Modelling the concrete-real environment interaction to predict service life

My doctoral thesis dealt with the development of a non-destructive technique for measuring corrosion of reinforcement. The technique was the polarization resistance method and I applied it when selecting corrosion inhibitors. After I obtained my doctorate, the director of my institute suggested to me that I change to another subject because he felt there was nothing more to be done in that area. Time has shown that, despite the fact that I was trying to move on to other subjects of research which represented important innovations (ultrahigh-performance concrete, concrete microstructure characterization with blended cements), many aspects in the corrosion field still appeared to be urgent and unknown. Fortunately, I resisted the temptation to change and persisted in exploring the frontiers of corrosion of reinforcement. As more time passes, so more aspects are identified which need definition if we wish to increase the prediction accuracy of service life modelling against, not only corrosion attack but, in general, any type of attack. In the present editorial I would like to focus on stressing the need to analyse much more the effect of climate and the environment on the concrete in order to deduce the mathematical laws of concrete-ambient interaction.

The *fib* Model Code for Concrete Structures 2010 introduces the most advanced trends for modelling concrete durability by adopting the full probabilistic treatment, the partial safety factor method and the deemed-to-satisfy approach. Models for chloride ingress, carbonation and freeze-thaw are presented which are at the frontier of present knowledge. However, on the load side, the environment, *fib* Model Code 2010 only makes vague references to exposure classes and number of freeze-thaw cycles. We lack of environmental models and mathematical expressions for how concrete interacts with the surrounding environment. In spite of the considerable literature on, for instance, sulphate attack or reinforcement corrosion, we have almost no cases that study rigorously the evolution of evaporable water content (degree of saturation) in real concretes, where the conditions are not isothermal, as in laboratories. We know cases of deterioration by sulphate attack, for instance, but we have almost no expressions on how the external concentration of sulphates affects the kinetics of the process in real non-isothermal conditions.

In this respect, I would like to share another anecdote about when I was asked by a student – not from my country – to supervise his thesis. He wanted to study the effect of real climates, for which he was planning to build a large environmental chamber, because he had obtained a well-funded grant and he said it would be necessary to reproduce the real daily and annual humidity-temperature cycles in the chamber. I suggested to him that the best chamber was the real environment and why not first expose the specimens in the natural outdoor conditions and follow them, together with the seasonal climate evolution, and use the grant for other applications. In the end I did not supervise his thesis because he preferred to buy the chamber.

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It is my conviction, after many years of laboratory testing, that we need much more scientific observation of real structures. We should not only try to describe phenomenological observations of oxides or cracks formed or expansions, but to find the mathematical expressions that could help calibrate the existing models for deterioration mechanisms.

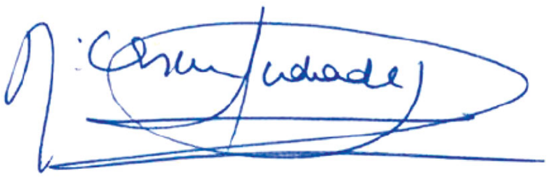
A particular case I would like to emphasize is that of the degree of water saturation of the concrete. There are almost no data in the literature on the degree of saturation of real concretes exposed to different exposure classes. Usually, the aggressivity in exposure classes is defined by "wet-dry cycles", but with no information on how many occur over one year, in a particular location, or how their frequency affects the amount of evaporable water remaining inside each concrete type. This is an aspect that is critical for all classes of possible damage where water usually plays the key kinetic role.

This aspect of having reliable models for environmental loads and their effect on the material and in the different deterioration processes is particularly relevant when global warming due to greenhouse effects are on an horizon that will likely be reached in the next 100 years. We cannot predict service lives of 100 years without first having models on the evolution of the water content and, for instance, the chloride quantities deposited due to marine aerosols and how these quantities will be affected by foreseen weather changes or the expected rise in temperature.

The problems of the lack of reliable and particular environmental models becomes more dramatic when we are asked to predict service lives > 100 years, as is the case when using concrete as an engineered barrier in nuclear installations, e.g. for radioactive waste disposal, where lives beyond 300–500 years are requested for medium radioactivity and thousands of years for highly radioactive waste. The challenge can only be undertaken looking back and realizing the survival of roman concretes (unreinforced, by the way) lasting over 2000 years. Their study is crucial for feeling more confident when addressing this particular challenge.

Can we predict concrete service lives beyond 50–100 years? In my opinion, an accurate prediction is not feasible unless the ambient condition is stably maintained. We cannot make accurate predictions if the exposure class is, for instance, carbonation exposed to the rain without knowing the rain regime, or of marine aerial structures if we do not know the amount of chloride deposition on the concrete surface, or freezing resistance under de-icing salts without having knowledge of the real freeze cycles occurring each year, or the sulphate attack for concretes in contact with the ground and having intermittent water flows with sulphates. The prediction in particular conditions is not, in general, accessible yet. We lack the necessary mathematical expressions despite the efforts made in the last decade to increase the accuracy of the models of concrete resistance to damage.

I finish with an invitation to researchers to enter this area of modelling the environmental loads and their interaction with real concrete, where many aspects still remain unknown. Actually, I have applied this recommendation to my own research and my research group has several structures instrumented and exposure sites in my country with different specimens that we follow from years ago. I am afraid that in reinforcement corrosion in particular, and concrete durability in more general terms, there are still many aspects to be explored – which will keep me from moving on to another area of research.



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