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Project:

Subject:

Designer:

Date:

Eurocode 2 Table of concrete design properties

Description:

Design aid - Table of concrete design properties including strength properties (fck, fcd, fctm, fctd) elastic deformation properties (Ecm), minimum longitudinal reinforcement against brittle failure, and minimum shear reinforcement

According to:

EN 1992-1-1:2004+AC2:2010 Sections 3.1.2, 3.1.3, 9.2.1.1(1)

Supported National Annexes:

Nationally Defined Parameters (NDPs) automatically filled for supported countries (left blank otherwise)

Input

Steel characteristic yield strength f_{yk} = 500 MPa

Nationally Defined Parameters

Concrete partial material safety factor γ_C = 1.5

Tables

Concrete Design Properties according to EN1992-1-1 (γ_c = 1.50, f_{yk} = 500 MPa)

Symbol	Description	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C4
f_{ck} (MPa)	Characteristic cylinder compressive strength	12	16	20	25	30	35	40	
$f_{ck,cube}$ (MPa)	Characteristic cube compressive strength	15	20	25	30	37	45	50	

Symbol	Description	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C4
f_{cm} (MPa)	Mean cylinder compressive strength	20	24	28	33	38	43	48	
f_{ctm} (MPa)	Mean tensile strength	1.57	1.90	2.21	2.56	2.90	3.21	3.51	3
E_{cm} (MPa)	Elastic modulus	27085	28608	29962	31476	32837	34077	35220	36
f_{cd} (MPa) (for α_{cc}=1.00)	Design compressive strength (for α_{cc}=1.00)	8.00	10.67	13.33	16.67	20.00	23.33	26.67	30
f_{cd} (MPa) (for	Design compressive	6.80	9.07	11.33	14.17	17.00	19.83	22.67	2

General material properties for reinforced concrete according to EN1992-1-1 §3.1

Material Property	Value
Density ρ	≈ 2500 kg/m^3
Unit weight γ	≈ 25.0 kN/m^3
Modulus of elasticity E_{cm} (secant value between σ_c = 0 and 0.4f_{cm})	see table above
Shear modulus G (in the elastic range)	$G = E / [2 \cdot (1 + \nu)]$
Poisson's ratio ν (uncracked concrete)	0.2
Poisson's ratio ν (cracked concrete)	0.0
Coefficient of linear thermal expansion α	10 ×10^{-6} °K^{-1}

Notes

1. According to EN1992-1-1 §3.1.3(2) the following modifications are applicable for the value of the concrete modulus of elasticity E_{cm}: a) for limestone aggregates the value should be reduced by 10%, b) for sandstone aggregates the value should be reduced by 30%, c) for basalt aggregates the value should be increased by 20%.

2. The values of concrete design compressive strength f_{cd} are given as a function of the reduction coefficient α_{cc} as defined in EN1992-1-1 §3.1.6(1)P. Please consult the National Annex about the appropriate value of α_{cc} for each specific design case.
3. The minimum longitudinal tension reinforcement ratio ρ_{min} is applicable for tension edges of beams, two-way slabs and principal direction of one-way slabs. This minimum reinforcement is required in order to avoid brittle failure. Typically a larger quantity of *minimum longitudinal reinforcement for crack control* is required in accordance with EN1992-1-1 §7.3.2. For the secondary reinforcement of one-way slabs the minimum reinforcement is 20% of the primary reinforcement in accordance with EN1992-1-1 §9.3.1.1(2).
4. The minimum shear reinforcement ratio $\rho_{w,min}$ is defined in EN1992-1-1 §9.2.2(5). It is applicable for beams even if design shear reinforcement is not required. For slabs it is applicable only when design shear reinforcement is required. It corresponds to the notional area $b_w s$ where b_w is the width of the web and s is the spacing of the shear reinforcement along the length of the member.
5. The minimum longitudinal tension reinforcement ratio ρ_{min} corresponds to the notional area $b_t d$ where b_t is the mean width of the tension zone and d is the effective depth of the cross-section.
6. According to EN1992-1-1 §9.2.1.1(1) Note 2 for the case of beams where a risk of brittle failure can be accepted, the minimum longitudinal tension reinforcement may be taken as 1.2 times the area required in ULS verification.

Details

Design values of concrete material properties according to EN1992-1-1

Unit weight γ

The unit weight of concrete γ is specified in *EN1991-1-1 Annex A*. For plain unreinforced concrete γ = 24 kN/m^3. For concrete with normal percentage of reinforcement or prestressing steel γ = 25 kN/m^3.

Characteristic compressive strength f_{ck}

The characteristic compressive strength f_{ck} is the first value in the concrete class designation, e.g. 30 MPa for C30/37 concrete. The value corresponds to the characteristic (5% fractile) cylinder strength according to EN 206-1. The strength classes of EN1992-1-1 are based on the characteristic strength classes determined at 28 days. The variation of characteristic compressive strength $f_{ck}(t)$ with time t is specified in *EN1992-1-1 §3.1.2(5)*.

Characteristic compressive cube strength $f_{ck,cube}$

The characteristic compressive cube strength $f_{ck,cube}$ is the second value in the concrete class designation, e.g. 37 MPa for C30/37 concrete. The value corresponds to the characteristic (5% fractile) cube strength according to EN 206-1.

Mean compressive strength f_{cm}

The mean compressive strength f_{cm} is related to the characteristic compressive strength f_{ck} as follows:

$$f_{cm} = f_{ck} + 8 \text{ MPa}$$

The variation of mean compressive strength $f_{cm}(t)$ with time t is specified in *EN1992-1-1 §3.1.2(6)*.

Design compressive strength f_{cd}

The design compressive strength f_{cd} is determined according to *EN1992-1-1 §3.1.6(1)P*:

$$f_{cd} = \alpha_{cc} \cdot f_{ck} / \gamma_C$$

where γ_C is the partial safety factor for concrete for the examined design state, as specified in *EN1992-1-1 §2.4.2.4* and the National Annex.

The coefficient α_{cc} takes into account the long term effects on the compressive strength and of unfavorable effects resulting from the way the load is applied. It is specified in *EN1992-1-1 §3.1.6(1)P* and the National Annex (for bridges see also *EN1992-2 §3.1.6(101)P* and the National Annex).

Characteristic tensile strength

The tensile strength under concentric axial loading is specified in *EN1992-1-1 Table 3.1*. The variability of the concrete tensile strength is given by the following formulas:

- Formula for mean tensile strength f_{ctm}

f_{ctm} [MPa] = $0.30 \cdot f_{ck}^{2/3}$ for concrete class ≤ C50/60

f_{ctm} [MPa] = $2.12 \cdot \ln[1+(f_{cm} / 10\text{ MPa})]$ for concrete class > C50/60

- Formula for 5% fractile tensile strength $f_{ctk,0.05}$

$f_{ctk,0.05} = 0.7 \cdot f_{ctm}$

- Formula for 95% fractile tensile strength $f_{ctk,0.95}$

$f_{ctk,0.95} = 1.3 \cdot f_{ctm}$

Design tensile strength f_{ctd}

The design tensile strength f_{ctd} is determined according to *EN1992-1-1 §3.1.6(2)P*:

$f_{ctd} = \alpha_{ct} \cdot f_{ctk,0.05} / \gamma_C$

where γ_C is the partial safety factor for concrete for the examined design state, as specified in *EN1992-1-1 §2.4.2.4* and the National Annex.

The coefficient α_{ct} takes into account long term effects on the tensile strength and of unfavorable effects, resulting from the way the load is applied. It is specified in *EN1992-1-1 §3.1.6(2)P* and the National Annex (for bridges see also *EN1992-2 §3.1.6(102)P* and the National Annex).

Modulus of elasticity E_{cm}

The elastic deformation properties of reinforced concrete depend on its composition and especially on the aggregates. Approximate values for the modulus of elasticity E_{cm} (secant value between $\sigma_c = 0$ and $0.4f_{cm}$) for concretes with quartzite aggregates, are given in *EN1992-1-1 Table 3.1* according to the following formula:

E_{cm} [MPa] = $22000 \cdot (f_{cm} / 10\text{ MPa})^{0.3}$

According to *EN1992-1-1 §3.1.3(2)* for limestone and sandstone aggregates the value of E_{cm} should be reduced by 10% and 30% respectively. For basalt aggregates the value of E_{cm} should be increased by 20%. The values of E_{cm} given in *EN1992-1-1* should be regarded as indicative for general applications, and they should be specifically assessed if the structure is likely to be sensitive to deviations from these general values.

The variation of the modulus of elasticity $E_{cm}(t)$ with time t is specified in *EN1992-1-1 §3.1.3(3)*.

Poisson ratio ν

According to *EN1992-1-1 §3.1.3(4)* the value of Poisson's ratio ν may be taken equal to $\nu = 0.2$ for uncracked concrete and $\nu = 0$ for cracked concrete.

Coefficient of thermal expansion α

According to *EN1992-1-1 §3.1.3(5)* the value of the linear coefficient of thermal expansion α may be taken equal to $\alpha = 10 \cdot 10^{-6}$ °K^{-1}, unless more accurate information is available.

Minimum longitudinal reinforcement ρ_{min} for beams and slabs

The minimum longitudinal tension reinforcement for beams and the main direction of slabs is specified in *EN1992-1-1 §9.2.1.1(1)*.

$$A_{s,min} = \max\{ 0.26 \cdot f_{ctm} / f_{yk}, 0.0013\} \cdot b_t \cdot d$$

where b_t is the mean width of the tension zone and d is the effective depth of the cross-section, f_{ctm} is the mean tensile strength of concrete, and f_{yk} is the characteristic yield strength of steel.

The minimum reinforcement is required to avoid brittle failure. Sections containing less reinforcement should be considered as unreinforced. Typically a larger quantity of *minimum longitudinal reinforcement for crack control* is required in accordance with *EN1992-1-1 §7.3.2*.

According to *EN1992-1-1 §9.2.1.1(1) Note 2* for the case of beams where a risk of brittle failure can be accepted, $A_{s,min}$ may be taken as 1.2 times the area required in ULS verification.

Minimum shear reinforcement $\rho_{w,min}$ for beams and slabs

The minimum shear reinforcement for beams and slabs is specified in *EN1992-1-1 §9.2.2(5)*.

$$\rho_{w,min} = 0.08 \cdot (f_{ck}^{0.5}) / f_{yk}$$

where f_{ck} is the characteristic compressive strength of concrete and f_{yk} is the characteristic yield strength of steel.

The shear reinforcement ratio is defined in *EN1992-1-1 §3.1.3(5)* as:

$$\rho_w = A_{sw} / [\, s \cdot b_w \cdot \sin(\alpha) \,]$$

where where b_w is the width of the web and s is the spacing of the shear reinforcement along the length of the member. The angle α corresponds to the angle between shear reinforcement and the longitudinal axis. For typical shear reinforcement with perpendicular legs α = 90° and sin(α) = 1.

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