CECS (2007)

Sun et al. [**?**] explained the model from CECS (2007), which describes the course of the carbonation depth $x_c(t)$ as follows:

$$x_c(t) = 3K_{CO_2}K_{kl}K_{kt}K_{ks}K_F T^{0,25} RH^{1,5}(1-RH)\left(\frac{58}{f_{cuk}} - 0,76\right) * \sqrt{t}$$

K_{CO_2}:	CO_2 density factor: [-]	$K_{CO_2} = \sqrt{\frac{c_{Co_2}}{0,03}}$
c_{CO_2}:	CO_2 density [%]	
K_{kl}:	location factor: [-]	$K_{kl} = 1,4$ for the corner of the component
		$K_{kl} = 1,0$ for other areas
K_{kt}:	curing factor: [-]	$K_{kt} = 1,2$
K_{ks}:	stress factor: [-]	$K_{ks} = 1,0$ for compression condition
		$K_{ks} = 1,1$ for tension condition
K_F:	fly ash factor: [-]	$K_F = 1,0 + 13,34 * F^{3,3}$
F:	fly ash content [weight ratio]	
T:	annual temperature [°C]	
RH:	annual relative humidity [-]	
f_{cuk}:	charasteristic strength [MPa]	

Guiglia, Taliano (2013)

The model of Guiglia and Taliano [2] is based on the fib-Model Code 2010 [**?**] (see Model 02) and on an extensive experimental campaign. In this campaign, 1350 compressive tests were performed as well as measurements of the carbonation depth on concrete samples up to 5 years old from important infrastructure structures, such as bridges and tunnels. The compressive strengths of the sampled concrete components ranged between 20 and 50 N/mm².
The carbonation depth $x_c(t)$ is described by Guiglia and Taliano as follows:

$$x_c(t) = 163 * \sqrt{k_e * f_{cm}^{-2,1}} \sqrt{t} \text{ for abutments and piers}$$
$$x_c(t) = 206 * \sqrt{k_e * f_{cm}^{-2,1}} \sqrt{t} \text{ for tunnels}$$

k_e:	environmental function (see Model 02)
f_{cm}:	mean value of the concrete compressive cylinder strenghth at 28 days [MPa]
t:	age of the structure [years]

Silva et al. (2014)

This model presented by Silva et al. [?] for calculating the carbonation depth of concrete is based on previous studies. From a total of 17 studies, 964 specimens with a wide range of concrete and environmental characteristics were used to build the model. The carbonation coefficient k is described differently for two different relative humidity ranges (RH). Exposure class XC2 corresponds to situations where the humidity is above 70%.

$$k = 3,355 * c * 0,019 * C - 0,042 * f_c + 10,83 \qquad \text{for RH} > 70\%$$
$$k = 0,556 * c * X - 0,148 * f_c + 18,734 \qquad \text{for RH} \leq 70\%$$

c:	CO_2-content [%]
C:	clinker content [kg/m³]
f_c:	28-day compressive strenght [MPa]
X:	exposure class factor

Table 1: Factor X, depending on the exposure class - according to [?]

Exposure Class	X
XC1	1
XC2	-
XC3	2
XC4	3

Yang et al.

This model by Yang et al. [] is based on previously researched carbonation relationships as well as numerous surveys of concrete carbonation with some additional data, such as environmental conditions and service life expectations of the components. In addition, a study was conducted to investigate the absorption of $CO2$ of two buildings with different environmental conditions. The carbonation coefficient depends on the water-cement ratio as well as some factors that take into account the relative humidity, the surface materials on the concrete, and the substitution degree of supplementary cementitious materials (SCMs) on the diffusivity. The carbonation depth $x_c(t)$ is described as follows:

$$x_c(t) = \sqrt{\frac{2D_{CO_2}(t)}{a_{CO_2}(t)} * C_{CO_2}} \tag{1}$$

$D_{CO_2}(t)$:	diffusion coefficient of CO_2 at time t [cm²/day] (Gl. 2)
$a_{CO_2}(t)$:	amount of absorbable CO_2 [g/cm³] (Gl. 5)
C_{CO_2}:	peripheral concentration by weight of CO_2 [g/cm³]

$$D_{CO_2}(t) = 136,6\beta_s\beta_f\beta_h * \left(\frac{a}{C}\right)^{0,1} + \left(\varepsilon_p(t)\right)^2 \tag{2}$$

β_s:	correction factor for the replacement of suppementary cementitious materials (SCMs) [-] (Tab. 2)
β_f:	represent the delayed carbonation process by finishing materials [-]
β_h:	represents the effect of relative humidity on the CO_2 diffusion rate [-] (Gl. 3)
a/C:	agreggate-to-cement ratio per weight [-]
$\varepsilon_p(t)$:	total porosity of cement paste at age t [-] (Gl. 4)

Table 2: β_s [-] - according to [?]

SCM	Ersetzte Menge durch SCMs [%]					
	0-10	10-20	20-30	30-40	40-50	50-80
FA	1,05	1,05	1,10	1,10	-	-
GGBS	1,05	1,10	1,15	1,20	1,35	1,40
SF	1,05	1,10	-	-	-	-

Table 3: β_f [-] - according to [?]

Material on concrete surface	Innenbereich						
	Nichts	Gips(G)	Mörtel(M)	Farbe(F)	M+G	M+F	Fliesen
β_f [-]	1,0	0,79	0,29	0,57	0,41	0,15	0,21

Material auf Betonoberfläche	Außenbereich			
	Nichts	Mörtel	Farbe	Fliesen
β_f [-]	1,0	0,28	0,8	0,7

$$\beta_h = \left(1 - \frac{RH}{100}\right)^{0,6} \tag{3}$$

$$\varepsilon_p(t) = \frac{0,1 + 2,62\left(\frac{W}{C}\right)^{4,2} * t}{1,5\left(\frac{W}{C}\right)^2 * t} \tag{4}$$

$$a_{CO_2}(t) = \alpha_h(t) * M_{ct}(t) * M_{CO_2} * 10^{-6}[g/cm] \tag{5}$$

$$\alpha_h(t) = \frac{t}{2,0+t} * \alpha_\infty \tag{6}$$

$$\alpha_\infty = \frac{1,031 * \frac{W}{C}}{0,194 + \frac{W}{C}} \tag{7}$$

$$M_{ct}(t) = 8,06C \tag{8}$$

RH: relative humidity [%]
W/C: water-to-cement ratio [-]
$\alpha_h(t)$: degree of hydration of cement paste at t [-] (Gl. 6)
$M_{ct}(t)$: molar concentration of the carbonatable constituents of the paste per unit volume of concrete at t [mol/cm³] (Gl. 8)
M_{CO_2}: molecular weight of CO_2, $M_{CO_2} = 44$[g/mol]
C: cement content [kg/m³]