74th RILEM 40th CCS

74th RILEM Annual Week & 40th Cement and Concrete Science Conference

31 AUGUST – 4 SEPTEMBER
SHEFFIELD – 2020

Conference Programme – Orals and Posters

The University Of Sheffield.

rilem

The Institute of Concrete Technology

IOM3 The Institute of Materials, Minerals and Mining

74th RILEM
40th CCS

74th RILEM Annual Week
& 40th Cement and Concrete
Science Conference
31 AUGUST – 4 SEPTEMBER
SHEFFIELD – 2020

Conference Programme – Orals and Posters

The University Of Sheffield.

rilem

The Institute of Concrete Technology

IOM3
The Institute of Materials, Minerals and Mining

The combined impact of temperature and crack width on the migration of chloride in concrete samples

Abbas S. AL-Ameeri[1,2], Charles Fentiman[3], Haider M. AL-Baghdadi[2]
[1] *School of Environment and Technology, University of Brighton, UK*
[2]*Department of Civil Engineering, University of Babylon, Babylon, Iraq*
[3] *Director, cement and concrete science, UK*
* Email(s): a.al-ameeri2@brighton.ac.uk ; abbas.alameeri.eng@uobabylon.edu.iq

ABSTRACT

Premature deterioration of concrete structures is currently a major global concern for the construction industry. It is a problem throughout the world, mainly due to carbonation and chloride-induced corrosion of reinforcement bars. The penetration of chloride ions is affected considerably by one or more of several major parameters, which may play at the same time; such as exposure temperature, in combination with different crack widths, which have a significant impact on reinforced concrete structures. The combined impact of chloride of environment temperature condition and crack widths on the migration of concentrated chloride condition in concrete were considered. Hence, the experimental programme involves the casting of concrete cylinders (dia. 100mm x 80 mm in height) with different water-cementitious materials ratios (w/cm) of 0.35, 0.45 and 0.55 and partial replacement of Portland cement with supplementary cementitious materials (SCMs) such as pulverized fuel ash (PFA) and ground granulated blast furnace slag (GGBS) with (w/cm) of 0.45. These samples also involve four different crack widths (0, 0.15 mm, 0.25 mm and 0.35 mm). These samples were exposed to three environment temperature conditions. Chloride penetration and diffusion coefficient were measured under non-steady-state diffusion at three environment temperature conditions (25°C, 30°C and 35°C). Based on the results obtained: (i) higher chloride penetration and migration coefficient of chloride (D_{nssm}) was achieved under higher temperature environmental conditions in combination with increasing crack width. (ii) The chloride penetration and migration coefficient (D_{nssm}) are considerably affected by the supplementary cementitious materials, w/cm ratio and porosity in concrete samples.

1. INTRODUCTION

Chloride ions attack is known to considerably affect the durability of concrete structures. Furthermore, exposure environment such as the temperature and relative humidity also influence the penetration of chloride in the concrete structures. As a result, the diffusivity of chloride has a significant impact on corrosion in concrete structures [1]. Temperature, relative humidity and carbonation have a considerable impact on the penetrability of external sources chloride ions such as de-icing salt [2]. The cracks in concrete structures are expected due to its weak tensile strength. The cracks may also be the result of deterioration and loss of durability of material or are worsened due to the degradation of the material. The durability of concrete structures is controlled by their capacity to delay the transport of ions and harmful fluids inside the concrete. The transport of chloride within uncracked concrete occurs due to a combination of the methods, diffusion, permeation and capillary sorption [2, 3]. In cracked concrete, the transport of chloride is by permeability, which is likely to significantly increase the transport of chloride ions inside concrete [4].

2. MATERIALS AND METHODS

The objective of this study is to determine the combined impact of chloride of environment temperature condition and crack widths on the migration of chloride in the concrete sample, as well as the impact of SCMs on the resistance of penetration of chloride. The migration of chloride resistance was examined on short concrete cylinders (dia. 100mm x 80 mm in height) at the age of 28 days. Four different crack width ranges, (0, 0.15mm, 0.25mm and 0.35mm) were employed. The chloride migration was accelerated by applying an electrical field on two different solutions, NaCl and NaOH according to NT Build 492:1999 [5]. The cracked face of the specimens was exposed to concentrated chloride solution of 10% of NaCl and three temperatures level (25 °C, 30 °C and 35 °C) have been separately used. This test is based on chloride penetration ion depth which is tested by spraying $AgNO_3$ solution with a concentration of 0.1 N on the split sample and measured the chloride penetration (x_d) due to a chemical reaction between Cl^- with Ag^+ to find chloride migration coefficient, D_{nssm}.

3. RESULTS AND DISCUSSION

3.1 Effect of temperature and crack width on penetration and migration coefficient of chloride

The results of the mixes depict that the chloride penetration depth (x_d) and chloride coefficient (D_{nssm}) due to migration and non- steady-state penetration is significantly increased with the combined increase in temperature and crack width as shown in Figure1. The resistance to penetration of chloride ions decreases and D_{nssm} increase with the increase in crack width for all mixes till a threshold crack width is reached, which is estimated to be around 0.15 mm. The crack width and depth influence the transport mechanism of chloride ion into the crack opening since wider cracks may allow the chloride solution to penetrate in the cracks. Hence, an increase in chloride penetration perpendicular to the crack walls can also be observed as shown in Figure 2. The increase in the chloride environment temperature magnifies the activation energy of chloride diffusion and the penetrability of chloride in concrete samples. Finally, the (x_d) and (D_{nssm}) are significantly influenced by the supplementary cementitious materials, w/c ratio in concrete samples. This can be clarified by the fact that the w/c ratio and SCMs affect the volume of internal voids or porosity in the concrete that in turn affects the chloride ions transport mechanisms in concrete, i.e. diffusion, permeation, sorption and permeability.

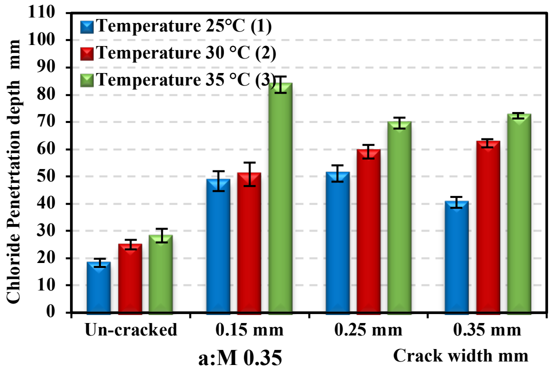

Figure 1: *The combined effect of crack width and temperature on chloride penetration depth (x_d)*

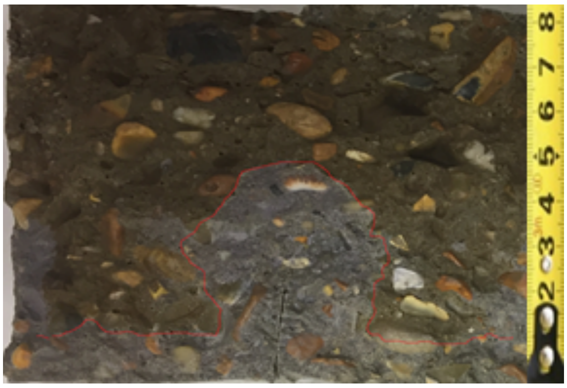

Figure 2: *Effect of crack on chloride penetration (M 0.35 with crack width 0.35mm at 30°C*

4. CONCLUSIONS

The penetration of chloride and D_{nssm} increase with the increase in crack width for all mixes till a threshold crack width is reached, which is estimated to be around 0.15 mm. Presence of crack up this crack width, the transport mechanism of chloride ion into the crack opening since wider cracks may allow the chloride solution to penetrate in the cracks. Hence, the chloride penetration perpendicular to the crack walls can also occur. The chloride environment temperature helps to increase the action of chloride diffusion and the penetrability of chloride in concrete samples. The SCMs increases the resistance of chloride penetration and decrease the chloride migration coefficient due to the refined pore structure of concrete that leads to decreasing the permeability of chloride ion in concrete samples.

5.REFERENCES

[1] Neville, A. M. (2011). "Properties of Concrete ". 5th edition. London, Pearson Education Limited.

[2] Dyer, T. (2014). "Concrete durability". Crc Press.

[3] Basheer, L., J. Kropp and D. J. Cleland (2001). "Assessment of the durability of concrete from its permeation properties: a review ". Construction and building materials 15(2-3), 93-103.

[4] Shao-feng, Z., L. Chun-hua and L. Rong-gui (2011). "Experimental determination of chloride penetration in cracked concrete beams". Procedia Engineering 24: 380-384.

[5] Nordic Council minister NT Build 492 (1999). " Chloride migration coefficient from nonsteady-state migration experiments".