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Example Manual

Chloride ingress model for reinforced concrete according to fib bulletin 34 and MC2010

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Table of Contents

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1. Problem Description

The chloride-ingress model associated with fib Bulletin 34 [1], Model Code for Service Life Design, is a performance-based durability model for reinforced concrete. It treats chloride-induced depassivation of reinforcement as a limit-state problem and predicts chloride content as a function of depth and time.

2. Input variables

Notation	Variable	Value	Unit
Δx	Convection zone thickness Delta x	8.9	mm
C_0	Initial chloride content	0.02	wt-%/cem*
$Cs\Delta x$	Substitute surface chloride at Delta x	0.7	wt-%/cem *
ΔRCM_{0_raw}	RCM** coefficient in (1e-12 m^2/s)	6.5	1e-12 m^2/s
kt	Transfer parameter	1	-
be	Temperature regression constant	4800	K
T_{ref}	Reference temperature	293	K
T_{real}	Real concrete temperature	283	K
α	Ageing exponent alpha	0.3	-
C_{crit}	Critical chloride threshold	0.4	wt-%/cem *
x_cover	Concrete cover depth (steel depth)	32	mm
t	Exposure time since chloride attack starts	20	years
x	Depth from exposed surface	40	mm

* wt-%/cem = mass percent by weight of cement

** RCM = Rapid Chloride Migration. It is the accelerated laboratory test used to obtain the chloride migration coefficient [1]

Input variables in this example case were taken from the example of fib Bulletin 59 [2].

3. Deterministic Calculation and Comments

A commonly used one-dimensional form of the model, explained also in [3] is:

$$C(x,t) = C0 + (Cs,\Delta x - C0) * [1 - \mathrm{erf}((x - \Delta x) / (2 * \mathrm{sqrt}(Dapp,C(t) * t)))]$$

with

$$Dapp,C(t) = ke * DRCM,0 * kt * A(t)$$

and

$$ke = \exp[\ be * (1/Tref - 1/Treal)\ ]$$

and

$$A(t) = (t0 / t)^\alpha$$

In practical use, the model is based on Fick’s second law of diffusion, but with two important engineering extensions: a near-surface convection zone and a time-dependent apparent diffusion coefficient. The convection zone represents the fact that the first millimetres of concrete exposed to chlorides are often influenced by wetting-drying and capillary transport, so transport there is not described well by pure diffusion alone. The time-dependent diffusion term reflects ageing of the concrete, that is, the gradual reduction of transport due to continued hydration and pore refinement.

In this formulation, ΔRCM,0 is typically obtained from the NT BUILD 492 Rapid Chloride Migration test. The model therefore combines a laboratory-derived transport indicator with a physics-based profile equation and practical correction factors. In service-life design, the most common engineering check is to compare the chloride content at reinforcement depth a with the critical chloride threshold Ccrit. Corrosion initiation is deemed to occur when C(x,t) >= Ccrit.

4. Literature

[1] fib Bulletin 34. Model Code for Service Life Design. fédération internationale du béton (fib), 2006.

[2] fib Bulletin 59. Condition control and assessment of reinforced concrete structures exposed to corrosive environments (carbonation/chlorides). State-of-art report. fédération internationale du béton (fib), 2011.

[3] Šomodíková, M., Strauss, A., and Zambon, I. fib models for modeling of chloride ion ingress and concrete carbonation: Levels of assessment of input parameters. Structural Concrete, 2020, 21(4), 1377–1384. https://doi.org/10.1002/suco.201900401