THEORY DOCUMENT

Eurocode in RSPile (V3.025)

EuroCode2 (EC2) Concrete Model

There are three different methods of calculating the stress strain relationship, namely the Parabolic curve, the Simplified (Bilinear), and the Rectangular Block. These methods use characteristic parameters derived from Table 3.1 in the Eurocode, which is shown in Table 1. Only the characteristic compressive strength, f_{ck}, is required from the user, and the rest of the parameters are derived from the table below.

Table 1 Strength and Deformation Characteristics for Concrete (Table 3.1 in EC2 (2004), p.29)

Strength classes for concrete															**Analytical relation / Explanation**
f_{ck} (MPa)	12	16	20	25	30	35	40	45	50	55	60	70	80	90	
$f_{ck,cube}$ (MPa)	15	20	25	30	37	45	50	55	60	67	75	85	95	105	2.8
f_{cm} (MPa)	20	24	28	33	38	43	48	53	58	63	68	78	88	98	$f_{cm} = f_{ck}+8$(MPa)
f_{ctm} (MPa)	1,6	1,9	2,2	2,6	2,9	3,2	3,5	3,8	4,1	4,2	4,4	4,6	4,8	5,0	$f_{ctm}=0,30\times f_{ck}^{(2/3)} \leq$C50/60 $f_{ctm}=2,12\cdot\ln(1+(f_{cm}/10))$ > C50/60
$f_{ctk,0,05}$ (MPa)	1,1	1,3	1,5	1,8	2,0	2,2	2,5	2,7	2,9	3,0	3,1	3,2	3,4	3,5	$f_{ctk;0,05} = 0,7\times f_{ctm}$ 5% fractile
$f_{ctk,0,95}$ (MPa)	2,0	2,5	2,9	3,3	3,8	4,2	4,6	4,9	5,3	5,5	5,7	6,0	6,3	6,6	$f_{ctk;0,95} = 1,3\times f_{ctm}$ 95% fractile
E_{cm} (GPa)	27	29	30	31	33	34	35	36	37	38	39	41	42	44	$E_{cm} = 22[(f_{cm})/10]^{0,3}$ (f_{cm} in MPa)
ε_{c1} (‰)	1,8	1,9	2,0	2,1	2,2	2,25	2,3	2,4	2,45	2,5	2,6	2,7	2,8	2,8	see Figure 3.2 ε_{c1} ($^0/_{00}$) $= 0,7\ f_{cm}^{0,31} \leq 2,8$
ε_{cu1} (‰)	3,5									3,2	3,0	2,8	2,8	2,8	see Figure 3.2 for $f_{ck} \geq 50$ Mpa ε_{cu1}($^0/_{00}$)$=2,8+27[(98-f_{cm})/100]^4$
ε_{c2} (‰)	2,0									2,2	2,3	2,4	2, 5	2,6	see Figure 3.3 for $f_{ck} \geq 50$ Mpa ε_{c2}($^0/_{00}$)$=2,0+0,085(f_{ck}-50)^{0,53}$
ε_{cu2} (‰)	3,5									3,1	2,9	2,7	2,6	2,6	see Figure 3.3 for $f_{ck} \geq 50$ Mpa ε_{cu2}($^0/_{00}$)$=2,6+35[(90-f_{ck})/100]^4$
n	2,0									1,75	1,6	1,45	1,4	1,4	for $f_{ck} \geq 50$ Mpa $n=1,4+23,4[(90- f_{ck})/100]^4$
ε_{c3} (‰)	1,75									1,8	1,9	2,0	2,2	2,3	see Figure 3.4 for $f_{ck} \geq 50$ Mpa ε_{c3}($^0/_{00}$)$=1,75+0,55[(f_{ck}-50)/40]$
ε_{cu3} (‰)	3,5									3,1	2,9	2,7	2,6	2,6	see Figure 3.4 for $f_{ck} \geq 50$ Mpa ε_{cu3}($^0/_{00}$)$=2,6+35[(90-f_{ck})/100]^4$

There are also a few user-defined factors that are important for determining the design values for concrete and steel strengths. These factors are

- k_t = default value 1.0
- k_f = default value 1.1 and it is only applied to the uncased piles. For cased piles, it is kept as 1.0

- α_{cc} = default value 1.0
- γ_c = 1.5 for persistent and transient situations and 1.2 for accidental one user defined with defaults
- γ_s = 1.15 for persistent and transient situations and 1.2 for accidental one user defined with defaults
- γ_a = default value 1.0

The design strength of the concrete is then calculated as $f_{cd} = k_t\ \alpha_{cc} f_{ck}/\gamma_c$.

As for the three methods for calculating concrete stresses, they are explained in the following sections

EC2 Parabolic Stress Strain Curve

$\sigma_c = f_{cd}\left[1 - \left(1 - \frac{\varepsilon_c}{\varepsilon_{c2}}\right)^n\right]$ for $0 \leq \varepsilon_c < \varepsilon_{c2}$ (*From eq.* 3.17 *in EC2* (2004), *p.*35)

$\sigma_c = f_{cd}$ for $\varepsilon_{c2} \leq \varepsilon_c \leq \varepsilon_{cu2}$ (*From eq.* 3.18 *in EC2* (2004), *p.*35)

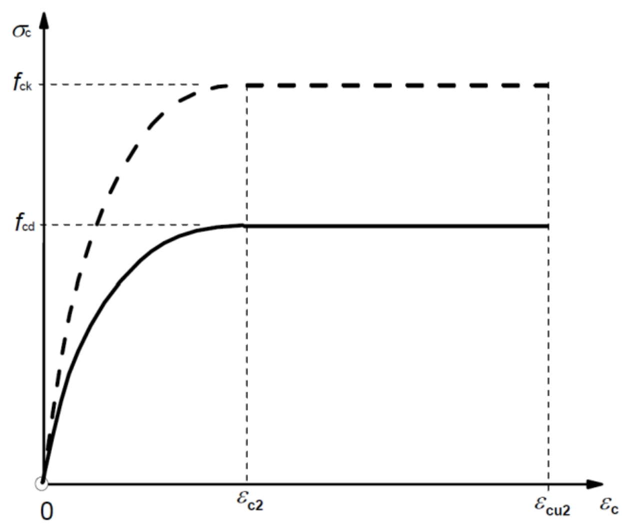

Figure 3.3: Parabola-rectangle diagram for concrete

Figure 3.3. Parabola-rectangle diagram for concrete under compression, EC2 (2004) p.35

values for $\varepsilon_{c2}, \varepsilon_{cu}, n\ are\ given\ in\ table\ 3.1\ of\ EC2\ (2004), p. 29$.

EC2 Simplified Elastic Plastic Stress Strain Relation (Bi-linear)

$\sigma_c = f_{cd} * \frac{\varepsilon_c}{\varepsilon_{c3}}$ for $0 \leq \varepsilon_c < \varepsilon_{c3}$

$\sigma_c = f_{cd}$ for $\varepsilon_{c3} \leq \varepsilon_c \leq \varepsilon_{cu3}$

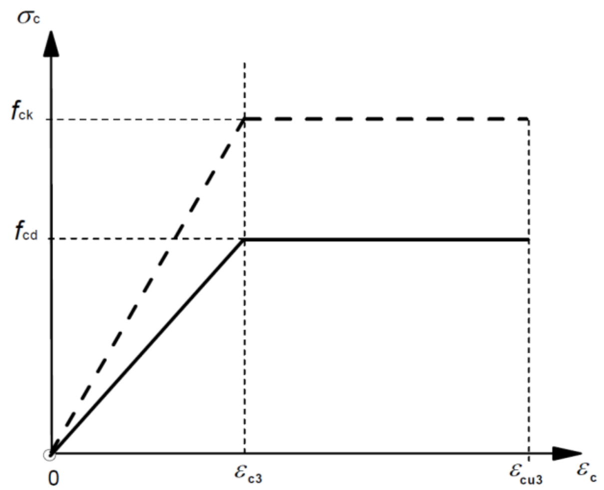

Figure 3.4: Bi-linear stress-strain relation.

Figure 3.4: Bi-linear stress-strain relation, EC2 (2004), p.35.

EC2 Rectangular Stress Block

Use definitions of stress block of ACI with following changes:

$use\ \lambda\ instead\ of\ \beta_1$ (beta1 you can find from Tara'

$use\ \eta f_{cd}\ instead\ of\ 0.85 f_c'$

$use\ \varepsilon_{cu3}\ instead\ of\ 0.003\ as\ fixed\ value\ for\ \varepsilon_{cu}$

where,

$if\ f_{ck} \leq 50MPa$

$\lambda = 0.8\ (Equation\ 3.19\ EC2, p.36)$

$\eta_{rectangular\ section} = 1.0\ (Equation\ 3.21\ EC2, p.36)$

$if\ f_{ck} > 50MPa$

$\lambda = 0.8 - \ (f_{ck} - 50)/400\ (Equation\ 3.21\ EC2, p.36)$

$\eta_{rectangular\ section} = 1.0 - \ (f_{ck} - 50)/200\ (Equation\ 3.22\ EC2\ (2004), p.36)$

General: $\eta_{circular\ section} = 0.9\eta_{rectangular\ section}$

Note: If the width of the compression zone decreases in the direction of the extreme compression fibre, the value $\eta\ f_{cd}$ should be reduced by 10%.

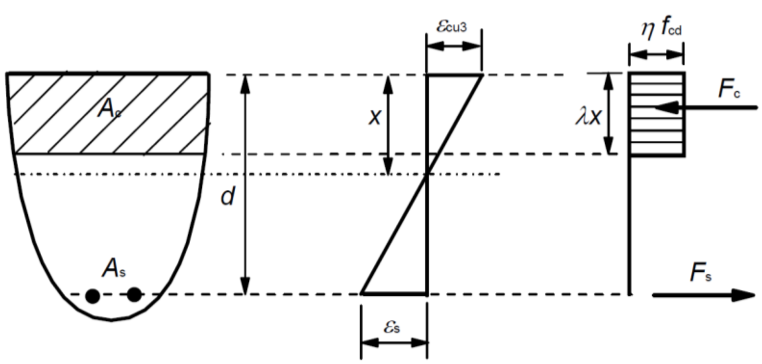

Figure 3.5: Rectangular stress distribution

Figure 3.5.Rectangular stress distribution,EC2 (2004),p.36

Steel Reinforcement and Steel Sections

The design strengths for the reinforcement and the sections (I-Beam, casing, and core etc.) are calculated by applying a factor to the characteristic strength, f_yk. For reinforcement, it is $f_{yd} = f_{yk}/\gamma_s$ and for sections, it is $f_{yd} = f_{yk}/\gamma_a$.

As for the stress calculation, given strain, it is the same as the existing, where a bilinear relationship is assumed.

Reduced Sections

Euro code considers reduced sections for cast-in-place concrete piles. The users would have an option to choose which enables the calculation with reduced sections. The reduced sections are calculated as follows (From 2.3.4.2, EC2 (2004)Supplementary requirements for cast in place piles, p.23):

$if\ d_{nom} < 400\ mm, d = d_{nom} - 20\ mm$
$if\ 400 \leq d_{nom} \leq 1000\ mm, d = 0.95\ d_{nom}$
$if\ d_{nom} > 1000\ mm, d = d_{nom} - 50\ mm$
Where d_{nom} is the nominal diameter of the pile.

For rectangular sections, the width and height are used instead of nominal diameter.

Note that the cased piles are excluded from the section reduction. In another word, even when the “use reduced section” option is selected, the interaction diagram of the case pile would still be calculated with the whole cross section.

References

EN 1992-1-1 (2004) (English): Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings [Authority: The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC](p.23, 29,35-36)

BS EN 19920101:2004.