

Early-age thermal cracking

Restrained thermal and shrinkage strain, crack-inducing strain, minimum steel and crack width · CIRIA C766, EN 1992-3 Ar

Reference	NAE-RC-022 · version 1.0
Standards	BS EN 1992-1-1:2004 with UK NA · PN-EN 1992-1-1:2008 with Polish NA (NDP sources listed on the NDP sheet) · EN 1992-3:2006 Annex L and M (informative) · method of CIRIA C766 (2018)
National Annex	Selectable: UK NA to BS EN 1992-1-1 or Polish NA to PN-EN 1992-1-1
Issued	29 October 2026

What it does

Risk of cracking and crack control for a wall or slab restrained by previously cast concrete while it cools from its early-age peak temperature and shrinks: restrained strain at early age and in the long term against the tensile strain capacity, crack-inducing strain for continuous edge or end restraint, minimum reinforcement, crack spacing and crack width for the bars on one face.

How to use

1. Open the Calculation sheet and select the National Annex.
2. Fill in the shaded input cells. Everything else is calculated.
3. Read the Results block; every step below it quotes its clause. Print or save as PDF for your calculation package.

Scope and limitations

The method of CIRIA C766 sections 3.2 to 3.6, written independently: restrained strain $\epsilon_r = Kc1 (\alpha_c T1 + \epsilon_{ca}(3)) R1$ at early age, plus $Kc1 ((\epsilon_{ca}(28) - \epsilon_{ca}(3)) + \alpha_c T2) R2 + Kc2 \epsilon_{cd} R3$ in the long term, with $Kc1 = 0.65$ and $Kc2 = 0.5$ (C766 Equation 3.1); tensile strain capacity under sustained load $1.08 f_{ctm}(3)/E_{cm}(3)$ and $1.40 f_{ctm}(28)/E_{cm}(28)$ (Equations 4.8, 4.9) with the properties of EN 1992-1-1 3.1.2 and a factor on E_{cm} for the aggregate entered by the user (EN 1992-1-1 3.1.3(2), or C766 4.9.2). Autogenous shrinkage by EN 1992-1-1 (3.11) to (3.13). Continuous edge restraint: $\epsilon_{cr} = \epsilon_r - 0.5 \epsilon_{ctu}$ (C766 Equation 3.10, refining EN 1992-3 M.3). End restraint: $\epsilon_{cr} = 0.5 \alpha_e k_c k_f f_{ctk} 0.05(t) (1 + 1/(\alpha_e p)) / E_s$ with $k_c = 1$, $k_f = 1.0$ ($h \leq 300$) to 0.65 ($h \geq 800$) and $\Delta c t = 0.5$ h per face (C766 Equation 3.12 and Table 3.2, refining EN 1992-3 M.1). Cracks are expected where $\epsilon_r > \epsilon_{ctu}$ (C766 3.2.1); no crack width is reported otherwise. Cracks formed at early age are kept in the long term: its width is at least the early-age width and at least $S_{r,max}$ times the long-term crack-inducing strain (an envelope; for end restraint it takes the 28-day strength, conservatively). Minimum steel per face $A_{s,min} = k_{Redge} k_c k_{Act} f_{ct,r} / f_{yk}$ with $f_{ct,r} = 0.7 f_{ctm}(t)$ (C766 Equations 3.19, 3.20), checked at each age at which cracks form (3 days with $k_{Redge} = 1 - 0.5 R1$; long term with 28-day strength and $1 - 0.5 \min(R2; R3)$; no cracking: the long-term value, 7.3.2(2)); a crack width is accepted only with $A_s \geq A_{s,min}$. k_c and k_f are those of EN 1992-1-1 7.3.2(2) for tension, as C766 Table 3.2 applies them. Crack spacing by EN 1992-1-1 (7.11) with $k_2 = 1.0$ (tension), $k_1 = 0.8$, or 1.14 for poor bond at early age (C766 3.5.2), and not less than 1.3 h where the bars are further apart than $5 (c + \phi/2)$ (7.3.4(3), the larger taken). The temperatures $T1$ and $T2$, the coefficient of thermal expansion, the drying shrinkage and the restraint factors are inputs: take them from C766 chapter 4 (T1: section 4.2 and its tables, restraint: section 4.8 and EN 1992-3 Annex L), from measurements or from the project specification. For the long term only the difference in movement between the member and its restraint counts (C766 3.3.1.2). Internal restraint (temperature differentials) and the simplified default method of C766 3.7 are not included. Concrete classes up to C50/60, $f_{yk} \leq 500$ MPa.

The second-generation EN 1992-1-1:2023 is not yet implemented.

Further reading and independent cross-check

- CIRIA C766 (2018), Control of cracking caused by restrained deformation in concrete: chapters 3 and 4 for the method and the input values.
- BS EN 1992-3:2006, Annexes L and M.
- The Concrete Centre, How to design concrete structures using Eurocode 2: Cracking.

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About NA Engineering

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Revision history

v1.0	29 Oct 2026 · First issue
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Project
Element
Date

Job no.
Made by
Checked

Inputs · concrete and reinforcement

Shaded cells only

	National Annex		UK NA (BS EN)	
Table 3.1	Concrete strength class		C30/37	
3.1.2(6)	Cement class		Class N	R: s = 0.20, N: 0.25, S: 0.38
3.1.3(2)	Aggregate factor on the modulus E_{cm}		1.00	0.7 to 1.2
EN 1992-1-1 3.1.3(2): quartzite 1.0, limestone 0.9, sandstone 0.7, basalt 1.2 (other aggregates: CIRIA C766 4.9.2 or tests).				
3.2.2	Reinforcement characteristic yield strength (≤ 500 MPa)	f_{yk}	500	MPa
EN 1992-3 M.1	Restraint		Continuous edge	Edge: wall on a base
	Section thickness	h	400	mm
7.3.4(3)	Cover to the bars controlling the cracks	c	40	mm
	Bars on each face: diameter	φ	16	mm
	Bars on each face: spacing	s	150	mm
C766 3.5.2	Bond at early age		Good	Poor: $k_1 = 1.14$
	Limiting crack width	w_{max}	0.20	mm Project requirement

Inputs · temperatures, shrinkage and restraint

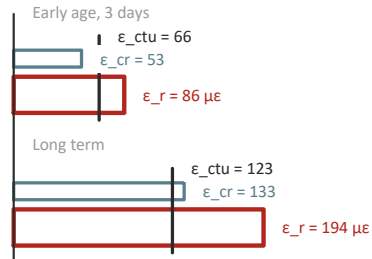
From C766 chapter 4 or tests

C766 4.2	Early-age temperature drop $T_1 = \text{peak} - \text{mean ambient}$	T_1	25.0	°C
C766 4.3	Long-term temperature drop T_2 (seasonal)	T_2	20.0	°C
C766 4.6	Coefficient of thermal expansion	α_c	10.0	$\mu\epsilon/^\circ\text{C}$
C766 4.7.2	Drying shrinkage (difference from the restraint)	ϵ_{cd}	150	$\mu\epsilon$
C766 4.8	Restraint factor at early age	R_1	0.50	
C766 4.8	Restraint factor, long-term thermal and autogenous	R_2	0.50	
C766 4.8	Restraint factor, drying shrinkage	R_3	0.50	
Inputs valid and consistent				OK

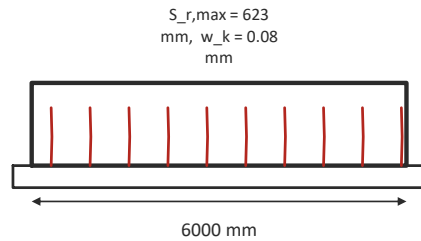
Results · per face, per metre

Early age: restrained strain / tensile strain capacity	$\epsilon_r / \epsilon_{ctu}$	1.29		! Cracks expected
Long term: restrained strain / tensile strain capacity	$\epsilon_r / \epsilon_{ctu}$	1.57		! Cracked
Minimum reinforcement $A_{s,min}$ / $A_{s,prov}$		0.42		OK
Crack width at early age (with $A_s \geq A_{s,min}$)	w_k	0.03	mm	OK
Crack width in the long term (with $A_s \geq A_{s,min}$)	w_k	0.08	mm	OK

Restrained strain against the tensile strain capacity · early age (top) and long term (bottom), microstrain



Elevation over 6 m, schematic · cracks at the maximum spacing where cracking is expected in the long term



Calculation · concrete properties

7.3.4(3)	Crack spacing coefficient	k_3	3.40	NDP sheet
7.3.4(3)	Crack spacing coefficient	k_4	0.425	NDP sheet
Table 3.1	Characteristic cylinder strength	f_{ck}	30	MPa
Table 3.1	Mean tensile strength	f_{ctm}	2.90	MPa
Table 3.1	Mean compressive strength $f_{ck} + 8$	f_{cm}	38	MPa
Table 3.1, 3.1.3(2)	Secant modulus at 28 days $22 (f_{cm}/10)^{0.3} \times \text{factor}$	E_{cm}	32837	MPa
3.1.2(6)	Cement coefficient	s	0.25	
(3.2)	Strength development at 3 days $\exp(s (1 - \sqrt{28/3}))$	$\beta_{cc(3)}$	0.598	
(3.4)	Mean tensile strength at 3 days $\beta_{cc(3)} f_{ctm}$ ($\alpha = 1$)	$f_{ctm(3)}$	1.73	MPa
(3.5)	Modulus at 3 days $(\beta_{cc(3)})^{0.3} E_{cm}$	$E_{cm(3)}$	28146	MPa
C766 (4.8)	Tensile strain capacity, early age $1.08 f_{ctm(3)} / E_{cm(3)}$	$\epsilon_{ctu(3)}$	0.000066	
C766 (4.9)	Tensile strain capacity, long term $1.40 f_{ctm} / E_{cm}$	$\epsilon_{ctu(28)}$	0.000123	
(3.12)	Final autogenous shrinkage $2.5 (f_{ck} - 10) \cdot 10^{-6}$	$\epsilon_{ca(\infty)}$	0.000050	
(3.13)	Autogenous shrinkage at 3 days $(1 - \exp(-0.2 \sqrt{3})) \epsilon_{ca(\infty)}$	$\epsilon_{ca(3)}$	0.000015	
(3.13)	Autogenous shrinkage at 28 days	$\epsilon_{ca(28)}$	0.000033	

Calculation · restrained and crack-inducing strain

C766 4.1.1	Creep coefficients Kc1 (early age), Kc2 (long term)	$K_{c1}; K_{c2}$	0.65; 0.50	
C766 (3.1)	Early age $\epsilon_r = Kc1 (\alpha_c T1 + \epsilon_{ca}(3)) R1$	$\epsilon_{r(3)}$	0.000086	
C766 (3.1)	Long term $+ Kc1 ((\epsilon_{ca}(28) - \epsilon_{ca}(3)) + \alpha_c T2) R2 + Kc2 \epsilon_{cd} R3$	ϵ_r	0.000194	
Table 3.1	Elastic modulus of the reinforcement	E_s	200000	MPa
	Bars provided on one face $1000 \pi \phi^2 / (4 s)$	A_s	1340	mm ² /m
C766 Table 3.2	Concrete in tension per face $A_{ct} = 0.5 h \cdot 1000$	A_{ct}	200000	mm ² /m
C766 Table 3.2	Coefficient k (1.0 at $h \leq 300$, 0.65 at $h \geq 800$)	k	0.930	
C766 Table 3.2	Coefficient kc (direct tension)	k_c	1.0	
C766 (3.12)	End restraint, early age: $0.5 \alpha_c k_c k_{fctk} 0.05 (1 + 1/(\alpha_c \rho)) / E_s$	ϵ_{cr}	0.000441	
C766 (3.10)	Edge restraint, early age: $\epsilon_r - 0.5 \epsilon_{ctu} (\geq 0)$	ϵ_{cr}	0.000053	
	Crack-inducing strain, early age (restraint entered)	ϵ_{cr}	0.000053	
C766 (3.12)	End restraint, long term: $0.5 \alpha_c k_c k_{fctk} 0.05 (1 + 1/(\alpha_c \rho)) / E_s$	ϵ_{cr}	0.000732	
C766 (3.10)	Edge restraint, long term: $\epsilon_r - 0.5 \epsilon_{ctu} (\geq 0)$	ϵ_{cr}	0.000133	
	Crack-inducing strain, long term (restraint entered)	ϵ_{cr}	0.000133	

Calculation · minimum steel, crack spacing and width (7.3)

C766 (3.19)	Early age: $k_{Redge} = 1 - 0.5 R1$ (end restraint: 1)	k_{Redge}	0.750	
C766 (3.20)	Early age: $A_{s,min} = k_{Redge} k_c k_{Act} 0.7 f_{ctm}(3) / f_{yk}$	$A_{s,min}$	338	mm ² /m
C766 (3.19)	Long term: $k_{Redge} = 1 - 0.5 \min(R2; R3)$ (end restraint: 1)	k_{Redge}	0.750	
C766 (3.20)	Long term: $A_{s,min}$ with $0.7 f_{ctm}(28)$	$A_{s,min}$	566	mm ² /m
7.3.2(2)	$A_{s,min}$ required (each age at which cracks form; none: 28 days)	$A_{s,min}$	566	mm ² /m
7.3.2	Bars provided $\geq A_{s,min}$	A_s	1340	mm ² /m
7.3.2(3)	Effective tension depth per face $\min(h/2; 2.5 (c + \phi/2))$	$h_{c,ef}$	120	mm
(7.10)	Effective reinforcement ratio $A_s / (1000 h_{c,ef})$	$\rho_{p,eff}$	0.0112	
C766 3.5.2	Bond coefficient k1 (poor bond at early age: 0.8 / 0.7)	k_1	0.800	
(7.11), 7.3.4(3)	Maximum crack spacing $k_3 c + k_4 k_1 \phi / \rho_{p,eff}$ ($k_2 = 1$)	$S_{r,max}$	623	mm
(7.8)	Crack width at early age $S_{r,max} \epsilon_{cr}$ (if cracked)	w_k	0.033	mm
(7.8)	Crack width in the long term ($\geq$ the early-age width)	w_k	0.083	mm

$S_{r,max}$: not less than 1.3 h where the bars are further apart than $5 (c + \phi/2)$ (7.3.4(3)). Widths are reported only where cracks form ($\epsilon_r > \epsilon_{ctu}$, C766 3.2.1). Cracks formed at early age stay open: the long-term width is at least the early-age one and the long-term crack-inducing strain (edge restraint: the cracks widen; end restraint: the 28-day strength, conservative). $A_{s,min}$ is checked for each age at which cracks form, with the restraint of that stage.

The early-age crack width uses the 3-day properties and the long-term width the 28-day ones (C766 3.3.1.2, 3.3.2.2). For end restraint the width depends on the tensile strength at cracking, not on the size of the strain; for edge restraint it follows the restrained strain, so reducing T1 or the restraint reduces it. Check the bars for the structural load cases separately (RC-003, RC-016).

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Nationally Determined Parameters

Values used by the Calculation sheet for the selected National Annex. Sources: UK NA to BS EN 1992-1-1:2004, Table NA.1; PN-EN 1992-1-1:2008, Załącznik krajowy NA. Edit only if your project specifies different values.

Parameter	Clause	UK NA	PL NA	Notes
Partial factor, concrete γ_c	2.4.2.4(1)	1.5	1.4	Persistent & transient. UK NA: recommended; PL: NA.2, Table NA.2
Partial factor, reinforcement γ_s	2.4.2.4(1)	1.15	1.15	UK NA: recommended; PL: NA.2, Table NA.2
α_{cc} (compression in flexure / axial)	3.1.6(1)	0.85	1	UK NA: 0.85; PL: recommended (NA.9)
α_{cc} (shear and punching)	3.1.6(1)	1	1	UK NA: 1.0 for other phenomena; PL: recommended (NA.9)
α_{ct} (design tensile strength)	3.1.6(2)	1	1	Recommended value in both annexes
CRd,c numerator (CRd,c = value / γ_c)	6.2.2(1), 6.4.4(1)	0.18	0.18	Recommended value in both annexes
k1 (axial stress term, punching)	6.4.4(1)	0.1	0.1	Recommended value in both annexes
$v_{Rd,max}$ factor ($v_{Rd,max} = \text{factor} \cdot v \cdot f_{cd}$)	6.4.5(3)	0.5	0.4	UK NA: 0.5 v fcd; PL: recommended value (NA.9), 0.4 v fcd since EN 1992-1-1 AC:2010 (PN-EN 1992-1-1:2008)
kmax ($v_{Ed} \leq k_{max} \cdot v_{Rd,c}$ at u1)	6.4.5	2	1.5	UK NA 6.4.5(3): 2 vRd,c. PL: no limit in PN-EN 1992-1-1:2008; 1.5 (A1:2014 recommendation) applied conse
ϕ_{large} (large bar threshold, mm)	8.8(1)	40	32	UK NA: 40 mm; PL: 32 mm recommended (NA.9)
cot θ upper limit (variable strut)	6.2.3(2)	2.5	2	UK NA: 2.5 (1.25 with axial tension); PL: NA.4, $1 \leq \cot \theta \leq 2.0$
k1 (x/d limit, $\delta \geq k_1 + k_2 x_u/d$)	5.5(4)	0.4	0.44	UK NA for $f_{yk} \leq 500$ MPa; PL: recommended (NA.9)
k2 (x/d limit, $\epsilon_{cu2} = 0.0035$)	5.5(4)	1	1.25	UK NA: $0.6 + 0.0014/\epsilon_{cu2}$; PL: $1.25(0.6 + 0.0014/\epsilon_{cu2})$
Upper limit on the (310/ σ_s) factor (0 = none)	7.4.2(2)	1.5	0	UK NA Table NA.5 Note 5: (310/ σ_s) or (500/ f_{yk})($A_{s,prov}/A_{s,req}$) ≤ 1.5 ; PL: none
L/d not to exceed 40 K (1 = applies)	7.4.2(2)	1	0	UK NA Table NA.5 Note 6; not in EN text
ϕ_{min} (longitudinal bars in columns, mm)	9.5.2(1)	12	6	UK NA: 12 mm; PL: NA.6, 6 mm
k3 (crack spacing)	7.3.4(3)	3.4	3.4	Recommended value in both annexes
k4 (crack spacing)	7.3.4(3)	0.425	0.425	Recommended value in both annexes