STEADY STATE CHLORIDE MIGRATION TEST FOR SLAG BLENDED MORTAR WITH DIFFERENT SLAG RATIO AND FINENESS

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1. INTRODUCTION

Reinforced concrete structures exposed to chloride-containing environments such as marine and de-icing conditions, are continuously subjected to chloride ions ingression. With chloride ions reaching steel reinforcement in concrete, an ion-exchange and de-passivation process occurs on the surface of reinforcement, resulting in steel corrosion and structure deterioration. On the other hand, when chloride ions ingress into pores of concrete, some are gradually bound by cement hydration products in physical and chemical forms, respectively, being named as chloride binding. Others continue moving further to reach steel rebars, which are known as free chloride ions. The ingress of free chloride ions is influenced by the pore structure of concrete. Generally, compare with concrete made from only Portland cement (OPC), incorporating ground granulated blast furnace slag cement (BFS) could be beneficial to chloride resistance due to its higher capacity for chloride binding and pore structure refinement. However, the influence of blast furnace slag on chloride resistance is highly affected by replacement ratio and fineness of slag. Because the ratio of slag to replace Portland cement widely ranges from 5% to above 70%, the studies on chloride migration in slag-incorporated concrete, particularly for high volume slag cases, are still insufficient. Therefore, in the present study, the effect of slag replacement level, fineness, and age are investigated on chloride migration property of slag-incorporated mortar by performing steady-state chloride migration test.

2. EXPERIMENTAL PROGRAM

BFS with fineness of 4,000 cm^2/g (Blaine value) was used to partially replace ordinary Portland cement (OPC) in four different replacement ratios (0, 20, 50, and 70%) by mass. Further, another two slags with 6,000, and 8,000 cm^2/g in Blaine values were also used for the replacement ratio of 70%. To merely highlight the influence of binder, mortar specimens without coarse aggregate were used instead of normal concrete. For each group, cylindrical specimens with diameter of 100mm and height of 200mm were prepared. The water-to-binder (cement + slag) ratio was constant (0.50) for all mortar types. After demolding, all the specimens were undertaken water curing to the age of 28 day and 91 days at 20°C. After curing for 28 and 91 days, three discs with a thickness of 50 cm were cut from each cylinder. Then, all specimens were coated with epoxy from the sides and applied with vacuum saturation. Finally, steady-state migration test was performed by placing the specimen between anode (NaOH) and cathode (NaCl) cells of migration device with a 15V-applied voltage, as seen in Fig. 1. The concentration of chloride ions in the downstream was being measured by taking solution and titrating with 0.01 mol/L $AgNO_3$ solution until the flux of ions reached a steady state. The steady state can be judged when the time-concentration curve tends to be a straight line (Fig. 2). Then, such constant flux of ions and chloride migration coefficient were calculated by Nernst-Plank Law equation.

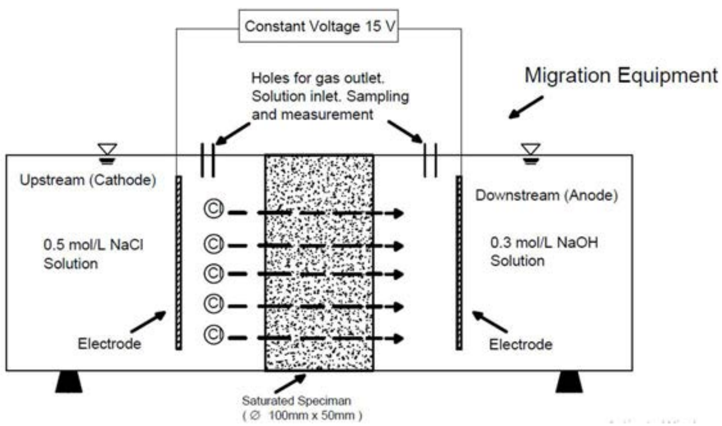

Fig. 1 Steady-state migration cell equipment

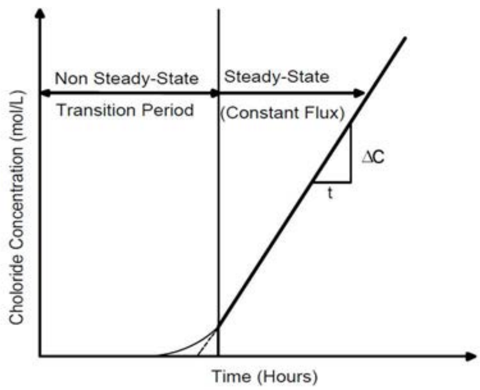

Fig. 2 Schematic representation of steady-state and non-steady-state conditions

3. RESULTS AND DISCUSSIONS

With the increase of slag ratio and fineness, the concentration of chloride ions decreased in downstream as shown in Fig. 3 and Fig. 4. Likewise, the chloride migration coefficient decreased as a result of increment in slag content and Blaine number shown in Fig. 5. Chloride migration coefficient is a preferred way of measuring resistance against chloride migration. With 20, 50, and 70% slag, the coefficient dropped by 48, 90, and 95%, for 28-day specimens, and 49, 87, and

Keywords: Blast furnace slag, Replacement ratio, Fineness, Chloride ion, Steady-state migration test
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98%, for 91-day specimens, respectively. Such drop could be attributed to lower Ca/Si ratio, higher tortuosity, and denser pore structure as a result of more slag incorporation. On the other hand, substituting OPC with 20, 50, and 70% BFS, the lag-time length increased from 73 to 146, 266 and 223 for 28-day ages and from 116 to 265, 433 and 323 hours for 91-day specimens, respectively, as illustrated in Fig. 6. Decrease in the length of lag-time of 70% slag is consistent with to its comparatively lower chloride binding capacity. Past studies from Luan and Fahmida indicate that up to 50% slag addition, the chloride binding increases, while 70% slag replacement may cause a decline, which can be interpreted with the relevantly lower reaction degree of slag and higher porosity at early age. The drop in lag-time of 70% slag was further compensated by increment of slag fineness degree. With the increase of fineness from 4000 to 6000 and 8000, the lag-time length increased by 1.3 and 1.4 times for 28-day age, and by 1.5 and 1.8 times for 91-day age specimens, respectively.

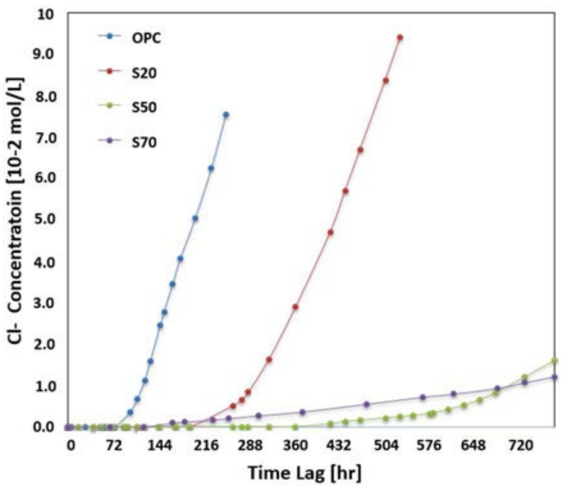

Fig. 3 Effect of slag ratio on chloride concentration

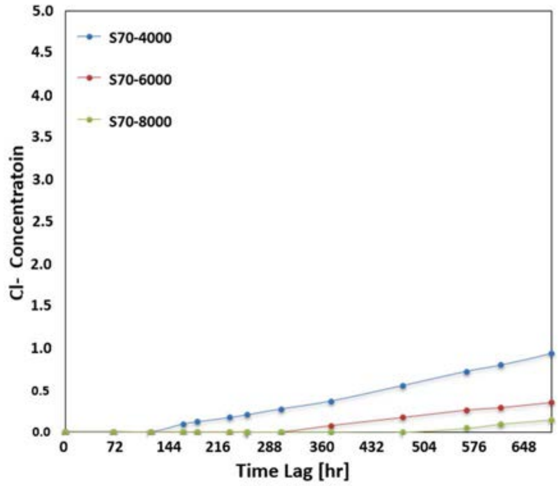

Fig. 4 Effect of fineness on chloride concentration

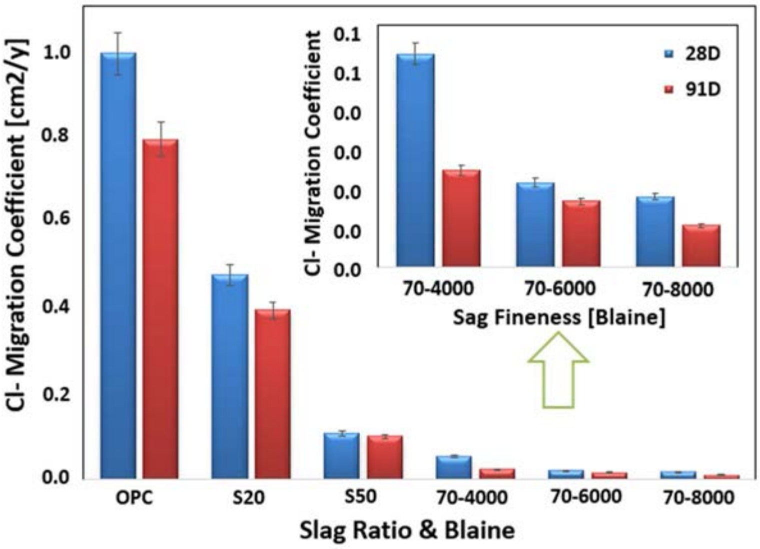

Fig. 5 Slag ratio and fineness on chloride migration coefficient

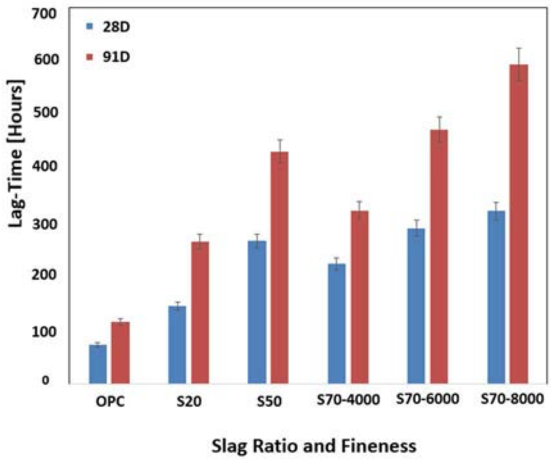

Fig. 6 Slag ratio and fineness on lag-time

4. CONCLUSIONS

With the increase of slag replacement ratio and fineness degree, chloride ion migration tended to be slower with smaller chloride migration coefficient due to lower Ca/Si ratio of hydration product, denser pore structure and higher tortuosity. On the other hand, up to 50% slag improved lag-time, while a further increase in slag load (70%) negatively affected the lag time. This is because that up to 50% slag replacement enhanced chloride binding, while 70% decreased the binding due to lower reactivity degree of slag. Such deficiency was compensated by means of increasing slag fineness degree.

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