

Carbonation Effect on the Chloride Profile

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1 Introduction

The chloride profiles obtained in marine environments can have a decreasing shape from the concrete surface or can present a maximum some mm inside the concrete (Andrade *et al.*, 1997; Andrade *et al.*, 2015). This “anomalous” profile departing from the fickian behaviour has been attributed to four main causes (Baroghel *et al.*, 2012; Qiang *et al.*, 2011; Lianfang *et al.*, 1999; Ngala *et al.*, 1997; Galan *et al.*, 2015): a) convection due to wet and dry cycling b) leaching of calcium and hydroxides, c) carbonation of the concrete skin or d) that the concrete “skin” has a different microstructure than of the concrete bulk. Present work contributes to study the effect of carbonation in the production of the profile maximum and in particular, analyses the impact in the chloride testing by pure diffusion (ponding test), because it is studied the effect of de-carbonating the external salt solution by boiling the water.

2 Experimental

The cement used was an OPC of low C_{3A} content (CEM I 52.5 N-SR). The specimens were of paste the w/c ratio was of 0.4. Three cylindrical paste specimens of 200 mm height and 150 mm diameter were moulded. They were cured during 7 days. After removing the specimens from the curing chamber, the three specimens were cut horizontally by its half, in order to have the tests by duplicate exposing the same surface (the cut one) to the salt solution. The following conditions were tested: Normal salt solution of 30 g/l of NaCl, De-carbonated: salt solution of 30 g/l de-carbonated by boiling the water before adding the salt in order to expel out the dissolved gases (air) and Pre-carbonated: the specimen was first carbonated and then submitted to the 30 g/l NaCl solution.

3 Results

The chloride profiles of the three set of specimens are given in figure 1. The three profiles differ significantly, mainly when the sample was previously carbonated. Each profile is the average of the duplicate samples, which gave very similar ones. The symbols here and in the rest of figures are: Set-1 (NaCl), set-2 (Cl+CO₂), set-3 (CO₂).

All the profiles of the three set show a maximum some mm far from the concrete surface. Contrary to what was expected the highest chloride concentration is shown by the set-2 with non-de-carbonated solution. The smallest chloride concentration is logically given by the sample previously carbonated, although the high difference between total and water-soluble chlorides indicates that there is significant amount of bound chlorides.

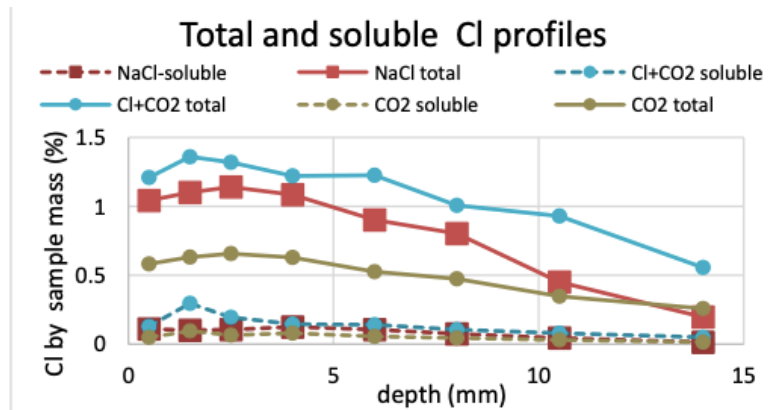


Figure 1. Chloride profiles of total and water soluble chlorides (average of the duplicated samples) of the three set of tests. The symbols here and in the rest of figures are: Set-1 (NaCl), set-2 (Cl+CO₂), set-3 (CO₂).

4 Conclusions

- The air (CO₂) content of the salt solution influences the chloride profile and in consequence, the calculated diffusion coefficient.
- The most aggressive condition (enabling higher chloride penetration) opposite to what was the hypothesis, is that of the standard salt solution (non-de-carbonated). This enables to confirm that present testing conditions for natural diffusion, are the most convenient ones.
- The pre-carbonation of the specimen leads into smaller amount of penetrated chlorides and a flatter profile.
- The production of the maximum in the chloride profile is attributed to the higher ionic mobility of the chlorides with respect to the carbonate/bicarbonates. Chloride binding is produced before the advance of the CO₃⁼/HCO₃⁼. When carbonation is produced behind the chloride penetration, chlorides are released that move forward making the profile to advance. In the external layers of concrete the bound chlorides are smaller due to the carbonation. This mechanism may contribute to the known as “aging effect”. Bound chlorides have to be in equilibrium with the free chlorides given by the corresponding isotherm.
- Previous carbonation decreases the amount of reactive sites for the chlorides although may not fully exhaust them. A maximum is also noticed in the pre-carbonated specimen attributed to the same mechanism than the non carbonated, as in the material remain sites for chloride adsorption.

References

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