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Service life prediction of reinforced concrete structures through modelling: A lucrative numbers game

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ABSTRACT:

In forthcoming years there will be a growing need for maintenance and repair of the existing infrastructure. During their operational service life infrastructure facilities have been exposed to a wide variety of environmental conditions eventually resulting in deterioration necessitating vast amounts of financial resources for rehabilitation. Corrosion of the embedded reinforcing steel, predominantly due to ingress of chlorides into the concrete cover, is commonly regarded as the major threat to long term durability of concrete structures, not only with respect to serviceability but on the long term also the structural load bearing capacity may be impaired.

During the last decades numerous mathematical models to describe chloride ingress into concrete and onset of corrosion have been developed, ranging from basic to very complex taking all kinds of physical and chemical processes on the transport mechanism into account. For most of these models it is explicitly claimed that they are *validated* and/or *calibrated*, however it is not clear, at least not to the asset owner, how in this context the qualification *validated* or *calibrated* actually has to be understood. The most advanced models are available as a software package, however, often these models are that complicated that for practioners they will be considered a “black box”. In addition, the input values used for the model parameters remain largely unknown or are considered stochastic variables characterised by a mean value and a standard deviation. In practice the statistical quantification of a model parameter is frequently referred to as being based on “expert opinion”, which generally has to be understood that due to a lack of data on a specific parameter the quantification has been merely based on some wild guess rather than on sound engineering judgement (in other words, a statistical approach is chosen because of a lack of data, whereas a certain amount of data is required to do proper statistics). The consequence is that the result of these calculations demonstrates a significant variation. As an example, Figure 1 shows the effect of the ageing factor, n, on the predicted probability corrosion initiation (assuming the mathematical model and the values used for other model parameters are correct). Not only in publications by academics but also in practice by consultants a probabilistic approach is often advocated, however such an approach is mostly preferred as to conceal the lack of responsibility, liability, information and knowledge. Consequently, it is concluded that prediction of (residual) service life of concrete structures is a lucrative business, based on playing with numbers as to achieve the desired, and hopefully also a realistic, outcome. Some illustrative examples from practice will be presented and critically discussed to support this conclusion.

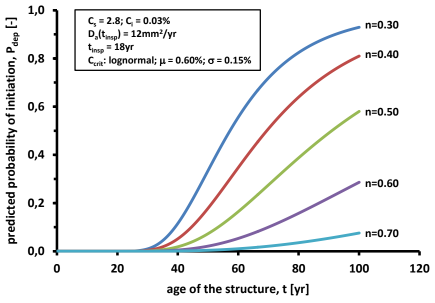

Fig. 1. *Predicted probability of initiation of reinforcement corrosion as a function of time, for different discrete values of the ageing factor n, and treating the critical chloride level as the only stochastic model parameter*

References:

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Mix designs targeting sustainable concretes require sufficient clinker content to ensure durability performance over the intended constructions service life

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ABSTRACT:

Clinker content in mix designs for many concrete constructions such as infrastructural works or those placed in or close to the marine environment in the Netherlands are low in comparison to most other regions in the world as the typical CEMIII/B-based binder system contains in general up to 70% Ground Granulated Blast Furnace Slag (GGBFS) and 30% clinker. Resulting in concretes, if sufficiently cured, characterized by a dense microstructure delivering high performance over long service lifetimes (durability) typically in chloride exposed environments. CEMIII/B-based concrete mixtures are therefore often considered as sustainable as the environmental footprint with respect to associated CO_2 emissions is relatively low due to the limited clinker content. Further reduction of clinker content and CO_2 footprint appear therefore attractive as the massive use of concrete as construction material could contribute to significant further reduction of CO_2 emissions in the Netherlands. Such binders as CEMIII/B, CEMIII/C even in combination with other type II additions or other very low clinker content mixes appear to perform well as test cubes cured for 28 days under standard test conditions deliver strength performance as required according to current codes.

However, recent field surveys have discovered several relatively young constructions (age < 10 years) which appear not able to deliver expected service life performance as these are characterized by high surface porosity and associated high water absorption capacities sometimes even associated with unacceptable rates of scaling of the concrete surface. Although so far no direct relationship between low clinker content and insufficient durability performance has been established due to lack of available data, we hypothesize that such a relationship could exist. Furthermore the question is, if curing under environmental conditions or derivate methods of curing, in view of the method described in the code delivers the same reliability.

We therefore advocate a further in-depth study in which the possible negative relationship between durability performance characteristics and clinker content of young concrete constructions is investigated. The objective of such a research program would be to establish the minimum required clinker content and curing conditions of concrete mix designs delivering both low environmental impact and robust durable constructions cast in situ under varying conditions which are often far from standardized norm test conditions.

A new precursor for bacteria-based self-healing concrete derived from organic waste streams

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ABSTRACT:

Crack formation is a common phenomenon affecting concrete performance. Cracks lead to ingress of water and deleterious materials into the concrete matrix, thereby increasing the risk of degradation and reducing the service life of structures. Maintenance and repair of concrete structures are undesirable because very money- and time-consuming. By preventing the water ingress into concrete, durability can be significantly enhanced. Bacteria-based self-healing concrete has the ability to heal cracks due to the bacterial conversion of incorporated organic compounds into calcium carbonate [1-2]. Precipitation of calcium carbonate seals the cracks, waterproofing and increasing the service life of structures and reducing reparation costs. However, one drawback about biogenic concrete is the high production costs of the currently-available healing precursors. Therefore, the aim of this paper is to propose an innovative organic mineral precursor which can be derived from organic waste streams, of which production is in line with the circular economy principle and ideally more affordable than that of other substrates. The proposed healing agent shows promising results regarding its limited effect on the hydration of Ordinary Portland (OPC) and blast furnace slag cement (BFSC). The self-healing capacity of OPC-based mortar with added-in healing precursor particles is also demonstrated through microscopic observations (Figure 1). Since this innovative system shows considerable compatibility with self-healing concrete, recommendations for future research to implement into the system are also discussed.

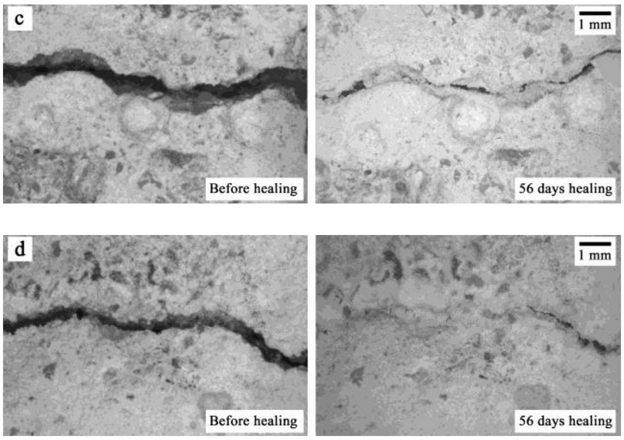

Fig. 1. *Surface cracks before (left) and after 56 days of self-healing incubation at RH > 95% and 20°C (right). Each two images refer to one sample of each series (a for C0, b for C56, c for B0 and d for B56).*

References:

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