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Example Manual

Carbonation model for reinforced concrete according to literature of Gehlen (based on fib Model Code 2010)

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Carbonation model for reinforced concrete according to fib Bulletin 34 and MC2010 modified by Gehlen

1. Problem Description

The carbonation model used for service-life assessment of reinforced concrete structures is the physical model developed in the DuraCrete project and slightly enhanced in DARTS [4]. The model is based on a diffusion-controlled process. It serves as the basis for reliability assessment of existing concrete structures with carbonation-induced depassivation. The model uses carbonation rate under standard test conditions k_{NAC} [1]. It is also rooted in fib Bulletin 34, Model Code for Service Life Design.

2. Input variables

Notation	Variable	Value	Unit
t	Time of exposure	50	years
k_{NAC}	Carbonation rate for standard test conditions	2	$mm/year^{0.5}$
RH_a	Relative humidity of ambient air	70	%
t_c	Curing time	7	days
b_c	Exponent of parameter for curing time	-0.567	-
C_a	CO2 concentration of ambient air	0.043	kg/m^3
p_{dr}	Probability of driving rain	1.000	-
ToW	Time of wetness, i.e., days with daily rainfall ≥ 2.5 mm	60	-
b_w	Regression exponent of weather function	0.446	-
RH_l	Reference (laboratory) humidity	65	%
f_e	Constant in factor describing humidity	5	-
g_e	Constant in factor describing humidity	2.5	-
C_l	CO_2 concentration during concrete testing in laborator	0.0426	kg/m^3
t_0	reference time (28 days)	0.0767	years

Input variables in this example case were taken from literature [1, 2, 4].

3. Deterministic Calculation and Comments

A commonly used form of the model, explained also in [1] is:

$$x_c(t) = k_{NAC} \cdot \sqrt{k_e \cdot k_c \cdot k_a} \cdot \sqrt{t} \cdot W(t)$$

with

$$k_e = \left(\frac{1 - \left(\frac{RH_a}{100}\right)^{f_e}}{1 - \left(\frac{RH_l}{100}\right)^{f_e}} \right)^{g_e} \qquad k_c = \left(\frac{t_c}{7}\right)^{b_c} \qquad k_a = \frac{C_a}{C_l}, \qquad W(t) = \left(\frac{t_0}{t}\right)^{\frac{(p_{dr} \cdot ToW)^{b_w}}{2}}$$

Environmental parameter | Curing parameter | CO_2 impact paramter | Weather parameter

The model is built up from experimentally and environmentally informed factors: material quality (k_{NAC}), humidity (k_e), curing (k_c), CO2 level (k_a), and wetting ($W(t)$). This makes the model suitable for performance-based durability assessment. Detailed explanation of the model's parameters as well as tables for values for different cements are provided in the referenced literature [1, 2, 3]

4. Literature

[1] Zambon, I.; Vidovic, A.; Strauss, A. Reliability of Existing Concrete Structures Determined with Physical Models—Carbonation Induced Corrosion. Solid State Phenom. 2017, 259, 255–260.

[2] Zambon, I.; Vidovic, A.; Strauss, A.; Jose, M. Condition Prediction of Existing Concrete Bridges as a Combination of Visual Inspection and Analytical Models of Deterioration. 2019

[3] Von Greve-Dierfeld, S.; Gehlen, C. Performance based durability design, carbonation part 2—Classification of concrete. Struct. Concr. 2016, 17, 523–532.

[4] DARTS—Durable and Reliable Tunnel Structures. Project with financial support of the European Commision under the Fifth Framework Program; GROWTH 2000 Project GRDI-25633; European Union: Brussels, Belgium, 2004.