

Beam bending & shear

Rectangular RC sections · EN 1992-1-1 §6.1, §6.2, §9.2 · UK NA / PN-EN

Reference	NAE-RC-004 · 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)
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

Ultimate limit state design of a rectangular reinforced concrete section: tension and, where needed, compression reinforcement for a bending moment, and vertical links for a shear force using the variable strut inclination method, with the minimum and maximum reinforcement rules for beams.

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

Rectangular section, one layer of tension bars and one of compression bars, no axial force. Rectangular stress block ($\lambda = 0.8$, $\eta = 1.0$) for concrete classes up to C50/60. The neutral axis is limited by 5.5(4) for the chosen redistribution ratio δ , with $\delta \geq 0.7$ (class B, C) or 0.8 (class A); the redistribution itself must come from a linear analysis meeting 5.5. Reinforcement $f_{yk} \leq 500$ MPa. Bars in one layer each, spacing to 8.2(2). Vertical links ($\alpha = 90^\circ$), no axial load in shear ($\alpha_{cp} = 0$), $\alpha_{cw} = 1.0$. Flanged sections, torsion, the shift rule (9.2.1.3) and the additional tensile force ΔF_{td} are outside the scope. VEd should be taken at the appropriate section (6.2.1(8)). The second-generation EN 1992-1-1:2023 is not yet implemented.

Further reading and independent cross-check

- The Concrete Centre, How to design concrete structures using Eurocode 2: Beams.
 - The Concrete Centre, Worked Examples to Eurocode 2: Volume 1.
 - The Concrete Centre, RC Spreadsheets v4, TCC11 Element Design (licensed product) can be used as an independent cross-check.
- NA Engineering is not affiliated with The Concrete Centre or CIRIA; their publications are referenced for information only.

About NA Engineering

NA Engineering is a structural engineering consultancy delivering structural design, reinforced concrete modelling and detailing, and steel detailing for residential, commercial, infrastructure, energy and refurbishment projects. We share tools like this one because good engineering should be transparent: every formula here is visible and referenced. If you need a design, a check or a full detailing package, talk to us.

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Disclaimer

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Revision history

v1.0	29 Oct 2026 · First issue
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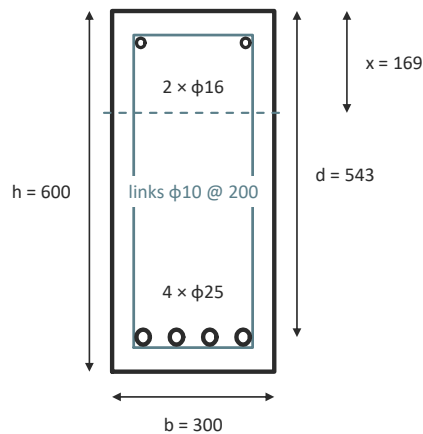
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Made by
Checked

Inputs · section
Shaded cells only

	National Annex		UK NA (BS EN)	
Table 3.1	Concrete strength class		C32/40	
3.2.2	Reinforcement characteristic yield strength (≤ 500 MPa)	f_{yk}	500	MPa
Annex C	Reinforcement ductility class		B	
8.2(2)	Maximum aggregate size	d_g	20	mm
	Section width	b	300	mm
	Section depth	h	600	mm
4.4.1	Nominal cover to links	c_{nom}	35	mm
	Link diameter	φ_w	10	mm
	Tension bar diameter	φ	25	mm
	Number of tension bars (one layer)	n	4	
	Compression bar diameter	φ_2	16	mm
	Number of compression bars (one layer)	n_2	2	

Your section, to scale · changes with every input


Inputs · actions and links
ULS design values

	Design bending moment	M_{Ed}	350.0	kNm
5.5(4)	Moment redistribution ratio (1.0 = none)	δ	1.00	≥ 0.7 (B, C) / 0.8 (A)
6.2.1(8)	Design shear force	V_{Ed}	250.0	kN
	Link yield strength	f_{ywk}	500	MPa
	Number of link legs	n_w	2	
	Link spacing	s	200	mm
	Inputs valid and consistent			OK

Results

	Tension reinforcement provided / required	A_{s1}	1.16		OK
	Compression reinforcement required	A_{s2}	0	mm ²	Not needed

If the compression bars are not above the neutral axis ($f_{sc} \leq 0$) the section cannot be designed with compression steel: increase the depth or the concrete class.

Concrete strut crushing $V_{Ed} / V_{Rd,max}$		0.44	OK
Shear: struts, links, longitudinal link spacing (A_{sw}/s prov / req)		1.67	OK
Strut inclination used	$\cot \vartheta$	2.50	

Calculation · bending

2.4.2.4(1)	Partial factor, concrete	γ_c	1.50	NDP sheet
2.4.2.4(1)	Partial factor, reinforcement	γ_s	1.15	NDP sheet
3.1.6(1)	Coefficient on compressive strength (flexure)	α_{cc}	0.85	NDP sheet
5.5(4)	Coefficient for x/d limit	k_1	0.40	NDP sheet
5.5(4)	Coefficient for x/d limit	k_2	1.00	NDP sheet
Table 3.1	Characteristic cylinder strength	f_{ck}	32	MPa
Table 3.1	Mean tensile strength	f_{ctm}	3.02	MPa
3.1.6(1)	Design compressive strength $\alpha_{cc} f_{ck} / \gamma_c$	f_{cd}	18.13	MPa
3.2.7	Design yield strength	f_{yd}	434.8	MPa
	Effective depth $h - c - \phi_w - \phi/2$	d	543	mm
	Depth to compression bars $c + \phi_w + \phi/2$	d_2	53	mm
	Moment ratio $M_{Ed} / (b d^2 f_{ck})$	K	0.124	
3.2.7	Neutral axis depth at first yield $\epsilon_{cu2} / (\epsilon_{cu2} + f_{yd}/E_s)$	ξ_y	0.617	
5.5(4)	Limiting neutral axis depth $\min((\delta - k_1) / k_2; \xi_y)$	$x_{u/d}$	0.600	
3.1.7(3)	Limiting K (α_{cc}/γ_c) $0.8 \xi (1 - 0.4 \xi)$	K'	0.207	
3.1.7(3)	Neutral axis depth ratio	x/d	0.312	
	Neutral axis depth	x	169	mm
	Lever arm $d (1 - 0.4 x/d) \leq 0.95 d$	z	475	mm
	Moment resisted by concrete at K'	M_{lim}	584.1	kNm
3.2.7	Stress in compression bars $E_s \epsilon_{cu2} (x - d_2)/x \leq f_{yd}$	f_{sc}	434.8	MPa
	Compression reinforcement required	$A_{s2,req}$	0	mm ²
	Tension reinforcement required	$A_{s1,req}$	1696	mm ²
	Tension reinforcement provided $n \pi \phi^2 / 4$	$A_{s1,prov}$	1963	mm ²
	Compression reinforcement provided	$A_{s2,prov}$	402	mm ²
(9.1N)	Minimum tension reinforcement $\max(0.26 f_{ctm}/f_{yk}; 0.0013) b d$	$A_{s,min}$	256	mm ²
9.2.1.1(3)	Maximum tension or compression reinforcement $0.04 A_c$	$A_{s,max}$	7200	mm ²
8.2(2)	Minimum clear gap, tension bars $\max(\phi; d_g + 5; 20)$	$a_{min,1}$	25	mm
8.2(2)	Minimum clear gap, compression bars $\max(\phi/2; d_g + 5; 20)$	$a_{min,2}$	25	mm
8.2(2)	Vertical clear distance between layers $h - 2c - 2\phi_w - \phi - \phi/2$	a_v	469	mm
8.2(2)	Minimum vertical clear distance $\max(\phi; \phi/2; d_g + 5; 20)$	$a_{min,v}$	25	mm
	Clear gap, tension bars $(b - 2c - 2\phi_w - n\phi)/(n - 1)$	a_1	37	mm
	Clear gap, compression bars	a_2	178	mm
	Tension bars $A_{s1,prov} \geq \max(A_{s1,req}; A_{s,min})$	A_{s1}	1963	mm ²
	Compression bars $A_{s2,prov} \geq A_{s2,req}$ (and above the neutral axis)	A_{s2}	402	mm ²
9.2.1.1(3)	Tension and compression areas each $\leq A_{s,max}$		1963	mm ²
8.2(2)	Tension bars fit in one layer $a_1 \geq a_{min}$	a_1	37	mm
8.2(2)	Compression bars fit in one layer $a_2 \geq a_{min,2}$	a_2	178	mm
8.2(2)	Vertical clear distance between layers $a_v \geq a_{min,v}$	a_v	469	mm

Calculation · shear

6.2.2(1), 6.4.4(1)	Coefficient $0.18 / \gamma_c$	$C_{Rd,c}$	0.120	NDP sheet
3.1.6(1)	Coefficient on compressive strength (shear)	α_{cc}	1.00	NDP sheet
6.2.3(2)	Upper limit of $\cot \theta$	$\cot \vartheta_{max}$	2.50	NDP sheet
6.2.2(1)	Size factor $1 + \sqrt{200/d} \leq 2$	k	1.607	
6.2.2(1)	Tension reinforcement ratio $A_{s1,prov} / (b d) \leq 0.02$	ρ_l	0.0121	Bars anchored beyond the section
(6.3N)	Minimum shear stress	v_{min}	0.403	MPa
(6.2)	Resistance without shear reinforcement	$V_{Rd,c}$	106.1	kN
6.2.3(1)	Inner lever arm $0.9 d$	z	488	mm

(6.6N)	Strength reduction factor $v_1 = 0.6 (1 - f_{ck}/250)$	v_1	0.523	
3.1.6(1)	Design compressive strength for shear	$f_{cd,v}$	21.33	MPa
(6.9)	Shear ratio $2 V_{Ed} / (b z v_1 f_{cd}) (= V_{Ed} / V_{Rd,max} \text{ at } 45^\circ)$		0.306	
6.2.3(2)	Strut inclination $1 \leq \cot \theta \leq \cot \theta_{max}$	$\cot \theta$	2.500	
(6.9)	Maximum shear resistance $b z v_1 f_{cd} / (\cot \theta + \tan \theta)$	$V_{Rd,max}$	563.8	kN
3.2.7	Design yield strength of links	f_{ywd}	434.8	MPa
(6.8)	Links required for V_{Ed} $V_{Ed} / (z f_{ywd} \cot \theta)$	$A_{sw/s}$	0.471	mm ² /mm
(9.5N)	Minimum links $0.08 \sqrt{f_{ck}} / f_{yk} \cdot b$	$A_{sw/s,min}$	0.272	mm ² /mm
	Links needed $\max(\text{required}; \text{minimum})$		0.471	mm ² /mm
	Links provided $n_w \pi \phi w^2 / 4 / s$	$A_{sw/s,prov}$	0.785	mm ² /mm
(6.8)	Shear resistance of links provided	$V_{Rd,s}$	416.8	kN
(9.6N)	Maximum longitudinal link spacing $0.75 d$	$s_{l,max}$	407	mm
(6.9)	Shear force against crushing of struts	V_{Ed}	250.0	kN
(6.8)	Links $A_{sw/s}$ provided $\geq$ needed		0.785	mm ² /mm
(9.6N)	Link spacing $s \leq 0.75 d$	s	200	mm

Not in the shear status: transverse spacing of legs and the additional tensile force in the longitudinal bars. Minimum links are provided even where $V_{Ed} \leq V_{Rd,c}$ (9.2.2(5)). Transverse spacing of legs should not exceed $0.75d$ or 600 mm (9.2.2(8)). Check the longitudinal bars for the additional tensile force from shear (6.2.3(7), shift rule 9.2.1.3).

Prepared with NA Engineering calculation tools · naengineering.uk · adrian@naengineering.uk. Free for use by competent engineers; see the About sheet for scope and disclaimer.

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)
$\alpha_{cc,pl}$ (plain concrete, compression)	12.3.1(1)	0.6	0.8	UK NA Table NA.1: 0.6; 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
vRd,max factor (vRd,max = factor · v · fcd)	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 (vEd ≤ kmax · vRd,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, $\delta \geq k1 + k2 x_u/d$)	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