

Deep beam

Simply supported deep beams · strut-and-tie, EN 1992-1-1 §6.5, §9.7 · UK NA / PN-EN

Reference	NAE-RC-044 · 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
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What it does

Design of a simply supported deep beam (span less than three times the depth, 5.3.1(3)) under a uniformly distributed load and a point load at midspan by a strut-and-tie model: tie force and bars, the support (CCT) and loaded (CCC) nodes and bearings, the bottle-shaped struts and their splitting force, the anchorage of the tie from the node face and the web mesh of 9.7.

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 beam of constant width, one span on two equal bearings, loads on the top face: a design UDL wEd over the span between bearing centres (include the self weight) and a design point load FEd at midspan on a plate as wide as the beam. Bearings as wide as the beam. Two trusses share one tie on the centroid of the bottom bars and one top chord: the UDL of each half span goes down a strut from a node at $l/4$, the point load down two struts from a node under the plate. Lever arm $z = \min(z0; zel)$: $z0$ from a compression block at the top at $k1 \cdot v' \cdot fcd$, $b \cdot y0 \cdot k1 \cdot v' \cdot fcd$ ($de - y0/2 = M$, and $zel = \min(0.2 \cdot (l + 2h); 0.6 \cdot l)$), the elastic deep-beam lever arm of CEB-FIP and CIRIA Guide 2 (extrapolated above $l/h = 2$, where $z0$ usually governs); $de = \min(h; l) - u$, as above a height l the wall only carries load down. Top node depth $y0$ where $z0$ governs, else $2 \cdot (de - z)$. Struts no flatter than 26.6° ($\cot \theta \leq 2$). Nodes to 6.5.4(4): at the support the two struts are taken as their resultant on a node of height $2u$ (Figure 6.27), bearing and strut face at $k2 \cdot v' \cdot fcd$; at the top the plate ($FEd / (a2 \cdot b)$) plus the whole UDL $/ b$, the top chord and the strut faces at $k1 \cdot v' \cdot fcd$, the point-load strut on $a2/2$ of the plate, the UDL node smeared over $l/2$; the top chord between the UDL nodes carries $Rw \cdot (l/4) / z$ and the midspan section the whole T . Each strut is checked at $0.6 \cdot v' \cdot fcd$ (6.5.2(2)) on its narrower end (conservative; the strut at the support on its share of the node face), and the splitting force (6.59) of a bottle (Figure 6.25 b) is carried by the mesh crossing the strut over $H/2$, the mesh shared by the two struts. Tie anchorage (8.4, as RC-001) from the inner face of the bearing (6.5.4(7)) within the end of the beam: straight, or for one layer a 90° bend up with the mandrel of Table 8.1N and (8.1) and a 5ϕ tail inside the mesh; bars above $\phi large$ are flagged for 8.8; good bond, $\alpha3 = \alpha4 = \alpha5 = 1$; between layers cd also $\leq$ half the clear gap. Mesh $As,dbmin$ and spacing of 9.7; the horizontal mesh bars start a clear gap above the top tie layer. Cover: $c \geq \phi$ (+ 5 mm for $dg > 32$) for bond (4.4.1.2) is checked; durability and fire cover are the user's. Crack widths, deflection, lateral stability of thin beams, loads hung from the bottom face, openings and continuous deep beams are not covered. 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

- EN 1992-1-1, 5.3.1, 5.6.4, 6.5, 8.3, 8.4 and 9.7.
- CIRIA Guide 2, The design of deep beams in reinforced concrete (lever arm zel).
- fib Bulletin 61, Design examples for strut-and-tie models.
- IStructE, Manual for the design of concrete building structures to Eurocode 2.

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Revision history

v1.0 30 Oct 2026 · First issue

Project
Element
Date

Job no.
Made by
Checked

Inputs · beam

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
8.2(2)	Maximum aggregate size	d_g	20	mm
	Beam width (thickness)	b	450	mm
	Overall depth	h	1800	mm
5.3.1(3)	Span between bearing centres ($l < 3h$: deep beam)	l	4500	mm
	End of the beam beyond the bearing centre ($\geq a_1/2$)	e	500	mm
	Support bearing length (along the span)	a_1	550	mm
	Load plate length at midspan (along the span)	a_2	600	mm
4.4.1	Nominal cover to the web mesh ($\geq \phi$ for bond; durability by the	c_{nom}	40	mm

Inputs · reinforcement

Tie bars inside the vertical mesh bars

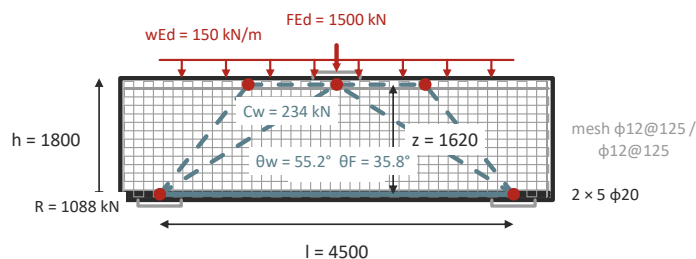
	Tie bars: diameter	ϕ_t	20	mm
	Tie bars: number in each layer	n_t	5	
	Tie bars: layers (clear gap between layers $\max(\phi; d_g + 5; 20)$)	n_l	2	
9.7(3)	Tie bar ends		Straight	
9.7(1)	Web mesh, vertical bars: diameter (outermost)	ϕ_v	12	mm
9.7(2)	Web mesh, vertical bars: spacing	s_v	125	mm
9.7(1)	Web mesh, horizontal bars: diameter	ϕ_h	12	mm
9.7(2)	Web mesh, horizontal bars: spacing	s_h	125	mm

Inputs · actions

ULS design values

	Uniformly distributed load over the span (with self weight)	w_{Ed}	150.0	kN/m
	Point load at midspan	F_{Ed}	1500	kN
	Inputs valid and consistent			OK

Your deep beam, to scale · elevation · struts (dashed), tie (solid) and nodes (red) of the two trusses



Results

Deep beam $l/h < 3$ and strut model valid ($\theta \geq 26.6^\circ$)	l/h	2.50	OK
Tie $A_{s,req} / A_{s,prov}$ (bars fit across the width)	A_s	0.93	OK
Support node (CCT): bearing and strut face $\sigma / k_2 v' f_{cd}$		0.57	OK
Top node (CCC): load plate, top chord, strut faces $\sigma / k_1 v' f_{cd}$		0.94	OK
Struts: body $0.6 v' f_{cd}$ and splitting force on the mesh		0.91	OK
Tie anchorage from the node face l_{bd} / l_{av} (and the bend)		0.88	OK
Web mesh 9.7: $A_{s,dbmin} / A_s$ and spacing		0.99	OK

No compression block fits at the top (z_0 not real): increase b , h or the concrete class. $\theta < 26.6^\circ$: the beam is too shallow for this model. $l/h \geq 3$: not a deep beam; design it as a beam (RC-004). Anchorage too short: lengthen the end of the beam, bend the bars up (9.7(3)) or use more, smaller bars.

Calculation · materials

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
3.1.6(2)	Coefficient on tensile strength	α_{ct}	1.00	NDP sheet
8.8(1)	Large bar threshold	ϕ_{large}	40	mm
6.5.4(4)a	k_1 (CCC node)	k_1	1.00	NDP sheet
6.5.4(4)b	k_2 (CCT node)	k_2	0.85	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
(6.57N)	$v' = 1 - f_{ck} / 250$ (recommended; UK NA and PL NA.9)	v'	0.872	
(6.60)	CCC node limit $k_1 v' f_{cd}$	$\sigma_{Rd,CCC}$	15.81	MPa
(6.61)	CCT node limit $k_2 v' f_{cd}$	$\sigma_{Rd,CCT}$	13.44	MPa
(6.56)	Strut with transverse tension $0.6 v' f_{cd}$	$\sigma_{Rd,max}$	9.49	MPa

Calculation · geometry and actions

5.3.1(3)	Span to depth l/h (< 3 : deep beam)	l/h	2.50	
8.2(2)	Clear gap between tie bars and layers $\max(\phi t; dg + 5; 20)$	a_{min}	25	mm
Figure 6.27	Tie centroid $c + \phi v + \phi t/2 + (nl - 1)(\phi t + a_{min})/2$	u	84.5	mm
	Effective depth $h - u$	d	1715.5	mm
	Active depth $\min(h; l) - u$	d_e	1715.5	mm
	Reaction from the UDL $wEd / 2$	R_w	337.5	kN
	Reaction from the point load $FEd / 2$	R_F	750.0	kN
	Support reaction $R_w + RF$	R	1087.5	kN
	Midspan moment $wEd l^2 / 8 + FEd l / 4$	M_{Ed}	2067.2	kNm
	Resultant of the struts at the support $a = M / R$	a	1900.9	mm

Calculation · trusses

6.5.4(4)a	Compression block at $k_1 v' f_{cd}$ ($de - v(de^2 - 2M / (b \sigma_{Rd,CCC}))$)	y_0	178.7	mm	N/A: no block fits
6.5	Lever arm from the node $z_0 = de - y_0/2$	z_0	1626.2	mm	
CIRIA Guide 2	Elastic deep-beam lever arm $\min(0.2(l + 2h); 0.6l)$	z_{el}	1620.0	mm	
	Lever arm used $\min(z_0; z_{el})$	z	1620.0	mm	
	Top node depth (z_0 governs: y_0 ; else $2(de - z)$)	y	191.0	mm	
6.5	Tie force M / z (= compression through the section at midspan)	T	1276.0	kN	
6.5	Top chord between the UDL nodes $R_w(l/4) / z$	C_w	234.4	kN	
	UDL struts to $l/4$ $\tan \theta_w = z / (l/4)$	$\tan \theta_w$	1.440		
	Point-load struts to $l/2$ $\tan \theta_F = z / (l/2)$	$\tan \theta_F$	0.720		
	Flattest strut present $\tan \theta \geq 0.5$ ($\theta \geq 26.6^\circ$)	$\tan \theta$	0.720		
	Angles θ_w, θ_F	θ_w	55.2	°	

		ϑ_F	35.8	°
6.5	UDL strut force $R_w / \sin \theta_w$	$F_{c,w}$	410.9	kN
6.5	Point-load strut force $RF / \sin \theta_F$	$F_{c,F}$	1283.6	kN
	Resultant at the support $\tan \theta = z / a$	$\tan \vartheta$	0.852	
	Resultant angle	ϑ	40.4	°
6.5	Resultant strut force $R / \sin \theta$	F_c	1676.6	kN

Calculation · tie

	Required T / f_{yd}	$A_{s,req}$	2935	mm ²	
	Provided $n_l n_t \pi \phi_t^2 / 4$	$A_{s,prov}$	3142	mm ²	
6.5.2(3)	Tie $A_{s,req} \leq A_{s,prov}$	$A_{s,prov}$	3142	mm ²	OK
	Side cover to the tie $c + \phi_v$ (bent bars: $+\phi_h$, inside the mesh)	c_s	52	mm	
	Clear gap $(b - 2c_s - n_t \phi_t) / (n_t - 1)$	a	61.5	mm	
8.2(2)	Tie bars fit $a \geq a_{min}$	a	61.5	mm	OK

Calculation · nodes

6.5.4(4)b	Support bearing $R / (a_1 b)$	$\sigma_{Ed,1}$	4.39	MPa	
Figure 6.27	Strut width at the support $a_1 \sin \theta + 2u \cos \theta$	w_1	485.4	mm	
6.5.4(4)b	Strut face at the support $F_c / (b w_1)$	$\sigma_{Ed,2}$	7.68	MPa	
(6.61)	Support node $\max(\sigma_{Ed,1}; \sigma_{Ed,2}) \leq k_2 v' f_{cd}$	σ_{Ed}	7.68	MPa	OK
6.5.4(4)a	Load plate $FE_d / (a_2 b) + wEd / b$ (whole UDL on the top face)	$\sigma_{Ed,3}$	5.89	MPa	
6.5.4(4)a	Midspan node, vertical face $T / (b y)$ (chord + point-load struts)	$\sigma_{Ed,4}$	14.85	MPa	
6.5.4(4)a	UDL strut, top end $y \cos \theta_w + (l/2) \sin \theta_w$ (smeared)	$w_{2,w}$	1957.0	mm	
6.5.4(4)a	Point-load strut, top end $y \cos \theta_F + (a_2/2) \sin \theta_F$	$w_{2,F}$	330.3	mm	
6.5.4(4)a	Strut faces at the top $\max(F_c / (b w_2))$	$\sigma_{Ed,5}$	8.64	MPa	
(6.60)	Top node $\max(\sigma_{Ed,3}; \sigma_{Ed,4}; \sigma_{Ed,5}) \leq k_1 v' f_{cd}$	σ_{Ed}	14.85	MPa	OK

Calculation · struts (0.6 v' fcd on the narrower end; splitting (6.59))

	UDL strut: length $\sqrt{a^2 + z^2}$, $a = l/4$	H_w	1972.3	mm	
Figure 6.25	UDL strut: narrower end $\min(w_1 \text{ share}; w_2)$	a_w	117.7	mm	
6.5.2(2)	UDL strut: stress on the narrower end $F_c / (b a)$	$\sigma_{c,w}$	7.76	MPa	
(6.59)	UDL strut: splitting force $\frac{1}{4} (1 - 0.7 a / (H/2)) F_c (\geq 0)$	$T_{s,w}$	94.1	kN	
6.5.3(3)	UDL: mesh $2 f_{yd} (A_{s,h} \sin^2 \theta + A_{s,v} \cos^2 \theta) H/2$	$T_{Rd,w}$	775.9	kN	
	Point-load strut: length $\sqrt{a^2 + z^2}$, $a = l/2$	H_F	2772.5	mm	
Figure 6.25	Point-load strut: narrower end $\min(w_1 \text{ share}; w_2)$	a_F	330.3	mm	
6.5.2(2)	Point-load strut: stress on the narrower end $F_c / (b a)$	$\sigma_{c,F}$	8.64	MPa	
(6.59)	Point-load strut: splitting force $\frac{1}{4} (1 - 0.7 a / (H/2)) F_c (\geq 0)$	$T_{s,F}$	267.4	kN	
6.5.3(3)	Point-load: mesh $2 f_{yd} (A_{s,h} \sin^2 \theta + A_{s,v} \cos^2 \theta) H/2$	$T_{Rd,F}$	1090.7	kN	
6.5.2(2), 6.5.3(3)	Struts $\sigma_c \leq 0.6 v' f_{cd}$; mesh shared $T_{s,w}/TR_{d,w} + T_{s,F}/TR_{d,F} \leq 1$		0.37		OK

Calculation · anchorage of the tie, 8.4

3.1.6(2)	Design tensile strength $\alpha_t 0.7 f_{ctm} / \gamma_c$	f_{ctd}	1.411	MPa	
Figure 8.2	Bond condition of the top layer (good: 1; else 0.7)	η_1	1.0		
(8.2)	Bond stress $2.25 \eta_1 \eta_2 f_{ctd}$	f_{bd}	3.18	MPa	
8.4.3(2)	Stress in the bars $T / A_{s,prov} (\leq f_{yd})$	σ_{sd}	406.2	MPa	
(8.3)	Basic length $\phi \sigma_{sd} / (4 f_{bd})$	$l_{b,rqd}$	640	mm	
Figure 8.3	Cover dimension $\min(a/2; \text{layer gap}/2; c_s)$	c_d	12.5	mm	
Table 8.2	α_1 (bend with $cd > 3 \phi$: 0.7)	α_1	1.00		
Table 8.2	α_2 straight $1 - 0.15 (cd - \phi)/\phi$; bend $1 - 0.15 (cd - 3\phi)/\phi$ (0.7 –	α_2	1.000		
(8.6)	Minimum $\max(0.3 l_{b,rqd}; 10 \phi; 100)$	$l_{b,min}$	200	mm	
(8.4)	Design anchorage length $\max(\alpha_1 \alpha_2 l_{b,rqd}; l_{b,min})$	l_{bd}	640	mm	
6.5.4(7)	Available $a_1/2 + e - c - \phi_v$ (bearing face to bar end)	l_{av}	723	mm	
9.7(3)	Anchorage $l_{bd} \leq l_{av}$	l_{bd}	640	mm	OK
8.3	Bend: bar force $\sigma_{sd} \pi \phi^2 / 4$ (full force, conservative)	F_{bt}	127.6	kN	
8.3	Bend: $ab = \min(\text{half the bar centres}; c_s + \phi/2)$	a_b	40.8	mm	
Table 8.1N, (8.1)	Bend: mandrel $\max(4\phi \text{ or } 7\phi; F_{bt} (1/ab + 1/(2\phi)) / f_{cd})$	φ_m	349	mm	

Figure 8.1 b	Bend: top of the 5 ϕ tail $y_{\text{top}} + \phi m/2 + \phi + 5\phi$	y_{tail}	401	mm	
8.3, 8.4.1	Bend: one layer, tail top $\leq h - c - \phi v$ (straight bars: n/a)	y_{tail}	401	mm	OK

Calculation · web mesh, 9.7

9.7(1)	As,dbmin / Ac (each face and direction)		0.002		NDP sheet
9.7(1)	Lower bound (0 = none)		0	mm ² /m	NDP sheet
9.7(1)	Minimum per face $\max(\text{ratio} \cdot b \cdot 1000; \text{lower bound})$	$A_{s,dbmin}$	900	mm ² /m	
	Horizontal bars per face $\pi \phi h^2 / 4 \cdot 1000 / sh$	$A_{s,h}$	905	mm ² /m	
	Vertical bars per face $\pi \phi v^2 / 4 \cdot 1000 / sv$	$A_{s,v}$	905	mm ² /m	
9.7(2)	Maximum spacing $\min(2b; 300)$	s_{max}	300	mm	
8.2(2)	Minimum clear gap, horizontal bars $\max(\phi h; dg + 5; 20)$	$a_{h,min}$	25	mm	
8.2(2)	Minimum clear gap, vertical bars $\max(\phi v; dg + 5; 20)$	$a_{v,min}$	25	mm	
9.7(1), (2)	As,h and As,v $\geq A_{s,dbmin}$; sh, sv $\leq s_{\text{max}}$; clear gaps $\geq a_{\text{min}}$	A_s	905	mm ² /m	OK
	Vertical bars per face (drawn)	n_v	44		
	Horizontal bars per face (drawn)	n_h	13		

The tie bars sit inside the vertical mesh bars, which wrap under them as U-bars (cover c to the mesh). Anchor the tie for its full force from the inner face of each bearing (6.5.4(7), 9.7(3)); the available length is the straight run to the bar end, which for a bend is the outer face of its upstand (Figure 8.1 b). Concentrated loads hung from the bottom face need their own hanger reinforcement. The mesh carries the splitting force of the bottle-shaped struts (6.5.3(3)); the two struts' bottles overlap, so the mesh is shared: the sum of their utilisations is checked. Check crack widths where the exposure needs it (7.3).

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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)
$\alpha_{cc,pl}$ (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
k1 (CCC node, $\sigma_{Rd,max} = k1 v' fcd$)	6.5.4(4)a	1	1	Recommended value in both annexes (UK NA Table NA.1; PL NA.9)
k2 (CCT node, $\sigma_{Rd,max} = k2 v' fcd$)	6.5.4(4)b	0.85	0.85	Recommended value in both annexes (UK NA Table NA.1; PL NA.9)
$A_s,dbmin$ / A_c (deep beam mesh, each face an	9.7(1)	0.002	0.001	UK NA: 0.2 % in each face; PL: recommended 0.001 A_c (NA.9)
$A_s,dbmin$ lower bound (mm ² /m, each face anc	9.7(1)	0	150	UK NA: 0.2 % only, no lower bound stated; PL: recommended 150 mm ² /m (NA.9)