FRILO Software
A NEMETSCHEK COMPANY

Durability, Creep Coefficient and Shrinkage Strain

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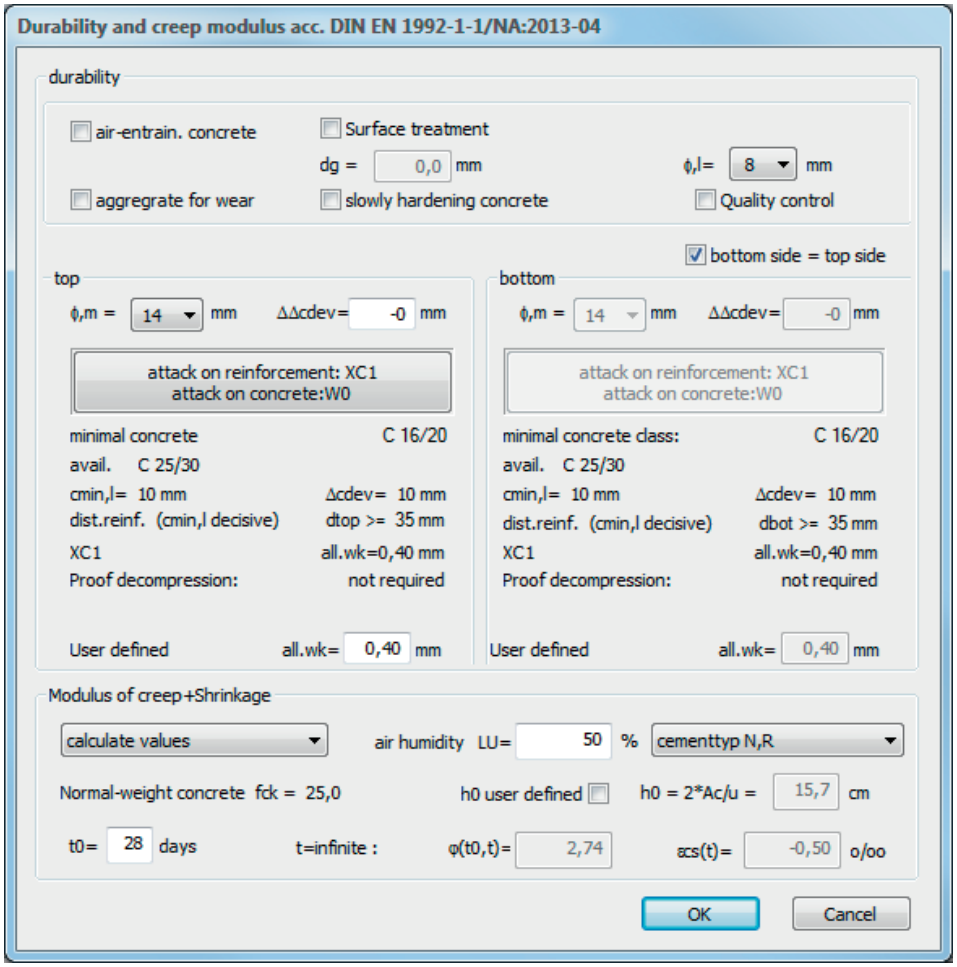


Durability, Creep Coefficient and Shrinkage Strain

Inhaltsverzeichnis

Abbreviations national annexes (acurrent versions)

NA-D:	DIN EN 1992-1-1/NA:2015-09
NA-A:	ÖNORM B 1992-1-1:2011
NA-GB:	NA to BS EN 1992-1-1/A2:2015-07
NA-I:	UNI EN 1992-1-1/NTC:2008
NA-PN	PN EN 1992-1-1:2008/NA:2010
EN2-0	EN 1992-1-1:2004/A1:2014

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).

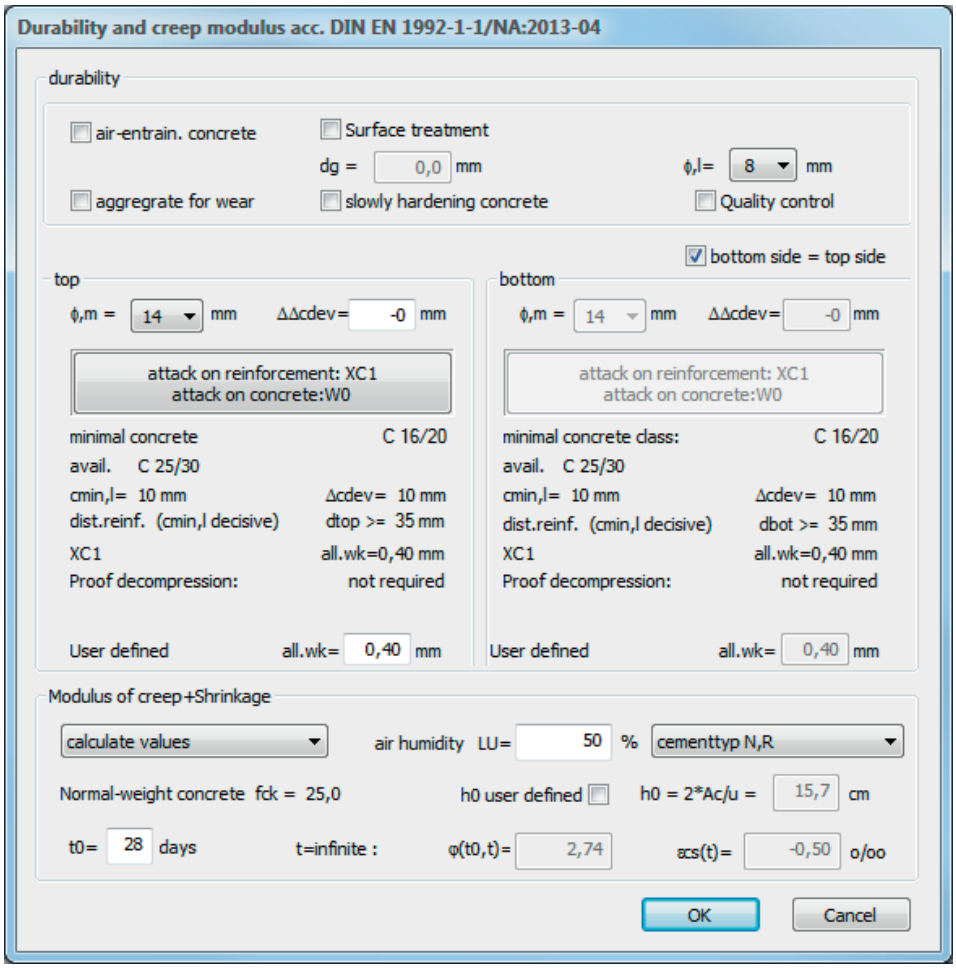
The durability requirements can be modified by user-defined inputs or influenced by particular component properties.

Air-entrained concrete	Allows a lower minimum concrete strength for particular exposure classes.
Earth-moist concrete	Only NA_D (Annex E Tab. A1DE) Allows a lower minimum concrete strength for exposure class XF4.
Addition for wear stress	No increase of the minimum concrete cover in case of wear stress, the aggregates must comply with particular wear requirements.
dg	Only NA_D (11.4.2 (1)) The maximum aggregate size of slight graining. For lightweight concrete, the maximum aggregate size of slight graining is an additional criterion for the minimum concrete cover.
Slowly hardening concrete	Only NA_D (Annex E Tab. A1DE) (Acc. to EN 206-1 with r < 0.3) allows a reduction of the minimum strength of the concrete by one class for the exposure classes XF2, XF3, XA2, XS2 and XD2.
Quality control	The production is subject to quality control – i.a. the concrete cover is measured (4.4.1.3 (3)) This option allows i.a. a reeduction of the dimensional allowance
dp / dh	The nominal diameter of the strand dp is an additional criterion for the minimum concrete cover when pre-tensioned concrete is used.
ϕ,l	The stirrup diameter is included in the calculation of the required reinforcement bar spacing.
Bottom side = top side	Many components have identical faces. This facilitates the input of additional data.
ϕ,m	The diameter of the reinforcing steel at the corresponding face is a criterion for the minimum concrete cover and is included in the calculation of the required reinforcement bar spacing.
ΔΔcdev	Differential size relative to the dimensional allowance on the respective face - Deduction (<0) when appropriate quality control is applied acc. to 4.4.1.3 (2) - Addition (>0) when pouring on sloped surfaces or in case of particular architectonic design requirements acc. to 4.4.13 (4).

all, wk 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).

The button 

allows you to access the Exposure class assignment dialog for the corresponding component face.



Exposure classes EN 1992 1-1

You should specify for each component and/or component face all relevant exposure classes 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 XS exclude each other.

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 results from the exposure classes assigned according to the cross section.

Reinforcement corrosion

	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 appropr. cement
NA_A	C20/25	C20/25	C25/30	C30/37	C25/30	C25/30	C35/45	--	--	--	Tab.9, no sea
NA_I	C25/30 AO	C25/30 AO	C25/30 AO	C28/35 AA	C28/35 AA	C35/45 AM	C35/45 AM	C28/35 AA	C35/45 AM	C35/45 AM	/57/ Tab.C.4.1.IV und Umgebungsklassen A0,AO,AA,AM nach NTC Tab. 4.1. III

AE: air-entraining

NA_I:

environment classes according to NTC Tab. 4.1. III

AO:	normal conditions	X0,XC1-3,XF1
AA:	aggressive environment	XC4, XD1, XS1, XF2-3, XA1-2
AM	very aggressive environment	XD2-3,XS2-3, XA3, XF4

Beton aggressive

	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
NA_I	C16/20 A0	C25/30 AO	C28/35 AA	C28/35 AA	C35/45 AM	C28/35 AA	C28/35 AA	C35/45 AM	/57/ Tab.C.4.1.IV and environment classes A0, AO, AA, AM acc. to NTC Tab. 4.1. III

NA_GB: in place of the exposure classes XA1, XA2, XA3 the ACEC classes (Bre Special Digest) have to be used. Acc. to / 62 / for this stress special concretes (Designated Concrete) with strength class C25 / 30th have to be used.

Nominal value of the concrete cover

cnom = cmin + Δcdev

cnom Nominal value of the concrete cover

cmin Minimum value of the concrete cover

Δcdev Dimensional allowance

The nominal value of the concrete cover of the longitudinal reinforcement cnom,l results for each component face from the maximum of cmin,B +Δcdev + db (stirrup decisive) or cmin,l + Δcdev.

The minimum spacing of the reinforcement layer results from cnom,l + ds/2.

	german brief description	english brief description
Diameter of reinforcing steel	ds	ϕ,m
Stirrup diameter	db	ϕ,l
Minimum concrete cover of longitudinal reinforcement	cMin,l	cMin,m
Minimum concrete cover of stirrup	cMin,b	cMin,l

Minimum concrete cover cmin

cmin = max (cmin,b; cmin,dur+Δcdur,γ- Δcdur,add- Δcdur,st; 10mm)

cmin,b due to bond

cmin,dur from ambient conditions

+Δcdur,γ additive safety element

Δcdur,st reduction due to rustproof steel

Δcdur,add reduction due to additional measures

cmin,b minimum concrete cover from bond (NDP, Tab. 4.2)

	Steel bar	Bar bundle	Strand	Tensioning wire	Comments
EN	ds a)	dv a)	1,5 · dp	2,5 · dp	a) when Dg > 32 mm + 5mm
NA_D	ds a)	dv a)	2,5 · dp 2,0 · dp (b)	3,0 · dp 2,5 · dp (b)	a) when Dg > 32 mm + 5mm b) when σp(0) <= 1000 N/mm²
NA_GB	=EN	=EN	=EN	=EN	
NA_A	=EN	=EN	=EN	=EN	
NA_I	=EN	=EN	=EN	=EN	[63]

cmin, 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.e.	10	20	25	30	35	40	Tab. 4.4DE, corresp. to S3
NA_GB	n.e.	15	25	30	35	40	50	Tab. NA.2 for minimum concrete class
NA_A	n.e.	15	25	25	30	30	40	Tab. 1
NA_I		25 AO		35 AA		45 AM		AO, AA, AM acc. to NTC Tab. 4.1. III

cmin, 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.e.	25	35	40	45	50	55	Tab. 4.5N, Line S4
NA_D	n.e.	20	30	35	40	45	50	Tab. 4.4DE, corresp. to S3
NA_GB	n.e.	15	25	30	35	40	50	Tab. NA.2 for minimum concrete class
NA_A	n.e.	25	35	35	40	40	50	Tab. 2
NA_I		35 AO		45 AA		50 AM		AO, AA, AM acc. to NTC Tab. 4.1. III

Δ**cdur,**γ 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	=EN	=EN	=EN	=EN	10	5	0	Tab.4.4DE, Tab.4.5DE building construction
NA_GB	=EN	=EN	=EN	=EN	=EN	=EN	=EN	
NA_A	=EN	=EN	=EN	=EN	=EN	=EN	=EN	
NA_I	=EN	=EN	=EN	=EN	=EN	=EN	=EN	[63]

Δ**cdur,st** reduction with rustproof steel acc. to 4.4.1.2 (7) NDP
This option is currently not supported by the application. This option can be taken into account by the correction value $\Delta\Delta$cdev manually.

	Δcdur,st	Comments
EN	0	
NA_D	cmin,dur- cmin,b	Only building construction
NA_GB	0	
NA_A	0	
NA_I	=EN	[63]

Δcdur,add reduction for concrete coating
This option is currently not supported by the application. This option can be taken into account by the correction value ΔΔcdev manually.

	ΔCdur,Add nach 4.4.1.2 (8))	Comments
EN	0	
NA_D	0	XD, permanent crack-sealing coating + maintenance contract
NA_GB	0	
NA_A	0	
NA_GB	=EN	
NA_A	=EN	
NA_I	=EN	[63]

NA_D since modification 2015-12: Δcdur,Add= 0 mm (until now Δcdur,Add= 10 mm)

Dimensional allowance Δc_{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 **ΔΔcdev** .

	Δcdev acc. to 4.4.1.3	Reduction in case of quality control	comment
EN	10 mm	5 mm a) 10 mm b)	a) measured concrete cover b) non-compliant components are discarded
NA_D	15 mm c)	5 mm	c) 10 mm in case of XC1 or cMin,Dur <= cMin,b
NA_GB	=EN	= EN	reduction to 10mm in the case of quality control
NA_A	5 mm d)	no reduction allowed	d) arrangement of the spacer according to Tab. 3
NA_I	=EN	=EN	[63]

b) This option is currently not supported by the application. This option can be taken into account by the correction value ΔΔcdev manually.

Permissible crack width according to Table 7.1

Stahlbetonbauteile

	X0, XC1	XC2/XC3/XC4	XS1-3, XD1-3	comment
EN	0,4 + Qk	0,3 + Qk	0,3 + Qk	Tab. 7.1N
D	=EN	=EN	=EN	Tab. 7.1DE
GB	0,3 + Qk	=EN	=EN	
A	=EN	=EN	=EN	
I	AO 0,3 + Qk 0,4 + Hk	AA 0,2 + Qk 0,3 + Hk	AM 0,2 + Qk 0,2 + Hk	A0,AO,AA,AM acc. to NTC Tab. 4.1. III

Prestressed concrete in composite:

	X0, XC1	XC2/XC4	XS1-3, XD1-3	
EN	0,2 + Hk	0,2+ Hk Dek. Qk	Dek. Hk	Tab. 7.1N
NA_D	=EN	=EN	subsequent composite: 0,2+ Hk and Dek. Qk immediate composite 0.2 + Sk and Dek. Hk	Tab. 7.1DE
NA_GB	=EN	=EN	=EN	
NA_A	=EN	=EN	subsequent composite: 0,2+ Hk and Dek. Qk immediate composite 0,2 + Sk and Dek. Hk	
NA_I	AO 0,3 + Qk 0,2 + Hk	AA 0,2 + Hk Dek.+ Qk	AM Dek. + Qk Sigt + Sk	A0,AO,AA,AM acc. to NTC Tab. 4.1. III

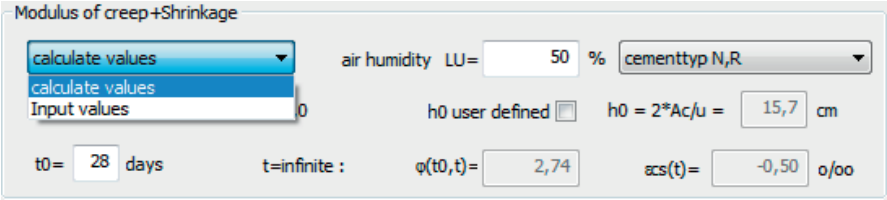
Qk quasi-permanent combination
Hk frequent combination
Sk rare combination
Dek Verification of decompression
Sigt Verification der tensile stresses

Permissible crack width user defined:

Die zulässige Rissbreite kann z.B. für Wasserbehälter auch strenger gefordert sein.
Dies zu berücksichtigen ist über eine nutzerdefinierte (freie) Eingabe möglich.

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.



Mode - Calculate values
- Set values by default

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

$h0 = 2 \cdot Ac / U$

Ac: cross sectional area

U: perimeter of the cross sectional area that is exposed to drying-out

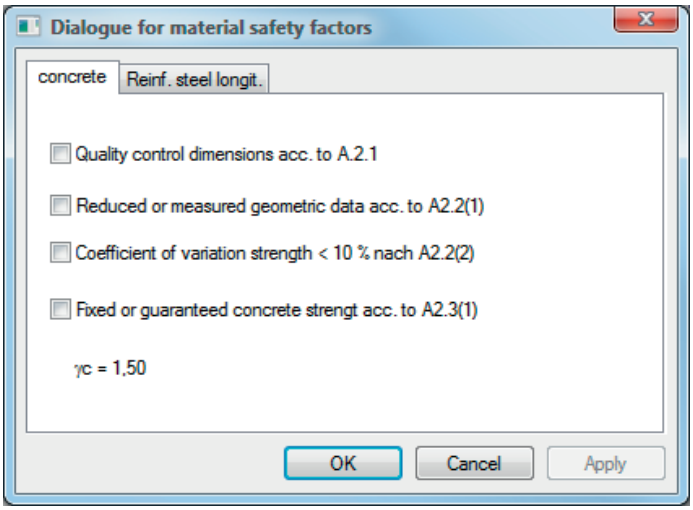
φ(t0,t) creep coefficient for $t = \infty$ with start of load impact t0.
The calculation is performed according to annex B und 11.3.3 (lightweight concrete).

εcs(t) shrinkage strain for $t = \infty$
The calculation is performed according to Section 3.1.4 (normal concrete), 11.3.3 (lightweight concrete) 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 γc=1,50 γs=1,15)

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



Concrete

γc possible reduction acc. to Annex A

	A2.1 reduced geometric deviations due to control γc,Red1	A2.2 (1) measured or diminished geometric data γc,Red2	A2,2 (2) Variation coefficient of concrete strength < 10 % γc,Red3	A2.3 concrete strength in the mixing plant determines the diminishing factor η (γc,Red* η)	A2.3 Minimum γc (γc,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
NA_I	1.4	none	none	none	1.4

Reinforcing steel longitudinal

γs possible reduction acc. to Annex A

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

Literatur

See document „Analyses on Reinforced Concrete Cross Sections“, chapter Literatur