Appendix C – Preliminary Structural Calculations

For

28, Charlotte Street

Fitzrovia

London W1T

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October 2022

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Job No.:	Sheet No.:	Rev:
1964	C1. 1	-

Job title: 28 Charlotte Street

Calculations:	Designed:	Date:	Ckd:
Area Loads	AB	26/10/2022	

Existing flat roof

Dead	Asphalt	0.40 kN/m^2
	Boarding	0.14 kN/m^2
	Insulation	0.05 kN/m^2
	Joists	0.15 kN/m^2
	Services	0.05 kN/m^2
	Plasterboard and skim coat	0.18 kN/m^2
		0.97 kN/m^2
	Imposed (allowing for maintenance of structure above)	1.50 kN/m^2

External brick wall

Dead	345mm brickwork	7.70 kN/m^2
	Plaster	0.25 kN/m^2
		7.95 kN/m^2

External brick wall

Dead	215mm brickwork	4.73 kN/m^2
	Plaster	0.25 kN/m^2
		4.98 kN/m^2

Proposed ground floor internal

Dead	Finishes	0.15 kN/m^2
	Screed	1.40 kN/m^2
	Insulation	0.05 kN/m^2
	200 dp joists	0.15 kN/m^2
	Services	0.15 kN/m^2
	Plasterboard and skim coat	0.18 kN/m^2
		2.08 kN/m^2
Imposed		1.50 kN/m^2
	Partitions	1.00 kN/m^2
		2.50 kN/m^2

Proposed basement floor

Dead	Finishes	0.15 kN/m^2
	75mm Screed	1.40 kN/m^2
	Insulation	0.05 kN/m^2
	300mm RC slab	7.20 kN/m^2
		8.80 kN/m^2
Imposed		1.50 kN/m^2
	Partitions	1.00 kN/m^2
		2.50 kN/m^2

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1964	C1. 2	-

Job title: 28 Charlotte Street

Calculations:	Designed:	Date:	Ckd:
Area Loads	AB	26/10/2022	0

Typical floor

Dead	Finishes	0.15 kN/m^2
	Boarding	0.14 kN/m^2
	Joists	0.15 kN/m^2
	Insulation	0.05 kN/m^2
	Services	0.05 kN/m^2
	Plasterboard and skim coat	0.18 kN/m^2
		0.72 kN/m^2
Imposed		1.50 kN/m^2
	Partitions	1.00 kN/m^2
		2.50 kN/m^2

RC Retaining wall

Dead	300mm reinf. Concrete	6.00 kN/m^2
	Render	0.60 kN/m^2
	Insulation & Waterproofing	0.20 kN/m^2
	Plaster	0.25 kN/m^2
		7.05 kN/m^2

FLOTATION SEMPLIFIED CHECKS

Flotation force = Uplift as noted below

Basement area =	36.15	m2	
GW above formation level =	1.40	m	assumed 1.8m below GL
Water weight =	10	kN/m3	
F = UPLIFT	**506**	**kN**	

Resistance

Reference	Area/L m2	Dead kN/m2	kN
Proposed ground floor	26.7	2.08	55.5
Basement RC walls 300 thk	47.27	7.20	340.3
Basement RC slab 300 thk	36.15	7.20	260.3
GF RC slab and beams 200 thk	8.1	4.80	38.9

Sum = **695 kN**

F.o.S = R / F 1.37 > 1.10 Acceptable

Anchor piles are not required

Refer to relevant sheet for RC Raft design under High Groundwater Pressure

Case 1: WATER UPLIFT

Design for water = 1.4 x 10	14.00	kN/m2		
SWT of 300 thk raft = 0.3 x 24 =	-7.20	kN/m2	6.80 kN/m2	uplift

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Job title: 28 Charlotte Street			
Calculations: Calculations	Designed: AB	Date: 26/10/2022	Ckd: 0

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Calculations:	Designed:	Date:	Ckd:
Calculations	AB	26/10/2022	0

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Job title: 28 Charlotte Street			
Calculations: Calculations	Designed: AB	Date: 26/10/2022	Ckd: 0

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Job No.:	Sheet No.:	Rev:
1964	C2. 1	-

Job title: 28 Charlotte Street

Calculations: Loads on elements | Designed: AB | Date: 26/10/2022 | Ckd: 0

Beam & Load description	Span	Area loads		Width	Location		UDL		Point loads	
		DL	LL		from	to	DL	LL	DL	LL
	mm	kN/m²	kN/m²	mm	mm	mm	kN/m	kN/m	kN	kN
GF steel beams										
	5200									
GF new timber floor		2.08	2.50	1630			3.39	4.08		
New basement side retaing walls supporting new GF beams										
GF new timber floor		2.08	2.50	2600			5.41	6.50		
GF RC beams to restrain top of side retaining wall										
	1630+1630+1630+1400									
retaining wall top propping force							4.00	16.20		
Piles on No 26 side										
	assumed indicative 1.5m centre									
GF	1500	2.08	2.50	2600					8.11	9.75
BF retaining wal	1500	7.20		2900					31.32	0.00
BF	1500	8.80	2.50	3300					43.56	12.38
									82.99	22.13
Piles on No 30 side										
	assumed indicative 1.5m centre									
GF	1500	2.08	2.50	2600					8.11	9.75
BF retaining wal	1500	7.20		2900					31.32	0.00
BF	1500	8.80	2.50	2500					33.00	9.38
									72.43	19.13
Piles to rear wall										
	assumed indicative 1.5m centre									
GF	1500	2.08	2.50	800					2.50	3.00
BF retaining wal	1500	7.20		2900					31.32	0.00
BF	1500	8.80	2.50	1050					13.86	3.94
GF Rc slab	1500	6.40	2.50	1000					9.60	3.75
									57.28	10.69

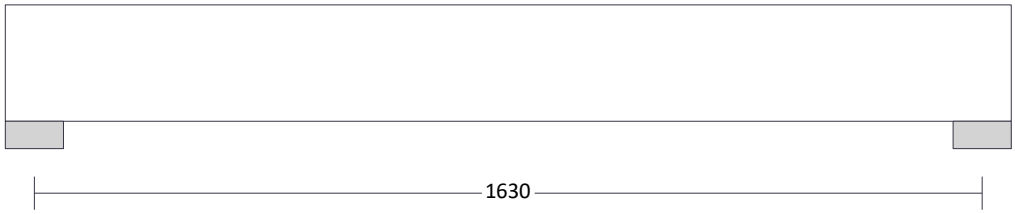
TIMBER JOIST ANALYSIS & DESIGN (EN1995-1-1:2004)

In accordance with EN1995-1-1:2004 + A2:2014 incorporating corrigendum June 2006 and the UK national annex

Tedds calculation version 1.0.06

Joist details

Joist spacing s_{Joist} = **400** mm



Forces input on Joist

Vertical permanent load on joist F_{G_Joist}= **2.10** kN/m^2

Vertical imposed load on joist F_{Q_Joist}= **2.50** kN/m^2

Joist loading details

Distributed loads

Vertical permanent load on joist p_G= **0.84** kN/m

Vertical imposed load on joist p_Q= **1.00** kN/m

Member results summary	Unit	Capacity	Maximum	Utilisation	Result
Bearing stress	N/mm^2	1.7	0.5	0.274	PASS
Bending stress	N/mm^2	16.2	2.8	0.175	PASS
Shear stress	N/mm^2	2.7	0.5	0.192	PASS
Beam stability check				0.175	PASS
Deflection	mm	6.5	1.1	0.170	PASS

ANALYSIS

Tedds calculation version 1.0.37

Loading

Self weight included (Permanent x 1)

Load combination factors

Load combination	Permanent	Imposed	Snow	Wind
1.35G + 1.50Q (Strength)	1.35	1.50	0.00	0.00
1.00G + 1.00Q (Service)	1.00	1.00	0.00	0.00

Member Loads

Member	Load case	Load Type	Orientation	Description
Member	Permanent	UDL	GlobalZ	0.84 kN/m at 0 m to 1.63 m
Member	Imposed	UDL	GlobalZ	1 kN/m at 0 m to 1.63 m

Results

Total deflection

1.35G + 1.50Q (Strength) - Total deflection

1.00G + 1.00Q (Service) - Total deflection

Node deflections

Load combination: 1.35G + 1.50Q (Strength)

Node	Deflection		Rotation	Co-ordinate system
	X (mm)	Z (mm)	(°)	
1	0	0	0.08032	
2	0	0	-0.08032	

Load combination: 1.00G + 1.00Q (Service)

Node	Deflection		Rotation	Co-ordinate system
	X (mm)	Z (mm)	(°)	
1	0	0	0.05616	
2	0	0	-0.05616	

Total base reactions

Load case/combination	Force	
	FX (kN)	FZ (kN)
1.35G + 1.50Q (Strength)	0	4.4
1.00G + 1.00Q (Service)	0	3.1

Element end forces

Load combination: 1.35G + 1.50Q (Strength)

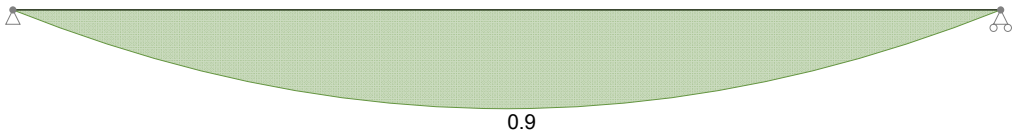
Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	1.63	1	0	-2.2	0
		2	0	-2.2	0

Load combination: 1.00G + 1.00Q (Service)

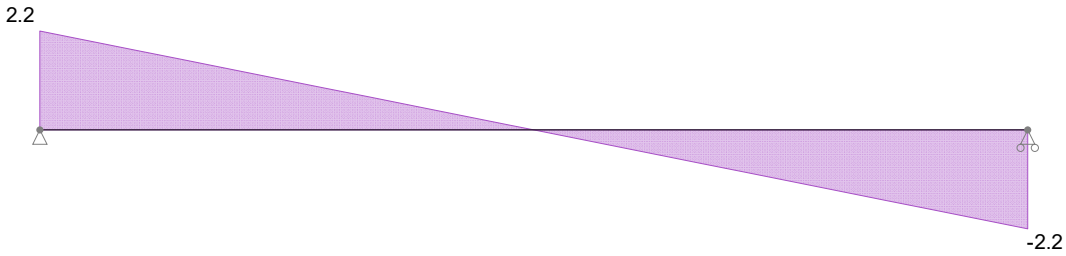
Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	1.63	1	0	-1.5	0
		2	0	-1.5	0

Forces

Strength combinations - Moment envelope (kNm)



Strength combinations - Shear envelope (kN)



Member results

Envelope - Strength combinations

Member	Position (m)	Shear force (kN)		Moment (kNm)	
Member	0	2.2 (max abs)		0 (min)	
	0.815	0		0.9 (max)	
	1.63	-2.2		0 (min)	

Tedds calculation version 2.2.17

Member - Span 1

Partial factor for material properties and resistances

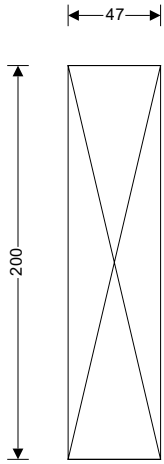
Partial factor γ_M = **1.300**

Member details

Load duration	Medium-term	Service class	2

Timber section details

Number of timber sections	N = **1**		
Breadth of sections	b = **47** mm	Depth of sections	h = **200** mm
Timber strength class	**C24**		



47x200 timber section
Cross-sectional area, A, 9400 mm^2
Section modulus, W_y, 313333.3 mm^3
Section modulus, W_z, 73633 mm^3
Second moment of area, I_y, 31333333 mm^4
Second moment of area, I_z, 1730383 mm^4
Radius of gyration, i_y, 57.7 mm
Radius of gyration, i_z, 13.6 mm
Timber strength class C24
Characteristic bending strength, $f_{m,k}$, 24 N/mm^2
Characteristic shear strength, $f_{v,k}$, 4 N/mm^2
Characteristic compression strength parallel to grain, $f_{c,0,k}$, 21 N/mm^2
Characteristic compression strength perpendicular to grain, $f_{c,90,k}$, 2.5 N/mm^2
Characteristic tension strength parallel to grain, $f_{t,0,k}$, 14.5 N/mm^2
Mean modulus of elasticity, $E_{0,mean}$, 11000 N/mm^2
Fifth percentile modulus of elasticity, $E_{0.05}$, 7400 N/mm^2
Shear modulus of elasticity, G_{mean}, 690 N/mm^2
Characteristic density, ρ_k, 350 kg/m^3
Mean density, ρ_{mean}, 420 kg/m^3

Span details

Bearing length L_b = **100** mm

Consider Combination 1 - 1.35G + 1.50Q (Strength)

Check design at start of span

Check compression perpendicular to the grain - cl.6.1.5

Des.perp.comp.stress $\sigma_{c,y,90,d}$ = **0.464** N/mm^2 Des.perp.comp.strength $f_{c,y,90,d}$ = **1.692** N/mm^2

Utilisation = **0.274**

PASS - Design perpendicular compression strength exceeds design perpendicular compression stress

Check shear force - Section 6.1.7

Design shear stress $\tau_{y,d}$ = **0.520** N/mm^2 Design shear strength $f_{v,y,d}$ = **2.708** N/mm^2

Utilisation = **0.192**

PASS - Design shear strength exceeds design shear stress

Check design 815 mm along span

Check bending moment - Section 6.1.6

Design bending stress $\sigma_{m,y,d}$ = **2.838** N/mm^2 Design bending strength $f_{m,y,d}$ = **16.246** N/mm^2

Utilisation = **0.175**

PASS - Design bending strength exceeds design bending stress

Check beams subjected to either bending or combined bending and compression - cl.6.3.3

Utilisation = **0.175**

PASS - Beam stability is acceptable

Check design at end of span

Check compression perpendicular to the grain - cl.6.1.5

Des.perp.comp.stress $\sigma_{c,y,90,d}$ = **0.464** N/mm^2 Des.perp.comp.strength $f_{c,y,90,d}$ = **1.692** N/mm^2

Utilisation = **0.274**

PASS - Design perpendicular compression strength exceeds design perpendicular compression stress

Check shear force - Section 6.1.7

Design shear stress $\tau_{y,d}$ = **0.520** N/mm^2 Design shear strength $f_{v,y,d}$ = **2.708** N/mm^2

Utilisation = **0.192**

PASS - Design shear strength exceeds design shear stress

Consider Combination 2 - 1.00G + 1.00Q (Service)

Check design 815 mm along span

Check y-y axis deflection - Section 7.2

Final deflection with creep $\delta_{y,Final}$ = **1.1** mm

Allowable deflection $\delta_{y,Allowable}$ = **6.5** mm

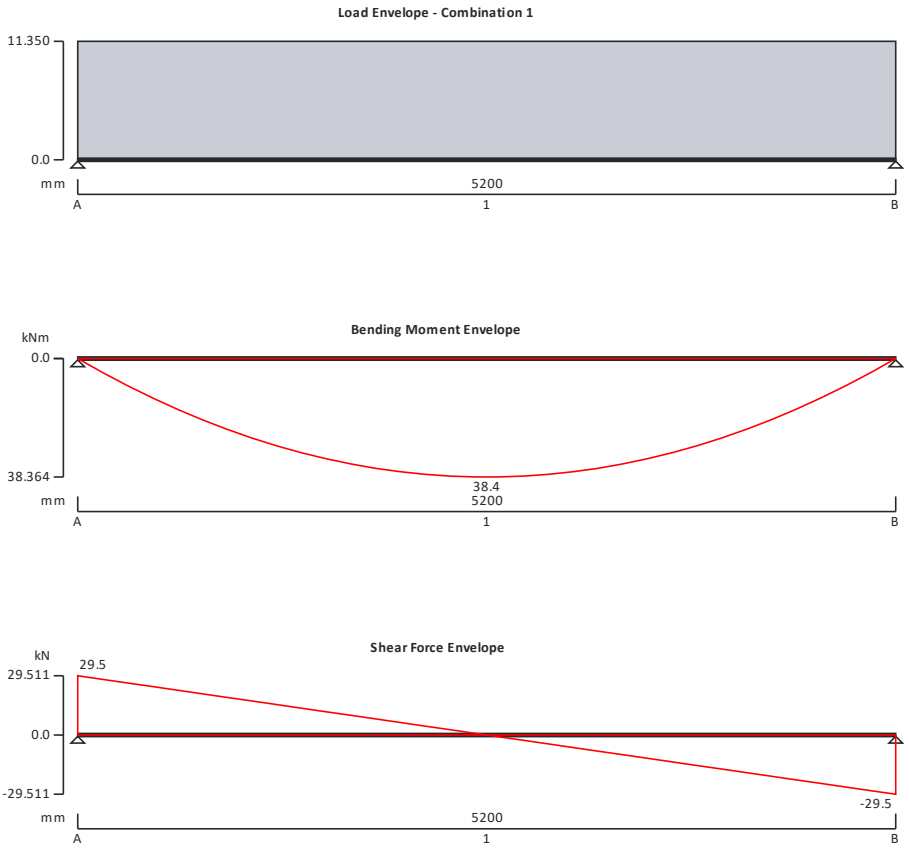
Utilisation = **0.17**

PASS - Allowable deflection exceeds final deflection

STEEL BEAM ANALYSIS & DESIGN (EN1993-1-1:2005)

In accordance with EN1993-1-1:2005 incorporating Corrigenda February 2006 and April 2009 and the UK national annex

TEDDS calculation version 3.0.14



Support conditions

Support A	Vertically restrained
	Rotationally free
Support B	Vertically restrained
	Rotationally free

Applied loading

Beam loads	Permanent self weight of beam × 1
	Permanent full UDL 3.4 kN/m
	Variable full UDL 4.1 kN/m

Load combinations

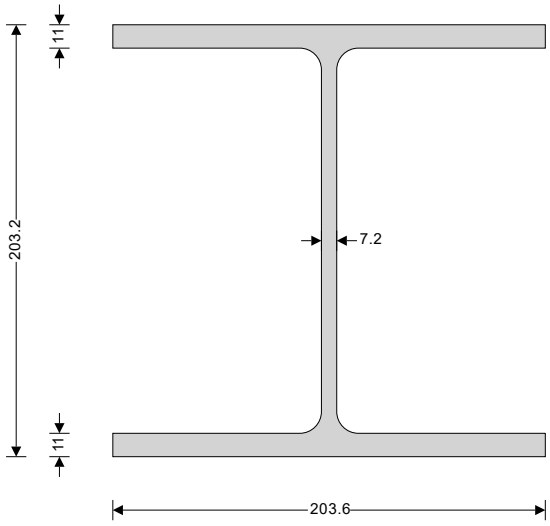
Load combination 1	Support A	Permanent × 1.35
		Variable × 1.50
		Permanent × 1.35
		Variable × 1.50
	Support B	Permanent × 1.35
		Variable × 1.50

Analysis results

Maximum moment	M_{max} = **38.4** kNm	M_{min} = **0** kNm
Maximum shear	V_{max} = **29.5** kN	V_{min} = **-29.5** kN
Deflection	δ_{max} = **7.9** mm	δ_{min} = **0** mm
Maximum reaction at support A	R_{A_max} = **29.5** kN	R_{A_min} = **29.5** kN
Unfactored permanent load reaction at support A	$R_{A\_Permanent}$ = **10** kN	
Unfactored variable load reaction at support A	$R_{A\_Variable}$ = **10.7** kN	
Maximum reaction at support B	R_{B_max} = **29.5** kN	R_{B_min} = **29.5** kN
Unfactored permanent load reaction at support B	$R_{B\_Permanent}$ = **10** kN	
Unfactored variable load reaction at support B	$R_{B\_Variable}$ = **10.7** kN	

Section details

Section type **UC 203x203x46 (BS4-1)** Steel grade **S355**



Section classification **Class 2**

Check shear - Section 6.2.6

Design shear force V_{Ed} = **30** kN Design shear resistance $V_{c,Rd}$ = **347.9** kN

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment M_{Ed} = **38.4** kNm Des.bending resist.moment $M_{c,Rd}$ = **176.6** kNm

Slenderness ratio for lateral torsional buckling

LTB slenderness ratio $\bar{\lambda}_{LT}$ = **1.493** Limiting slenderness ratio $\bar{\lambda}_{LT,0}$ = **0.400**

$\bar{\lambda}_{LT}$ > $\bar{\lambda}_{LT,0}$ - Lateral torsional buckling cannot be ignored

Design resistance for buckling - Section 6.3.2.1

Des.buckling resist.moment $M_{b,Rd}$ = **76** kNm

PASS - Design buckling resistance moment exceeds design bending moment

Check compression - Section 6.2.4

Design compression force N_{Ed} = **83** kN Design resistance of section $N_{c,Rd}$ = **2085** kN

Design resistance for buckling - Section 6.3.1.1

Design buckling resistance $N_{b,y,Rd}$ = **1546.5** kN

PASS - Design buckling resistance exceeds design compression force

Design resistance for buckling - Section 6.3.1.1

Design buckling resistance $N_{b,z,Rd}$ = **788.6** kN

PASS - Design buckling resistance exceeds design compression force

Check torsional and torsional-flexural buckling

Torsional buckling force $N_{cr,T}$ = **2770.7** kN Torsional-flexural buckling $N_{cr,TF}$ = **2770.7** kN

Design resistance for buckling - Section 6.3.1.1

Design buckling resistance $N_{b,T,Rd}$ = **1292.6** kN

PASS - Design buckling resistance exceeds design compression force

Combined bending and axial force - Section 6.2.9

Bending and axial force check $N_{Ed} <= \min(0.25 \times N_{pl,Rd}, 0.5 \times h_w \times t_w \times f_y / \gamma_{M0})$

No allowance on the plastic moment need to be accounted for due to the effect of axial force

Interaction factors k_{ij} for members not susceptible to torsional deformations - Table B.1

Interaction formulae $N_{Ed} / (\chi_y \times N_{Rk} / \gamma_{M1}) + k_{yy} \times M_{Ed} / (\chi_{LT} \times M_{Rk} / \gamma_{M1})$ = **0.548**

$N_{Ed} / (\chi_z \times N_{Rk} / \gamma_{M1}) + k_{zy} \times M_{Ed} / (\chi_{LT} \times M_{Rk} / \gamma_{M1})$ = **0.402**

PASS - Combined bending and compression checks are satisfied

Check vertical deflection - Section 7.2.1

Consider deflection due to permanent and variable loads

Limiting deflection δ_{lim} = **14.4** mm Maximum deflection δ = **7.892** mm

PASS - Maximum deflection does not exceed deflection limit

RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.9.16

Retaining wall details

Stem type	Propped cantilever
Stem height	h_{stem} = **2700** mm
Prop height	h_{prop} = **2700** mm
Stem thickness	t_{stem} = **300** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **25** kN/m^3
Toe length	l_{toe} = **1000** mm
Base thickness	t_{base} = **350** mm
Base density	γ_{base} = **25** kN/m^3
Height of retained soil	h_{ret} = **2700** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **0** mm
Height of water	h_{water} = **2700** mm
Water density	γ_w = **9.8** kN/m^3

Retained soil properties

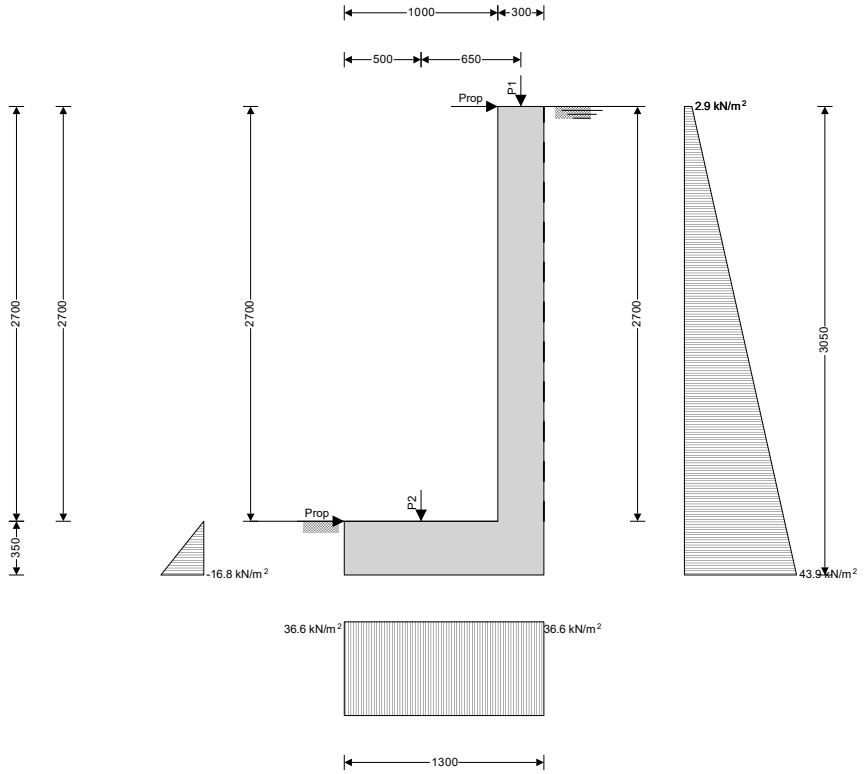
Soil type	Medium dense well graded sand and gravel
Moist density	γ_{mr} = **20** kN/m^3
Saturated density	γ_{sr} = **22.3** kN/m^3
Characteristic effective shear resistance angle	$\phi'_{r.k}$ = **30** deg
Characteristic wall friction angle	$\delta_{r.k}$ = **15** deg

Base soil properties

Soil type	Very loose brick hardcore
Soil density	γ_b = **13** kN/m^3
Characteristic effective shear resistance angle	$\phi'_{b.k}$ = **26** deg
Characteristic wall friction angle	$\delta_{b.k}$ = **13** deg
Characteristic base friction angle	$\delta_{bb.k}$ = **17.3** deg
Presumed bearing capacity	$P_{bearing}$ = **50** kN/m^2

Loading details

Variable surcharge load	$Surcharge_Q$ = **10** kN/m^2
Vertical line load at 1150 mm	P_{G1} = **5.4** kN/m
	P_{Q1} = **6.5** kN/m
Vertical line load at 500 mm	P_{G2} = **1.6** kN/m
	P_{Q2} = **2.5** kN/m



General arrangement - sketch pressures relate to bearing check

Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem}$ = **1300** mm
Saturated soil height	$h_{sat} = h_{water} + d_{cover}$ = **2700** mm
Moist soil height	$h_{moist} = h_{ret} - h_{water}$ = **0** mm
Length of surcharge load	$l_{sur} = l_{heel}$ = **0** mm
- Distance to vertical component	$x_{sur\_v} = l_{base} - l_{heel} / 2$ = **1300** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret}$ = **3050** mm
- Distance to horizontal component	$x_{sur\_h} = h_{eff} / 2$ = **1525** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem}$ = **0.81** m^2
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2$ = **1150** mm
Area of wall base	$A_{base} = l_{base} \times t_{base}$ = **0.455** m^2
- Distance to vertical component	$x_{base} = l_{base} / 2$ = **650** mm

Using Coulomb theory

Active pressure coefficient	$K_A = \sin(\alpha + \phi'_{r.k})^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta_{r.k}) \times [1 + \sqrt{[\sin(\phi'_{r.k} + \delta_{r.k}) \times \sin(\phi'_{r.k} - \beta) / (\sin(\alpha - \delta_{r.k}) \times \sin(\alpha + \beta))]}]^2)$ = **0.301**
Passive pressure coefficient	$K_P = \sin(90 - \phi'_{b.k})^2 / (\sin(90 + \delta_{b.k}) \times [1 - \sqrt{[\sin(\phi'_{b.k} + \delta_{b.k}) \times \sin(\phi'_{b.k}) / (\sin(90 + \delta_{b.k}))]}]^2)$ = **3.787**

Bearing pressure check

Vertical forces on wall

Wall stem	$F_{stem} = A_{stem} \times \gamma_{stem}$ = **20.3** kN/m
Wall base	$F_{base} = A_{base} \times \gamma_{base}$ = **11.4** kN/m

Line loads	$F_{P\_v} = P_{G1} + P_{Q1} + P_{G2} + P_{Q2} =$ **16** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{P\_v} + F_{water\_v} =$ **47.6** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_A \times \cos(\delta_{r.k}) \times Surcharge_Q \times h_{eff} =$ **8.9** kN/m
Saturated retained soil	$F_{sat\_h} = K_A \times \cos(\delta_{r.k}) \times (\gamma_{sr} - \gamma_w) \times (h_{sat} + h_{base})^2 / 2 =$ **16.8** kN/m
Water	$F_{water\_h} = \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2 =$ **45.6** kN/m
Base soil	$F_{pass\_h} = -K_P \times \cos(\delta_{b.k}) \times \gamma_b \times (d_{cover} + h_{base})^2 / 2 =$ **-2.9** kN/m
Total	$F_{total\_h} = F_{sur\_h} + F_{sat\_h} + F_{water\_h} + F_{moist\_h} + F_{pass\_h} =$ **68.4** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem} =$ **23.3** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} =$ **7.4** kNm/m
Surcharge load	$M_{sur} = -F_{sur\_h} \times x_{sur\_h} =$ **-13.5** kNm/m
Line loads	$M_P = (P_{G1} + P_{Q1}) \times p_1 + (P_{G2} + P_{Q2}) \times p_2 =$ **15.7** kNm/m
Saturated retained soil	$M_{sat} = -F_{sat\_h} \times x_{sat\_h} =$ **-17.1** kNm/m
Water	$M_{water} = -F_{water\_h} \times x_{water\_h} =$ **-46.4** kNm/m
Moist retained soil	$M_{moist} = -F_{moist\_h} \times x_{moist\_h} =$ **0** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sur} + M_P + M_{sat} + M_{water} + M_{moist} =$ **-30.6** kNm/m

Check bearing pressure

Propping force to stem	$F_{prop\_stem} = (F_{total\_v} \times l_{base} / 2 - M_{total}) / (h_{prop} + t_{base}) =$ **20.2** kN/m
Propping force to base	$F_{prop\_base} = F_{total\_h} - F_{prop\_stem} =$ **48.2** kN/m
Moment from propping force	$M_{prop} = F_{prop\_stem} \times (h_{prop} + t_{base}) =$ **61.6** kNm/m
Distance to reaction	$\bar{x} = (M_{total} + M_{prop}) / F_{total\_v} =$ **650** mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 =$ **0** mm
Loaded length of base	$l_{load} = l_{base} =$ **1300** mm
Bearing pressure at toe	$q_{toe} = F_{total\_v} / l_{base} \times (1 - 6 \times e / l_{base}) =$ **36.6** kN/m^2
Bearing pressure at heel	$q_{heel} = F_{total\_v} / l_{base} \times (1 + 6 \times e / l_{base}) =$ **36.6** kN/m^2
Factor of safety	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) =$ **1.365**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1

Tedds calculation version 2.9.16

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class	C32/40
Characteristic compressive cylinder strength	$f_{ck} =$ **32** N/mm^2
Characteristic compressive cube strength	$f_{ck,cube} =$ **40** N/mm^2
Mean value of compressive cylinder strength	$f_{cm} = f_{ck} + 8$ N/mm^2 = **40** N/mm^2
Mean value of axial tensile strength	$f_{ctm} = 0.3$ N/mm^2 $\times (f_{ck} / 1$ N/mm$^2)^{2/3} =$ **3.0** N/mm^2
5% fractile of axial tensile strength	$f_{ctk,0.05} = 0.7 \times f_{ctm} =$ **2.1** N/mm^2
Secant modulus of elasticity of concrete	$E_{cm} = 22$ kN/mm^2 $\times (f_{cm} / 10$ N/mm$^2)^{0.3} =$ **33346** N/mm^2
Partial factor for concrete - Table 2.1N	$\gamma_C =$ **1.50**
Compressive strength coefficient - cl.3.1.6(1)	$\alpha_{cc} =$ **0.85**
Design compressive concrete strength - exp.3.15	$f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C =$ **18.1** N/mm^2
Maximum aggregate size	$h_{agg} =$ **20** mm

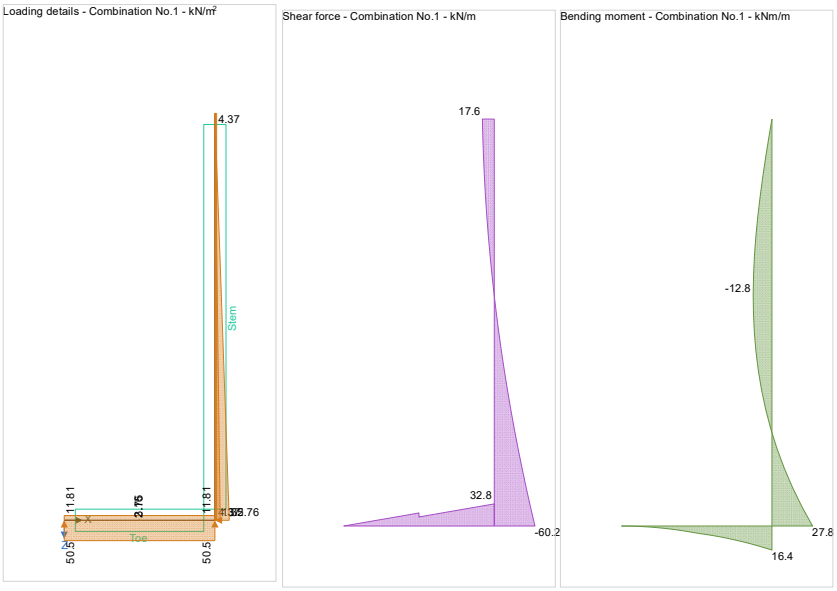
Ultimate strain - Table 3.1	ε_{cu2} = **0.0035**
Shortening strain - Table 3.1	ε_{cu3} = **0.0035**
Effective compression zone height factor	λ = **0.80**
Effective strength factor	η = **1.00**
Bending coefficient k_1	K_1 = **0.40**
Bending coefficient k_2	$K_2 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2})$ = **1.00**
Bending coefficient k_3	K_3 =**0.40**
Bending coefficient k_4	$K_4 = 1.00 \times (0.6 + 0.0014/\varepsilon_{cu2})$ =**1.00**

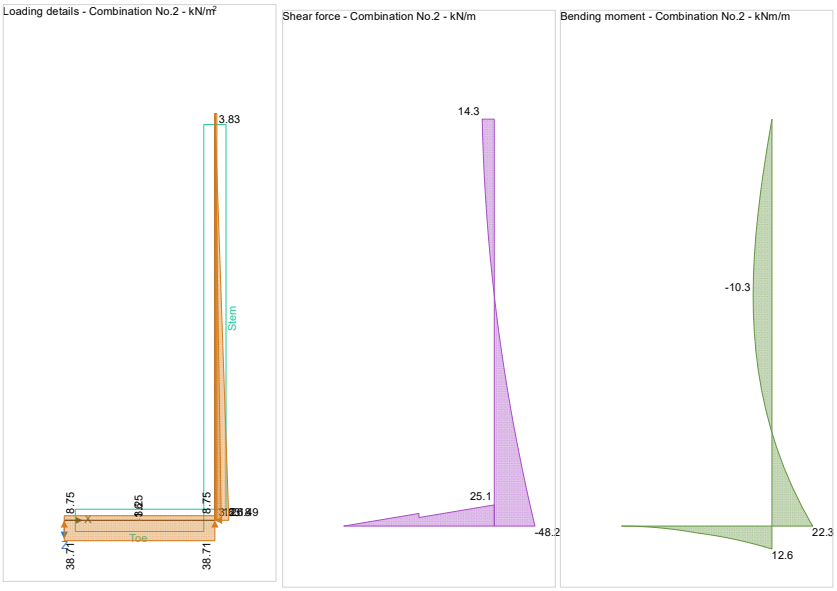
Reinforcement details

Characteristic yield strength of reinforcement	f_{yk} = **500** N/mm^2
Modulus of elasticity of reinforcement	E_s = **200000** N/mm^2
Partial factor for reinforcing steel - Table 2.1N	γ_S = **1.15**
Design yield strength of reinforcement	$f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm^2

Cover to reinforcement

Front face of stem	c_{sf} = **25** mm
Rear face of stem	c_{sr} = **50** mm
Top face of base	c_{bt} = **25** mm
Bottom face of base	c_{bb} = **75** mm





Check stem design at 1350 mm

Depth of section — h = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1 — M = **12.8** kNm/m

Depth to tension reinforcement — $d = h - c_{sf} - \phi_{sx} - \phi_{sfM} / 2$ = **257** mm

$K = M / (d^2 \times f_{ck})$ = **0.006**

$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C) \times (1 - \lambda \times (\delta - K_1)/(2 \times K_2)) \times (\lambda \times (\delta - K_1)/(2 \times K_2))$

K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm — $z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **244** mm

Depth of neutral axis — $x = 2.5 \times (d - z)$ = **32** mm

Area of tension reinforcement required — $A_{sfM.req} = M / (f_{yd} \times z)$ = **121** mm²/m

Tension reinforcement provided — 12 dia.bars @ 200 c/c

Area of tension reinforcement provided — $A_{sfM.prov} = \pi \times \phi_{sfM}^2 / (4 \times s_{sfM})$ = **565** mm²/m

Minimum area of reinforcement - exp.9.1N — $A_{sfM.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **404** mm²/m

Maximum area of reinforcement - cl.9.2.1.1(3) — $A_{sfM.max} = 0.04 \times h$ = **12000** mm²/m

$\max(A_{sfM.req}, A_{sfM.min}) / A_{sfM.prov}$ = **0.715**

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio — $\rho_0 = \sqrt{(f_{ck} / 1\ N/mm^2)} / 1000$ = **0.006**

Required tension reinforcement ratio — $\rho = A_{sfM.req} / d$ = **0.000**

Required compression reinforcement ratio — $\rho' = A_{sfM.2.req} / d_2$ = **0.000**

Structural system factor - Table 7.4N — K_b = **1**

Reinforcement factor - exp.7.17 — $K_s = \min(500\ N/mm^2 / (f_{yk} \times A_{sfM.req} / A_{sfM.prov}), 1.5)$ = **1.5**

Limiting span to depth ratio - exp.7.16.a — $\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b)$ = **40**

Actual span to depth ratio — h_{prop} / d = **10.5**

PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3

Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **8.7** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sfM.prov} \times z)$ = **63.4** N/mm^2
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **89292** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **3.0** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{sfM.prov} / A_{c.eff}$ = **0.006**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **5.998**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{sf} + k_1 \times k_2 \times k_4 \times \phi_{sfM} / \rho_{p.eff}$ = **407** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.077** mm
	w_k / w_{max} = **0.258**
	PASS - Maximum crack width is less than limiting crack width

Check stem design at base of stem

Depth of section	h = **300** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **27.8** kNm/m
Depth to tension reinforcement	$d = h - c_{sr} - \phi_{sr} / 2$ = **244** mm
	$K = M / (d^2 \times f_{ck})$ = **0.015**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C) \times (1 - \lambda \times (\delta - K_1)/(2 \times K_2)) \times (\lambda \times (\delta - K_1)/(2 \times K_2))$
	K' = **0.207**
	K' > K - No compression reinforcement is required
Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **232** mm
Depth of neutral axis	$x = 2.5 \times (d - z)$ = **31** mm
Area of tension reinforcement required	$A_{sr.req} = M / (f_{yd} \times z)$ = **276** mm^2/m
Tension reinforcement provided	12 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{sr.prov} = \pi \times \phi_{sr}^2 / (4 \times s_{sr})$ = **565** mm^2/m
Minimum area of reinforcement - exp.9.1N	$A_{sr.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **384** mm^2/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{sr.max} = 0.04 \times h$ = **12000** mm^2/m
	$\max(A_{sr.req}, A_{sr.min}) / A_{sr.prov}$ = **0.678**
	PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Deflection control - Section 7.4

Reference reinforcement ratio	$\rho_0 = \sqrt{(f_{ck} / 1\ \text{N/mm}^2)} / 1000$ = **0.006**
Required tension reinforcement ratio	$\rho = A_{sr.req} / d$ = **0.001**
Required compression reinforcement ratio	$\rho' = A_{sr.2.req} / d_2$ = **0.000**
Structural system factor - Table 7.4N	K_b = **1**
Reinforcement factor - exp.7.17	$K_s = \min(500\ \text{N/mm}^2 / (f_{yk} \times A_{sr.req} / A_{sr.prov}), 1.5)$ = **1.5**

Limiting span to depth ratio - exp.7.16.a	$\min(K_s \times K_b \times [11 + 1.5 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times \rho_0 / \rho + 3.2 \times \sqrt{(f_{ck} / 1\ N/mm^2)} \times (\rho_0 / \rho - 1)^{3/2}], 40 \times K_b) =$ **40**
Actual span to depth ratio	$h_{prop} / d =$ **11.1**
	PASS - Span to depth ratio is less than deflection control limit

Crack control - Section 7.3

Limiting crack width	$w_{max} =$ **0.3** mm
Variable load factor - EN1990 – Table A1.1	$\psi_2 =$ **0.6**
Serviceability bending moment	$M_{sls} =$ **19.2** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{sr.prov} \times z) =$ **146.6** N/mm^2
Load duration	Long term
Load duration factor	$k_t =$ **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff} =$ **89833** mm^2/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm} =$ **3.0** N/mm^2
Reinforcement ratio	$\rho_{p.eff} = A_{sr.prov} / A_{c.eff} =$ **0.006**
Modular ratio	$\alpha_e = E_s / E_{cm} =$ **5.998**
Bond property coefficient	$k_1 =$ **0.8**
Strain distribution coefficient	$k_2 =$ **0.5**
	$k_3 =$ **3.4**
	$k_4 =$ **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{sr} + k_1 \times k_2 \times k_4 \times \phi_{sr} / \rho_{p.eff} =$ **494** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	$w_k =$ **0.217** mm
	$w_k / w_{max} =$ **0.724**
	PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force	$V =$ **60.2** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C =$ **0.120**
	$k = \min(1 + \sqrt{(200\ mm / d)}, 2) =$ **1.905**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr.prov} / d, 0.02) =$ **0.002**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} =$ **0.521** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c} =$ **127.1** kN/m
	$V / V_{Rd.c} =$ **0.474**
	PASS - Design shear resistance exceeds design shear force

Check stem design at prop

Depth of section	$h =$ **300** mm

Rectangular section in shear - Section 6.2

Design shear force	$V =$ **17.6** kN/m
	$C_{Rd,c} = 0.18 / \gamma_C =$ **0.120**
	$k = \min(1 + \sqrt{(200\ mm / d)}, 2) =$ **1.905**
Longitudinal reinforcement ratio	$\rho_l = \min(A_{sr1.prov} / d, 0.02) =$ **0.002**
	$v_{min} = 0.035\ N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5} =$ **0.521** N/mm^2
Design shear resistance - exp.6.2a & 6.2b	$V_{Rd.c} = \max(C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}, v_{min}) \times d$
	$V_{Rd.c} =$ **127.1** kN/m

$V / V_{Rd.c}$ = **0.139**

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Minimum area of reinforcement – cl.9.6.3(1)	$A_{sx.req} = \max(0.25 \times A_{sr.prov}, 0.001 \times t_{stem})$ = **300** mm²/m
Maximum spacing of reinforcement – cl.9.6.3(2)	s_{sx_max} = **400** mm
Transverse reinforcement provided	12 dia.bars @ 200 c/c
Area of transverse reinforcement provided	$A_{sx.prov} = \pi \times \phi_{sx}^2 / (4 \times s_{sx})$ = **565** mm²/m

PASS - Area of reinforcement provided is greater than area of reinforcement required

Check base design at toe

Depth of section	h = **350** mm

Rectangular section in flexure - Section 6.1

Design bending moment combination 1	M = **16.4** kNm/m
Depth to tension reinforcement	$d = h - c_{bb} - \phi_{bb} / 2$ = **269** mm
	$K = M / (d^2 \times f_{ck})$ = **0.007**
	$K' = (2 \times \eta \times \alpha_{cc}/\gamma_C) \times (1 - \lambda \times (\delta - K_1)/(2 \times K_2)) \times (\lambda \times (\delta - K_1)/(2 \times K_2))$
	K' = **0.207**

K' > K - No compression reinforcement is required

Lever arm	$z = \min(0.5 + 0.5 \times (1 - 2 \times K / (\eta \times \alpha_{cc} / \gamma_C))^{0.5}, 0.95) \times d$ = **256** mm
Depth of neutral axis	$x = 2.5 \times (d - z)$ = **34** mm
Area of tension reinforcement required	$A_{bb.req} = M / (f_{yd} \times z)$ = **147** mm²/m
Tension reinforcement provided	12 dia.bars @ 200 c/c
Area of tension reinforcement provided	$A_{bb.prov} = \pi \times \phi_{bb}^2 / (4 \times s_{bb})$ = **565** mm²/m
Minimum area of reinforcement - exp.9.1N	$A_{bb.min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times d$ = **423** mm²/m
Maximum area of reinforcement - cl.9.2.1.1(3)	$A_{bb.max} = 0.04 \times h$ = **14000** mm²/m
	$\max(A_{bb.req}, A_{bb.min}) / A_{bb.prov}$ = **0.748**

PASS - Area of reinforcement provided is greater than area of reinforcement required

Library item: Rectangular single output

Crack control - Section 7.3

Limiting crack width	w_{max} = **0.3** mm
Variable load factor - EN1990 – Table A1.1	ψ_2 = **0.6**
Serviceability bending moment	M_{sls} = **12.4** kNm/m
Tensile stress in reinforcement	$\sigma_s = M_{sls} / (A_{bb.prov} \times z)$ = **85.8** N/mm²
Load duration	Long term
Load duration factor	k_t = **0.4**
Effective area of concrete in tension	$A_{c.eff} = \min(2.5 \times (h - d), (h - x) / 3, h / 2)$
	$A_{c.eff}$ = **105458** mm²/m
Mean value of concrete tensile strength	$f_{ct.eff} = f_{ctm}$ = **3.0** N/mm²
Reinforcement ratio	$\rho_{p.eff} = A_{bb.prov} / A_{c.eff}$ = **0.005**
Modular ratio	$\alpha_e = E_s / E_{cm}$ = **5.998**
Bond property coefficient	k_1 = **0.8**
Strain distribution coefficient	k_2 = **0.5**
	k_3 = **3.4**
	k_4 = **0.425**
Maximum crack spacing - exp.7.11	$s_{r.max} = k_3 \times c_{bb} + k_1 \times k_2 \times k_4 \times \phi_{bb} / \rho_{p.eff}$ = **635** mm
Maximum crack width - exp.7.8	$w_k = s_{r.max} \times \max(\sigma_s - k_t \times (f_{ct.eff} / \rho_{p.eff}) \times (1 + \alpha_e \times \rho_{p.eff}), 0.6 \times \sigma_s) / E_s$
	w_k = **0.163** mm

w_k / w_{max} = **0.545**

PASS - Maximum crack width is less than limiting crack width

Rectangular section in shear - Section 6.2

Design shear force — V = **32.8** kN/m

$C_{Rd,c}$ = 0.18 / γ_C = **0.120**

k = min(1 + √(200 mm / d), 2) = **1.862**

Longitudinal reinforcement ratio — ρ_l = min($A_{bb.prov}$ / d, 0.02) = **0.002**

v_{min} = 0.035 $N^{1/2}/mm \times k^{3/2} \times f_{ck}^{0.5}$ = **0.503** N/mm²

Design shear resistance - exp.6.2a & 6.2b — $V_{Rd.c}$ = max($C_{Rd.c} \times k \times (100\ N^2/mm^4 \times \rho_l \times f_{ck})^{1/3}$, v_{min}) × d

$V_{Rd.c}$ = **135.3** kN/m

V / $V_{Rd.c}$ = **0.242**

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

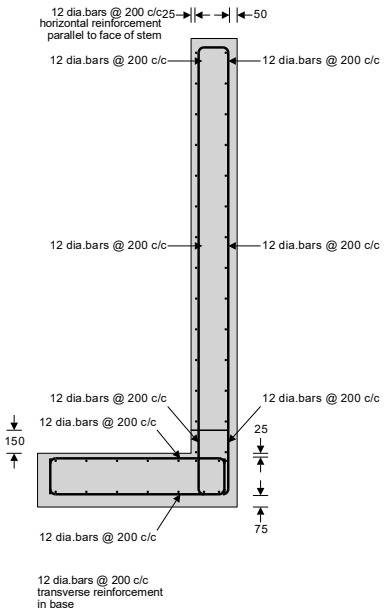
Minimum area of reinforcement – cl.9.3.1.1(2) — $A_{bx.req}$ = 0.2 × $A_{bb.prov}$ = **113** mm²/m

Maximum spacing of reinforcement – cl.9.3.1.1(3) — s_{bx_max} = **450** mm

Transverse reinforcement provided — 12 dia.bars @ 200 c/c

Area of transverse reinforcement provided — $A_{bx.prov}$ = π × ϕ_{bx}^2 / (4 × s_{bx}) = **565** mm²/m

PASS - Area of reinforcement provided is greater than area of reinforcement required



Reinforcement details

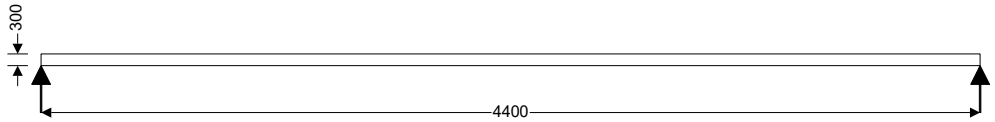
RC SLAB DESIGN

In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex

Tedds calculation version 1.0.22

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Support 1					
Tension reinf.	mm^2/m	565	415	0.734	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Shear	kN/m	133.7	38.0	0.284	PASS
Span 1					
Tension reinf.	mm^2/m	565	344	0.609	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Allow. span-to-depth ratio		20.09	40.00	0.502	PASS
Support 2					
Tension reinf.	mm^2/m	565	415	0.734	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Shear	kN/m	133.7	38.0	0.284	PASS
Cover					
Min cover top	mm	30	22	0.733	PASS
Min cover bottom	mm	75	22	0.293	PASS



Slab definition

Slab reference name	**basement slab**
Overall slab depth	h = **300** mm
Number of spans	N_{spans} = **1**
First support	**Monolithic**
Last support	**Monolithic**
Nominal cover to top reinforcement	c_{nom_t} = **30** mm
Nominal cover to bottom reinforcement	c_{nom_b} = **75** mm

Loading

Ratio of quasi-permanent to ultimate load	r_q = **0.620**

Concrete properties

Concrete strength class	C32/40
Characteristic cylinder strength	f_{ck} = **32** N/mm^2
Partial factor (Table 2.1N)	γ_C = **1.50**
Compressive strength factor (cl. 3.1.6)	α_{cc} = **0.85**
Design compressive strength (cl. 3.1.6)	f_{cd} = **18.1** N/mm^2
Mean axial tensile strength (Table 3.1)	$f_{ctm} = 0.30\ N/mm^2 \times (f_{ck} / 1\ N/mm^2)^{2/3}$ = **3.0** N/mm^2
Maximum aggregate size	d_g = **20** mm

Reinforcement properties

Characteristic yield strength	f_{yk} = **500** N/mm^2
Partial factor (Table 2.1N)	γ_S = **1.15**
Design yield strength (fig. 3.8)	$f_{yd} = f_{yk} / \gamma_S$ = **434.8** N/mm^2

Concrete cover to reinforcement

Nominal cover to top reinforcement	c_{nom_t} = **30** mm
Nominal cover to bottom reinforcement	c_{nom_b} = **75** mm
Fire resistance period to top of slab	R_{top} = **60** min
Fire resistance period to bottom of slab	R_{btm} = **30** min
Axis distance to top reinft (Table 5.8)	a_{fi_t} = **20** mm
Axis distance to bottom reinft (Table 5.8)	a_{fi_b} = **10** mm
Max bar diameter in top	ϕ_{max_t} = **12** mm
Max bar diameter in bottom	ϕ_{max_b} = **12** mm
Min. top cover requirement with regard to bond	$c_{min,b\_t} = \phi_{max\_t}$ = **12** mm
Min. btm cover requirement with regard to bond	$c_{min,b\_b} = \phi_{max\_b}$ = **12** mm
Reinforcement fabrication	**Not subject to QA system**
Cover allowance for deviation	Δc_{dev} = **10** mm
Min. required nominal cover to top reinft	$c_{nom\_t\_min} = \max(a_{fi\_t} - \phi_{max\_t} / 2, c_{min,b\_t} + \Delta c_{dev})$ = **22.0** mm
Min. required nominal cover to bottom reinft	$c_{nom\_b\_min} = \max(a_{fi\_b} - \phi_{max\_b} / 2, c_{min,b\_b} + \Delta c_{dev})$ = **22.0** mm

PASS - There is sufficient cover to the top reinforcement

PASS - There is sufficient cover to the bottom reinforcement

Bending design checks

Redistribution ratio	δ = **1.0**
Limiting value of K	$K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

Reinforcement design at midspan of span 1 (cl.6.1)

Length of span 1	l_1 = **4400** mm
Design bending moment	M_{p1} = **27.8** kNm/m
Reinforcement provided	**12 mm dia. bars at 200 mm centres**
Area provided	A_{sp1} = **565** mm²/m
Effective depth to tension reinforcement	$d_{p1} = h - c_{nom\_b} - \phi_{p1} / 2$ = **219.0** mm
K factor	$K = M_{p1} / (b \times d_{p1}^2 \times f_{ck})$ = **0.018**

K < K' - Compression reinforcement is not required

Lever arm	$z = \min(0.95 \times d_{p1}, d_{p1} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$
	z = **208.0** mm
Area of reinforcement required for bending	$A_{sp1\_m} = M_{p1} / (f_{yd} \times z)$ = **307** mm²/m
Minimum area required	$A_{sp1\_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{p1}$ = **344** mm²/m
Area of reinforcement required	$A_{sp1\_req} = \max(A_{sp1\_m}, A_{sp1\_min})$ = **344** mm²/m

PASS - Area of tension reinforcement provided is adequate (0.609)

Check reinforcement spacing

Reinforcement service stress	$\sigma_s = (f_{yk} / \gamma_S) \times \min((A_{sp1\_m}/A_{sp1}), 1.0) \times r_q$ = **146.5** N/mm²
Maximum allowable spacing (Table 7.3N)	s_{max_p1} = **300** mm
Actual bar spacing	s_{p1} = **200** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at support 1 (cl.6.1)

Design bending moment	M_{n1} = **27.8** kNm/m
Reinforcement provided	**12 mm dia. bars at 200 mm centres**
Area provided	A_{sn1} = **565** mm²/m
Effective depth to tension reinforcement	$d_{n1} = h - c_{nom\_t} - \phi_{n1} / 2$ = **264.0** mm
K factor	$K = M_{n1} / (b \times d_{n1}^2 \times f_{ck})$ = **0.012**

K < K' - Compression reinforcement is not required

Lever arm
$z = \min(0.95 \times d_{n1}, d_{n1} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$
$z =$ **250.8** mm

Area of reinforcement required for bending
$A_{sn1\_m} = M_{n1} / (f_{yd} \times z) =$ **255** mm²/m

Minimum area required
$A_{sn1\_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{n1} =$ **415** mm²/m

Area of reinforcement required
$A_{sn1\_req} = \max(A_{sn1\_m}, A_{sn1\_min}) =$ **415** mm²/m

PASS - Area of tension reinforcement provided is adequate (0.734)

Check reinforcement spacing

Reinforcement service stress
$\sigma_s = (f_{yk} / \gamma_S) \times \min((A_{sn1\_m}/A_{sn1}), 1.0) \times r_q =$ **121.5** N/mm²

Maximum allowable spacing (Table 7.3N)
$s_{max\_n1} =$ **300** mm

Actual bar spacing
$s_{n1} =$ **200** mm

PASS - The reinforcement spacing is acceptable

Reinforcement design at support 2 (cl.6.1)

Design bending moment
$M_{n2} =$ **27.8** kNm/m

Reinforcement provided
12 mm dia. bars at 200 mm centres

Area provided
$A_{sn2} =$ **565** mm²/m

Effective depth to tension reinforcement
$d_{n2} = h - c_{nom\_t} - \phi_{n2} / 2 =$ **264.0** mm

K factor
$K = M_{n2} / (b \times d_{n2}^2 \times f_{ck}) =$ **0.012**

K < K' - Compression reinforcement is not required

Lever arm
$z = \min(0.95 \times d_{n2}, d_{n2} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$
$z =$ **250.8** mm

Area of reinforcement required for bending
$A_{sn2\_m} = M_{n2} / (f_{yd} \times z) =$ **255** mm²/m

Minimum area required
$A_{sn2\_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{n2} =$ **415** mm²/m

Area of reinforcement required
$A_{sn2\_req} = \max(A_{sn2\_m}, A_{sn2\_min}) =$ **415** mm²/m

PASS - Area of tension reinforcement provided is adequate (0.734)

Check reinforcement spacing

Reinforcement service stress
$\sigma_s = (f_{yk} / \gamma_S) \times \min((A_{sn2\_m}/A_{sn2}), 1.0) \times r_q =$ **121.5** N/mm²

Maximum allowable spacing (Table 7.3N)
$s_{max\_n2} =$ **300** mm

Actual bar spacing
$s_{n2} =$ **200** mm

PASS - The reinforcement spacing is acceptable

Shear design checks

Shear resistance constant (cl. 6.2.2)
$C_{Rd,c} = 0.18$ N/mm² / $\gamma_C =$ **0.12** N/mm²

Shear capacity check at support 1

Shear force
$V_1 =$ **38.0** kN/m

Effective depth factor (cl. 6.2.2)
$k = \min(2.0, 1 + (200 \text{ mm} / d_{n1})^{0.5}) =$ **1.870**

Reinforcement ratio
$\rho_l = \min(0.02, A_{sn1} / (b \times d_{n1})) =$ **0.0021**

Minimum shear resistance (Exp. 6.3N)
$V_{Rd,c\_min} = 0.035$ N/mm² $\times k^{1.5} \times (f_{ck} / 1$ N/mm²$)^{0.5} \times b \times d_{n1}$
$V_{Rd,c\_min} =$ **133.7** kN/m

Shear resistance (Exp. 6.2a)
$V_{Rd,c1} = \max(V_{Rd,c\_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{n1})$
$V_{Rd,c1} =$ **133.7** kN/m

PASS - Shear capacity is adequate (0.284)

Shear capacity check at support 2

Shear force
$V_2 =$ **38.0** kN/m

Effective depth factor (cl. 6.2.2) $k = \min(2.0, 1 + (200\ mm / d_{n2})^{0.5}) = \mathbf{1.870}$

Reinforcement ratio $\rho_l = \min(0.02, A_{sn2} / (b \times d_{n2})) = \mathbf{0.0021}$

Minimum shear resistance (Exp. 6.3N) $V_{Rd,c\_min} = 0.035\ N/mm^2 \times k^{1.5} \times (f_{ck} / 1\ N/mm^2)^{0.5} \times b \times d_{n2}$

$V_{Rd,c\_min} = \mathbf{133.7}$ kN/m

Shear resistance (Exp. 6.2a) $V_{Rd,c2} = \max(V_{Rd,c\_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1\ N/mm^2))^{0.333} \times b \times d_{n2})$

$V_{Rd,c2} = \mathbf{133.7}$ kN/m

PASS - Shear capacity is adequate (0.284)

Deflection checks

Basic span-to-depth ratio deflection check span 1 (cl. 7.4.2)

Reference reinforcement ratio $\rho_0 = (f_{ck} / 1\ N/mm^2)^{0.5} / 1000 = \mathbf{0.0057}$

Required tension reinforcement ratio $\rho = \max(0.0035, A_{sp1\_m} / (b \times d_{p1})) = \mathbf{0.0035}$

Required compression reinforcement ratio $\rho' = A_{scp1\_req} / (b \times d_{p1}) = \mathbf{0.0000}$

Structural system factor (Table 7.4N) $K_\delta = \mathbf{1.0}$

Basic span-to-depth ratio limit (Exp. 7.16a) $ratio_{lim1\_bas} = K_\delta \times [11 + 1.5 \times (f_{ck}/1\ N/mm^2)^{0.5} \times \rho_0/\rho + 3.2 \times (f_{ck}/1\ N/mm^2)^{0.5} \times (\rho_0/\rho - 1)^{1.5}]$

$ratio_{lim1\_bas} = \mathbf{33.47}$

Modified span-to-depth ratio limit

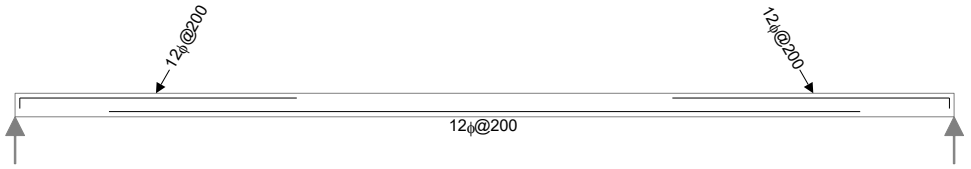
$ratio_{lim1} = \min(40 \times K_\delta, \min(1.5, (500\ N/mm^2 / f_{yk}) \times (A_{sp1} / A_{sp1\_m})) \times ratio_{lim1\_bas}) = \mathbf{40.00}$

Actual span-to-depth ratio $ratio_{act1} = l_1 / d_{p1} = \mathbf{20.09}$

PASS - Span-to-depth ratio is acceptable (0.502)

Reinforcement sketch

The following sketch is indicative only. Note that additional reinforcement may be required in accordance with clauses 9.2.1.2, 9.2.1.4 and 9.2.1.5 of EN 1992-1-1:2004 to meet detailing rules.



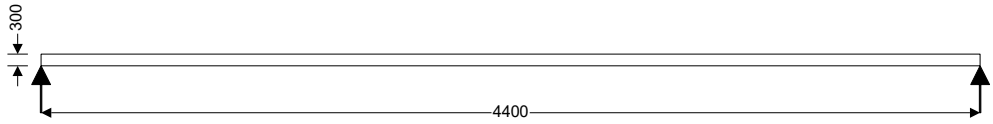
RC SLAB DESIGN

In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex

Tedds calculation version 1.0.22

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Support 1					
Tension reinf.	mm^2/m	565	415	0.734	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Shear	kN/m	118.6	22.5	0.190	PASS
Span 1					
Tension reinf.	mm^2/m	565	344	0.609	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Allow. span-to-depth ratio		20.09	40.00	0.502	PASS
Support 2					
Tension reinf.	mm^2/m	565	415	0.734	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Shear	kN/m	118.6	22.5	0.190	PASS
Cover					
Min cover bottom	mm	75	22	0.293	PASS



Slab definition

Slab reference name	**basement slab**
Overall slab depth	h = **300** mm
Number of spans	N_{spans} = **1**
First support	**Simple**
Last support	**Simple**
Nominal cover to bottom reinforcement	c_{nom_b} = **75** mm

Loading

Ratio of quasi-permanent to ultimate load	r_q = **0.620**

Concrete properties

Concrete strength class	C32/40
Characteristic cylinder strength	f_{ck} = **32** N/mm^2
Partial factor (Table 2.1N)	γ_C = **1.50**
Compressive strength factor (cl. 3.1.6)	α_{cc} = **0.85**
Design compressive strength (cl. 3.1.6)	f_{cd} = **18.1** N/mm^2
Mean axial tensile strength (Table 3.1)	$f_{ctm} = 0.30\ N/mm^2 \times (f_{ck} / 1\ N/mm^2)^{2/3}$ = **3.0** N/mm^2
Maximum aggregate size	d_g = **20** mm

Reinforcement properties

Characteristic yield strength	f_{yk} = **500** N/mm^2
Partial factor (Table 2.1N)	γ_S = **1.15**
Design yield strength (fig. 3.8)	$f_{yd} = f_{yk} / \gamma_S$ = **434.8** N/mm^2

Concrete cover to reinforcement

Nominal cover to bottom reinforcement	c_{nom_b} = **75** mm

Fire resistance period to bottom of slab	R_{btm} = **30** min
Axis distance to bottom reinft (Table 5.8)	a_{fi_b} = **10** mm
Max bar diameter in bottom	ϕ_{max_b} = **12** mm
Min. btm cover requirement with regard to bond	$c_{min,b\_b} = \phi_{max\_b}$ = **12** mm
Reinforcement fabrication	**Not subject to QA system**
Cover allowance for deviation	Δc_{dev} = **10** mm
Min. required nominal cover to bottom reinft	$c_{nom\_b\_min} = \max(a_{fi\_b} - \phi_{max\_b} / 2, c_{min,b\_b} + \Delta c_{dev})$ = **22.0** mm
	PASS - There is sufficient cover to the bottom reinforcement

Bending design checks

Redistribution ratio	δ = **1.0**
Limiting value of K	$K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208**

Reinforcement design at midspan of span 1 (cl.6.1)

Length of span 1	l_1 = **4400** mm
Design bending moment	M_{p1} = **24.8** kNm/m
Reinforcement provided	**12 mm dia. bars at 200 mm centres**
Area provided	A_{sp1} = **565** mm²/m
Effective depth to tension reinforcement	$d_{p1} = h - c_{nom\_b} - \phi_{p1} / 2$ = **219.0** mm
K factor	$K = M_{p1} / (b \times d_{p1}^2 \times f_{ck})$ = **0.016**
	K < K' - Compression reinforcement is not required
Lever arm	$z = \min(0.95 \times d_{p1}, d_{p1} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$
	z = **208.0** mm
Area of reinforcement required for bending	$A_{sp1\_m} = M_{p1} / (f_{yd} \times z)$ = **274** mm²/m
Minimum area required	$A_{sp1\_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{p1}$ = **344** mm²/m
Area of reinforcement required	$A_{sp1\_req} = \max(A_{sp1\_m}, A_{sp1\_min})$ = **344** mm²/m
	PASS - Area of tension reinforcement provided is adequate (0.609)

Check reinforcement spacing

Reinforcement service stress	$\sigma_s = (f_{yk} / \gamma_S) \times \min((A_{sp1\_m}/A_{sp1}), 1.0) \times r_q$ = **130.4** N/mm²
Maximum allowable spacing (Table 7.3N)	s_{max_p1} = **300** mm
Actual bar spacing	s_{p1} = **200** mm
	PASS - The reinforcement spacing is acceptable

Shear design checks

Shear resistance constant (cl. 6.2.2)	$C_{Rd,c}$ = 0.18 N/mm² / γ_C = **0.12** N/mm²

Shear capacity check at support 1

Shear force	V_1 = **22.5** kN/m
Reinforcement provided	**12 mm dia. bars at 200 mm centres**
Area provided	A_{sd1} = **565** mm²/m
Effective depth	$d_{d1} = h - c_{nom\_b} - \phi_{d1} / 2$ = **219.0** mm
Effective depth factor (cl. 6.2.2)	$k = \min(2.0, 1 + (200 \text{ mm} / d_{d1})^{0.5})$ = **1.956**
Reinforcement ratio	$\rho_l = \min(0.02, A_{sd1} / (b \times d_{d1}))$ = **0.0026**
Minimum shear resistance (Exp. 6.3N)	$V_{Rd,c\_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{d1}$
	V_{Rd,c_min} = **118.6** kN/m
Shear resistance (Exp. 6.2a)	$V_{Rd,c1} = \max(V_{Rd,c\_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{d1})$
	$V_{Rd,c1}$ = **118.6** kN/m
	PASS - Shear capacity is adequate (0.190)

Shear capacity check at support 2

Shear force	V_2 = **22.5** kN/m
Reinforcement provided	**12 mm dia. bars at 200 mm centres**
Area provided	A_{sd2} = **565** mm²/m
Effective depth	$d_{d2} = h - c_{nom\_b} - \phi_{d2} / 2$ = **219.0** mm
Effective depth factor (cl. 6.2.2)	$k = \min(2.0, 1 + (200\ mm / d_{d2})^{0.5})$ = **1.956**
Reinforcement ratio	$\rho_l = \min(0.02, A_{sd2} / (b \times d_{d2}))$ = **0.0026**
Minimum shear resistance (Exp. 6.3N)	$V_{Rd,c\_min} = 0.035\ N/mm^2 \times k^{1.5} \times (f_{ck} / 1\ N/mm^2)^{0.5} \times b \times d_{d2}$
	V_{Rd,c_min} = **118.6** kN/m
Shear resistance (Exp. 6.2a)	$V_{Rd,c2} = \max(V_{Rd,c\_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1\ N/mm^2))^{0.333} \times b \times d_{d2})$
	$V_{Rd,c2}$ = **118.6** kN/m

PASS - Shear capacity is adequate (0.190)

Deflection checks

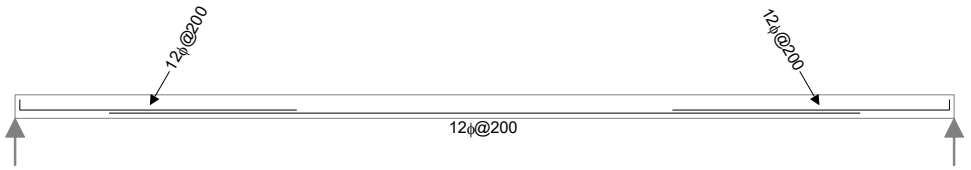
Basic span-to-depth ratio deflection check span 1 (cl. 7.4.2)

Reference reinforcement ratio	$\rho_0 = (f_{ck} / 1\ N/mm^2)^{0.5} / 1000$ = **0.0057**
Required tension reinforcement ratio	$\rho = \max(0.0035, A_{sp1\_m} / (b \times d_{p1}))$ = **0.0035**
Required compression reinforcement ratio	$\rho' = A_{scp1\_req} / (b \times d_{p1})$ = **0.0000**
Structural system factor (Table 7.4N)	K_δ = **1.0**
Basic span-to-depth ratio limit (Exp. 7.16a)	$ratio_{lim1\_bas} = K_\delta \times [11 + 1.5 \times (f_{ck}/1\ N/mm^2)^{0.5} \times \rho_0/\rho + 3.2 \times (f_{ck}/1\ N/mm^2)^{0.5} \times (\rho_0/\rho - 1)^{1.5}]$
	$ratio_{lim1\_bas}$ = **33.47**
Modified span-to-depth ratio limit	$ratio_{lim1} = \min(40 \times K_\delta, \min(1.5, (500\ N/mm^2 / f_{yk}) \times (A_{sp1} / A_{sp1\_m})) \times ratio_{lim1\_bas})$ = **40.00**
Actual span-to-depth ratio	$ratio_{act1} = l_1 / d_{p1}$ = **20.09**

PASS - Span-to-depth ratio is acceptable (0.502)

Reinforcement sketch

The following sketch is indicative only. Note that additional reinforcement may be required in accordance with clauses 9.2.1.2, 9.2.1.4 and 9.2.1.5 of EN 1992-1-1:2004 to meet detailing rules.



RC MEMBER ANALYSIS & DESIGN (EN1992-1-1:2004)

In accordance with EN1992-1-1:2004 incorporating Corrigenda January 2008 and the UK national annex

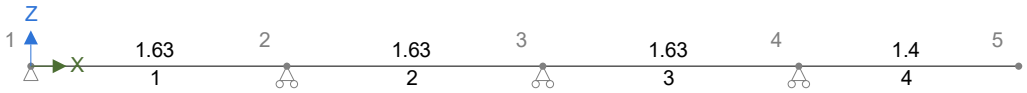
Tedds calculation version 3.3.08

ANALYSIS

Tedds calculation version 1.0.37

Geometry

Geometry (m) - Concrete (C32 2500 Quartzite) - R 200x475

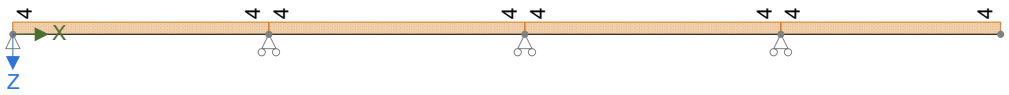


Span	Length (m)	Section	Start Support	End Support
1	1.63	R 200x475	Pinned	Roller Pin X
2	1.63	R 200x475	Roller Pin X	Roller Pin X
3	1.63	R 200x475	Roller Pin X	Roller Pin X
4	1.4	R 200x475	Roller Pin X	Free
R 200x475: Area 950 cm^2, Inertia Major 178620 cm^4, Inertia Minor 31667 cm^4, Shear area parallel to Minor 792 cm^2, Shear area parallel to Major = 792 cm^2				
Concrete (C32 2500 Quartzite): Density 2500 kg/m^3, Youngs 33.3457645 kN/mm^2, Shear 13.8940685 kN/mm^2, Thermal 0.00001 $°C^{-1}$				

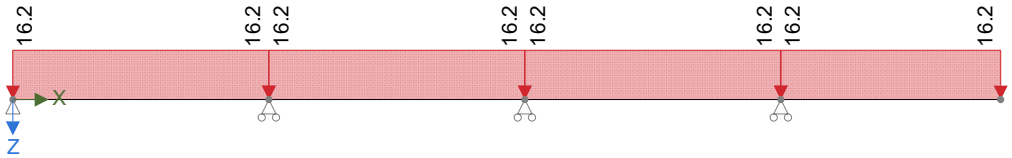
Loading

Self weight included

Permanent - Loading (kN/m)



Imposed - Loading (kN/m)



Load combination factors

Load combination	Self Weight	Permanent	Imposed
1.35G + 1.5Q + 1.5RQ (Strength)	1.35	1.35	1.50
1.0G + 1.0Q + 1.0RQ (Service)	1.00	1.00	1.00
1.0G + 1.0ψ_2Q (Quasi)	1.00	1.00	0.30

Member Loads

Member	Load case	Load Type	Orientation	Description
Beam	Permanent	UDL	GlobalZ	4 kN/m

Member	Load case	Load Type	Orientation	Description
Beam	Imposed	UDL	GlobalZ	16.2 kN/m

Results

Reactions

Load case: Self Weight

Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	1.5	0
2	0	4.6	0
3	0	2.1	0
4	0	6.5	0

Load case: Permanent

Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	2.5	0
2	0	7.9	0
3	0	3.6	0
4	0	11.1	0

Load case: Imposed

Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	10.2	0
2	0	32	0
3	0	14.6	0
4	0	45.1	0

Load combination: 1.35G + 1.5Q + 1.5RQ (Strength)

Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	20.7	0
2	0	64.8	0
3	0	29.6	0
4	0	91.5	0

Load combination: 1.0G + 1.0Q + 1.0RQ (Service)

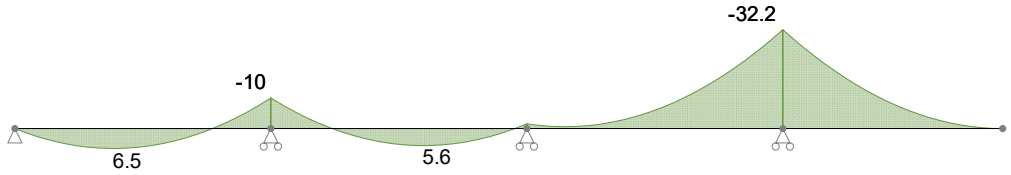
Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	14.2	0
2	0	44.4	0
3	0	20.3	0
4	0	62.8	0

Load combination: 1.0G + 1.0ψ_2Q (Quasi)

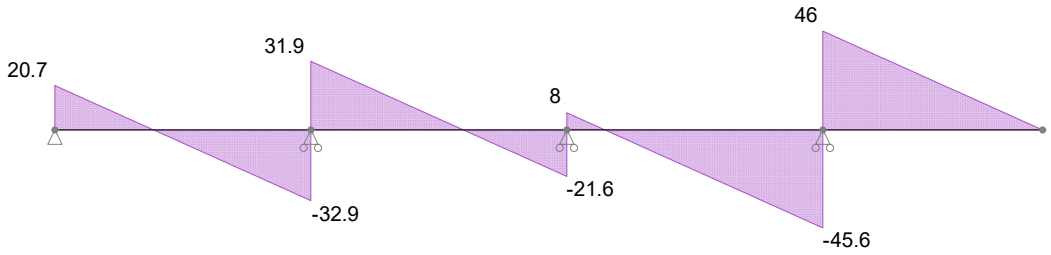
Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	7	0
2	0	22.1	0
3	0	10.1	0
4	0	31.2	0

Forces

Strength combinations - Moment envelope (kNm)



Strength combinations - Shear envelope (kN)



Concrete details (Table 3.1 - Strength and deformation characteristics for concrete)

Concrete strength class	C32/40	Char. comp. cylinder strength	f_{ck} = **32** N/mm^2
Design comp conc. strength	f_{cwd} = **21.3** N/mm^2	Maximum aggregate size	h_{agg} = **20** mm

Reinforcement details

Char. yield strength of rinf.	f_{yk} = **500** N/mm^2	Partial factor for reinf. steel	γ_S = **1.15**
Design yield strength of reinf.	f_{yd} = **435** N/mm^2		

Nominal cover to reinforcement

Nominal cover to top reinf	c_{nom_t} = **25** mm	Nominal cover to bottom reinf	c_{nom_b} = **50** mm
Nominal cover to side reinf	c_{nom_s} = **35** mm		

Fire resistance

Standard fire resistance period	R = **60** min	No. sides exposed to fire	3
Minimum width of beam	b_{min} = **120** mm		

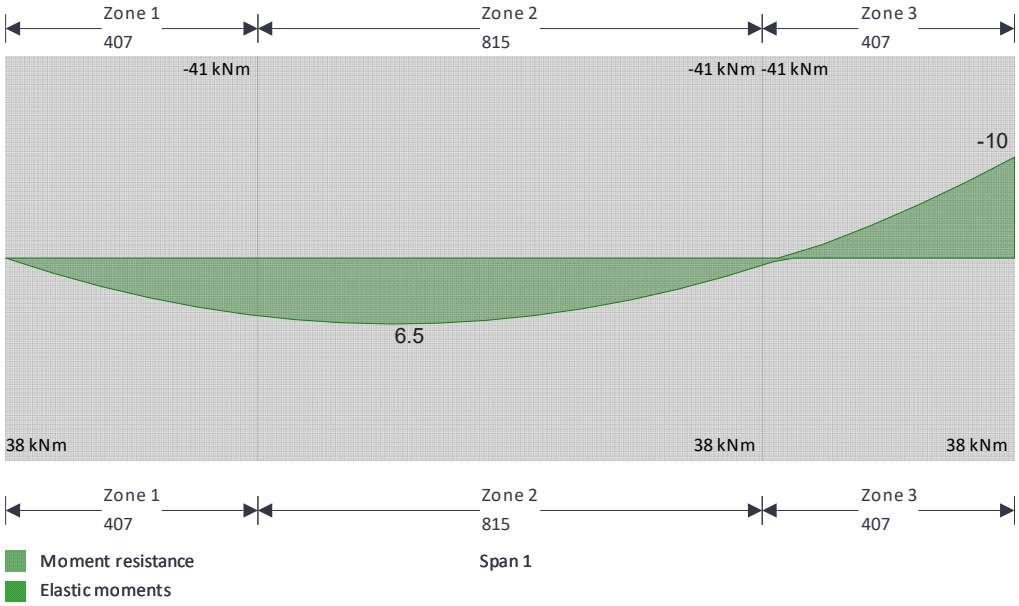
Beam - Span 1

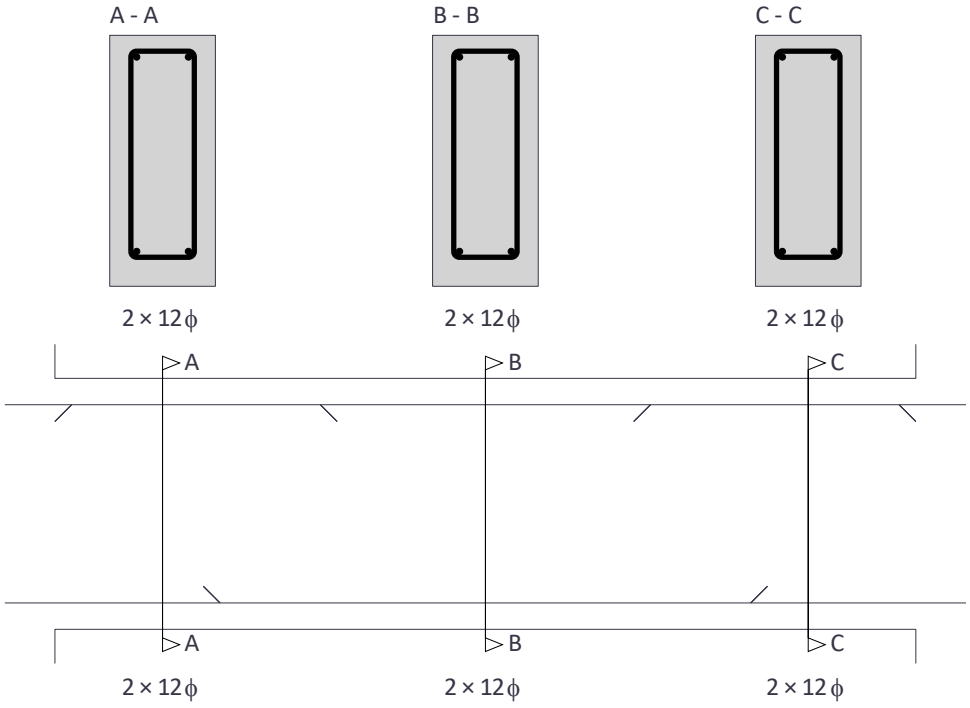
Rectangular section details

Section width	b = **200** mm	Section depth	h = **475** mm

PASS - Minimum dimensions for fire resistance met

Moment design





Zone 1 (0 mm - 407 mm) Positive moment - section 6.1

Design bending moment	M = **5.7** kNm	Effective depth tension reinf.	d = **409** mm
Area of tension reinf. req'd	$A_{s,req}$ = **34** mm^2	Area of tension reinf. prov	$A_{s,prov}$ = **226** mm^2
Min area of reinf. (exp.9.1N)	$A_{s,min}$ = **129** mm^2	Max area reinf. (cl.9.2.1.1(3))	$A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width	w_k = **0.30** mm	Min area reinf req'd (exp.7.1)	$A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **1.9**kNm

Actual tension bar spacing s_{bar} = **98** mm Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Zone 1 (0 mm - 407 mm) Negative moment - section 6.1

Design bending moment M = **1.6** kNm Effective depth tension reinf. d = **434** mm

Area of tension reinf. req'd $A_{s,req}$ = **9** mm^2 Area of tension reinf. prov $A_{s,prov}$ = **226** mm^2

Min area of reinf. (exp.9.1N) $A_{s,min}$ = **136** mm^2 Max area reinf. (cl.9.2.1.1(3)) $A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **0.0**kNm

Actual tension bar spacing s_{bar} = **98** mm Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Minimum bar spacing (Section 8.2)

Top bar spacing s_{top} = **86.0** mm Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **86.0** mm Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Zone 2 (407 mm - 1223 mm) Positive moment - section 6.1

Design bending moment M = **6.5** kNm Effective depth tension reinf. d = **409** mm

Area of tension reinf. req'd $A_{s,req}$ = **38** mm^2 Area of tension reinf. prov $A_{s,prov}$ = **226** mm^2

Min area of reinf. (exp.9.1N) $A_{s,min}$ = **129** mm^2 Max area reinf. (cl.9.2.1.1(3)) $A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **2.2**kNm

Actual tension bar spacing s_{bar} = **98** mm Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Deflection control - Section 7.4

Allow. span to depth ratio $span\_to\_depth_{allow}$ = **52.000** Actual span to depth ratio $span\_to\_depth_{actual}$ = **3.985**

PASS - Actual span to depth ratio is within the allowable limit

Minimum bar spacing (Section 8.2)

Top bar spacing s_{top} = **86.0** mm Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **86.0** mm Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Zone 3 (1223 mm - 1630 mm) Positive moment - section 6.1

Design bending moment M = **0.7** kNm Effective depth tension reinf. d = **409** mm

Area of tension reinf. req'd $A_{s,req}$ = **4** mm^2 Area of tension reinf. prov $A_{s,prov}$ = **226** mm^2

Min area of reinf. (exp.9.1N) $A_{s,min}$ = **129** mm^2 Max area reinf. (cl.9.2.1.1(3)) $A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **0.2**kNm

Actual tension bar spacing s_{bar} = **98** mm Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Zone 3 (1223 mm - 1630 mm) Negative moment - section 6.1

Design bending moment M = **10.0** kNm Effective depth tension reinf. d = **434** mm

Area of tension reinf. req'd $A_{s,req}$ = **56** mm^2 Area of tension reinf. prov $A_{s,prov}$ = **226** mm^2

Min area of reinf. (exp.9.1N) $A_{s,min}$ = **136** mm^2 Max area reinf. (cl.9.2.1.1(3)) $A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **3.4**kNm

Actual tension bar spacing s_{bar} = **98** mm Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Minimum bar spacing (Section 8.2)

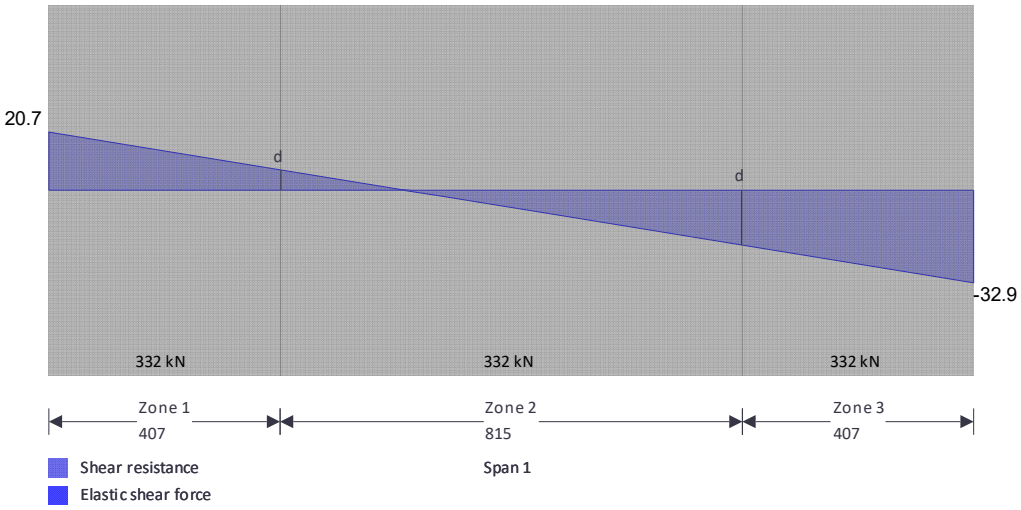
Top bar spacing s_{top} = **86.0** mm Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

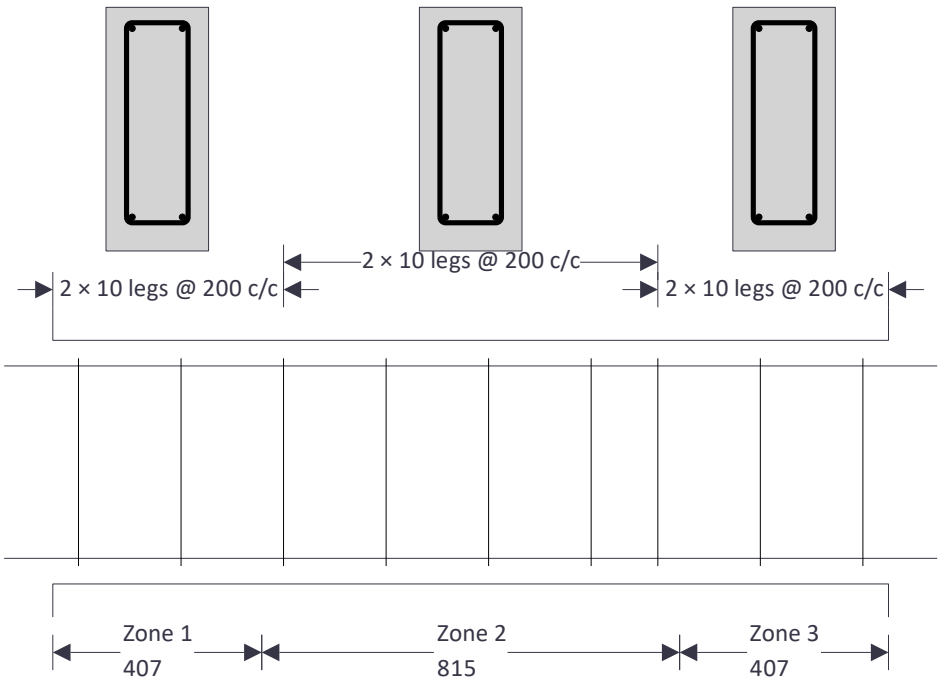
PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **86.0** mm Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Shear design





Angle of comp. shear strut θ_{max} = 45 deg — Strength reduction factor v_1 = **0.523**

Compression chord coefficient α_{cw} = **1.00** — Minimum area of shear reinf. $A_{sv,min}$ = **181** mm²/m

Zone 1 (0 mm - 407 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **21** kN — Max design shear resistance $V_{Rd,max}$ = **434** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force V_{Ed} = **7** kN — Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m

Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **307** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Zone 2 (407 mm - 1223 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **19** kN — Max design shear resistance $V_{Rd,max}$ = **434** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force V_{Ed} = **19** kN — Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m

Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **307** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Zone 3 (1223 mm - 1630 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **33** kN — Max design shear resistance $V_{Rd,max}$ = **434** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force V_{Ed} = **19** kN — Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m

Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **307** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

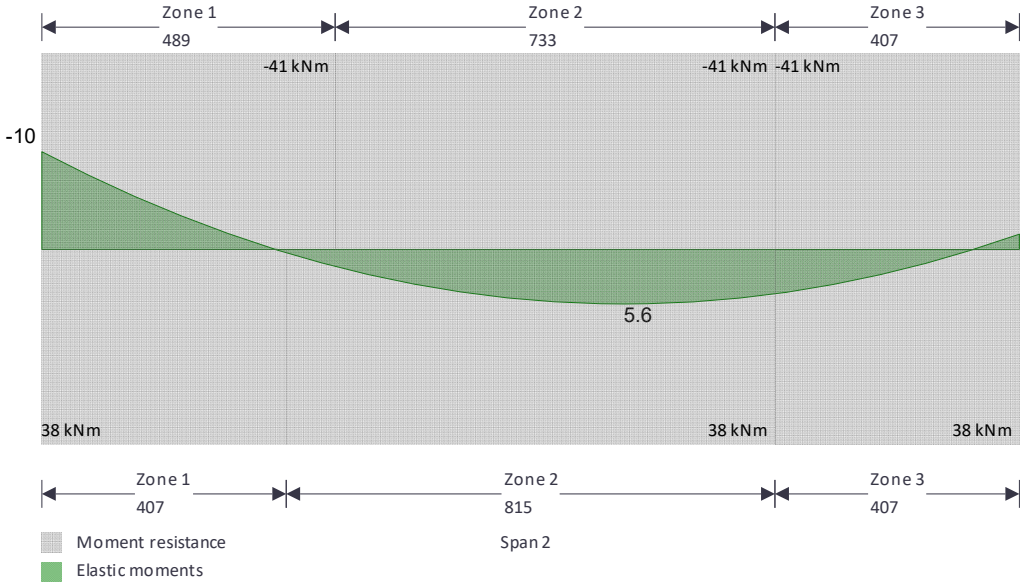
Beam - Span 2

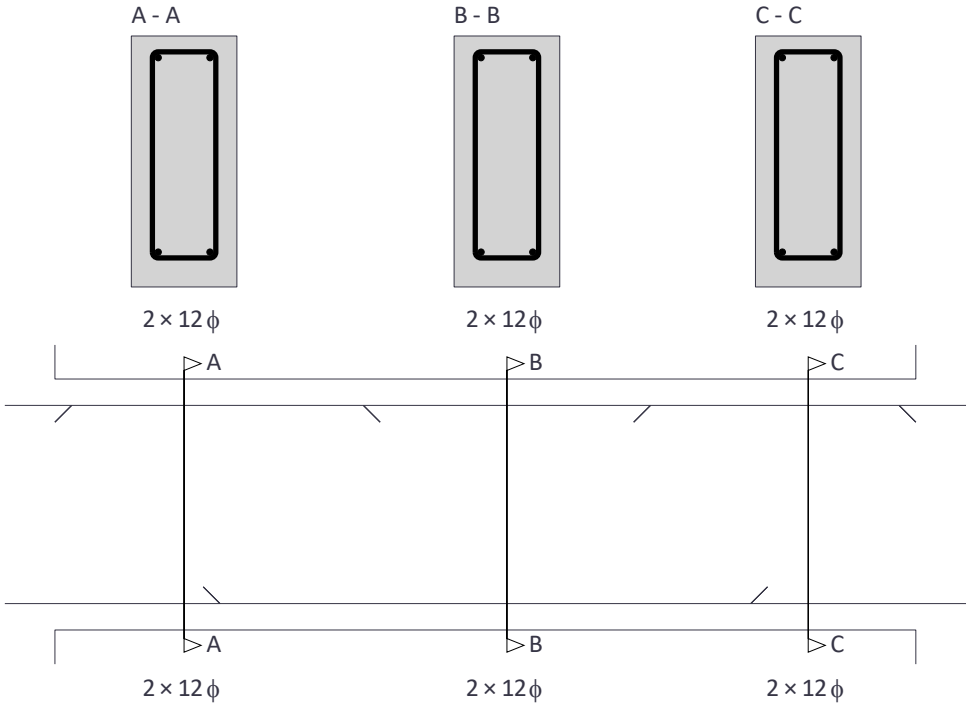
Rectangular section details

Section width b = **200** mm Section depth h = **475** mm

PASS - Minimum dimensions for fire resistance met

Moment design





Zone 1 (0 mm - 407 mm) Positive moment - section 6.1

Design bending moment	M = **0.3** kNm	Effective depth tension reinf.	d = **409** mm
Area of tension reinf. req'd	$A_{s,req}$ = **2** mm^2	Area of tension reinf. prov	$A_{s,prov}$ = **226** mm^2
Min area of reinf. (exp.9.1N)	$A_{s,min}$ = **129** mm^2	Max area reinf. (cl.9.2.1.1(3))	$A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm — Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **177** mm²

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **0.1**kNm

Actual tension bar spacing s_{bar} = **98** mm — Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Zone 1 (0 mm - 489 mm) Negative moment - section 6.1

Design bending moment M = **10.0** kNm — Effective depth tension reinf. d = **434** mm

Area of tension reinf. req'd $A_{s,req}$ = **56** mm² — Area of tension reinf. prov $A_{s,prov}$ = **226** mm²

Min area of reinf. (exp.9.1N) $A_{s,min}$ = **136** mm² — Max area reinf. (cl.9.2.1.1(3)) $A_{s,max}$ = **3800** mm²

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm — Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **177** mm²

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **3.4**kNm

Actual tension bar spacing s_{bar} = **98** mm — Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Minimum bar spacing (Section 8.2)

Top bar spacing s_{top} = **86.0** mm — Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **86.0** mm — Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Zone 2 (407 mm - 1223 mm) Positive moment - section 6.1

Design bending moment M = **5.6** kNm — Effective depth tension reinf. d = **409** mm

Area of tension reinf. req'd $A_{s,req}$ = **33** mm² — Area of tension reinf. prov $A_{s,prov}$ = **226** mm²

Min area of reinf. (exp.9.1N) $A_{s,min}$ = **129** mm² — Max area reinf. (cl.9.2.1.1(3)) $A_{s,max}$ = **3800** mm²

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm — Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **177** mm²

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **1.9**kNm

Actual tension bar spacing s_{bar} = **98** mm — Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Deflection control - Section 7.4

Allow. span to depth ratio $span\_to\_depth_{allow}$ = **60.000** — Actual span to depth ratio $span\_to\_depth_{actual}$ = **3.985**

PASS - Actual span to depth ratio is within the allowable limit

Minimum bar spacing (Section 8.2)

Top bar spacing s_{top} = **86.0** mm — Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **86.0** mm — Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Zone 3 (1223 mm - 1630 mm) Positive moment - section 6.1

Design bending moment M = **4.5** kNm — Effective depth tension reinf. d = **409** mm

Area of tension reinf. req'd $A_{s,req}$ = **27** mm² — Area of tension reinf. prov $A_{s,prov}$ = **226** mm²

Min area of reinf. (exp.9.1N)	$A_{s,min}$ = **129** mm^2	Max area reinf. (cl.9.2.1.1(3))	$A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width	w_k = **0.30** mm	Min area reinf req'd (exp.7.1)	$A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment	M_{QP} = **1.5**kNm		
Actual tension bar spacing	s_{bar} = **98** mm	Max bar spacing (Table 7.3N)	$s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Zone 3 (1223 mm - 1630 mm) Negative moment - section 6.1

Design bending moment	M = **1.6** kNm	Effective depth tension reinf.	d = **434** mm
Area of tension reinf. req'd	$A_{s,req}$ = **9** mm^2	Area of tension reinf. prov	$A_{s,prov}$ = **226** mm^2
Min area of reinf. (exp.9.1N)	$A_{s,min}$ = **136** mm^2	Max area reinf. (cl.9.2.1.1(3))	$A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width	w_k = **0.30** mm	Min area reinf req'd (exp.7.1)	$A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment	M_{QP} = **0.5**kNm		
Actual tension bar spacing	s_{bar} = **98** mm	Max bar spacing (Table 7.3N)	$s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Minimum bar spacing (Section 8.2)

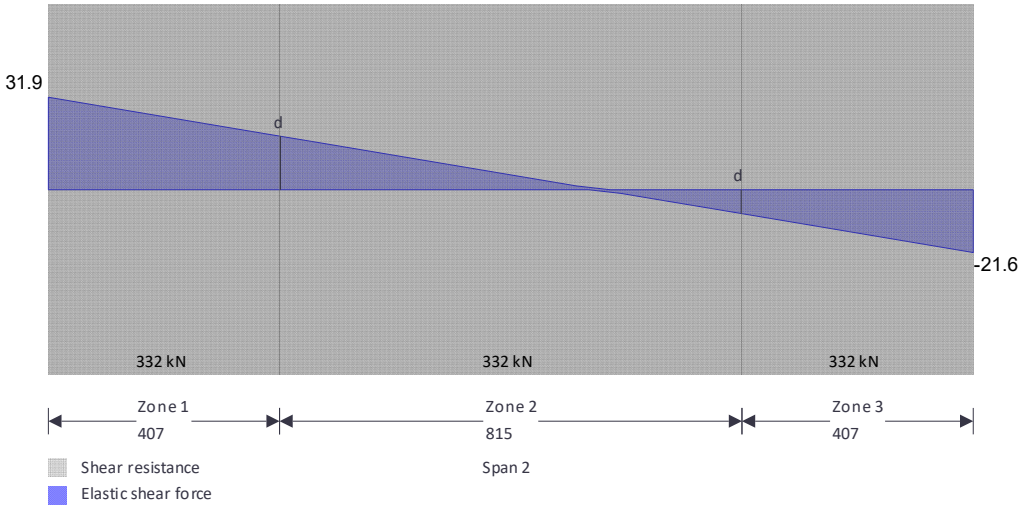
Top bar spacing	s_{top} = **86.0** mm	Min allow. top bar spacing	$s_{top,min}$ = **25.0** mm

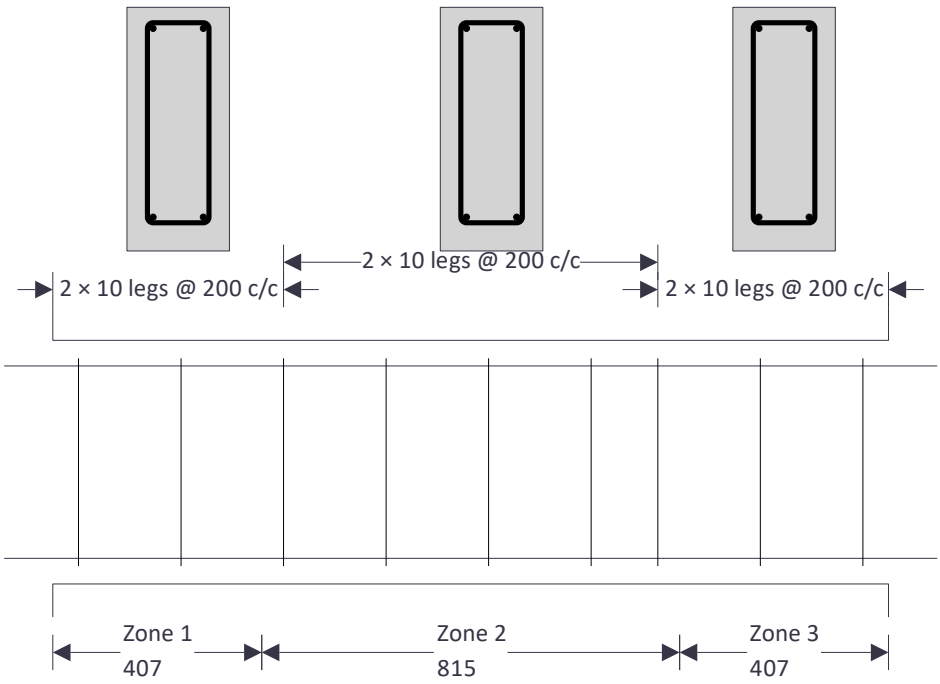
PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing	s_{bot} = **86.0** mm	Min allow. bottom bar spacing	$s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Shear design





Angle of comp. shear strut θ_{max} = 45 deg
Strength reduction factor v_1 = **0.523**
Compression chord coefficient α_{cw} = **1.00**
Minimum area of shear reinf. $A_{sv,min}$ = **181** mm²/m

Zone 1 (0 mm - 407 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **32** kN
Max design shear resistance $V_{Rd,max}$ = **434** kN
PASS - Design shear force at support is less than maximum design shear resistance
Design shear force V_{Ed} = **18** kN
Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m
Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m
PASS - Area of shear reinforcement provided exceeds minimum required
Max. long. spacing - exp.9.6N $s_{vl,max}$ = **307** mm
PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Zone 2 (407 mm - 1223 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **19** kN
Max design shear resistance $V_{Rd,max}$ = **434** kN
PASS - Design shear force at support is less than maximum design shear resistance
Design shear force V_{Ed} = **18** kN
Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m
Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m
PASS - Area of shear reinforcement provided exceeds minimum required
Max. long. spacing - exp.9.6N $s_{vl,max}$ = **307** mm
PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Zone 3 (1223 mm - 1630 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **22** kN
Max design shear resistance $V_{Rd,max}$ = **434** kN
PASS - Design shear force at support is less than maximum design shear resistance
Design shear force V_{Ed} = **8** kN
Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m
Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m
PASS - Area of shear reinforcement provided exceeds minimum required
Max. long. spacing - exp.9.6N $s_{vl,max}$ = **307** mm
PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

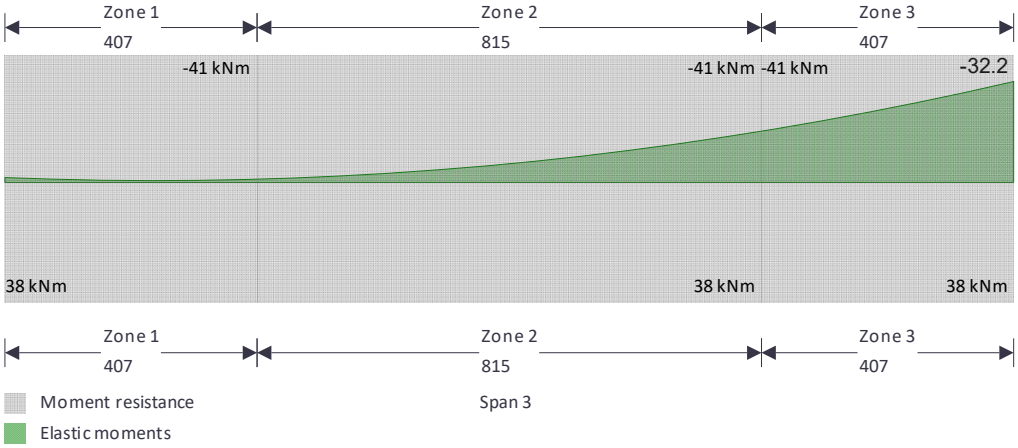
Beam - Span 3

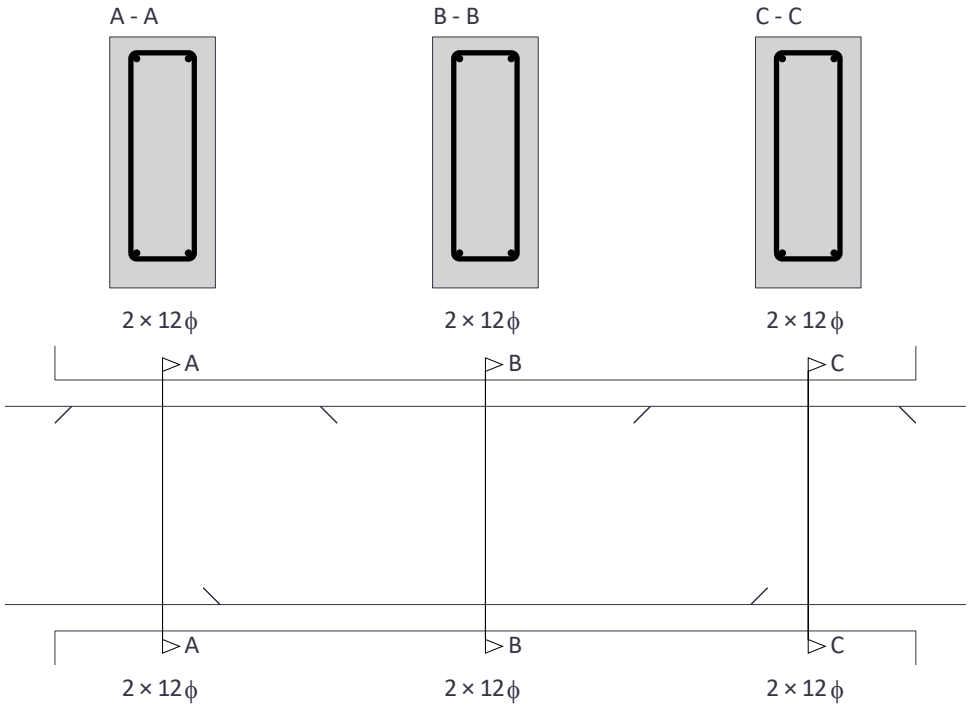
Rectangular section details

Section width b = **200** mm Section depth h = **475** mm

PASS - Minimum dimensions for fire resistance met

Moment design





Zone 1 (0 mm - 407 mm) Negative moment - section 6.1

Design bending moment	M = **1.6** kNm	Effective depth tension reinf.	d = **434** mm
Area of tension reinf. req'd	$A_{s,req}$ = **9** mm^2	Area of tension reinf. prov	$A_{s,prov}$ = **226** mm^2
Min area of reinf. (exp.9.1N)	$A_{s,min}$ = **136** mm^2	Max area reinf. (cl.9.2.1.1(3))	$A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width	w_k = **0.30** mm	Min area reinf req'd (exp.7.1)	$A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **0.5**kNm

Actual tension bar spacing s_{bar} = **98** mm Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Minimum bar spacing (Section 8.2)

Top bar spacing s_{top} = **86.0** mm Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **86.0** mm Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Zone 2 (407 mm - 1223 mm) Negative moment - section 6.1

Design bending moment M = **16.4** kNm Effective depth tension reinf. d = **434** mm

Area of tension reinf. req'd $A_{s,req}$ = **91** mm^2 Area of tension reinf. prov $A_{s,prov}$ = **226** mm^2

Min area of reinf. (exp.9.1N) $A_{s,min}$ = **136** mm^2 Max area reinf. (cl.9.2.1.1(3)) $A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **5.6**kNm

Actual tension bar spacing s_{bar} = **98** mm Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Deflection control - Section 7.4

Allow. span to depth ratio $span\_to\_depth_{allow}$ = **60.000** Actual span to depth ratio $span\_to\_depth_{actual}$ = **3.756**

PASS - Actual span to depth ratio is within the allowable limit

Minimum bar spacing (Section 8.2)

Top bar spacing s_{top} = **86.0** mm Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **86.0** mm Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Zone 3 (1223 mm - 1630 mm) Negative moment - section 6.1

Design bending moment M = **32.2** kNm Effective depth tension reinf. d = **434** mm

Area of tension reinf. req'd $A_{s,req}$ = **180** mm^2 Area of tension reinf. prov $A_{s,prov}$ = **226** mm^2

Min area of reinf. (exp.9.1N) $A_{s,min}$ = **136** mm^2 Max area reinf. (cl.9.2.1.1(3)) $A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **11.0**kNm

Actual tension bar spacing s_{bar} = **98** mm Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Minimum bar spacing (Section 8.2)

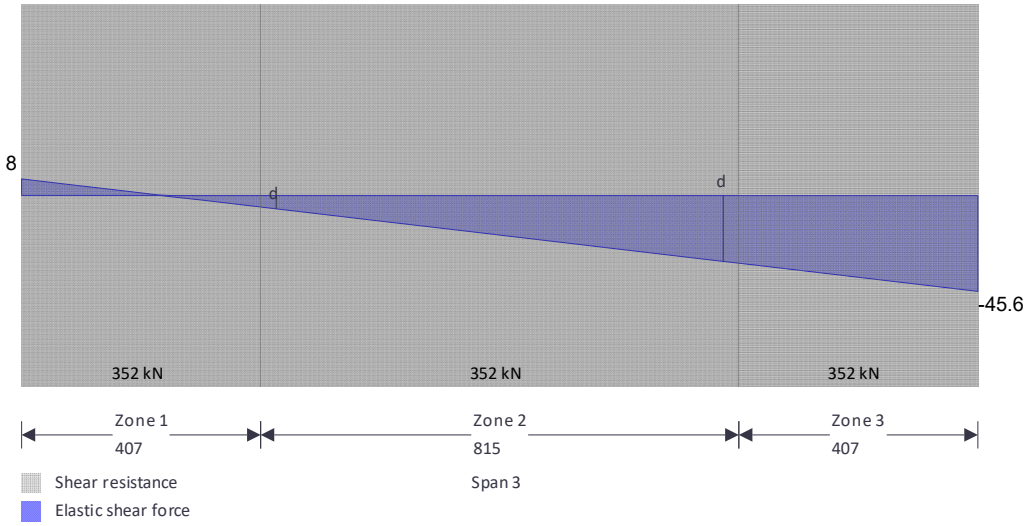
Top bar spacing s_{top} = **86.0** mm Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

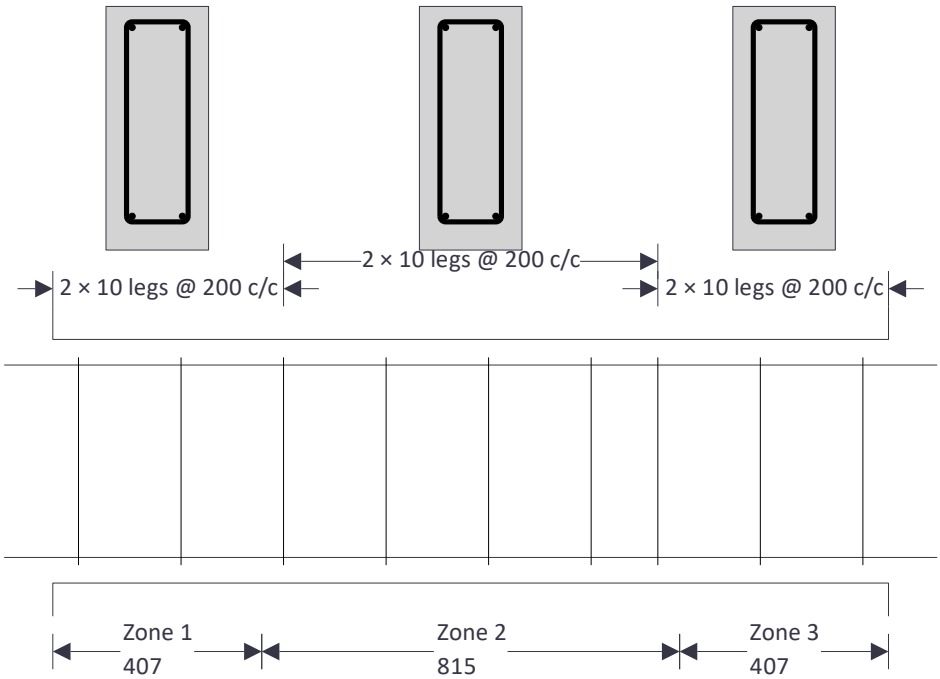
PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **86.0** mm Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Shear design





Angle of comp. shear strut θ_{max} = 45 deg
Strength reduction factor v_1 = **0.523**
Compression chord coefficient α_{cw} = **1.00**
Minimum area of shear reinf. $A_{sv,min}$ = **181** mm²/m

Zone 1 (0 mm - 407 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **8** kN
Max design shear resistance $V_{Rd,max}$ = **460** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force V_{Ed} = **6** kN
Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m
Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **326** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Zone 2 (407 mm - 1223 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **31** kN — Max design shear resistance $V_{Rd,max}$ = **460** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force V_{Ed} = **31** kN — Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m

Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **326** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Zone 3 (1223 mm - 1630 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **46** kN — Max design shear resistance $V_{Rd,max}$ = **460** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force V_{Ed} = **31** kN — Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m

Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **326** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

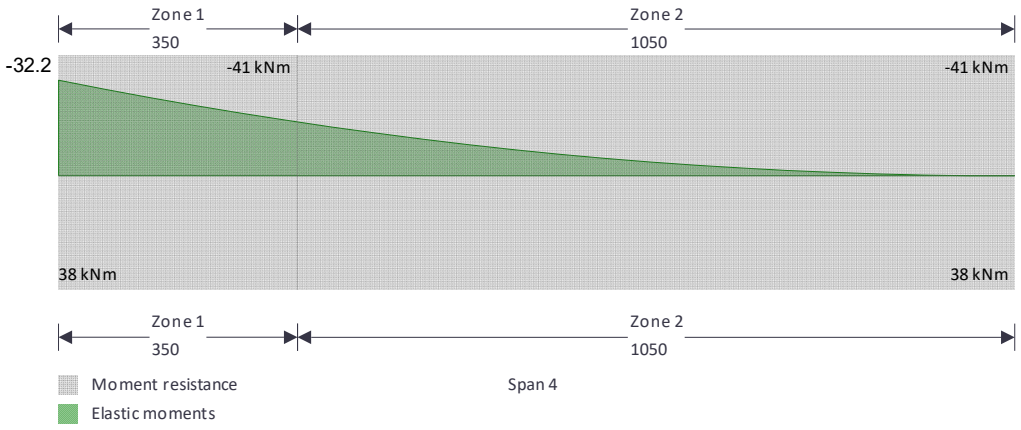
Beam - Span 4

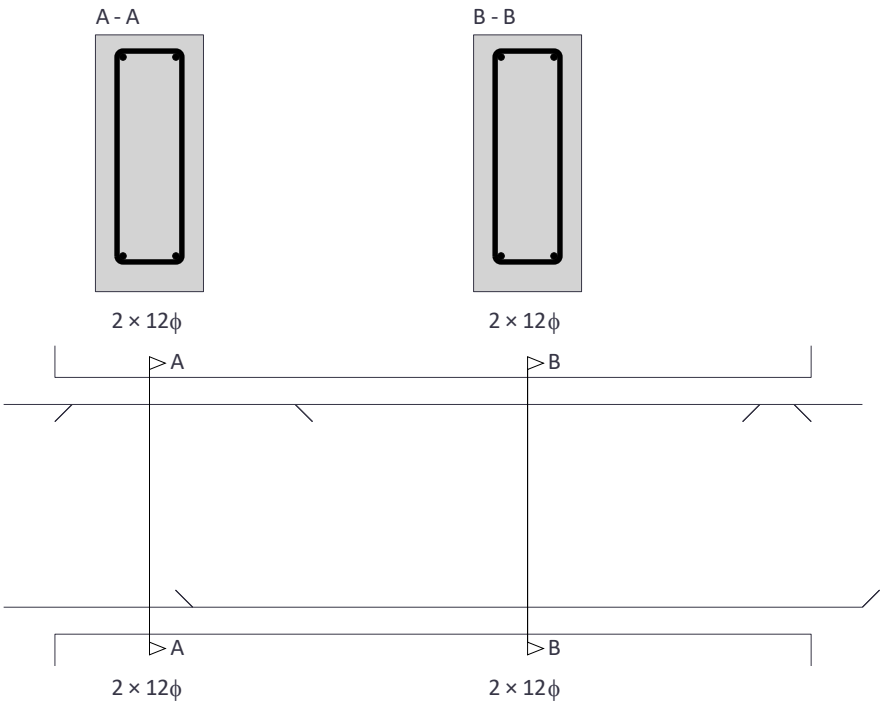
Rectangular section details

Section width b = **200** mm — Section depth h = **475** mm

PASS - Minimum dimensions for fire resistance met

Moment design





Zone 1 (0 mm - 350 mm) Negative moment - section 6.1

Design bending moment	M = **32.2** kNm	Effective depth tension reinf.	d = **434** mm
Area of tension reinf. req'd	$A_{s,req}$ = **180** mm^2	Area of tension reinf. prov	$A_{s,prov}$ = **226** mm^2
Min area of reinf. (exp.9.1N)	$A_{s,min}$ = **136** mm^2	Max area reinf. (cl.9.2.1.1(3))	$A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width	w_k = **0.30** mm	Min area reinf req'd (exp.7.1)	$A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment	M_{QP} = **11.0**kNm		
Actual tension bar spacing	s_{bar} = **98** mm	Max bar spacing (Table 7.3N)	$s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Deflection control - Section 7.4

Allow. span to depth ratio	$span\_to\_depth_{allow}$ = **16.000**	Actual span to depth ratio	$span\_to\_depth_{actual}$ = **3.226**

PASS - Actual span to depth ratio is within the allowable limit

Minimum bar spacing (Section 8.2)

Top bar spacing	s_{top} = **86.0** mm	Min allow. top bar spacing	$s_{top,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing	s_{bot} = **86.0** mm	Min allow. bottom bar spacing	$s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Zone 2 (350 mm - 1400 mm) Negative moment - section 6.1

Design bending moment	M = **18.1** kNm	Effective depth tension reinf.	d = **434** mm
Area of tension reinf. req'd	$A_{s,req}$ = **101** mm^2	Area of tension reinf. prov	$A_{s,prov}$ = **226** mm^2
Min area of reinf. (exp.9.1N)	$A_{s,min}$ = **136** mm^2	Max area reinf. (cl.9.2.1.1(3))	$A_{s,max}$ = **3800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width	w_k = **0.30** mm	Min area reinf req'd (exp.7.1)	$A_{sc,min}$ = **177** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **6.2**kNm

Actual tension bar spacing s_{bar} = **98** mm Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Minimum bar spacing (Section 8.2)

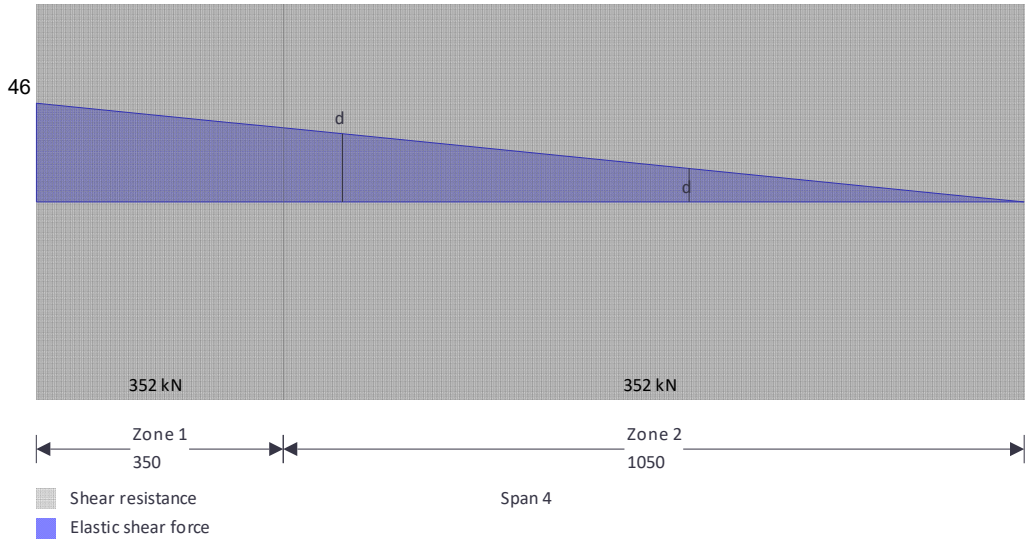
Top bar spacing s_{top} = **86.0** mm Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

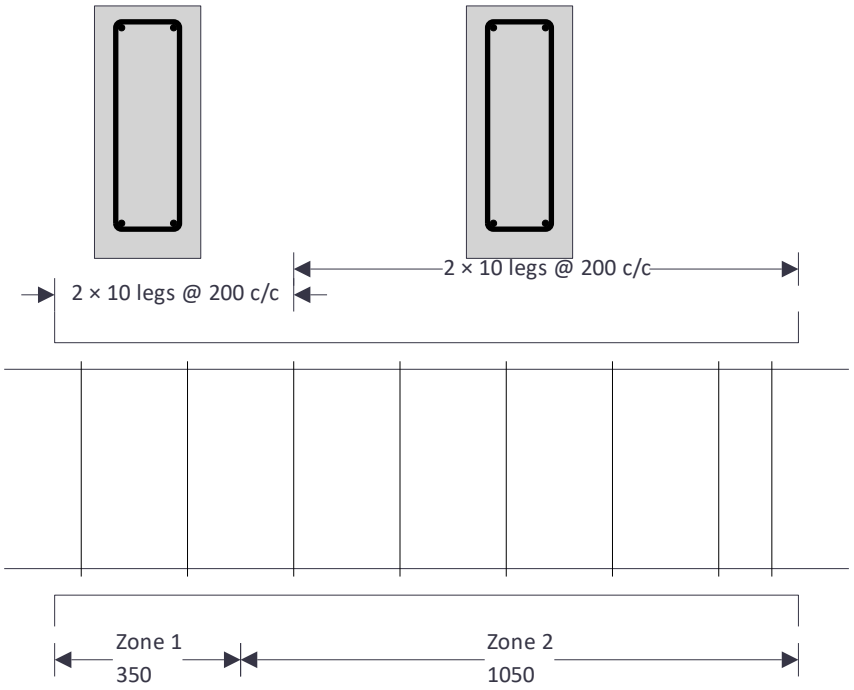
PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **86.0** mm Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Shear design





Angle of comp. shear strut θ_{max} = 45 deg Strength reduction factor v_1 = **0.523**

Compression chord coefficient α_{cw} = **1.00** Minimum area of shear reinf. $A_{sv,min}$ = **181** mm²/m

Zone 1 (0 mm - 350 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **46** kN Max design shear resistance $V_{Rd,max}$ = **460** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force V_{Ed} = **32** kN Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m

Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **326** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Zone 2 (350 mm - 1400 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **32** kN Max design shear resistance $V_{Rd,max}$ = **460** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force V_{Ed} = **32** kN Area shear reinf. req'd $A_{sv,req}$ = **181** mm²/m

Area of shear reinf prov. $A_{sv,prov}$ = **785** mm²/m

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **326** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

RC MEMBER ANALYSIS & DESIGN (EN1992-1-1:2004)

In accordance with EN1992-1-1:2004 incorporating Corrigenda January 2008 and the UK national annex

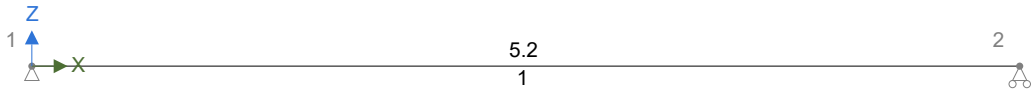
Tedds calculation version 3.3.08

ANALYSIS

Tedds calculation version 1.0.37

Geometry

Geometry (m) - Concrete (C32 2500 Quartzite) - R 200x850



Span	Length (m)	Section	Start Support	End Support
1	5.2	R 200x850	Pinned	Roller Pin X
R 200x850: Area 1700 cm^2, Inertia Major 1023542 cm^4, Inertia Minor 56667 cm^4, Shear area parallel to Minor 1417 cm^2, Shear area parallel to Major = 1417 cm^2				
Concrete (C32 2500 Quartzite): Density 2500 kg/m^3, Youngs 33.3457645 kN/mm^2, Shear 13.8940685 kN/mm^2, Thermal 0.00001 $°C^{-1}$				

Loading

Self weight included

Permanent - Loading (kN/m)

Imposed - Loading (kN/m)

Load combination factors

Load combination	Self Weight	Permanent	Imposed
1.35G + 1.5Q + 1.5RQ (Strength)	1.35	1.35	1.50
1.0G + 1.0Q + 1.0RQ (Service)	1.00	1.00	1.00
1.0G + 1.0ψ_2Q (Quasi)	1.00	1.00	0.30

Member Loads

Member	Load case	Load Type	Orientation	Description
Beam	Permanent	UDL	GlobalZ	4 kN/m
Beam	Imposed	UDL	GlobalZ	16.2 kN/m

Results

Reactions

Load case: Self Weight

Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	10.8	0
2	0	10.8	0

Load case: Permanent

Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	10.4	0
2	0	10.4	0

Load case: Imposed

Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	42.1	0
2	0	42.1	0

Load combination: 1.35G + 1.5Q + 1.5RQ (Strength)

Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	91.8	0
2	0	91.8	0

Load combination: 1.0G + 1.0Q + 1.0RQ (Service)

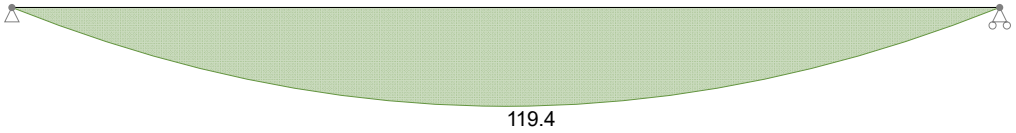
Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	63.4	0
2	0	63.4	0

Load combination: 1.0G + 1.0ψ_2Q (Quasi)

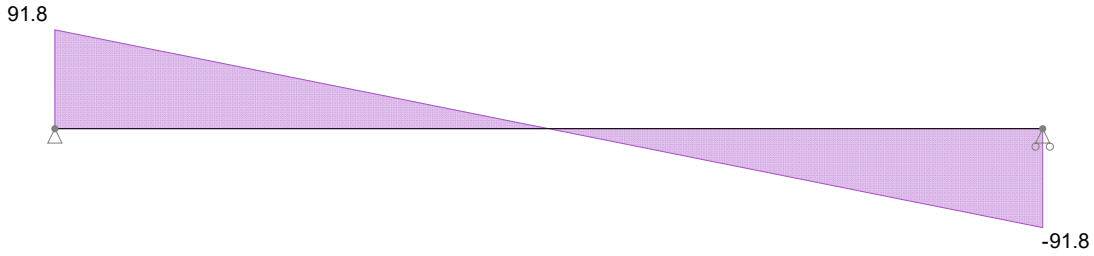
Node	Force		Moment
	Fx (kN)	Fz (kN)	My (kNm)
1	0	33.9	0
2	0	33.9	0

Forces

Strength combinations - Moment envelope (kNm)



Strength combinations - Shear envelope (kN)



Concrete details (Table 3.1 - Strength and deformation characteristics for concrete)

Concrete strength class	C32/40	Char. comp. cylinder strength	f_{ck} = **32** N/mm^2
Design comp conc. strength	f_{cwd} = **21.3** N/mm^2	Maximum aggregate size	h_{agg} = **20** mm

Reinforcement details

Char. yield strength of rinf.	f_{yk} = **500** N/mm^2	Partial factor for reinf. steel	γ_S = **1.15**
Design yield strength of reinf.	f_{yd} = **435** N/mm^2		

Nominal cover to reinforcement

Nominal cover to top reinf	c_{nom_t} = **25** mm	Nominal cover to bottom reinf	c_{nom_b} = **50** mm
Nominal cover to side reinf	c_{nom_s} = **35** mm		

Fire resistance

Standard fire resistance period	R = **60** min	No. sides exposed to fire	3
Minimum width of beam	b_{min} = **120** mm		

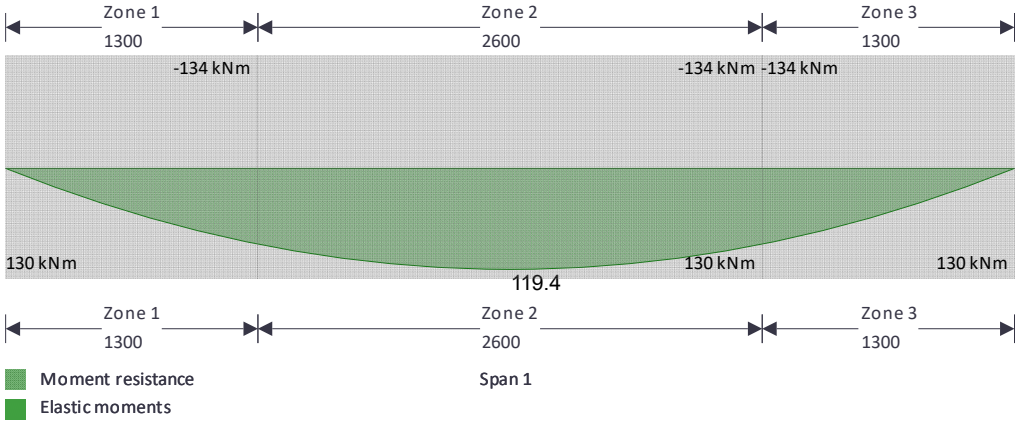
Beam - Span 1

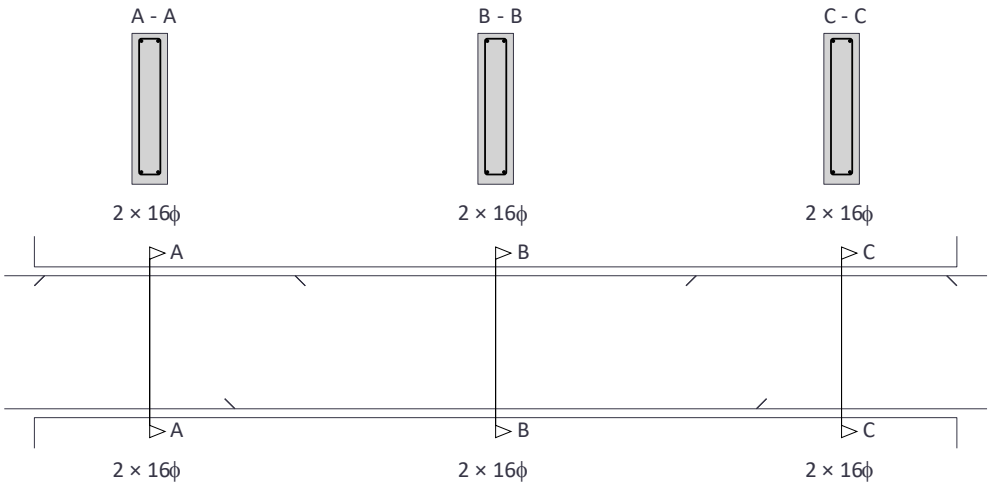
Rectangular section details

Section width	b = **200** mm	Section depth	h = **850** mm

PASS - Minimum dimensions for fire resistance met

Moment design





Zone 1 (0 mm - 1300 mm) Positive moment - section 6.1

Design bending moment	M = **89.6** kNm	Effective depth tension reinf.	d = **782** mm
Area of tension reinf. req'd	$A_{s,req}$ = **277** mm^2	Area of tension reinf. prov	$A_{s,prov}$ = **402** mm^2
Min area of reinf. (exp.9.1N)	$A_{s,min}$ = **246** mm^2	Max area reinf. (cl.9.2.1.1(3))	$A_{s,max}$ = **6800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width	w_k = **0.30** mm	Min area reinf req'd (exp.7.1)	$A_{sc,min}$ = **313** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment	M_{QP} = **33.0**kNm		
Actual tension bar spacing	s_{bar} = **94** mm	Max bar spacing (Table 7.3N)	$s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Zone 1 (0 mm - 1300 mm) Negative moment - section 6.1

Design bending moment	M = **29.9** kNm	Effective depth tension reinf.	d = **807** mm
Area of tension reinf. req'd	$A_{s,req}$ = **90** mm^2	Area of tension reinf. prov	$A_{s,prov}$ = **402** mm^2
Min area of reinf. (exp.9.1N)	$A_{s,min}$ = **254** mm^2	Max area reinf. (cl.9.2.1.1(3))	$A_{s,max}$ = **6800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width	w_k = **0.30** mm	Min area reinf req'd (exp.7.1)	$A_{sc,min}$ = **313** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment	M_{QP} = **0.0**kNm		
Actual tension bar spacing	s_{bar} = **94** mm	Max bar spacing (Table 7.3N)	$s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Minimum bar spacing (Section 8.2)

Top bar spacing	s_{top} = **78.0** mm	Min allow. top bar spacing	$s_{top,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing	s_{bot} = **78.0** mm	Min allow. bottom bar spacing	$s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Zone 2 (1300 mm - 3900 mm) Positive moment - section 6.1

Design bending moment	M = **119.4** kNm	Effective depth tension reinf.	d = **782** mm
Area of tension reinf. req'd	$A_{s,req}$ = **370** mm^2	Area of tension reinf. prov	$A_{s,prov}$ = **402** mm^2
Min area of reinf. (exp.9.1N)	$A_{s,min}$ = **246** mm^2	Max area reinf. (cl.9.2.1.1(3))	$A_{s,max}$ = **6800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm — Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **313** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **44.0**kNm

Actual tension bar spacing s_{bar} = **94** mm — Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Deflection control - Section 7.4

Allow. span to depth ratio span_to_depth$_{allow}$ = **52.000** — Actual span to depth ratio span_to_depth$_{actual}$ = **6.650**

PASS - Actual span to depth ratio is within the allowable limit

Minimum bar spacing (Section 8.2)

Top bar spacing s_{top} = **78.0** mm — Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **78.0** mm — Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Zone 3 (3900 mm - 5200 mm) Positive moment - section 6.1

Design bending moment M = **89.6** kNm — Effective depth tension reinf. d = **782** mm

Area of tension reinf. req'd $A_{s,req}$ = **277** mm^2 — Area of tension reinf. prov $A_{s,prov}$ = **402** mm^2

Min area of reinf. (exp.9.1N) $A_{s,min}$ = **246** mm^2 — Max area reinf. (cl.9.2.1.1(3)) $A_{s,max}$ = **6800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm — Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **313** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **33.0**kNm

Actual tension bar spacing s_{bar} = **94** mm — Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Zone 3 (3900 mm - 5200 mm) Negative moment - section 6.1

Design bending moment M = **29.9** kNm — Effective depth tension reinf. d = **807** mm

Area of tension reinf. req'd $A_{s,req}$ = **90** mm^2 — Area of tension reinf. prov $A_{s,prov}$ = **402** mm^2

Min area of reinf. (exp.9.1N) $A_{s,min}$ = **254** mm^2 — Max area reinf. (cl.9.2.1.1(3)) $A_{s,max}$ = **6800** mm^2

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Maximum crack width w_k = **0.30** mm — Min area reinf req'd (exp.7.1) $A_{sc,min}$ = **313** mm^2

PASS - Area of tension reinforcement provided exceeds minimum required for crack control

Quasi-permanent moment M_{QP} = **0.0**kNm

Actual tension bar spacing s_{bar} = **94** mm — Max bar spacing (Table 7.3N) $s_{bar,max}$ = **300** mm

PASS - Maximum bar spacing exceeds actual bar spacing for crack control

Minimum bar spacing (Section 8.2)

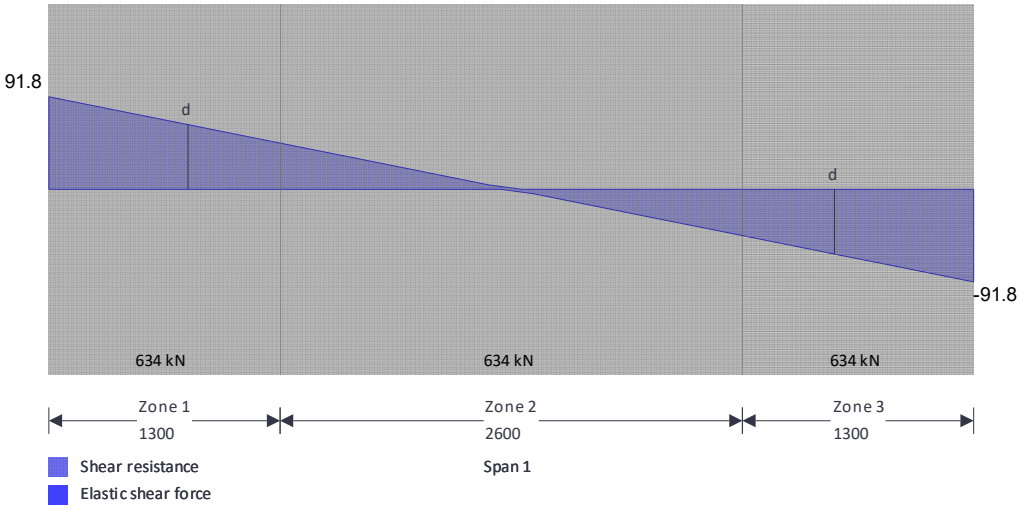
Top bar spacing s_{top} = **78.0** mm — Min allow. top bar spacing $s_{top,min}$ = **25.0** mm

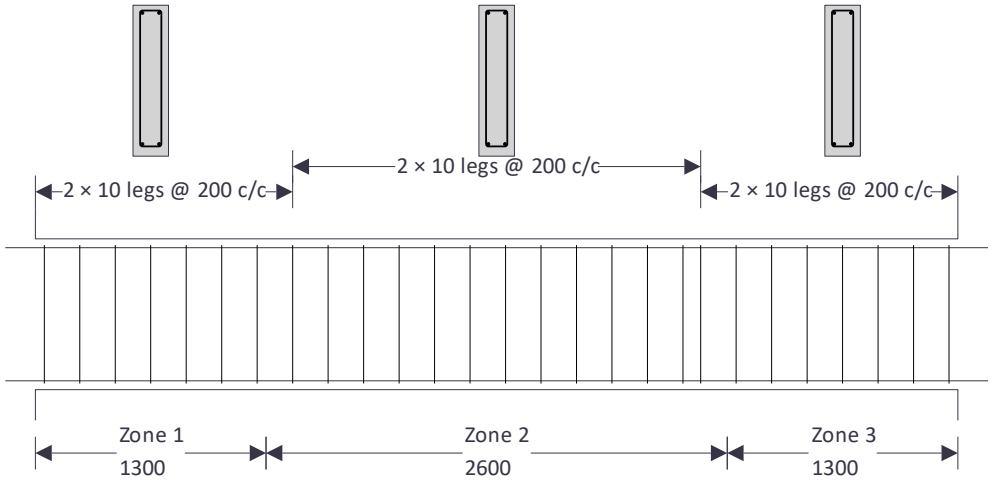
PASS - Actual bar spacing exceeds minimum allowable

Bottom bar spacing s_{bot} = **78.0** mm — Min allow. bottom bar spacing $s_{bot,min}$ = **25.0** mm

PASS - Actual bar spacing exceeds minimum allowable

Shear design





Angle of comp. shear strut	θ_{max} = 45 deg	Strength reduction factor	v_1 = **0.523**
Compression chord coefficient	α_{cw} = **1.00**	Minimum area of shear reinf.	$A_{sv,min}$ = **181** mm²/m

Zone 1 (0 mm - 1300 mm) shear - section 6.2

Shear force at support	$V_{Ed,max}$ = **92** kN	Max design shear resistance	$V_{Rd,max}$ = **829** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force	V_{Ed} = **64** kN	Area shear reinf. req'd	$A_{sv,req}$ = **181** mm²/m
Area of shear reinf prov.	$A_{sv,prov}$ = **785** mm²/m		

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **587** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Zone 2 (1300 mm - 3900 mm) shear - section 6.2

Shear force at support	$V_{Ed,max}$ = **46** kN	Max design shear resistance	$V_{Rd,max}$ = **829** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force	V_{Ed} = **46** kN	Area shear reinf. req'd	$A_{sv,req}$ = **181** mm²/m
Area of shear reinf prov.	$A_{sv,prov}$ = **785** mm²/m		

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **587** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum

Zone 3 (3900 mm - 5200 mm) shear - section 6.2

Shear force at support $V_{Ed,max}$ = **92** kN Max design shear resistance $V_{Rd,max}$ = **829** kN

PASS - Design shear force at support is less than maximum design shear resistance

Design shear force V_{Ed} = **64** kN Area shear reinf. req'd $A_{sv,req}$ = **181** mm^2/m

Area of shear reinf prov. $A_{sv,prov}$ = **785** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Max. long. spacing - exp.9.6N $s_{vl,max}$ = **587** mm

PASS - Longitudinal spacing of shear reinforcement provided is less than maximum