An international review of chloride ingress into structural concrete

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Every now and again it is necessary to take stock of what we know about a particular subject and collect the information together in a readable, cogent form so that researchers and practitioners may benefit. This is one such publication and, while it is a report rather than a book, I applaud the efforts of the authors.

The report is a review covering chloride ingress into structural concrete. It covers issues such as at what rate ingress occurs and why, how chloride levels are measured and what remediation techniques can be used. The report is split into five main sections and comprises 162 pages of professionally presented data that has become the hallmark of Taywood Engineering Ltd, and performed under contract to the Transport Research Laboratory.

The work has been painstakingly put together and culled from published data in journals, conference proceedings, research establishment reports, and in this regard represents a comprehensive set of data in a readable form. There is a selected reference list comprising approximately 300 entries.

The report consists of four sections, following an introduction that covers the form of the corrosion problem in question, mechanisms of chloride ingress, true and effective diffusion coefficients and related matters.

The second section is the longest in the report and deals with the influence of concreting materials, mix design and curing, and their effects on either assisting or preventing chloride ingress, but also deals with contentious subjects such as the threshold level for activation of corrosion as well as the chloride ion binding capacity of concrete. What exactly is the chloride binding to? Is it the hydrated or the unhydrated material or both? The importance of using minimum water/cement ratios to reduce the diffusion coefficients is highlighted, but raises the issue of exactly what happens to the hydrating materials at very low water/cement ratios.

Engineers always favour pragmatic quantification, and therefore relationships such as those for strength grade and diffusion coefficient are attractive, but could you have a high strength mix that was porous? It is only when you see the data presented both from laboratory work and field experience that one can draw a link between theory and practice. Much information in this report will permit one to do that on a case-by-case basis. Laboratory and field data are presented for both old and modern concretes.

The role of PFA, slags, and silica fume and their effect on diffusion coefficients are all addressed. There would appear to be an interesting role for integral waterproofing admixtures, particularly for the lower

grade concretes. There would appear to be a need for more basic studies on the binding capacity of chloride in certain types of concrete. I was pleased to see the importance of the chloride ion/hydroxyl ion ratio getting considerable exposure and the maintenance of this ratio in preventing corrosion. What value should be used – 0.6 (Hausman) or 0.3 (Rasheeduzzafar)?

There is some strange comment about the period of wet cure and chloride threshold levels. Caustic alkalis go into solution almost immediately. However, increased alkalinity can result from more hydration of the cement creating more calcium hydroxide. Distinguishing between the two can be quite difficult. Some very useful figures are presented, particularly in Table 2.3, but threshold levels of chloride expressed as a percentage by weight of cement are only meaningful if the concrete has not carbonated. All these data must address the issue of assessing the risk of corrosion. Linking laboratory data with site responses is difficult and somewhat ambiguous. For instance, what has the threshold level got to do with water/cement ratio? It is surely a condition relative to the steel and not to the concrete.

Section three deals with methods for the detection of chloride ingress and the chloride gradient. The various methods, both direct and indirect, are usefully reviewed. Despite the large range of tests of varying sophistication available, those that we are all familiar with still seem to predominate.

Section four deals with techniques used for studying chloride ingress and covers classical diffusion tests as well as accelerated methods.

The final section deals with research needs and raises the issue yet again of reliable threshold chloride levels as well as the need for methods to permit *in situ* chloride monitoring.

The book ends with two appendices dealing with surface chloride levels and chloride diffusion coefficients, respectively. This is most interesting and, as well as detailing information on diffusion coefficients on cement pastes and concrete derived from laboratory measurements, there are also data derived from natural exposure tests and from real structures.

On balance, this is a most useful and thoroughly executed piece of work that will be a necessary adjunct not only to researchers and designers but also the checkers of specifications and those concerned with monitoring the well-being of structures both during and after construction. I recommend it almost without reserve.

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