

# Durability, Creep Coefficient and Shrinkage Strain

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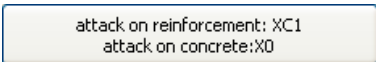
# Durability according to EN 1992 1-1

The following requirements depending on the exposure class result from the necessity to ensure durability:

- Minimum strength of the concrete
- Minimum concrete cover and dimensional allowance
- Permissible crack width and load combination for the crack width proof
- If necessary, requirements and load combination for the decompression proof

You can assign each component face to a different exposure class (the top and bottom face of horizontal, and the left and right face of vertical components).

The durability requirements can be modified by user-defined inputs or influenced by particular component properties.

The button  allows you to access the [Exposure class assignment](#) dialog for the corresponding component face.

- |                                 |   |
|---------------------------------|---|
| <b>Air-entrained concrete</b>   | Only NA_D (Annex E Tab. E.1DE)<br>Allows a lower minimum concrete strength for particular exposure classes.                     |
| <b>Earth-moist concrete</b>     | Only NA_D (Annex E Tab. A1DE)<br>Allows a lower minimum concrete strength for exposure class XF4.                               |
| <b>Addition for wear stress</b> | No increase of the minimum concrete cover in case of wear stress, the aggregates must comply with particular wear requirements. |

<b>dg</b>	<p>Only NA_D (11.4.2 (1))</p> <p>The maximum aggregate size of slight graining.</p> <p>For lightweight concrete, the maximum aggregate size of slight graining is an additional criterion for the minimum concrete cover.</p>
<b>Slowly curing concrete</b>	<p>Only NA_D (Annex E Tab. A1DE)</p> <p>(Acc. to EN 206-1 with <math>r &lt; 0.3</math>) allows a reduction of the minimum strength of the concrete by one class for the exposure classes XF2, XF3, XA2, XS2 and XD2.</p>
<b>dp</b>	<p>The nominal diameter of the strand <math>d_p</math> is an additional criterion for the minimum concrete cover when pre-tensioned concrete is used.</p>
<b>db</b>	<p>The stirrup diameter <math>d_b</math> is included in the calculation of the required reinforcement bar spacing.</p>
<b>Bottom face = top face</b>	<p>Many components have identical faces. This facilitates the input of additional data.</p>
<b>ds</b>	<p>The diameter of the reinforcing steel <math>d_s</math> at the corresponding face is a criterion for the minimum concrete cover and is included in the calculation of the required reinforcement bar spacing.</p>
<b><math>\Delta\Delta c</math></b>	<p>Differential size relative to the dimensional allowance on the respective face</p> <ul style="list-style-type: none"> <li>- Deduction (<math>&lt;0</math>) when appropriate quality control is applied acc. to 4.4.1.3 (2)</li> <li>- Addition (<math>&gt;0</math>) when pouring on sloped surfaces or in case of particular architectonic design requirements acc. to 4.4.13 (4).</li> </ul>
<b>zul wk</b>	<p>Permissible crack width resulting from the exposure classes. (A more stringent crack width might be required for water tanks for instance. You can take this into consideration via user-defined inputs).</p>

## Exposure classes EN 1992 1-1

You should specify for each component and/or component face all relevant exposure classes, the reinforcement corrosion and the concrete attacks in accordance with table 4.1, for wear stresses in accordance with 4.4.1.2 (13) as well as for alkali-aggregate reaction (only NA-D). The combination of these factors is used in the calculation of the [Requirements to ensure durability](#).

The exposure classes XD and XC exclude each other.

The screenshot shows a software dialog box titled "classes of exposition". It is organized into two main sections: "reinforcem. corrosion" and "attack on concrete".

- reinforcem. corrosion**
  - XC**: A dropdown menu is set to "XC1 dry or always wet (Construction unit Interior (normal air humidity) or always under water)".
  - XD Chloride, excluded seawater**: A dropdown menu is set to "XD no risk".
  - XS Chloride in the sea**: A dropdown menu is set to "XD no risk".
- attack on concrete**
  - XF freeze with or without**: A dropdown menu is set to "XD no risk".
  - XA chemical attack**: A dropdown menu is set to "XD no risk".
  - XM wear demand**: A dropdown menu is set to "XD no risk".
  - XW Alkali- silicic acid reaction**: A dropdown menu is set to "W0 almost dry".

At the bottom right of the dialog, there are "OK" and "Cancel" buttons.

You are not allowed to assign the value "no risk" in all categories of exposure classes to reinforced components!

# Durability requirements EN 1992 1-1

## Minimum strength of the concrete

The minimum strength of the concrete (NDP) results from the exposure classes assigned according to the cross section.

	XC1	XC2	XC3	XC4	XD1	XD2	XD3	XS1	XS2	XS3	Comments
EN	C20/25	C25/30	C30/37	C30/37	C30/37	C30/37	C35/45	C30/37	C35/45	C35/45	Tab. E.1N
NA_D	C16/20	C16/20	C20/25	C25/30	C30/37 a	C35/45 a,c	C35/45 a	C30/37 a	C35/45 a,c	C35/45 a	Tab. E.1DE a: with AE –1 cl. c: slowly curing –1 cl.
NA_GB	C20/25	C25/30	C25/30	C25/30	C28/35	C28/35 a	C35/45	C35/45 a	C28/35 a	C40/50 a	Tab. NA.2 cmin reduced: +cl a: also lower with apprpr. cement
NA_A	C20/25	C20/25	C25/30	C30/37	C25/30	C25/30	C35/45	--	--	--	Tab.9

	X0	XF1	XF2	XF3	XF4	XA1	XA2	XA3	Comments
EN	C12/15	C30/37	C25/30	C30/37	?	C30/37	C30/37	C35/45	Tab. E.1N
NA_D	C12/15	C25/30	C35/45 c, C25/30 LP b	C35/45 c, C25/30 LP b	C30/37 b,d,e	C25/30	C35/45 a,c	C35/45 a	Tab. E.1DE a: with AE–1 cl. b: with AE c: slowly curing –1cl d: earth-moist concr.
NA_GB	--	C25/30	C25/30	C25/30	C28/35	a	a	a	BS 8500-1 Tab.A.14 a: XA1,2,3 not considered
NA_A	--	C25/30	C25/30 a	C25/30	C25/30 a	C25/30	C35/45	C35/45	Tab. 9 a: AE considered

## Nominal value of the concrete cover

$$c_{nom} = c_{min} + \Delta c_{dev}$$

$c_{nom}$  Nominal value of the concrete cover

$c_{min}$  Minimum value of the concrete cover

$\Delta c_{dev}$  Dimensional allowance

The nominal value of the concrete cover of the longitudinal reinforcement  $c_{nom,L}$  results for each component face from the maximum of  $c_{min,B} + \Delta c_{dev} + d_b$  (stirrup decisive) or  $c_{min,L} + \Delta c_{dev}$ .

The minimum spacing of the reinforcement layer results from  $c_{nom,L} + d_s/2$ .

$d_s$  Diameter of reinforcing steel

$d_b$  Stirrup diameter

$c_{min,L}$  Minimum concrete cover of longitudinal reinforcement

$c_{min,B}$  Minimum concrete cover of stirrup

### Minimum concrete cover $c_{min}$

$c_{min} = \max(c_{min,b}; c_{min,dur} + \Delta c_{dur,\gamma} - \Delta c_{dur,add} - \Delta c_{dur,st}; 10\text{mm})$

$c_{min,b}$  due to bond

$c_{min,dur}$  from ambient conditions

$+\Delta c_{dur,\gamma}$  additive safety element

$\Delta c_{dur,st}$  reduction due to rustproof steel

$\Delta c_{dur,add}$  reduction due to additional measures

**$c_{min,b}$**  minimum concrete cover from bond (NDP, Tab. 4.2)

	Steel bar	Bar bundle	Strand	Tensioning wire	Sheaths	Comments
EN	ds a)	dv a)	$1.5 \cdot dp$	$2.5 \cdot dp$	Round: D Rectangular: $\max(B, 0,5H)$	a) when $D_g > 32 \text{ mm} + 5\text{mm}$
NA_D	ds a)	dv a)	$2.5 \cdot dp$ $2.0 \cdot dp$ (b)	$3.0 \cdot dp$ $2.5 \cdot dp$ (b)	= EN < 80 mm	a) when $D_g > 32 \text{ mm} + 5\text{mm}$ b) when $\sigma_p(0) \leq 1000 \text{ N/mm}^2$
NA_GB	=EN	=EN	=EN	=EN	=EN	=EN
NA_A	=EN	=EN	=EN	=EN	=EN	=EN

**$c_{min, dur}$**  minimum concrete cover from ambient conditions for reinforcing steel (NDP)

	X0	XC1	XC2/XC3	XC4	XD1/XS1	XD2/XS2	XD3/XS3	Comments
EN	10	15	25	30	35	40	45	Tab. 4.4N, Line S4
NA_D	n.a.	10	20	25	30	35	40	Tab. 4.4DE, corresp. to S3
NA_GB	n.a.	15	25	30	35	40	50	Tab. NA.2 for minimum concrete class
NA_A	n.a.	15	25	25	30	30	40	Tab. 1

**$c_{min, dur}$**  minimum concrete cover from ambient conditions for tensioning steel (NDP)

	X0	XC1	XC2/XC3	XC4	XD1/XS1	XD2/XS2	XD3/XS3	Comments
EN	n.a.	25	35	40	45	50	55	Tab. 4.5N, Line S4
NA_D	n.a.	20	30	35	40	45	50	Tab. 4.4DE, corresp. to S3
NA_GB	n.a.	15	25	30	35	40	50	Tab. NA.2 for minimum concrete class
NA_A	n.a.	25	35	35	40	40	50	Tab. 2

$\Delta c_{dur,\gamma}$  additive safety element according to 4.4.1.2 (6) NDP

	X0	XC1	XC2/XC3	XC4	XD1/XS1	XD2/XS2	XD3/XS3	Comments
EN	0	0	0	0	0	0	0	
NA_D	0	0	0	0	10	5	0	Tab.4.4DE, Tab.4.5DE building construction
NA_GB	0	0	0	0	0	0	0	
NA_A	0	0	0	0	0	0	0	

$\Delta c_{dur,st}$  reduction with rustproof steel acc. to 4.4.1.2 (7) NDP  
This option is currently not supported by the application.

	$\Delta c_{dur,st}$	Comments
EN	0	
NA_D	$c_{min,dur} - c_{min,b}$	Only building construction
NA_GB	0	
NA_A	0	

$\Delta c_{dur,add}$  reduction for concrete coating

	$\Delta C_{dur,Add}$ acc. to 4.4.1.2 (8))	Comments
EN	0	
NA_D	10 mm	XD, permanent crack-sealing coating + maintenance contract
NA_GB	0	
NA_A	0	

### Dimensional allowance $\Delta c_{dev}$

The dimensional allowance (NDP) shall take unplanned deviations into consideration and is calculated separately for each component face acc. to para. 4.4.1.3

It can be reduced in accordance with paragraph (3) if appropriate quality assurance measures are applied and must be increased in accordance with paragraph (4) if the concrete is poured on an uneven surface.

The user must apply these corrections manually by entering a value for  $\Delta \Delta c$ .

	$\Delta c_{dev}$ acc. to 4.4.1.3	Comments
EN	10 mm	Reduction up to 10 mm with appropriate quality assurance.
NA_D	15 mm	10 mm when XC1 or $c_{Min,Dur} \leq c_{Min,b}$ Reduction by 5 mm with appropriate quality assurance (only bldg. construction)
NA_GB	10 mm	Reduction up to 10 mm with appropriate quality assurance.
NA_A	5 mm	No reduction if spacers are arranged acc. to table 3

### Permissible crack width

The considered NAs all require the proof of a permissible crack width of 0.3 mm for reinforced concrete components of exposure class XC2 and higher.

The proof for XC1 is based on a crack width of 0.4 mm for aesthetical reasons (exception NA\_GB: 0.3 mm)

The decisive load combination is the quasi-permanent load combination (Qk).

Due to the fact that the tensioning bars are highly susceptible to corrosion, pre-stressed concrete components have to comply with higher requirements in regard to the load combinations (infrequent (Sk), frequent (Hk) and the permissible crack width to be proven. In some cases, a proof of decompression (Dec.) might be required for particular load combinations,

The regulations may differ in the national annexes.

Post-tensioned concrete:

	X0, XC1	XC2/XC4	XS1-3, XD1-3
EN	0.2 + Hk	0.2+ Hk and Dec. Qk	Dec. Hk
NA_D	0.2 + Hk	0.2+ Hk and Dec. Qk	0.2+ Hk and Dec. Qk
NA_GB	0.2+ Hk	0.2+ Hk and Dec. Qk	Dec. Hk
NA_A	0.2+ Hk	0.2+ Hk and Dec. Qk	0.2+ Hk and Dec. Qk

Pre-tensioned concrete:

	X0, XC1	XC2/XC4	XS1-3, XD1-3
EN	0.2 + Hk	0.2+ Hk and Dec. Qk	Dec. Hk
NA_D	0.2 + Hk	0.2+ Hk and Dec. Qk	0.2+ Sk and Dec. Hk
NA_GB	0.2+ Hk	0.2+ Hk and Dec. Qk	Dec. Hk
NA_A	0.2+ Hk	0.2+ Hk and Dec. Qk	0.2+ Sk and Dec. Hk

A more stringent crack width limit might be required for water tanks for instance.  
You can take this into consideration via a user-defined input.

# Creep coefficient and shrinkage strain EN 1992 1-1

In this dialog, you can either calculate creep coefficients in accordance with the boundary conditions or set user-defined values by default.

modulus of creep+shrinkage

calculate values  air humidity  % cementtyp N,R

normal weight concrete fck = 20,0 h0 user defined  h0 = 2\*Ac/u  cm

t0=  days t=infinite :  $\varphi(t_0,t)=$    $\epsilon_{cs}(t)=$   o/oo

**LU** air humidity 40 ... 100 %  
**T0** Start of load impact 1 ... 10000 days

**Cement** classes S (slowly), N (standard), R (fast curing)  
 NA\_D: assignment acc. to DAfStb H.525 Tab. H9.3

**h0** effective component thickness  
 $h_0 = 2 \cdot A_c / U$   
 Ac: cross sectional area  
 U: perimeter of the cross sectional area that is exposed to drying-out

**Mode** - Calculate values  
 - Set values by default

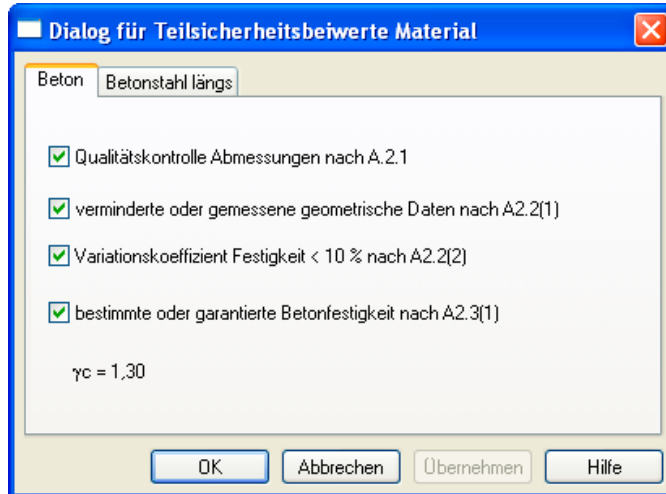
$\varphi(t_0,t)$  creep coefficient for  $t = \infty$  with start of load impact  $t_0$ .  
 The calculation is performed according to annex B.

$\epsilon_{cs}(t)$  shrinkage strain for  $t = \infty$   
 NA\_D: acc. to DAfStb Booklet 525, p. 65 ff.  
 NA\_GB: chapter 3.1.3 (6) and annex B  
 NA\_A: chapter 3.1.3 (6) and annex B

# Partial safety factors for material EN 1992 1-1

You can enable or disable the quality attributes required for the reduction of the partial safety factors in accordance with Annex A in separate dialogs for concrete and reinforcing steel (design options, button  $\gamma_c=1,50 \ \gamma_s=1,15$ )

The attributes are enabled or disabled depending on whether they are permitted according to the relevant national Annex.



## Concrete

$\gamma_c$  possible reduction acc. to Annex A

	A2.1 reduced geometric deviations due to control $\gamma_c, Red1$	A2.2 (1) measured or diminished geometric data $\gamma_c, Red2$	A2.2 (2) Variation coefficient of concrete strength < 10 % $\gamma_c, Red3$	A2.3 concrete strength in the mixing plant determines the diminishing factor $\eta$ ( $\gamma_c, Red^* \eta$ )	A2.3 Minimum $\gamma_c$ ( $\gamma_c, Red4$ )
EN	1.4	1.45	1.35	0.85	1.30
NA_D	None	None	None	0.9	1.35
NA_GB	=EN	=EN	=EN	=EN	=EN
NA_A	=EN	=EN	=EN	=EN	=EN

## Reinforcing steel longitudinal

$\gamma_s$  possible reduction acc. to Annex A

	A2.1 reduced geometric deviations due to control $\gamma_s, Red1$	A2.2 (1) measured or diminished geometric data $\gamma_s, Red2$
NA_EN	1.10	1.05
NA_D	None	None
NA_GB	=EN2	=EN2
NA_A	=EN2	=EN2