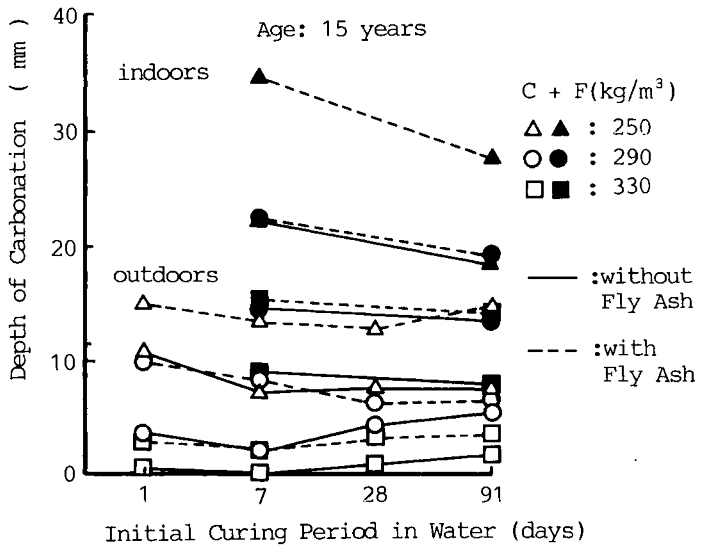

Figure 6 Influence of Initial Curing Period in Water on Depth of Carbonation

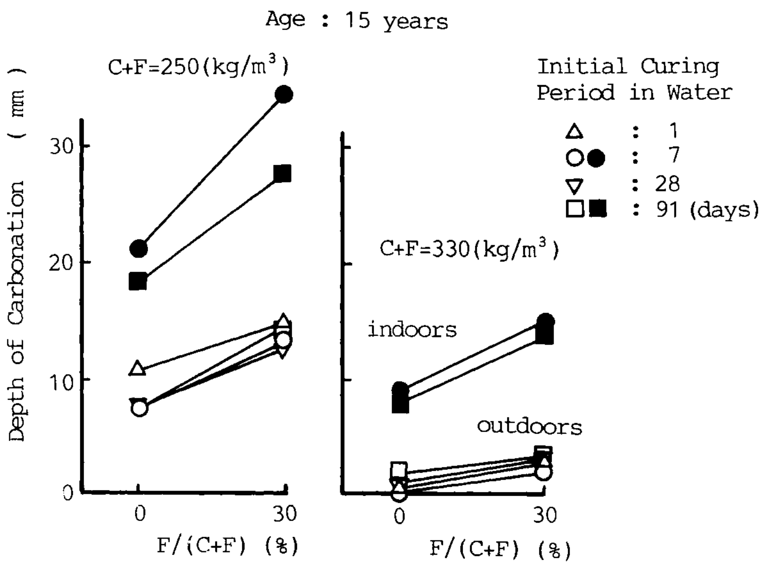

Figure 7 Influence of Fly Ash Replacement on Depth of Carbonation

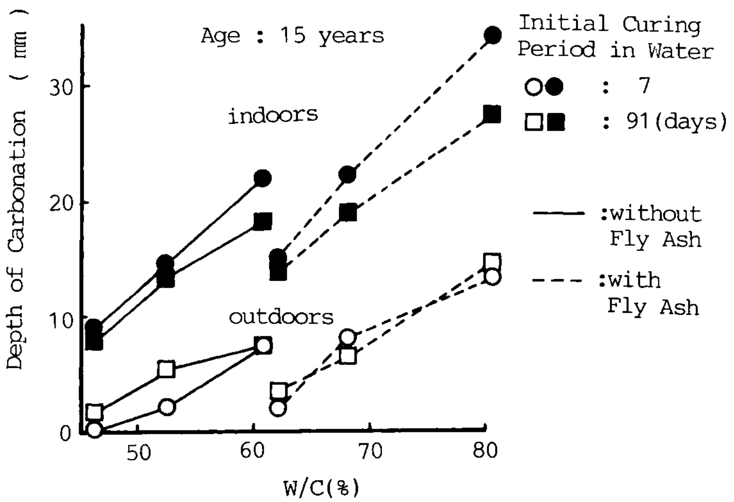

Figure 8 Relation between Water-Cement Ratio and Depth of Carbonation

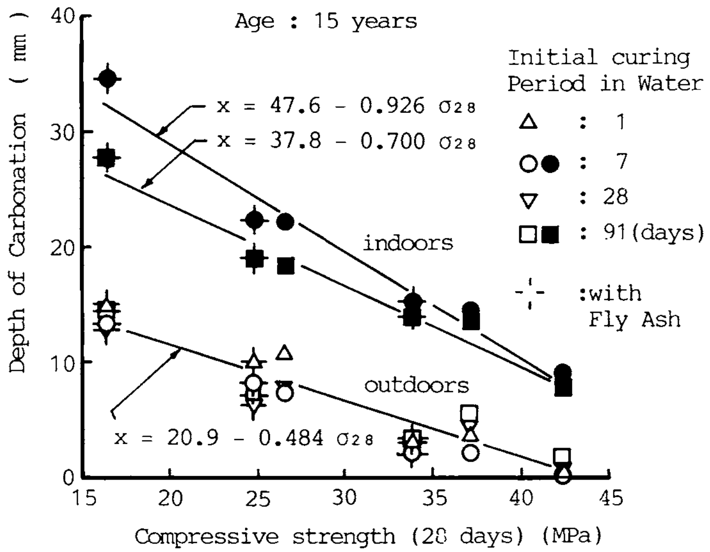

Figure 9 Relation between Compressive Strength and Depth of Carbonation

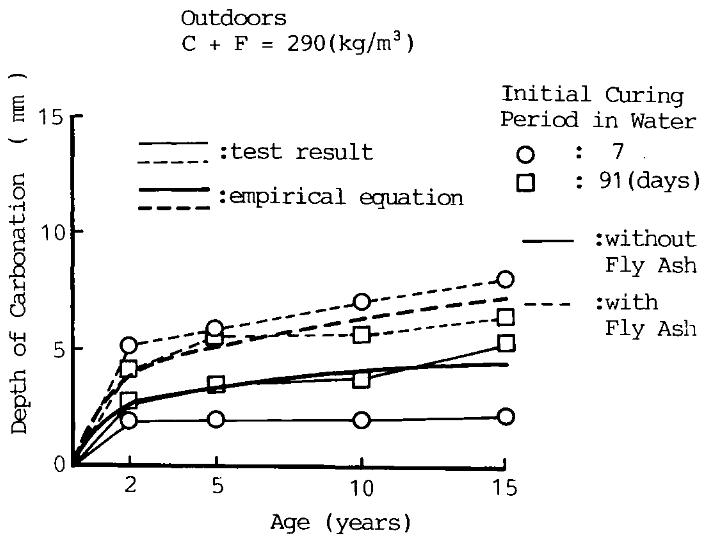

Figure 10 Comparison of Estimated Values with Test Results (outdoors)

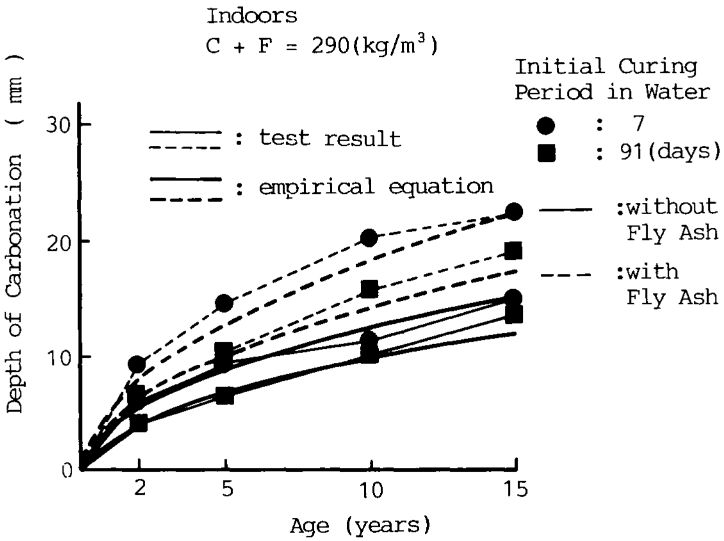

Figure 11 Comparison of Estimated Values with Test Results (indoors)

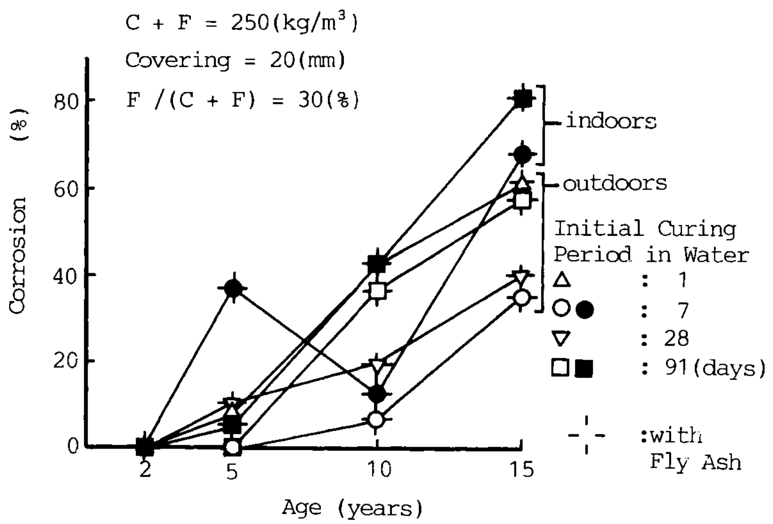

Figure 12 Relation between Age and Corrosion

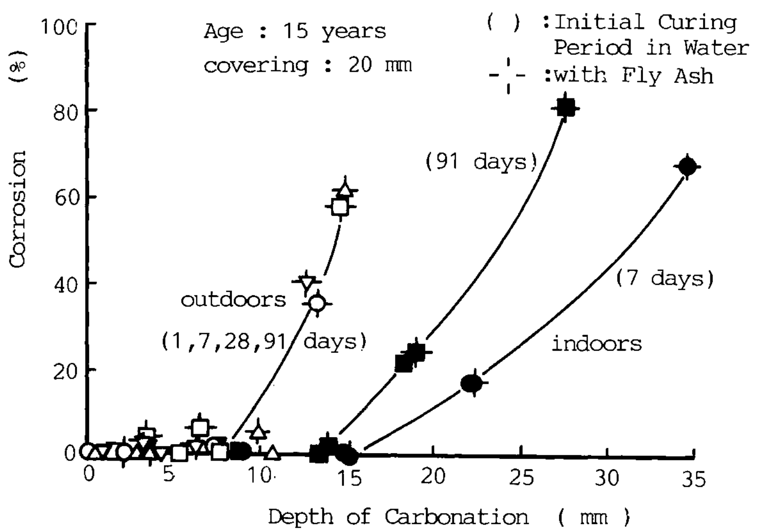

Figure 13 Influence of Depth of Carbonation on Corrosion

Carbonation of Concrete with Low-Calcium Fly Ash and Granulated Blast Furnace Slag: Influence of Air-Entraining Agents and Freezing-and-Thawing Cycles

by A. M. Paillere, M. Raverdy, and G. Grimaldi

Synopsis : Carbonation of concrete is increased in the presence of a high percentage of granulated blast-furnace slag in the cement and is also enhanced after subjecting concrete to freezing and thawing cycles.

Air entraining agents do not modify the carbonation when the concrete containing portland or cements with low-calcium fly ash and granulated blast-furnace slag (< 20 %) is subjected to freeze-thaw cycles. Carbonation is increased in the cement containing 84 % of slag.

Uncarbonated concrete resists freezing and thawing better than that carbonated previously.

Keywords: air-entraining agents; blast-furnace slag; carbonation; concretes; fly ash; freeze-thaw durability; mortars (material); strength.

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INTRODUCTION

Carbonation can improve or deteriorate concrete. The surface formation of microcrystals which occur due to carbonation process makes concrete less permeable to penetration of aggressive ions. However if carbonation proceeds the pH of concrete is lowered so that steel reinforcement is more easily attacked by aggressive ions. The thickness of carbonated layer depends on compactness of concrete, microcracking, and the type of cement.

The present investigation deals with the carbonation of concrete as a function of the nature of cement (with or without slag or fly ash).

Our investigations also cover the influence of microcracks in mortars. Our previous work on air entraining agents (1) showed that they promote microcracks in the air bubbles they create (figures 1 and 2). In order to assess the risks associated with the carbonated concrete under the freeze actions, studies were done on air-entrained mortars.

SCOPE OF INVESTIGATION

The investigation includes two parts.

The first part dealt with the depth of carbonation penetration as a function of the cement composition (pure Portland cement : CPA, cement containing low calcium fly ash : CPAC or granulated blast furnace slag : CPAL), air entraining agent, chemical composition and the occluded air content.

The program included

- accelerated carbonation tests for 75 days, on very small cylindrical mortar specimens, made with 4 Portland cements with varying C_3S and C_3A contents and with 4 types of air entraining agents ;

- gradual carbonation tests during 3, 6, 12, 24 months on mortar (ISO) specimens, made with one of the Portland cements tested by the accelerated method (CPA with C_3S = 60 %), with one CPAC and two CPAL cements.

In the second part, the investigations dealt with the combined effect of freeze and carbonation as a function of the nature of cement and the air content in mortars. It includes two steps. The first step concerns the measurement of the carbonation depth in a mortar which was previously microcracked. The second step dealt with a mortar previously carbonated that was subsequently exposed to freeze-thaw cycles.

ISO mortar prisms were used.

A Portland cement containing 60 % C_3S was chosen because C_3S enhances carbonation. A CPAL and a CPAC cements were chosen with medium contents of slag (18.6 %) and fly ash (16 %). A CLK cement with more than 80 % of slag was also studied for assessing the risks associated with high slag content cements. Air entraining agent was a pure vinsol-resin based product.

Each series was made with 5 %, 10 % or 15 % air.

Some specimens, at 28 days, were subjected to carbonation and then to various freeze-thaw cycles (5, 10, 15 or 20).

Some specimens, at the age of 28 days, were subjected to freeze-thaw cycles and then to carbonation for 6 months.

The carbonation depth and ultimate compressive strength were determined on all samples.

MATERIALS

Cements

In the first step of program including accelerated carbonation tests, 4 Portland cements (CPA) were studied. Their C_3S contents are shown in table 1.

In the gradual carbonation tests, (3, 6 , 12 or 24 months) the cements were :

- one CPA (numbered 5) with 60 % of C_3S
- one CPAC with 22 % low-calcium fly ash,
- one CPAL with 18.6 % granulated blast-furnace slag
- one CPAL with 24 % granulated blast-furnace slag

In the second part, the mortars were made with the CPA n° 5, one CPAC with 16 % fly ash, one CPAL with 18.6 % slag and one CLK cement containing 84 % slag and 16 % clinker.