Understanding the Durability of Concrete Containing SCMs

Karen Scrivener [1,*]

[1] Laboratory of Construction Materials, EPFL, Switzerland

Increasing the use of supplementary cementitious materials (SCMs) in concrete remains by far the most practical way to reduce the CO_2 emission associated with cement and concrete. Supplies of the traditional SCMs, blast furnace slag and coal fly ash, are limited and will continue to decrease due to efforts to reduce global warming. Calcined clays can be produced in effectively unlimited quantities and open up new possibilities to increase substitution levels. To use all these materials with confidence we need to understand their durability from a generic, mechanistic standpoint.

In general, SCM improve most aspects of durability – chloride ingress, alkali silica reaction and resistance to sulfate ions. On the other hand, carbonation rates will be more rapid due to the reduced buffer to react with incoming CO_2. Nevertheless carbonation rates fulfil the requirements in most standards and in the vast majority of applications moisture levels are much too low to allow active corrosion even once the concrete is carbonated.

Understanding the resistance to chloride penetration is particularly interesting, as the corrosion of reinforcing bars due to chloride ions is by far the number one cause of durability issues with concrete. Traditionally chloride ingress is considered to be a function of the porosity of the concrete. Of course, porosity is a major factor, but our recent studies show that it is far from the whole story. For example, LC3-50 paste with a w/b ratio of 0.5 has a higher porosity than OPC with a w/b ratio of 0.3, but an effective diffusion coefficient of chloride 3-4 times lower (Figure 1).

Researchers frequently attribute the lower diffusion to the "tortuosity" of the pore structure, but this is in fact a circular argument as "tortuosity" figures are derived from the ratio of ion diffusion (or conductivity) in free solution to the diffusion (or conductivity) in the sample. The figures derived are far higher than can be explained by simple geometric arguments. It must be appreciated that even for concrete cured under water the saturated pore network is made up of pores in the range of 10 nm. There may be some refinement of the connected pore sizes in blended systems, but this is not enough to explain the large difference in diffusion rates.

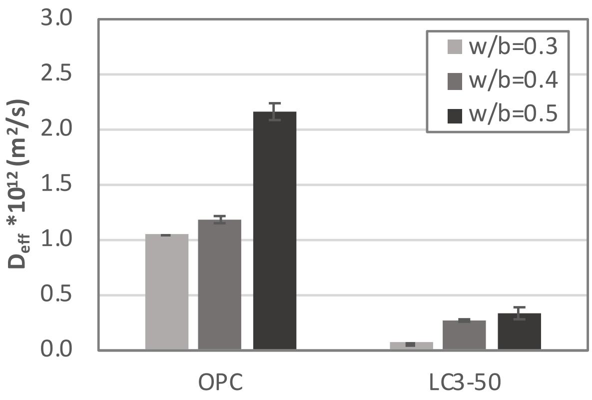

Figure 1. effective Cl diffusion for OPC and LC3 pastes adapted from Wilson et al. [1]

Our recent work indicates two other factors play a major role. First the ionic concentration of the pore solution. As shown in Sui et al [2] the diffusion seems to be strongly correlated this the concentration of [Na + K]. On a simplistic level it higher numbers of charge balancing Na^+ and K^+ allow higher levels of Cl^- in solution.

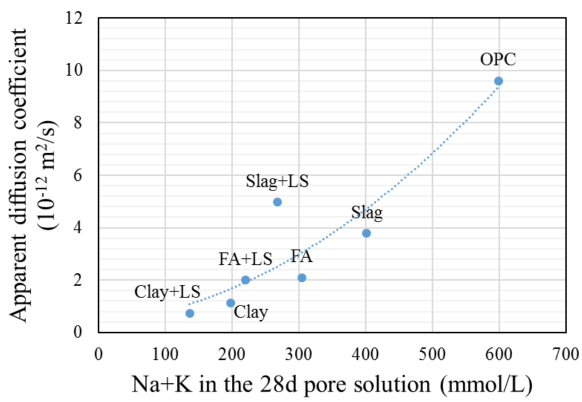

Figure 2. Relation between apparent diffusions coefficient for various blended systems with the alkali concentration in the pore solution, from Sui et al [2].

* Corresponding author: karen.scrivener@epfl.ch

A second factor, which is not yet well understood, is the composition of the C-(A)-S-H, which changes significantly between OPC and blended systems. The simulations from the recently completed thesis on Khalil Ferjoui in our group indicates this *may* explain the difference, but critical information on the actual surface structure of C-(A)-S-H is still lacking.

This work illustrates that we need to change our thinking of the factors affecting durability and evolve our use of “durability indicators” accordingly. With respect to resistance to chloride ingress the bulk resistivity, which can be measured very quickly and easily seems to be the best indicator.

References

1. W. Wilson, F Georget, K. Scrivener, Cem. & Con. Res., **140**, 106264 (2021)
2. S. Sui, F. Georget, H. Maraghechi, W. Sun, K. Scrivener, Cem. & Con. Res., **124**, 105783 (2019)