

 MshStructure Nicosia Haspolat via mersin 10	Project					Job Ref.	
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RC BEAM ANALYSIS & DESIGN (ACI318-2019 (22))

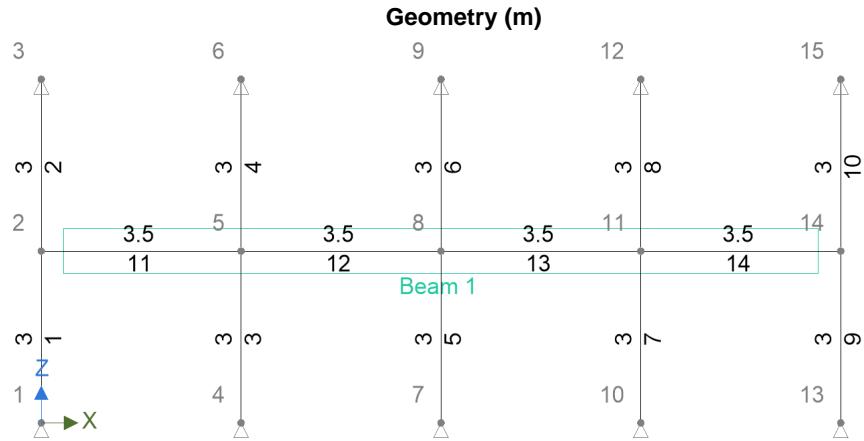
In accordance with ACI318-2019 (22)

Tedds calculation version 3.3.18

ANALYSIS

Tedds calculation version 1.0.38

Geometry



Materials

Name	Density (kg/m³)	Youngs Modulus kN/mm²	Shear Modulus kN/mm²	Thermal Coefficient °C⁻¹
Concrete Column	2402.7664096	28.9579433	12.0658097	0.00001
Concrete (2901 150)	2402.7664096	22.512568	12.0658097	0.00001

Sections

Name	Area (cm²)	Moment of inertia		Shear area parallel to	
		Major (cm⁴)	Minor (cm⁴)	Minor (cm²)	Major (cm²)
C30x30	900	67500	67500	750	750
B30x50	1500	312500	112500	1250	1250

Nodes

Node	Co-ordinates		Freedom			Coordinate system		Spring		
	X (m)	Z (m)	X	Z	Rot.	Name	Angle (°)	X (kN/m)	Z (kN/m)	Rot. kNm/°
1	0	0	Fixed	Fixed	Free		0	0	0	0
2	0	3	Free	Free	Free		0	0	0	0
3	0	6	Fixed	Fixed	Free		0	0	0	0
4	3.5	0	Fixed	Fixed	Free		0	0	0	0
5	3.5	3	Free	Free	Free		0	0	0	0
6	3.5	6	Fixed	Fixed	Free		0	0	0	0
7	7	0	Fixed	Fixed	Free		0	0	0	0
8	7	3	Free	Free	Free		0	0	0	0
9	7	6	Fixed	Fixed	Free		0	0	0	0

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Node	Co-ordinates		Freedom			Coordinate system		Spring		
	X (m)	Z (m)	X	Z	Rot.	Name	Angle (°)	X (kN/m)	Z (kN/m)	Rot. kNm/°
10	10.5	0	Fixed	Fixed	Free		0	0	0	0
11	10.5	3	Free	Free	Free		0	0	0	0
12	10.5	6	Fixed	Fixed	Free		0	0	0	0
13	14	0	Fixed	Fixed	Free		0	0	0	0
14	14	3	Free	Free	Free		0	0	0	0
15	14	6	Fixed	Fixed	Free		0	0	0	0

Elements

Element	Length (m)	Nodes		Section		Material	Releases			Rotated
		Start	End	Start	End		Start moment	End moment	Axial	
1	3	1	2	C30x30		Concrete Column	Fixed	Fixed	Fixed	
2	3	2	3	C30x30		Concrete Column	Fixed	Fixed	Fixed	
3	3	4	5	C30x30		Concrete Column	Fixed	Fixed	Fixed	
4	3	5	6	C30x30		Concrete Column	Fixed	Fixed	Fixed	
5	3	7	8	C30x30		Concrete Column	Fixed	Fixed	Fixed	
6	3	8	9	C30x30		Concrete Column	Fixed	Fixed	Fixed	
7	3	10	11	C30x30		Concrete Column	Fixed	Fixed	Fixed	
8	3	11	12	C30x30		Concrete Column	Fixed	Fixed	Fixed	
9	3	13	14	C30x30		Concrete Column	Fixed	Fixed	Fixed	
10	3	14	15	C30x30		Concrete Column	Fixed	Fixed	Fixed	
11	3.5	2	5	B30x50		Concrete (2901 150)	Fixed	Fixed	Fixed	
12	3.5	5	8	B30x50		Concrete (2901 150)	Fixed	Fixed	Fixed	
13	3.5	8	11	B30x50		Concrete (2901 150)	Fixed	Fixed	Fixed	
14	3.5	11	14	B30x50		Concrete (2901 150)	Fixed	Fixed	Fixed	

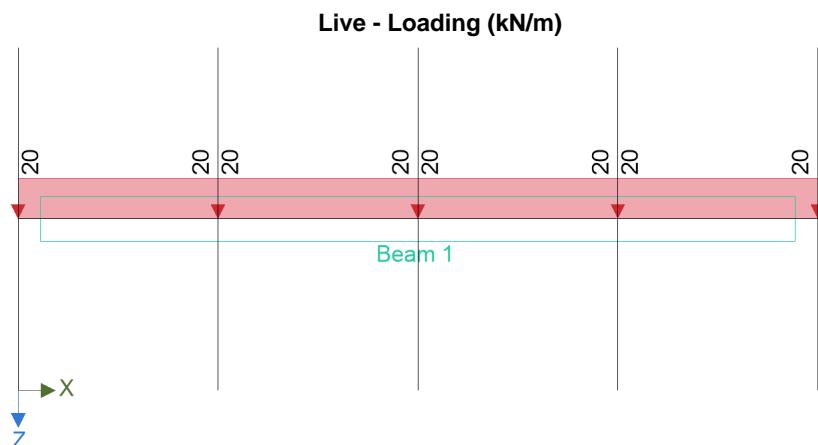
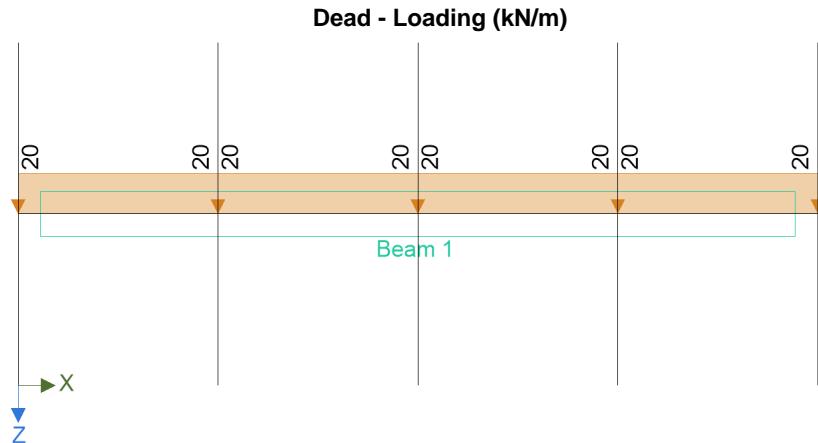
Members

Name	Elements	
	Start	End
Beam 1	11	14

Loading

Self weight included

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Load combination factors

Load combination	Self Weight	Dead	Live
1.4D (Strength)	1.40	1.40	
1.2D + 1.6L (Strength)	1.20	1.20	1.60
1.0D + 1.0L (Service)	1.00	1.00	1.00

Member Loads

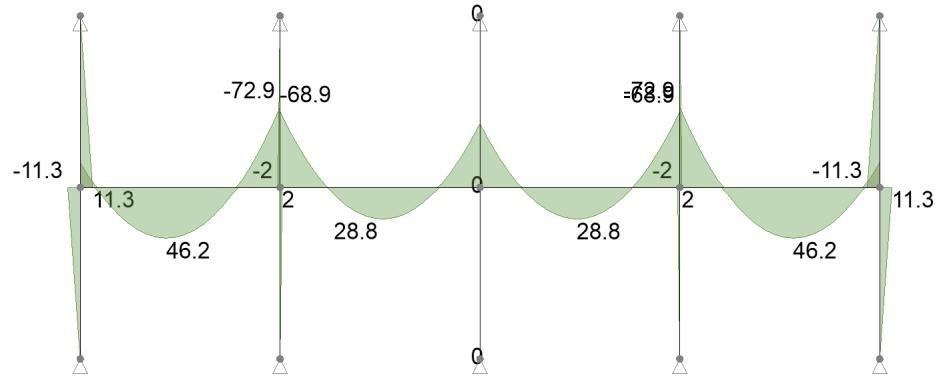
Member	Load case	Load Type	Orientation	Description
Beam 1	Dead	UDL	GlobalZ	20 kN/m
Beam 1	Live	UDL	GlobalZ	20 kN/m

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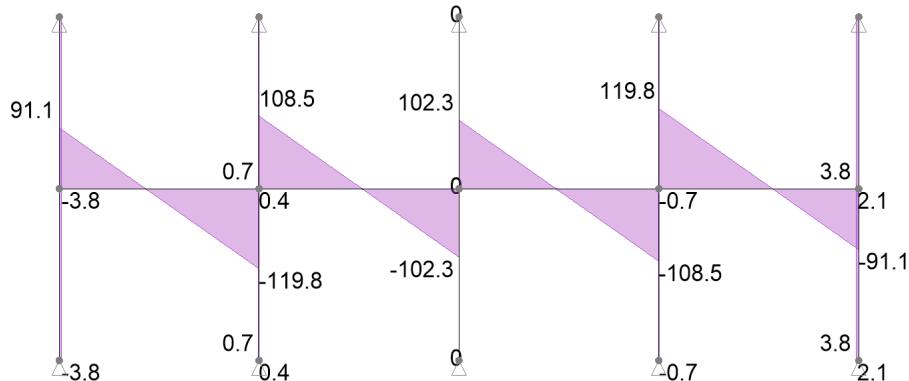
Results

Forces

Strength combinations - Moment envelope (kNm)



Strength combinations - Shear envelope (kN)



Concrete details

Compressive strength of concrete

$$f'_c = 20 \text{ MPa}$$

Density of reinforced concrete

$$w_c = 24 \text{ kN/m}^3$$

Concrete type

Normal weight

Modulus of elasticity of concrete (cl.19.2.2.1)

$$E = (w_c / 1 \text{ lb/ft}^3)^{1.5} \times 33 \text{ psi} \times (f'_c / 1 \text{ psi})^{0.5} = 22513 \text{ MPa}$$

Strength reduction factor for shear

$$\phi_s = 0.75$$

Reinforcement details

Yield strength of reinforcement

$$f_y = 420 \text{ MPa}$$

Compression-controlled strain limit (cl.21.2.2.1)

$$\varepsilon_{ty} = f_y / E_s = 0.00210$$

Nominal cover to reinforcement

Cover to top reinforcement

$$C_{nom_t} = 35 \text{ mm}$$

Cover to bottom reinforcement

$$C_{nom_b} = 35 \text{ mm}$$

Cover to side reinforcement

$$C_{nom_s} = 35 \text{ mm}$$

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Moment adjustment table

$$R_n / f'_c = M / (0.9 \times f'_c \times b \times 0.9h^2)$$

$$\epsilon_t = 3 \times ((\beta_1 / (1 - \sqrt{1 - 40/17 \times R_n/f})) - 1) / 1000$$

Adjustment is allowed when $\epsilon_t \geq 0.0075$ up to the maximum allowable specified

Location	Iteration No.	M _{red} (kNm)	R _n / f' _c	ε _f	Adjustment (%)	Final allow. adjustment
Support 1	1	19.4	0.0579	0.0331	20.0	20.0
	2	15.5	0.0464	0.0424	20.0	
Support 2	1	69.7	0.2077	0.0059	0.0	0.0
Support 3	1	57.9	0.1727	0.0081	8.1	9.2
	2	52.6	0.1587	0.0092	9.2	
Support 4	1	73.1	0.2180	0.0054	0.0	0.0
Support 5	1	19.4	0.0579	0.0331	20.0	20.0
	2	15.5	0.0464	0.0424	20.0	

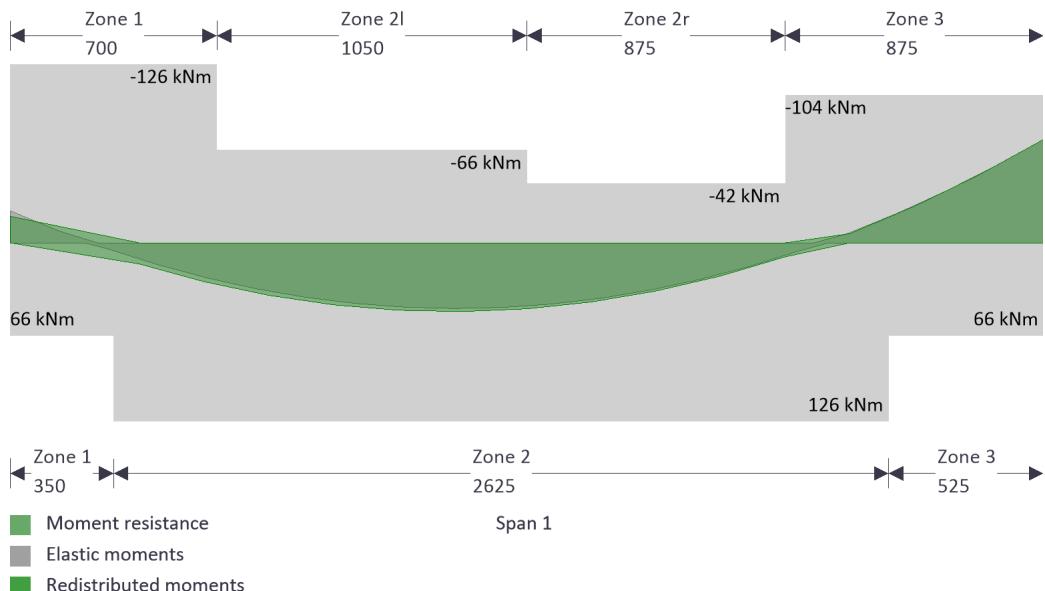
Beam 1 - Span 1

Rectangular section details

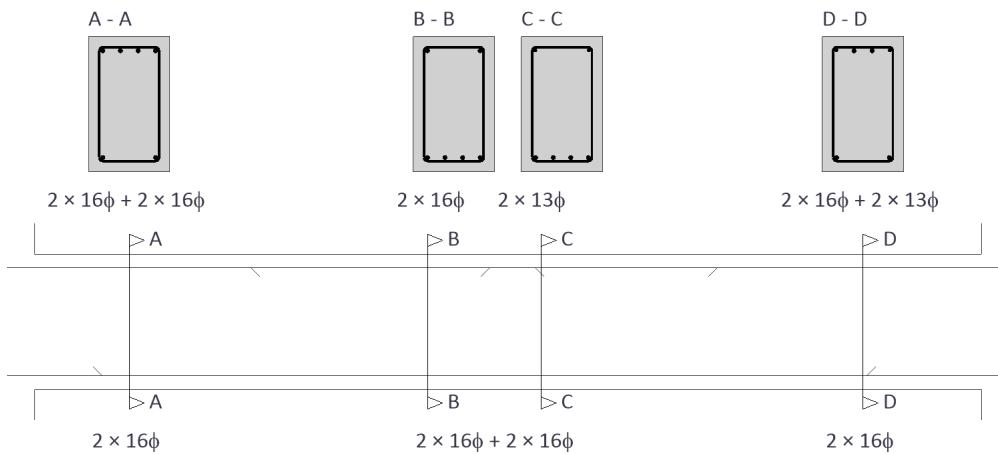
Section width **b = 300 mm**

Section depth **h = 500 mm**

Moment design



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Zone 1 - Positive moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section	$M_u = \text{abs}(M_{m1_s1_z1_max_red}) = 9.07 \text{ kNm}$
Effective depth to tension reinforcement	$d = 447.5 \text{ mm}$
Tension reinforcement provided	$2 \times 16\phi$
Area of tension reinforcement provided	$A_{s,prov} = 402 \text{ mm}^2$
Minimum area of reinforcement (cl.9.6.1.2)	$A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = 72 \text{ mm}^2$
PASS - Area of reinforcement provided is greater than minimum area of reinforcement required	
Stress block depth factor (cl.22.2.2.4.3)	$\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = 0.85$
Depth of equivalent rectangular stress block	$a = A_{s,prov} \times f_y / (0.85 \times f'_c \times b) = 33 \text{ mm}$
Depth to neutral axis	$c = a / \beta_1 = 39 \text{ mm}$
Net tensile strain in extreme tension fibers	$\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = 0.03146$
Net tensile strain in tension controlled zone	
Strength reduction factor (cl.21.2.1)	$\phi_f = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{t,y}) / (0.003), 0.65), 0.9) = 0.90$
Nominal moment strength	$M_n = A_{s,prov} \times f_y \times (d - a / 2) = 72.8 \text{ kNm}$
Design moment strength	$\phi M_n = M_n \times \phi_f = 65.5 \text{ kNm}$
PASS - Required moment strength is less than design moment strength	

Flexural cracking

Max. center to center spacing of tension reinf.	$S_{b,max} = S_{bot} + \phi m1_s1_z1_b_L1 = 195 \text{ mm}$
Service load stress in reinforcement (cl.24.3.2)	$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$
Clear cover of reinforcement	$C_c = C_{nom_b} + \phi_v = 45 \text{ mm}$
Maximum allowable bot bar spacing (Table 24.3.2)	$S_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$
PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing	

Zone 1 - Negative moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section	$M_u = \text{abs}(M_{m1_s1_z1_min_red}) = 18.72 \text{ kNm}$
Effective depth to tension reinforcement	$d = 447.5 \text{ mm}$
Tension reinforcement provided	$2 \times 16\phi + 2 \times 16\phi$
Area of tension reinforcement provided	$A_{s,prov} = 804 \text{ mm}^2$
Minimum area of reinforcement (cl.9.6.1.2)	$A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = 149 \text{ mm}^2$

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

Stress block depth factor (cl.22.2.2.4.3) $\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = \mathbf{0.85}$

Depth of equivalent rectangular stress block $a = A_{s,\text{prov}} \times f_y / (0.85 \times f'_c \times b) = \mathbf{66 \text{ mm}}$

Depth to neutral axis $c = a / \beta_1 = \mathbf{78 \text{ mm}}$

Net tensile strain in extreme tension fibers $\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = \mathbf{0.01423}$

Net tensile strain in tension controlled zone

$\phi_f = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ty}) / (0.003), 0.65), 0.9) = \mathbf{0.90}$

$M_n = A_{s,\text{prov}} \times f_y \times (d - a / 2) = \mathbf{140.0 \text{ kNm}}$

$\phi M_n = M_n \times \phi_f = \mathbf{126.0 \text{ kNm}}$

PASS - Required moment strength is less than design moment strength

Flexural cracking

Max. center to center spacing of tension reinf. $s_{t,max} = s_{top} + \phi m_{1,s1,z1,t,L1} = \mathbf{65 \text{ mm}}$

Service load stress in reinforcement (cl.24.3.2) $f_s = 2/3 \times f_y = \mathbf{280 \text{ N/mm}^2}$

Clear cover of reinforcement $C_c = C_{nom,t} + \phi_v = \mathbf{45 \text{ mm}}$

Maximum allowable top bar spacing (Table 24.3.2) $s_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = \mathbf{264 \text{ mm}}$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

Spacing limits for reinforcement

Top bar clear spacing $s_{top} = (b - (2 \times (C_{nom,s} + \phi m_{1,s1,z1,v}) + \phi m_{1,s1,z1,t,L1} \times N_{m1,s1,z1,t,L1} + \phi m_{1,s1,z2,t,L1} \times N_{m1,s1,z2,t,L1})) / ((N_{m1,s1,z1,t,L1} + N_{m1,s1,z2,t,L1}) - 1) = \mathbf{49 \text{ mm}}$

Min. allowable top bar clear spacing (cl.25.2.1) $s_{top,min} = \mathbf{25 \text{ mm}}$

Bottom bar clear spacing $s_{bot} = (b - (2 \times (C_{nom,s} + \phi m_{1,s1,z1,v}) + \phi m_{1,s1,z1,b,L1} \times N_{m1,s1,z1,b,L1})) / (N_{m1,s1,z1,b,L1} - 1) = \mathbf{179 \text{ mm}}$

Min. allowable bottom bar clear spacing (cl.25.2.1) $s_{bot,min} = \mathbf{25 \text{ mm}}$

PASS - Actual bar spacing exceeds minimum allowable

Zone 2 - Positive moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section $M_u = \text{abs}(M_{m1,s1,z2,max,red}) = \mathbf{48.42 \text{ kNm}}$

Effective depth to tension reinforcement $d = \mathbf{447.5 \text{ mm}}$

Tension reinforcement provided $2 \times 16\phi + 2 \times 16\phi$

Area of tension reinforcement provided $A_{s,\text{prov}} = \mathbf{804 \text{ mm}^2}$

Minimum area of reinforcement (cl.9.6.1.2) $A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi}), 200 \text{ psi}} \times b \times d / f_y, 4/3 \times A_{s,des}) = \mathbf{391 \text{ mm}^2}$

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

Stress block depth factor (cl.22.2.2.4.3) $\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = \mathbf{0.85}$

Depth of equivalent rectangular stress block $a = A_{s,\text{prov}} \times f_y / (0.85 \times f'_c \times b) = \mathbf{66 \text{ mm}}$

Depth to neutral axis $c = a / \beta_1 = \mathbf{78 \text{ mm}}$

$\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = \mathbf{0.01423}$

Net tensile strain in tension controlled zone

$\phi_f = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ty}) / (0.003), 0.65), 0.9) = \mathbf{0.90}$

$M_n = A_{s,\text{prov}} \times f_y \times (d - a / 2) = \mathbf{140.0 \text{ kNm}}$

$\phi M_n = M_n \times \phi_f = \mathbf{126.0 \text{ kNm}}$

PASS - Required moment strength is less than design moment strength

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Flexural cracking

Max. center to center spacing of tension reinf.

$$S_{b,max} = S_{bot} + \phi m_{1,s1,z2,b,L1} = 65 \text{ mm}$$

Service load stress in reinforcement (cl.24.3.2)

$$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$$

Clear cover of reinforcement

$$C_c = C_{nom,b} + \phi_v = 45 \text{ mm}$$

Maximum allowable bot bar spacing (Table 24.3.2) $S_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

Control of deflections (Section 24.2)

Concrete density factor

$$K_w = 1.00$$

Reinforcement yield strength factor

$$K_f = 0.4 + f_y / 100000 \text{ psi} = 1.01$$

Minimum thickness of beam (Table 9.3.1.1)

$$h_{min} = (L_{m1,s1} / 18.5) \times K_w \times K_f = 191 \text{ mm}$$

PASS - Thickness of beam exceeds minimum thickness

Spacing limits for reinforcement

Top bar clear spacing

$$S_{top} = (b - (2 \times (C_{nom,s} + \phi m_{1,s1,z2,v}) + \phi m_{1,s1,z2r,t,L1} \times N_{m1,s1,z2r,t,L1})) / (N_{m1,s1,z2r,t,L1} - 1) = 186 \text{ mm}$$

Min. allowable top bar clear spacing (cl.25.2.1)

$$S_{top,min} = 25 \text{ mm}$$

Bottom bar clear spacing

$$S_{bot} = (b - (2 \times (C_{nom,s} + \phi m_{1,s1,z2,v}) + \phi m_{1,s1,z2,b,L1} \times N_{m1,s1,z2,b,L1} + \phi m_{1,s1,z1,b,L1} \times N_{m1,s1,z1,b,L1})) / ((N_{m1,s1,z2,b,L1} + N_{m1,s1,z1,b,L1}) - 1) = 49 \text{ mm}$$

Min. allowable bottom bar clear spacing (cl.25.2.1)

$$S_{bot,min} = 25 \text{ mm}$$

PASS - Actual bar spacing exceeds minimum allowable

Zone 3 - Negative moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section

$$M_u = \text{abs}(M_{m1,s1,z3,min_red}) = 72.88 \text{ kNm}$$

Effective depth to tension reinforcement

$$d = 448.1 \text{ mm}$$

Tension reinforcement provided

$$2 \times 16\phi + 2 \times 13\phi$$

Area of tension reinforcement provided

$$A_{s,prov} = 655 \text{ mm}^2$$

Minimum area of reinforcement (cl.9.6.1.2)

$$A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = 441 \text{ mm}^2$$

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

Stress block depth factor (cl.22.2.2.4.3)

$$\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = 0.85$$

Depth of equivalent rectangular stress block

$$a = A_{s,prov} \times f_y / (0.85 \times f'_c \times b) = 54 \text{ mm}$$

Depth to neutral axis

$$c = a / \beta_1 = 64 \text{ mm}$$

Net tensile strain in extreme tension fibers

$$\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = 0.01817$$

Net tensile strain in tension controlled zone

Strength reduction factor (cl.21.2.1)

$$\phi_r = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ly}) / (0.003), 0.65), 0.9) = 0.90$$

Nominal moment strength

$$M_n = A_{s,prov} \times f_y \times (d - a / 2) = 115.9 \text{ kNm}$$

Design moment strength

$$\phi M_n = M_n \times \phi_r = 104.3 \text{ kNm}$$

PASS - Required moment strength is less than design moment strength

Flexural cracking

Max. center to center spacing of tension reinf.

$$S_{t,max} = S_{top} + \phi m_{1,s1,z3,t,L1} = 67 \text{ mm}$$

Service load stress in reinforcement (cl.24.3.2)

$$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$$

Clear cover of reinforcement

$$C_c = C_{nom,t} + \phi_v = 45 \text{ mm}$$

Maximum allowable top bar spacing (Table 24.3.2) $S_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

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Spacing limits for reinforcement

Top bar clear spacing

$$S_{top} = (b - (2 \times (C_{nom_s} + \phi m_{1,s1,z3,v}) + \phi m_{1,s1,z3,t,L1} \times N_{m1,s1,z3,t,L1} + \phi m_{1,s1,z2,r,t,L1} \times N_{m1,s1,z2,r,t,L1})) / ((N_{m1,s1,z3,t,L1} + N_{m1,s1,z2,r,t,L1}) - 1) = 51 \text{ mm}$$

Min. allowable top bar clear spacing (cl.25.2.1)

$$S_{top,min} = 25 \text{ mm}$$

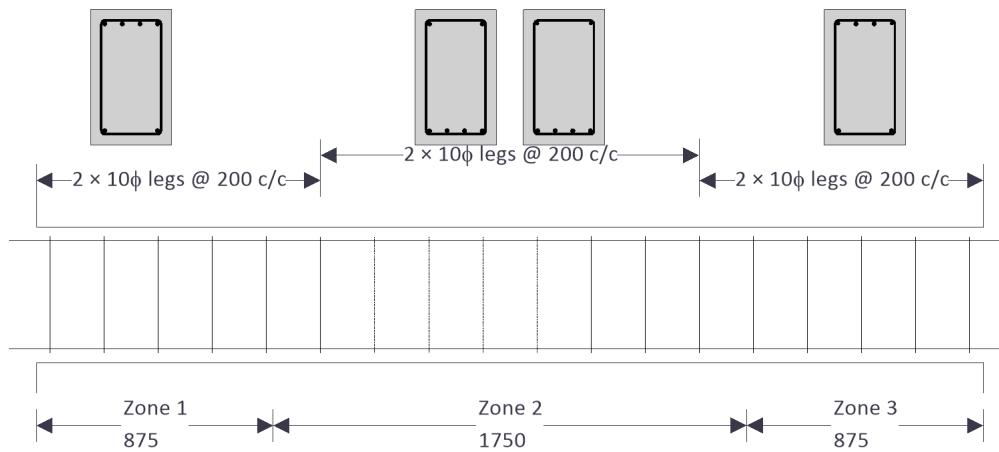
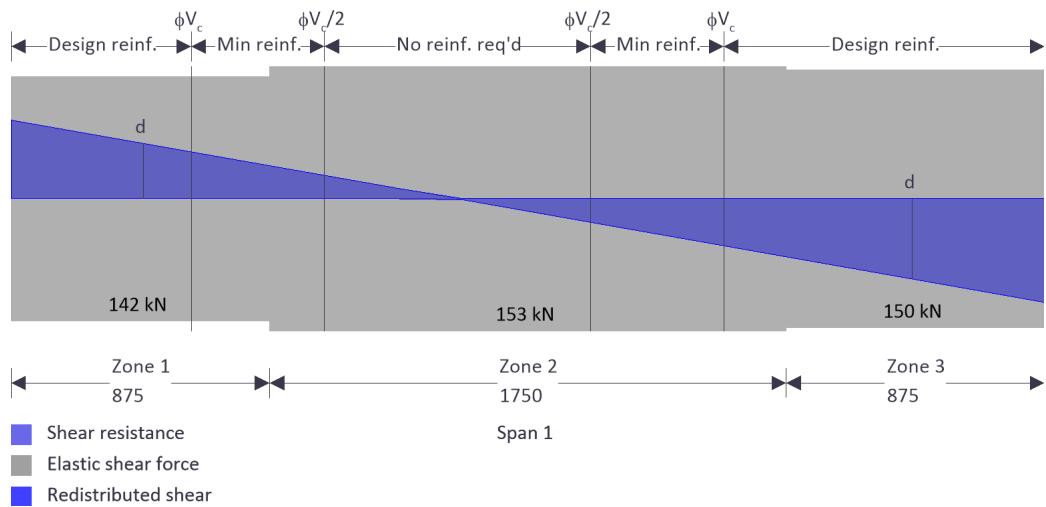
Bottom bar clear spacing

$$S_{bot} = (b - (2 \times (C_{nom_s} + \phi m_{1,s1,z3,v}) + \phi m_{1,s1,z3,b,L1} \times N_{m1,s1,z3,b,L1})) / (N_{m1,s1,z3,b,L1} - 1) = 179 \text{ mm}$$

Min. allowable bottom bar clear spacing (cl.25.2.1) $S_{bot,min} = 25 \text{ mm}$

PASS - Actual bar spacing exceeds minimum allowable

Shear design



Rectangular section in shear

Concrete weight modification factor

$$\lambda = 1.00$$

Location where min. reinf. is req'd (V_u less ϕV_c)

Between 610 mm and 2413 mm

Location where no reinf. is req'd (V_u less $\phi V_c / 2$)

Between 1061 mm and 1962 mm

Maximum reinforcement shear strength

$$\phi V_{s,max} = \phi_s \times 8 \text{ psi} \times \sqrt{(\min(f'_c, 10000 \text{ psi}) / 1 \text{ psi}) \times b \times d} = 299.1 \text{ kN}$$

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Minimum area of shear reinf. (Table 9.6.3.4) $A_{sv,min} = \max(50 \text{ psi}, 0.75 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})} \times b / \min(f_y, 60000 \text{ psi}) = 250 \text{ mm}^2/\text{m}$

Zone 1

Effective depth of long. reinf. used for shear zone

$d = 447 \text{ mm}$

Size effect factor (cl. 22.5.5.1.3)

$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$

Area of longitudinal reinforcement

$A_{st} = 402 \text{ mm}^2$

Ratio of longitudinal reinforcement

$\rho_w = A_{st} / (b \times d) = 0.003$

Concrete shear strength (Table 22.5.5.1)

$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 43.1 \text{ kN}$

Design shear force at 447mm from support

$V_u = 64.1 \text{ kN}$

Reinf. shear strength required (eqn. 22.5.1.1)

$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 21.0 \text{ kN}$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3)

$A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 151 \text{ mm}^2/\text{m}$

Area of shear reinforcement required

$A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 250 \text{ mm}^2/\text{m}$

Shear reinforcement provided

$2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

Area of shear reinforcement provided

$A_{sv,prov} = 713 \text{ mm}^2/\text{m}$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2) $s_{vl,max} = d / 2 = 223.7 \text{ mm}$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

Zone 2

Effective depth of long. reinf. used for shear zone

$d = 447 \text{ mm}$

Size effect factor (cl. 22.5.5.1.3)

$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$

Area of longitudinal reinforcement

$A_{st} = 804 \text{ mm}^2$

Ratio of longitudinal reinforcement

$\rho_w = A_{st} / (b \times d) = 0.006$

Concrete shear strength (Table 22.5.5.1)

$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 54.3 \text{ kN}$

Design shear force within zone

$V_u = 67.2 \text{ kN}$

Reinf. shear strength required (eqn. 22.5.1.1)

$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 12.9 \text{ kN}$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3)

$A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 93 \text{ mm}^2/\text{m}$

Area of shear reinforcement required

$A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 250 \text{ mm}^2/\text{m}$

Shear reinforcement provided

$2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

Area of shear reinforcement provided

$A_{sv,prov} = 713 \text{ mm}^2/\text{m}$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2) $s_{vl,max} = d / 2 = 223.7 \text{ mm}$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

Zone 3

Effective depth of long. reinf. used for shear zone

$d = 447 \text{ mm}$

Size effect factor (cl. 22.5.5.1.3)

$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$

Area of longitudinal reinforcement

$A_{st} = 655 \text{ mm}^2$

Ratio of longitudinal reinforcement

$\rho_w = A_{st} / (b \times d) = 0.005$

Concrete shear strength (Table 22.5.5.1)

$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 50.7 \text{ kN}$

Design shear force at 447mm from support

$V_u = 93.0 \text{ kN}$

Reinf. shear strength required (eqn. 22.5.1.1)

$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 42.2 \text{ kN}$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3)

$A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 304 \text{ mm}^2/\text{m}$

Area of shear reinforcement required

$A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 304 \text{ mm}^2/\text{m}$

Shear reinforcement provided

$2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

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Area of shear reinforcement provided

$$A_{sv,prov} = 713 \text{ mm}^2/\text{m}$$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2) $s_{vl,max} = d / 2 = 223.7 \text{ mm}$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

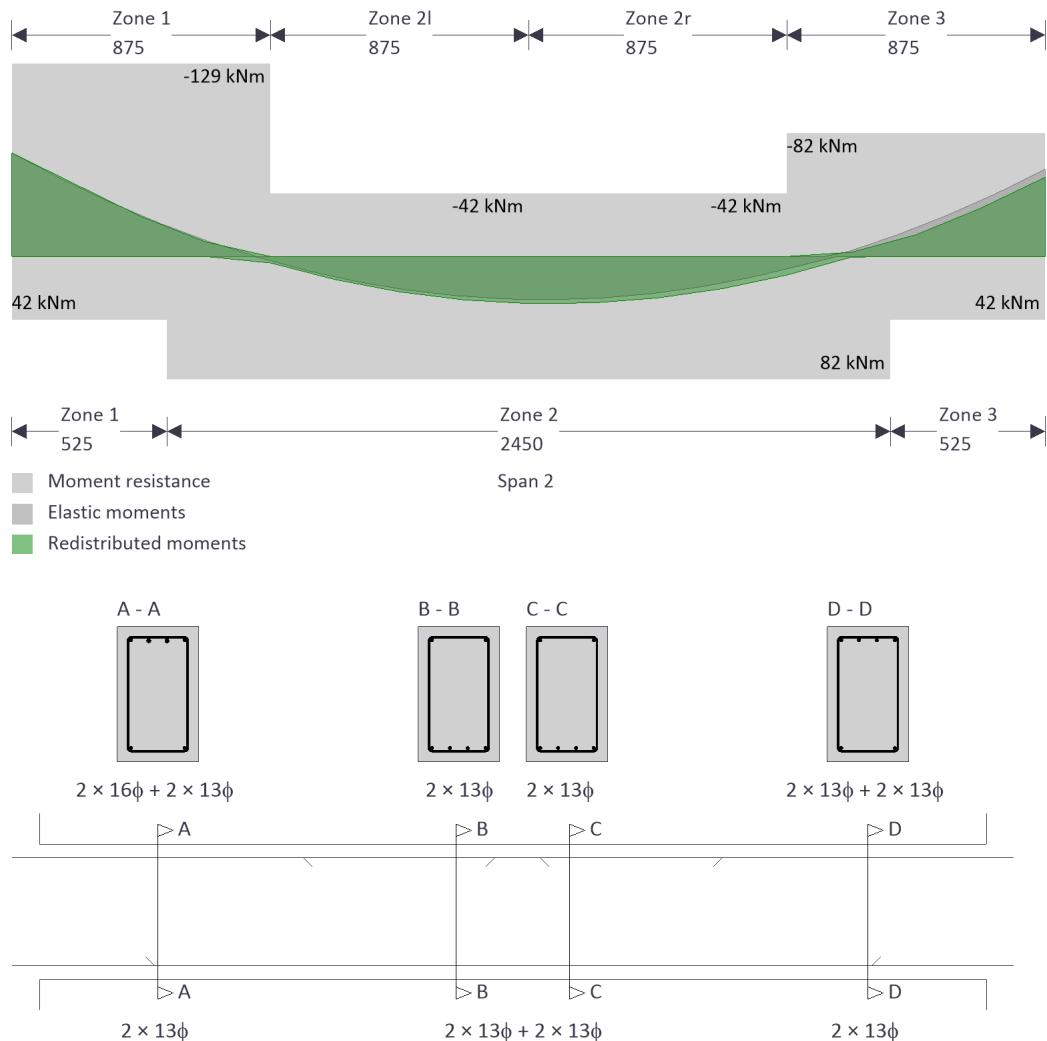
Beam 1 - Span 2

Rectangular section details

Section width $b = 300 \text{ mm}$

Section depth $h = 500 \text{ mm}$

Moment design



Zone 1 - Negative moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section

$$M_u = \text{abs}(M_{m1_s2_z1_min_red}) = 68.94 \text{ kNm}$$

Effective depth to tension reinforcement

$$d = 446.9 \text{ mm}$$

Tension reinforcement provided

$$2 \times 19\phi + 2 \times 13\phi$$

Area of tension reinforcement provided

$$A_{s,prov} = 823 \text{ mm}^2$$

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Minimum area of reinforcement (cl.9.6.1.2) $A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = 440 \text{ mm}^2$

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

Stress block depth factor (cl.22.2.2.4.3) $\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = 0.85$

Depth of equivalent rectangular stress block $a = A_{s,prov} \times f_y / (0.85 \times f'_c \times b) = 68 \text{ mm}$

Depth to neutral axis $c = a / \beta_1 = 80 \text{ mm}$

Net tensile strain in extreme tension fibers $\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = 0.01381$

Net tensile strain in tension controlled zone

$\phi_f = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ly}) / (0.003), 0.65), 0.9) = 0.90$

$M_n = A_{s,prov} \times f_y \times (d - a / 2) = 142.8 \text{ kNm}$

$\phi M_n = M_n \times \phi_f = 128.6 \text{ kNm}$

PASS - Required moment strength is less than design moment strength

Flexural cracking

Max. center to center spacing of tension reinf.

$$S_{t,max} = S_{top} + \phi m_{1,s2,z1,t,L1} = 65 \text{ mm}$$

Service load stress in reinforcement (cl.24.3.2)

$$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$$

Clear cover of reinforcement

$$C_c = C_{nom,t} + \phi v = 45 \text{ mm}$$

Maximum allowable top bar spacing (Table 24.3.2) $s_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

Spacing limits for reinforcement

Top bar clear spacing

$$S_{top} = (b - (2 \times (C_{nom,s} + \phi m_{1,s2,z1,v}) + \phi m_{1,s2,z1,t,L1} \times N_{m1,s2,z1,t,L1} + \phi m_{1,s2,z2,t,L1} \times N_{m1,s2,z2,t,L1})) / ((N_{m1,s2,z1,t,L1} + N_{m1,s2,z2,t,L1}) - 1) = 51 \text{ mm}$$

$$S_{top,min} = 25 \text{ mm}$$

Min. allowable top bar clear spacing (cl.25.2.1)

$$S_{bot} = (b - (2 \times (C_{nom,s} + \phi m_{1,s2,z1,v}) + \phi m_{1,s2,z1,b,L1} \times N_{m1,s2,z1,b,L1})) / (N_{m1,s2,z1,b,L1} - 1) = 186 \text{ mm}$$

Min. allowable bottom bar clear spacing (cl.25.2.1)

$$S_{bot,min} = 25 \text{ mm}$$

PASS - Actual bar spacing exceeds minimum allowable

Zone 2 - Positive moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section

$$M_u = \text{abs}(M_{m1,s2,z2,max_red}) = 31.54 \text{ kNm}$$

Effective depth to tension reinforcement

$$d = 449.1 \text{ mm}$$

Tension reinforcement provided

$$2 \times 13\phi + 2 \times 13\phi$$

Area of tension reinforcement provided

$$A_{s,prov} = 507 \text{ mm}^2$$

Minimum area of reinforcement (cl.9.6.1.2)

$$A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = 251 \text{ mm}^2$$

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

Stress block depth factor (cl.22.2.2.4.3)

$$\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = 0.85$$

Depth of equivalent rectangular stress block

$$a = A_{s,prov} \times f_y / (0.85 \times f'_c \times b) = 42 \text{ mm}$$

Depth to neutral axis

$$c = a / \beta_1 = 49 \text{ mm}$$

Net tensile strain in extreme tension fibers

$$\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = 0.02445$$

Net tensile strain in tension controlled zone

$$\phi_f = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ly}) / (0.003), 0.65), 0.9) = 0.90$$

$$M_n = A_{s,prov} \times f_y \times (d - a / 2) = 91.1 \text{ kNm}$$

Design moment strength

$$\phi M_n = M_n \times \phi_f = 82.0 \text{ kNm}$$

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PASS - Required moment strength is less than design moment strength

Flexural cracking

Max. center to center spacing of tension reinf.

$$S_{b,max} = S_{bot} + \phi m_1 s_2 z_2 b L_1 = 66 \text{ mm}$$

Service load stress in reinforcement (cl.24.3.2)

$$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$$

Clear cover of reinforcement

$$C_c = C_{nom,b} + \phi v = 45 \text{ mm}$$

Maximum allowable bot bar spacing (Table 24.3.2) $S_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

Control of deflections (Section 24.2)

Concrete density factor

$$K_w = 1.00$$

Reinforcement yield strength factor

$$K_f = 0.4 + f_y / 100000 \text{ psi} = 1.01$$

Minimum thickness of beam (Table 9.3.1.1)

$$h_{min} = (L_{m1,s2} / 21.0) \times K_w \times K_f = 168 \text{ mm}$$

PASS - Thickness of beam exceeds minimum thickness

Spacing limits for reinforcement

Top bar clear spacing

$$S_{top} = (b - (2 \times (C_{nom,s} + \phi m_1 s_2 z_2 v) + \phi m_1 s_2 z_2 r_t L_1) \times N_{m1,s2,z2r_t,L1}) /$$

$$(N_{m1,s2,z2r_t,L1} - 1) = 186 \text{ mm}$$

Min. allowable top bar clear spacing (cl.25.2.1)

$$S_{top,min} = 25 \text{ mm}$$

Bottom bar clear spacing

$$S_{bot} = (b - (2 \times (C_{nom,s} + \phi m_1 s_2 z_2 v) + \phi m_1 s_2 z_2 b L_1 \times N_{m1,s2,z2b,L1} +$$

$$\phi m_1 s_2 z_1 b L_1 \times N_{m1,s2,z1b,L1})) / ((N_{m1,s2,z2b,L1} + N_{m1,s2,z1b,L1}) - 1) = 53 \text{ mm}$$

Min. allowable bottom bar clear spacing (cl.25.2.1) $S_{bot,min} = 25 \text{ mm}$

PASS - Actual bar spacing exceeds minimum allowable

Zone 3 - Negative moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section

$$M_u = \text{abs}(M_{m1,s2,z3,min_red}) = 52.78 \text{ kNm}$$

Effective depth to tension reinforcement

$$d = 449.1 \text{ mm}$$

Tension reinforcement provided

$$2 \times 13\phi + 2 \times 13\phi$$

Area of tension reinforcement provided

$$A_{s,prov} = 507 \text{ mm}^2$$

Minimum area of reinforcement (cl.9.6.1.2)

$$A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = 425 \text{ mm}^2$$

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

Stress block depth factor (cl.22.2.2.4.3)

$$\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = 0.85$$

Depth of equivalent rectangular stress block

$$a = A_{s,prov} \times f_y / (0.85 \times f'_c \times b) = 42 \text{ mm}$$

Depth to neutral axis

$$c = a / \beta_1 = 49 \text{ mm}$$

Net tensile strain in extreme tension fibers

$$\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = 0.02445$$

Net tensile strain in tension controlled zone

Strength reduction factor (cl.21.2.1)

$$\phi_t = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ty}) / (0.003), 0.65), 0.9) = 0.90$$

Nominal moment strength

$$M_n = A_{s,prov} \times f_y \times (d - a / 2) = 91.1 \text{ kNm}$$

Design moment strength

$$\phi M_n = M_n \times \phi_t = 82.0 \text{ kNm}$$

PASS - Required moment strength is less than design moment strength

Flexural cracking

Max. center to center spacing of tension reinf.

$$S_{t,max} = S_{top} + \phi m_1 s_2 z_3 t L_1 = 66 \text{ mm}$$

Service load stress in reinforcement (cl.24.3.2)

$$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$$

Clear cover of reinforcement

$$C_c = C_{nom,t} + \phi v = 45 \text{ mm}$$

Maximum allowable top bar spacing (Table 24.3.2) $S_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$

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PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

Spacing limits for reinforcement

Top bar clear spacing

$$S_{top} = (b - (2 \times (C_{nom_s} + \phi m_{1,s2,z3_v}) + \phi m_{1,s2,z3_t,L1} \times N_{m1,s2,z3_t,L1} + \phi m_{1,s2,z2r,t,L1} \times N_{m1,s2,z2r,t,L1})) / ((N_{m1,s2,z3_t,L1} + N_{m1,s2,z2r,t,L1}) - 1) = 53 \text{ mm}$$

Min. allowable top bar clear spacing (cl.25.2.1)

$$S_{top,min} = 25 \text{ mm}$$

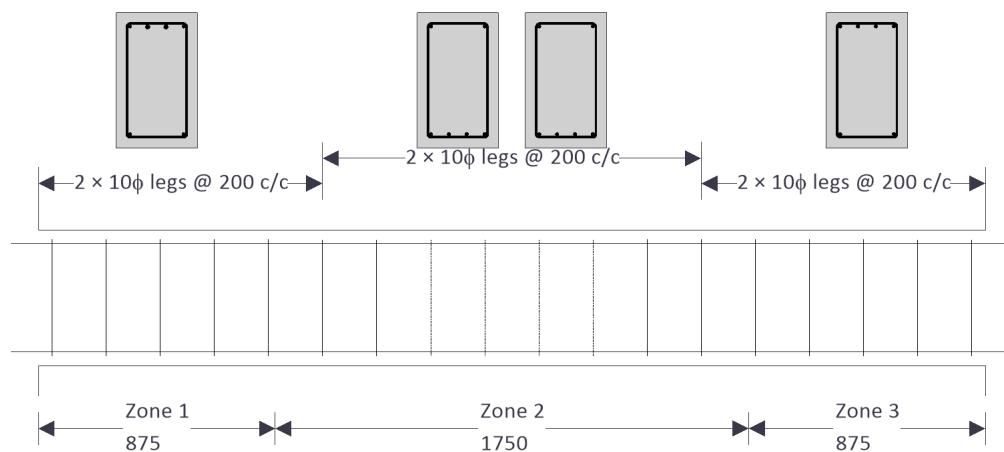
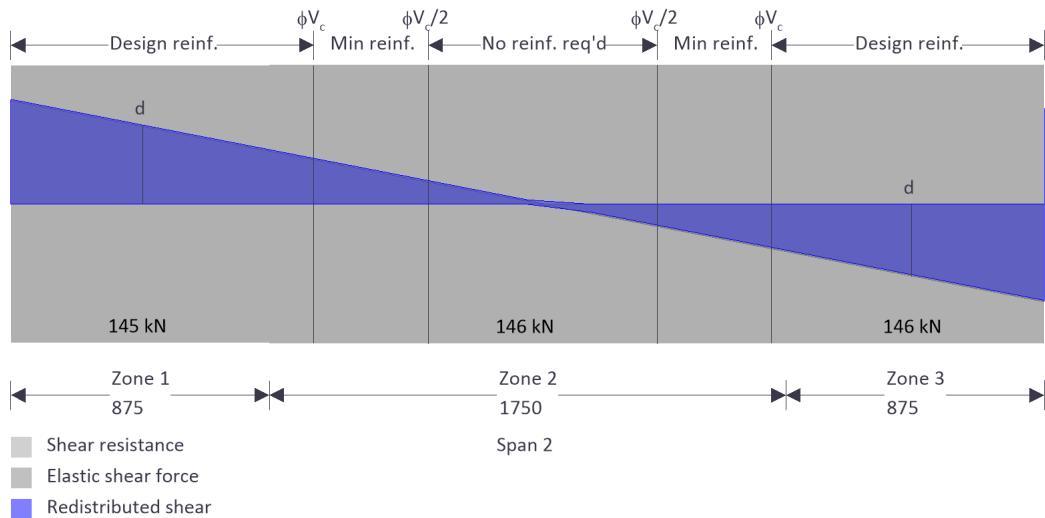
Bottom bar clear spacing

$$S_{bot} = (b - (2 \times (C_{nom_s} + \phi m_{1,s2,z3_v}) + \phi m_{1,s2,z3_b,L1} \times N_{m1,s2,z3_b,L1})) / (N_{m1,s2,z3_b,L1} - 1) = 186 \text{ mm}$$

Min. allowable bottom bar clear spacing (cl.25.2.1) $S_{bot,min} = 25 \text{ mm}$

PASS - Actual bar spacing exceeds minimum allowable

Shear design



Rectangular section in shear

Concrete weight modification factor

$$\lambda = 1.00$$

Location where min. reinf. is req'd (V_u less ϕV_c)

Between 1026 mm and 2576 mm

Location where no reinf. is req'd (V_u less $\phi V_c / 2$)

Between 1414 mm and 2189 mm

Maximum reinforcement shear strength

$$\phi V_{s,max} = \phi_s \times 8 \text{ psi} \times \sqrt{(\min(f'_c, 10000 \text{ psi}) / 1 \text{ psi}) \times b \times d} = 300.2 \text{ kN}$$

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Minimum area of shear reinf. (Table 9.6.3.4) $A_{sv,min} = \max(50 \text{ psi}, 0.75 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})} \times b / \min(f_y, 60000 \text{ psi}) = 250 \text{ mm}^2/\text{m}$

Zone 1

Effective depth of long. reinf. used for shear zone

$d = 447 \text{ mm}$

Size effect factor (cl. 22.5.5.1.3)

$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$

Area of longitudinal reinforcement

$A_{st} = 507 \text{ mm}^2$

Ratio of longitudinal reinforcement

$\rho_w = A_{st} / (b \times d) = 0.004$

Concrete shear strength (Table 22.5.5.1)

$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 46.5 \text{ kN}$

Design shear force at 447mm from support

$V_u = 83.1 \text{ kN}$

Reinf. shear strength required (eqn. 22.5.1.1)

$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 36.6 \text{ kN}$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3)

$A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 264 \text{ mm}^2/\text{m}$

Area of shear reinforcement required

$A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 264 \text{ mm}^2/\text{m}$

Shear reinforcement provided

$2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

Area of shear reinforcement provided

$A_{sv,prov} = 713 \text{ mm}^2/\text{m}$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2) $s_{vl,max} = d / 2 = 223.5 \text{ mm}$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

Zone 2

Effective depth of long. reinf. used for shear zone

$d = 449 \text{ mm}$

Size effect factor (cl. 22.5.5.1.3)

$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$

Area of longitudinal reinforcement

$A_{st} = 507 \text{ mm}^2$

Ratio of longitudinal reinforcement

$\rho_w = A_{st} / (b \times d) = 0.004$

Concrete shear strength (Table 22.5.5.1)

$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 46.7 \text{ kN}$

Design shear force within zone

$V_u = 57.3 \text{ kN}$

Reinf. shear strength required (eqn. 22.5.1.1)

$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 10.6 \text{ kN}$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3)

$A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 76 \text{ mm}^2/\text{m}$

Area of shear reinforcement required

$A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 250 \text{ mm}^2/\text{m}$

Shear reinforcement provided

$2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

Area of shear reinforcement provided

$A_{sv,prov} = 713 \text{ mm}^2/\text{m}$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2) $s_{vl,max} = d / 2 = 224.6 \text{ mm}$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

Zone 3

Effective depth of long. reinf. used for shear zone

$d = 449 \text{ mm}$

Size effect factor (cl. 22.5.5.1.3)

$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$

Area of longitudinal reinforcement

$A_{st} = 507 \text{ mm}^2$

Ratio of longitudinal reinforcement

$\rho_w = A_{st} / (b \times d) = 0.004$

Concrete shear strength (Table 22.5.5.1)

$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 46.7 \text{ kN}$

Design shear force at 449mm from support

$V_u = 75.3 \text{ kN}$

Reinf. shear strength required (eqn. 22.5.1.1)

$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 28.6 \text{ kN}$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3)

$A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 205 \text{ mm}^2/\text{m}$

Area of shear reinforcement required

$A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 250 \text{ mm}^2/\text{m}$

Shear reinforcement provided

$2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

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Area of shear reinforcement provided

$$A_{sv,prov} = 713 \text{ mm}^2/\text{m}$$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2)

$$s_{vl,max} = d / 2 = 224.6 \text{ mm}$$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

Beam 1 - Span 3

Rectangular section details

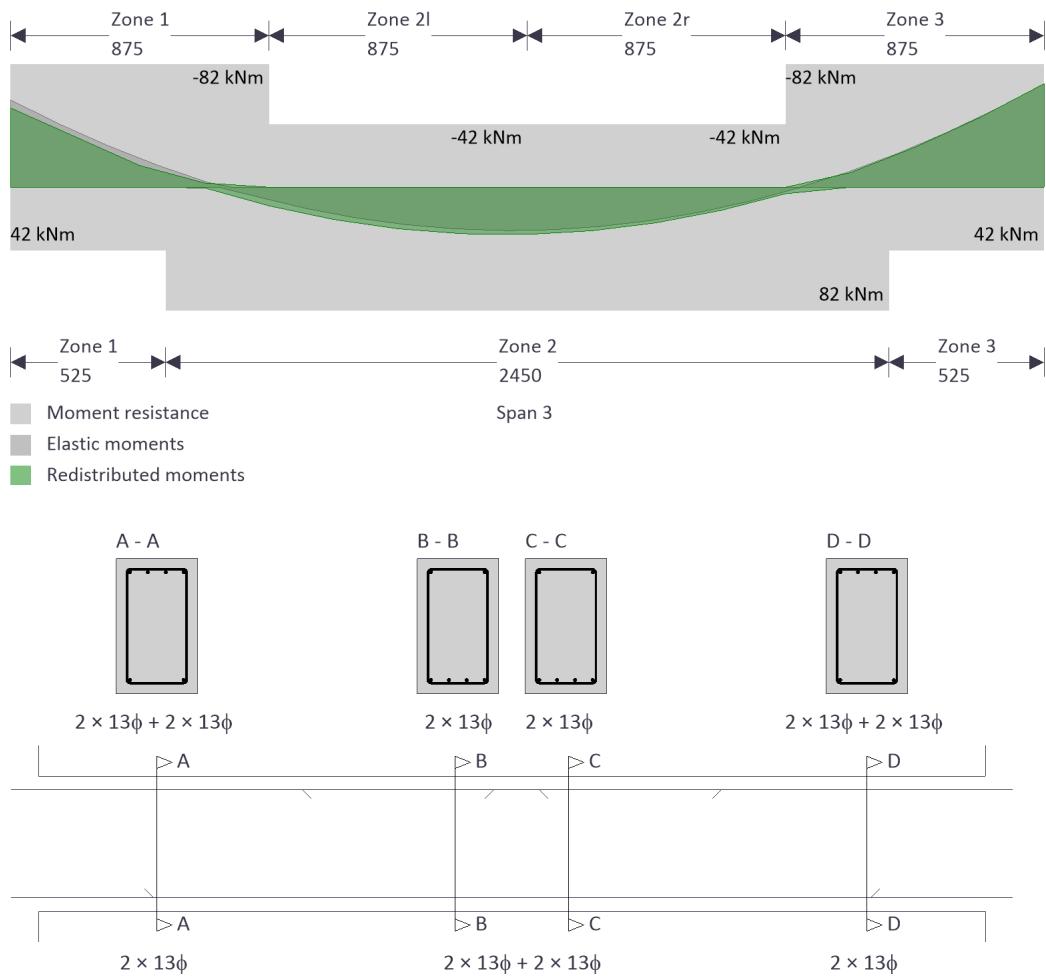
Section width

$$b = 300 \text{ mm}$$

Section depth

$$h = 500 \text{ mm}$$

Moment design



Zone 1 - Negative moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section

$$M_u = \text{abs}(M_{m1_s3_z1_min_red}) = 52.78 \text{ kNm}$$

Effective depth to tension reinforcement

$$d = 449.1 \text{ mm}$$

Tension reinforcement provided

$$2 \times 13\phi + 2 \times 13\phi$$

Area of tension reinforcement provided

$$A_{s,prov} = 507 \text{ mm}^2$$

Minimum area of reinforcement (cl.9.6.1.2)

$$A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = 425 \text{ mm}^2$$

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

Stress block depth factor (cl.22.2.2.4.3) $\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = \mathbf{0.85}$

Depth of equivalent rectangular stress block $a = A_{s,\text{prov}} \times f_y / (0.85 \times f'_c \times b) = \mathbf{42 \text{ mm}}$

Depth to neutral axis $c = a / \beta_1 = \mathbf{49 \text{ mm}}$

Net tensile strain in extreme tension fibers $\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = \mathbf{0.02445}$

Net tensile strain in tension controlled zone

$\phi_f = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ty}) / (0.003), 0.65), 0.9) = \mathbf{0.90}$

$M_n = A_{s,\text{prov}} \times f_y \times (d - a / 2) = \mathbf{91.1 \text{ kNm}}$

$\phi M_n = M_n \times \phi_f = \mathbf{82.0 \text{ kNm}}$

PASS - Required moment strength is less than design moment strength

Flexural cracking

Max. center to center spacing of tension reinf. $s_{t,max} = s_{top} + \phi m_{1,s3,z1,t,L1} = \mathbf{66 \text{ mm}}$

Service load stress in reinforcement (cl.24.3.2) $f_s = 2/3 \times f_y = \mathbf{280 \text{ N/mm}^2}$

Clear cover of reinforcement $C_c = C_{nom,t} + \phi_v = \mathbf{45 \text{ mm}}$

Maximum allowable top bar spacing (Table 24.3.2) $s_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = \mathbf{264 \text{ mm}}$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

Spacing limits for reinforcement

Top bar clear spacing $s_{top} = (b - (2 \times (C_{nom,s} + \phi m_{1,s3,z1,v}) + \phi m_{1,s3,z1,t,L1} \times N_{m1,s3,z1,t,L1} + \phi m_{1,s3,z2,t,L1} \times N_{m1,s3,z2,t,L1})) / ((N_{m1,s3,z1,t,L1} + N_{m1,s3,z2,t,L1}) - 1) = \mathbf{53 \text{ mm}}$

Min. allowable top bar clear spacing (cl.25.2.1) $s_{top,min} = \mathbf{25 \text{ mm}}$

Bottom bar clear spacing $s_{bot} = (b - (2 \times (C_{nom,s} + \phi m_{1,s3,z1,v}) + \phi m_{1,s3,z1,b,L1} \times N_{m1,s3,z1,b,L1})) / (N_{m1,s3,z1,b,L1} - 1) = \mathbf{186 \text{ mm}}$

Min. allowable bottom bar clear spacing (cl.25.2.1) $s_{bot,min} = \mathbf{25 \text{ mm}}$

PASS - Actual bar spacing exceeds minimum allowable

Zone 2 - Positive moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section $M_u = \text{abs}(M_{m1,s3,z2,max,red}) = \mathbf{31.54 \text{ kNm}}$

Effective depth to tension reinforcement $d = \mathbf{449.1 \text{ mm}}$

Tension reinforcement provided $2 \times 13\phi + 2 \times 13\phi$

Area of tension reinforcement provided $A_{s,\text{prov}} = \mathbf{507 \text{ mm}^2}$

Minimum area of reinforcement (cl.9.6.1.2) $A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = \mathbf{251 \text{ mm}^2}$

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

Stress block depth factor (cl.22.2.2.4.3) $\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = \mathbf{0.85}$

Depth of equivalent rectangular stress block $a = A_{s,\text{prov}} \times f_y / (0.85 \times f'_c \times b) = \mathbf{42 \text{ mm}}$

Depth to neutral axis $c = a / \beta_1 = \mathbf{49 \text{ mm}}$

Net tensile strain in extreme tension fibers $\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = \mathbf{0.02445}$

Net tensile strain in tension controlled zone

$\phi_f = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ty}) / (0.003), 0.65), 0.9) = \mathbf{0.90}$

$M_n = A_{s,\text{prov}} \times f_y \times (d - a / 2) = \mathbf{91.1 \text{ kNm}}$

$\phi M_n = M_n \times \phi_f = \mathbf{82.0 \text{ kNm}}$

PASS - Required moment strength is less than design moment strength

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Flexural cracking

Max. center to center spacing of tension reinf.

$$S_{b,max} = S_{bot} + \phi m_1 s_3 z_2 b L_1 = 66 \text{ mm}$$

Service load stress in reinforcement (cl.24.3.2)

$$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$$

Clear cover of reinforcement

$$C_c = C_{nom_b} + \phi_v = 45 \text{ mm}$$

Maximum allowable bot bar spacing (Table 24.3.2) $S_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

Control of deflections (Section 24.2)

Concrete density factor

$$K_w = 1.00$$

Reinforcement yield strength factor

$$K_f = 0.4 + f_y / 100000 \text{ psi} = 1.01$$

Minimum thickness of beam (Table 9.3.1.1)

$$h_{min} = (L_{m1_s3} / 21.0) \times K_w \times K_f = 168 \text{ mm}$$

PASS - Thickness of beam exceeds minimum thickness

Spacing limits for reinforcement

Top bar clear spacing

$$S_{top} = (b - (2 \times (C_{nom_s} + \phi m_1 s_3 z_2 v) + \phi m_1 s_3 z_2 r_t L_1 \times N_{m1_s3_z2r_t_L1})) / (N_{m1_s3_z2r_t_L1} - 1) = 186 \text{ mm}$$

Min. allowable top bar clear spacing (cl.25.2.1)

$$S_{top,min} = 25 \text{ mm}$$

Bottom bar clear spacing

$$S_{bot} = (b - (2 \times (C_{nom_s} + \phi m_1 s_3 z_2 v) + \phi m_1 s_3 z_2 b L_1 \times N_{m1_s3_z2b_L1} + \phi m_1 s_3 z_1 b L_1 \times N_{m1_s3_z1b_L1})) / ((N_{m1_s3_z2b_L1} + N_{m1_s3_z1b_L1}) - 1) = 53 \text{ mm}$$

Min. allowable bottom bar clear spacing (cl.25.2.1)

$$S_{bot,min} = 25 \text{ mm}$$

PASS - Actual bar spacing exceeds minimum allowable

Zone 3 - Negative moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section

$$M_u = \text{abs}(M_{m1_s3_z3_min_red}) = 68.94 \text{ kNm}$$

Effective depth to tension reinforcement

$$d = 449.1 \text{ mm}$$

Tension reinforcement provided

$$2 \times 13\phi + 2 \times 13\phi$$

Area of tension reinforcement provided

$$A_{s,prov} = 507 \text{ mm}^2$$

Minimum area of reinforcement (cl.9.6.1.2)

$$A_{s,min} = \max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi}), 200 \text{ psi}} \times b \times d / f_y = 442 \text{ mm}^2$$

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

Stress block depth factor (cl.22.2.2.4.3)

$$\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = 0.85$$

Depth of equivalent rectangular stress block

$$a = A_{s,prov} \times f_y / (0.85 \times f'_c \times b) = 42 \text{ mm}$$

Depth to neutral axis

$$c = a / \beta_1 = 49 \text{ mm}$$

Net tensile strain in extreme tension fibers

$$\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = 0.02445$$

Net tensile strain in tension controlled zone

$$\phi_t = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ty}) / (0.003), 0.65), 0.9) = 0.90$$

$$M_n = A_{s,prov} \times f_y \times (d - a / 2) = 91.1 \text{ kNm}$$

$$\phi M_n = M_n \times \phi_t = 82.0 \text{ kNm}$$

PASS - Required moment strength is less than design moment strength

Flexural cracking

Max. center to center spacing of tension reinf.

$$S_{t,max} = S_{top} + \phi m_1 s_3 z_3 t L_1 = 66 \text{ mm}$$

Service load stress in reinforcement (cl.24.3.2)

$$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$$

Clear cover of reinforcement

$$C_c = C_{nom_t} + \phi_v = 45 \text{ mm}$$

Maximum allowable top bar spacing (Table 24.3.2) $S_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

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Spacing limits for reinforcement

Top bar clear spacing

$$S_{top} = (b - (2 \times (C_{nom_s} + \phi m_{1,s3,z3,v}) + \phi m_{1,s3,z3,t,L1} \times N_{m1,s3,z3,t,L1} + \phi m_{1,s3,z2,r,t,L1} \times N_{m1,s3,z2,r,t,L1})) / ((N_{m1,s3,z3,t,L1} + N_{m1,s3,z2,r,t,L1}) - 1) = 53 \text{ mm}$$

Min. allowable top bar clear spacing (cl.25.2.1)

$$S_{top,min} = 25 \text{ mm}$$

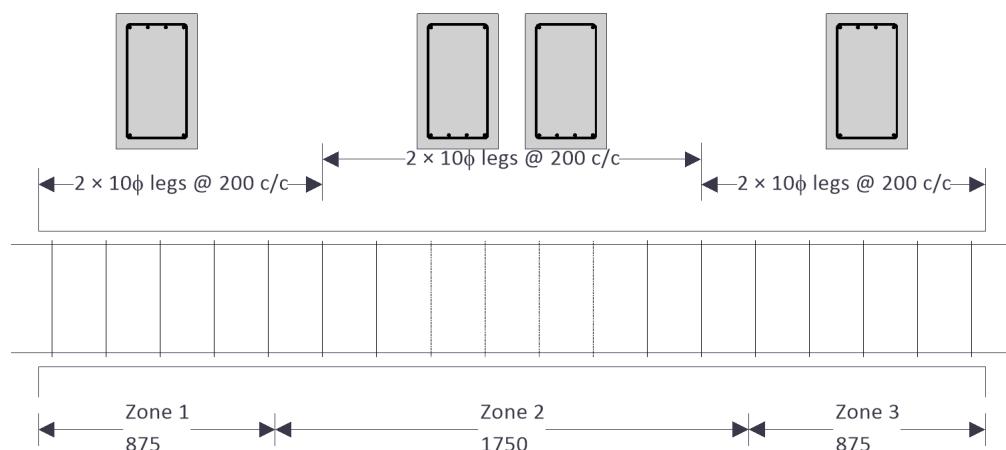
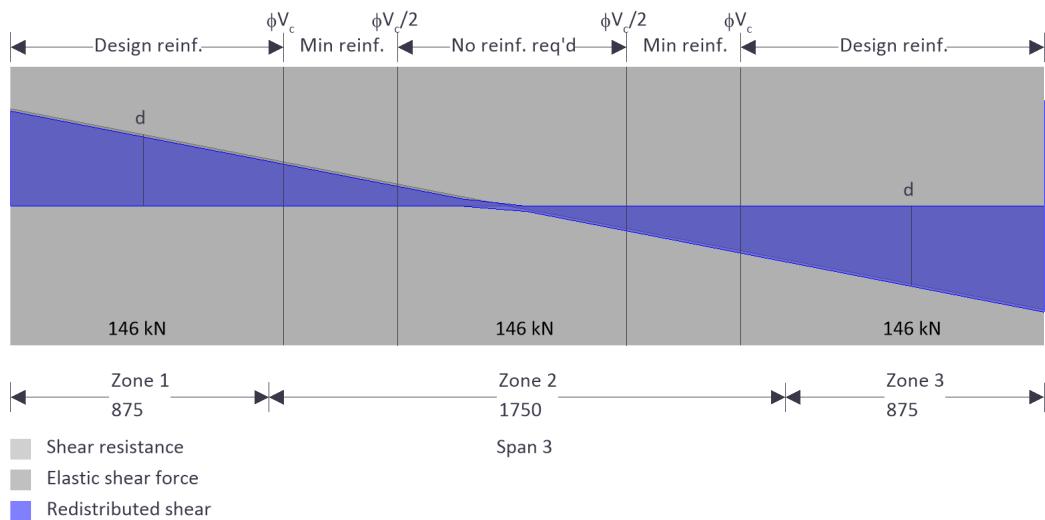
Bottom bar clear spacing

$$S_{bot} = (b - (2 \times (C_{nom_s} + \phi m_{1,s3,z3,v}) + \phi m_{1,s3,z3,b,L1} \times N_{m1,s3,z3,b,L1})) / (N_{m1,s3,z3,b,L1} - 1) = 186 \text{ mm}$$

Min. allowable bottom bar clear spacing (cl.25.2.1) $S_{bot,min} = 25 \text{ mm}$

PASS - Actual bar spacing exceeds minimum allowable

Shear design



Rectangular section in shear

Concrete weight modification factor

$$\lambda = 1.00$$

Location where min. reinf. is req'd (V_u less ϕV_c)

Between 924 mm and 2474 mm

Location where no reinf. is req'd (V_u less $\phi V_c / 2$)

Between 1311 mm and 2086 mm

Maximum reinforcement shear strength

$$\phi V_{s,max} = \phi_s \times 8 \text{ psi} \times \sqrt{(\min(f'_c, 10000 \text{ psi}) / 1 \text{ psi}) \times b \times d} = 300.2 \text{ kN}$$

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Minimum area of shear reinf. (Table 9.6.3.4) $A_{sv,min} = \max(50 \text{ psi}, 0.75 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})} \times b / \min(f_y, 60000 \text{ psi}) = 250 \text{ mm}^2/\text{m}$

Zone 1

Effective depth of long. reinf. used for shear zone

$d = 449 \text{ mm}$

Size effect factor (cl. 22.5.5.1.3)

$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$

Area of longitudinal reinforcement

$A_{st} = 507 \text{ mm}^2$

Ratio of longitudinal reinforcement

$\rho_w = A_{st} / (b \times d) = 0.004$

Concrete shear strength (Table 22.5.5.1)

$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 46.7 \text{ kN}$

Design shear force at 449mm from support

$V_u = 75.3 \text{ kN}$

Reinf. shear strength required (eqn. 22.5.1.1)

$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 28.6 \text{ kN}$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3)

$A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 205 \text{ mm}^2/\text{m}$

Area of shear reinforcement required

$A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 250 \text{ mm}^2/\text{m}$

Shear reinforcement provided

$2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

Area of shear reinforcement provided

$A_{sv,prov} = 713 \text{ mm}^2/\text{m}$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2) $s_{vl,max} = d / 2 = 224.6 \text{ mm}$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

Zone 2

Effective depth of long. reinf. used for shear zone

$d = 449 \text{ mm}$

Size effect factor (cl. 22.5.5.1.3)

$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$

Area of longitudinal reinforcement

$A_{st} = 507 \text{ mm}^2$

Ratio of longitudinal reinforcement

$\rho_w = A_{st} / (b \times d) = 0.004$

Concrete shear strength (Table 22.5.5.1)

$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 46.7 \text{ kN}$

Design shear force within zone

$V_u = 58.3 \text{ kN}$

Reinf. shear strength required (eqn. 22.5.1.1)

$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 11.6 \text{ kN}$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3)

$A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 83 \text{ mm}^2/\text{m}$

Area of shear reinforcement required

$A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 250 \text{ mm}^2/\text{m}$

Shear reinforcement provided

$2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

Area of shear reinforcement provided

$A_{sv,prov} = 713 \text{ mm}^2/\text{m}$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2) $s_{vl,max} = d / 2 = 224.6 \text{ mm}$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

Zone 3

Effective depth of long. reinf. used for shear zone

$d = 449 \text{ mm}$

Size effect factor (cl. 22.5.5.1.3)

$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$

Area of longitudinal reinforcement

$A_{st} = 507 \text{ mm}^2$

Ratio of longitudinal reinforcement

$\rho_w = A_{st} / (b \times d) = 0.004$

Concrete shear strength (Table 22.5.5.1)

$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 46.7 \text{ kN}$

Design shear force at 449mm from support

$V_u = 84.0 \text{ kN}$

Reinf. shear strength required (eqn. 22.5.1.1)

$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 37.3 \text{ kN}$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3)

$A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 268 \text{ mm}^2/\text{m}$

Area of shear reinforcement required

$A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 268 \text{ mm}^2/\text{m}$

Shear reinforcement provided

$2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

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Area of shear reinforcement provided

$$A_{sv,prov} = 713 \text{ mm}^2/\text{m}$$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2)

$$S_{vl,max} = d / 2 = 224.6 \text{ mm}$$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

Beam 1 - Span 4

Rectangular section details

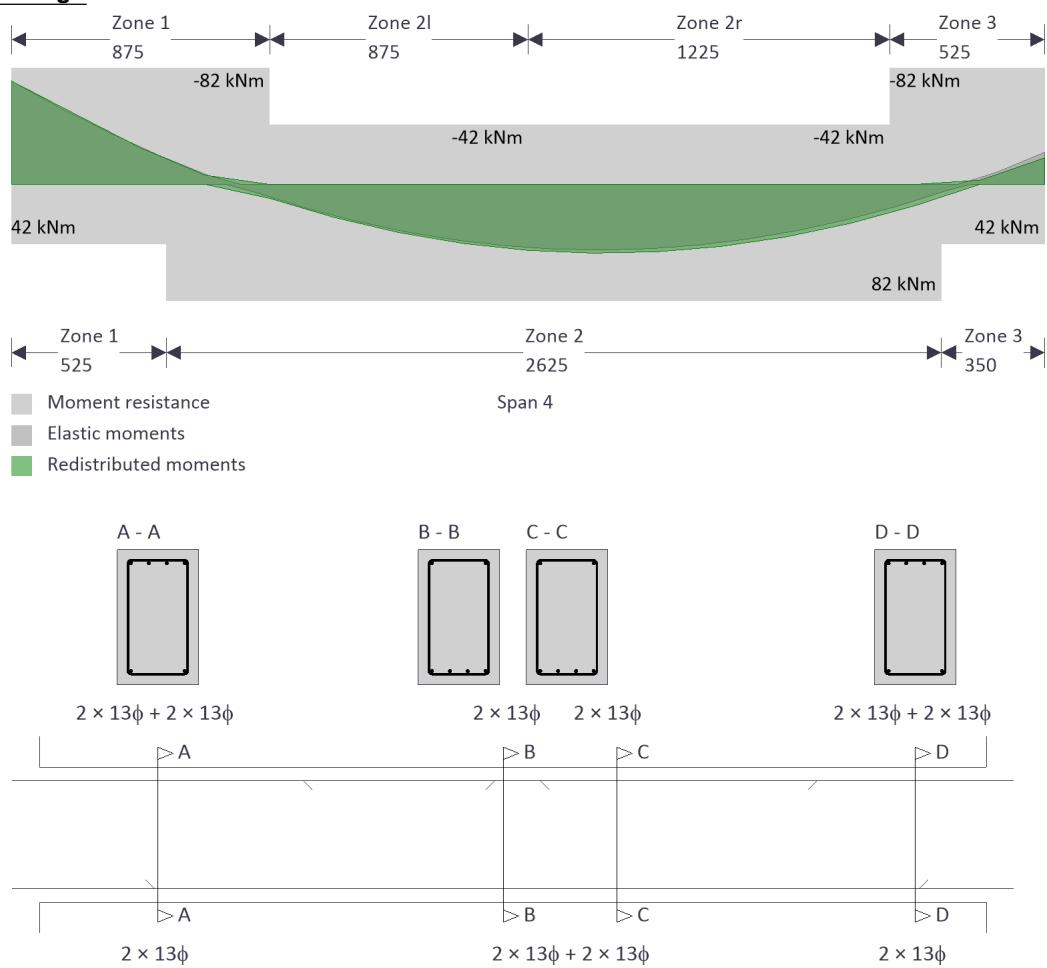
Section width

$$b = 300 \text{ mm}$$

Section depth

$$h = 500 \text{ mm}$$

Moment design



Zone 1 - Negative moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section

$$M_u = \text{abs}(M_{m1_s4_z1_min_red}) = 72.88 \text{ kNm}$$

Effective depth to tension reinforcement

$$d = 449.1 \text{ mm}$$

Tension reinforcement provided

$$2 \times 13\phi + 2 \times 13\phi$$

Area of tension reinforcement provided

$$A_{s,prov} = 507 \text{ mm}^2$$

Minimum area of reinforcement (cl.9.6.1.2)

$$A_{s,min} = \max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi}), 200 \text{ psi}} \times b \times d / f_y) = 442 \text{ mm}^2$$

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

Stress block depth factor (cl.22.2.2.4.3)

$$\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = 0.85$$

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Depth of equivalent rectangular stress block	$a = A_{s,prov} \times f_y / (0.85 \times f'_c \times b) = 42 \text{ mm}$
Depth to neutral axis	$c = a / \beta_1 = 49 \text{ mm}$
Net tensile strain in extreme tension fibers	$\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = 0.02445$
Strength reduction factor (cl.21.2.1)	Net tensile strain in tension controlled zone $\phi_f = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ty}) / (0.003), 0.65), 0.9) = 0.90$
Nominal moment strength	$M_n = A_{s,prov} \times f_y \times (d - a / 2) = 91.1 \text{ kNm}$
Design moment strength	$\phi M_n = M_n \times \phi_f = 82.0 \text{ kNm}$
	PASS - Required moment strength is less than design moment strength
Flexural cracking	
Max. center to center spacing of tension reinf.	$S_{stop} = S_{top} + \phi m_{1,s4,z1,t,L1} = 66 \text{ mm}$
Service load stress in reinforcement (cl.24.3.2)	$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$
Clear cover of reinforcement	$C_c = C_{nom,t} + \phi v = 45 \text{ mm}$
Maximum allowable top bar spacing (Table 24.3.2)	$S_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$
	PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing
Spacing limits for reinforcement	
Top bar clear spacing	$S_{stop} = (b - (2 \times (C_{nom,s} + \phi m_{1,s4,z1,v}) + \phi m_{1,s4,z1,t,L1} \times N_{m1,s4,z1,t,L1} + \phi m_{1,s4,z2,t,L1} \times N_{m1,s4,z2,t,L1})) / ((N_{m1,s4,z1,t,L1} + N_{m1,s4,z2,t,L1}) - 1) = 53 \text{ mm}$
Min. allowable top bar clear spacing (cl.25.2.1)	$S_{stop,min} = 25 \text{ mm}$
Bottom bar clear spacing	$S_{bot} = (b - (2 \times (C_{nom,s} + \phi m_{1,s4,z1,v}) + \phi m_{1,s4,z1,b,L1} \times N_{m1,s4,z1,b,L1})) / (N_{m1,s4,z1,b,L1} - 1) = 186 \text{ mm}$
Min. allowable bottom bar clear spacing (cl.25.2.1)	$S_{bot,min} = 25 \text{ mm}$
	PASS - Actual bar spacing exceeds minimum allowable
Zone 2 - Positive moment. Rectangular section in flexure (Section 9.5.2)	
Factored bending moment at section	$M_u = \text{abs}(M_{m1,s4,z2,max_red}) = 48.42 \text{ kNm}$
Effective depth to tension reinforcement	$d = 449.1 \text{ mm}$
Tension reinforcement provided	$2 \times 13\phi + 2 \times 13\phi$
Area of tension reinforcement provided	$A_{s,prov} = 507 \text{ mm}^2$
Minimum area of reinforcement (cl.9.6.1.2)	$A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = 389 \text{ mm}^2$
	PASS - Area of reinforcement provided is greater than minimum area of reinforcement required
Stress block depth factor (cl.22.2.2.4.3)	$\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = 0.85$
Depth of equivalent rectangular stress block	$a = A_{s,prov} \times f_y / (0.85 \times f'_c \times b) = 42 \text{ mm}$
Depth to neutral axis	$c = a / \beta_1 = 49 \text{ mm}$
Net tensile strain in extreme tension fibers	$\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = 0.02445$
	Net tensile strain in tension controlled zone
Strength reduction factor (cl.21.2.1)	$\phi_f = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ty}) / (0.003), 0.65), 0.9) = 0.90$
Nominal moment strength	$M_n = A_{s,prov} \times f_y \times (d - a / 2) = 91.1 \text{ kNm}$
Design moment strength	$\phi M_n = M_n \times \phi_f = 82.0 \text{ kNm}$
	PASS - Required moment strength is less than design moment strength
Flexural cracking	
Max. center to center spacing of tension reinf.	$S_{b,max} = S_{bot} + \phi m_{1,s4,z2,b,L1} = 66 \text{ mm}$
Service load stress in reinforcement (cl.24.3.2)	$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$

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Clear cover of reinforcement

$$c_c = c_{nom_b} + \phi_v = 45 \text{ mm}$$

Maximum allowable bot bar spacing (Table 24.3.2) $s_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

Control of deflections (Section 24.2)

Concrete density factor

$$K_w = 1.00$$

Reinforcement yield strength factor

$$K_f = 0.4 + f_y / 100000 \text{ psi} = 1.01$$

Minimum thickness of beam (Table 9.3.1.1)

$$h_{min} = (L_{m1_s4} / 18.5) \times K_w \times K_f = 191 \text{ mm}$$

PASS - Thickness of beam exceeds minimum thickness

Spacing limits for reinforcement

Top bar clear spacing

$$s_{top} = (b - (2 \times (c_{nom_s} + \phi_{m1_s4_z2_v}) + \phi_{m1_s4_z2r_t_L1} \times N_{m1_s4_z2r_t_L1})) / (N_{m1_s4_z2r_t_L1} - 1) = 186 \text{ mm}$$

Min. allowable top bar clear spacing (cl.25.2.1)

$$s_{top,min} = 25 \text{ mm}$$

Bottom bar clear spacing

$$s_{bot} = (b - (2 \times (c_{nom_s} + \phi_{m1_s4_z2_v}) + \phi_{m1_s4_z2_b_L1} \times N_{m1_s4_z2_b_L1} + \phi_{m1_s4_z1_b_L1} \times N_{m1_s4_z1_b_L1})) / ((N_{m1_s4_z2_b_L1} + N_{m1_s4_z1_b_L1}) - 1) = 53 \text{ mm}$$

Min. allowable bottom bar clear spacing (cl.25.2.1)

$$s_{bot,min} = 25 \text{ mm}$$

PASS - Actual bar spacing exceeds minimum allowable

Zone 3 - Positive moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section

$$M_u = \text{abs}(M_{m1_s4_z3_max_red}) = 9.07 \text{ kNm}$$

Effective depth to tension reinforcement

$$d = 449.1 \text{ mm}$$

Tension reinforcement provided

$$2 \times 13\phi$$

Area of tension reinforcement provided

$$A_{s,prov} = 253 \text{ mm}^2$$

Minimum area of reinforcement (cl.9.6.1.2)

$$A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = 72 \text{ mm}^2$$

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

Stress block depth factor (cl.22.2.2.4.3)

$$\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = 0.85$$

Depth of equivalent rectangular stress block

$$a = A_{s,prov} \times f_y / (0.85 \times f'_c \times b) = 21 \text{ mm}$$

Depth to neutral axis

$$c = a / \beta_1 = 25 \text{ mm}$$

Net tensile strain in extreme tension fibers

$$\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = 0.05189$$

Net tensile strain in tension controlled zone

Strength reduction factor (cl.21.2.1)

$$\phi_t = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ly}) / (0.003), 0.65), 0.9) = 0.90$$

Nominal moment strength

$$M_n = A_{s,prov} \times f_y \times (d - a / 2) = 46.7 \text{ kNm}$$

Design moment strength

$$\phi M_n = M_n \times \phi_t = 42.0 \text{ kNm}$$

PASS - Required moment strength is less than design moment strength

Flexural cracking

Max. center to center spacing of tension reinf.

$$s_{b,max} = s_{bot} + \phi_{m1_s4_z3_b_L1} = 198 \text{ mm}$$

Service load stress in reinforcement (cl.24.3.2)

$$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$$

Clear cover of reinforcement

$$c_c = c_{nom_b} + \phi_v = 45 \text{ mm}$$

Maximum allowable bot bar spacing (Table 24.3.2) $s_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

Zone 3 - Negative moment. Rectangular section in flexure (Section 9.5.2)

Factored bending moment at section

$$M_u = \text{abs}(M_{m1_s4_z3_min_red}) = 18.72 \text{ kNm}$$

Effective depth to tension reinforcement

$$d = 449.1 \text{ mm}$$

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Tension reinforcement provided	$2 \times 13\phi + 2 \times 13\phi$
Area of tension reinforcement provided	$A_{s,prov} = 507 \text{ mm}^2$
Minimum area of reinforcement (cl.9.6.1.2)	$A_{s,min} = \min(\max(3 \text{ psi} \times \sqrt{(f'_c / 1 \text{ psi})}, 200 \text{ psi}) \times b \times d / f_y, 4/3 \times A_{s,des}) = 148 \text{ mm}^2$

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

$$\beta_1 = \min(\max(0.85 - 0.05 \times (f'_c - 4 \text{ ksi}) / 1 \text{ ksi}, 0.65), 0.85) = 0.85$$

$$a = A_{s,prov} \times f_y / (0.85 \times f'_c \times b) = 42 \text{ mm}$$

$$c = a / \beta_1 = 49 \text{ mm}$$

$$\epsilon_t = 0.003 \times (d_o - c) / \max(c, 0.001 \text{ in}) = 0.02445$$

Net tensile strain in tension controlled zone

$$\phi_t = \min(\max(0.65 + 0.25 \times (\epsilon_t - \epsilon_{ty}) / (0.003), 0.65), 0.9) = 0.90$$

$$M_n = A_{s,prov} \times f_y \times (d - a / 2) = 91.1 \text{ kNm}$$

$$\phi M_n = M_n \times \phi_t = 82.0 \text{ kNm}$$

PASS - Required moment strength is less than design moment strength

Flexural cracking

$$\text{Max. center to center spacing of tension reinf.}$$

$$S_{t,max} = S_{top} + \phi m_{1,s4,z3,t,L1} = 66 \text{ mm}$$

$$\text{Service load stress in reinforcement (cl.24.3.2)}$$

$$f_s = 2/3 \times f_y = 280 \text{ N/mm}^2$$

$$\text{Clear cover of reinforcement}$$

$$C_c = C_{nom,t} + \phi v = 45 \text{ mm}$$

$$\text{Maximum allowable top bar spacing (Table 24.3.2)} \quad S_{max} = \min(15\text{in} \times 40000\text{psi} / f_s - 2.5 \times c_c, 12\text{in} \times 40000\text{psi} / f_s) = 264 \text{ mm}$$

PASS - Maximum allowable tension reinforcement spacing exceeds actual spacing

Spacing limits for reinforcement

$$\text{Top bar clear spacing}$$

$$S_{top} = (b - (2 \times (C_{nom,s} + \phi m_{1,s4,z3,v}) + \phi m_{1,s4,z3,t,L1} \times N_{m1,s4,z3,t,L1} + \phi m_{1,s4,z2r,t,L1} \times N_{m1,s4,z2r,t,L1})) / ((N_{m1,s4,z3,t,L1} + N_{m1,s4,z2r,t,L1}) - 1) = 53 \text{ mm}$$

$$\text{Min. allowable top bar clear spacing (cl.25.2.1)}$$

$$S_{top,min} = 25 \text{ mm}$$

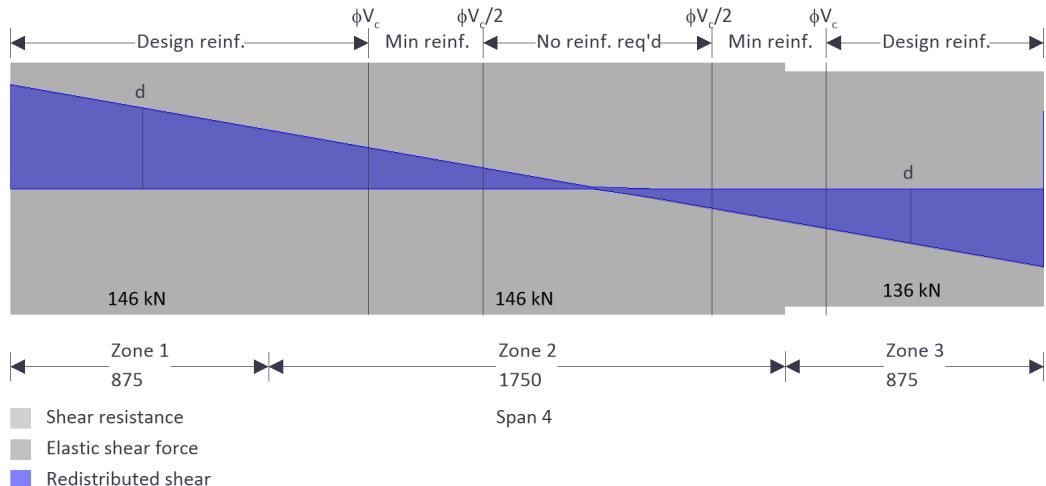
$$\text{Bottom bar clear spacing}$$

$$S_{bot} = (b - (2 \times (C_{nom,s} + \phi m_{1,s4,z3,v}) + \phi m_{1,s4,z3,b,L1} \times N_{m1,s4,z3,b,L1})) / (N_{m1,s4,z3,b,L1} - 1) = 186 \text{ mm}$$

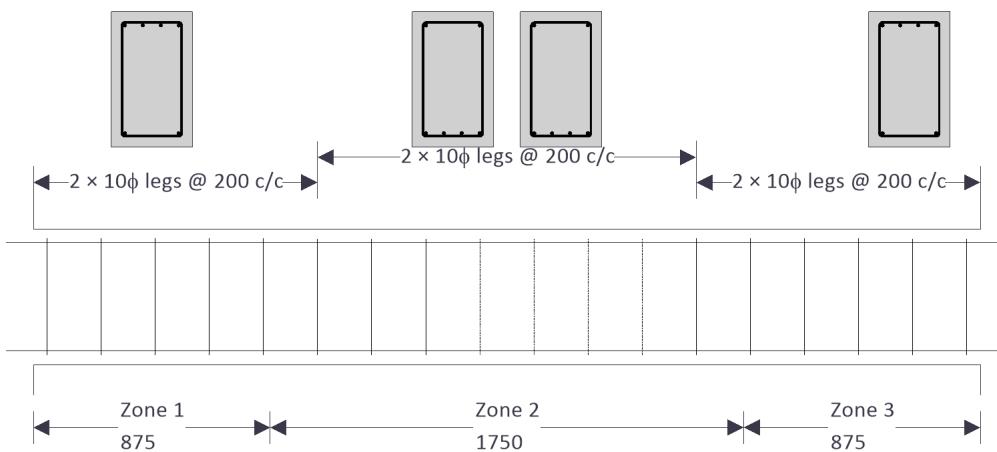
$$\text{Min. allowable bottom bar clear spacing (cl.25.2.1)} \quad S_{bot,min} = 25 \text{ mm}$$

PASS - Actual bar spacing exceeds minimum allowable

Shear design



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Rectangular section in shear

Concrete weight modification factor

$$\lambda = 1.00$$

Location where min. reinf. is req'd (V_u less ϕV_c)

Between 1213 mm and 2763 mm

Location where no reinf. is req'd (V_u less $\phi V_c / 2$)

Between 1601 mm and 2376 mm

Maximum reinforcement shear strength

$$\phi V_{s,max} = \phi_s \times 8 \text{ psi} \times \sqrt{\min(f'_c, 10000 \text{ psi}) / 1 \text{ psi}} \times b \times d = 300.2 \text{ kN}$$

Minimum area of shear reinf. (Table 9.6.3.4)

$$A_{sv,min} = \max(50 \text{ psi}, 0.75 \text{ psi} \times \sqrt{f'_c / 1 \text{ psi}}) \times b / \min(f_y, 60000 \text{ psi}) = 250 \text{ mm}^2/\text{m}$$

Zone 1

Effective depth of long. reinf. used for shear zone

$$d = 449 \text{ mm}$$

Size effect factor (cl. 22.5.5.1.3)

$$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$$

Area of longitudinal reinforcement

$$A_{st} = 507 \text{ mm}^2$$

Ratio of longitudinal reinforcement

$$\rho_w = A_{st} / (b \times d) = 0.004$$

Concrete shear strength (Table 22.5.5.1)

$$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 46.7 \text{ kN}$$

Design shear force at 449mm from support

$$V_u = 93.8 \text{ kN}$$

Reinf. shear strength required (eqn. 22.5.1.1)

$$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 47.2 \text{ kN}$$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3)

$$A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 338 \text{ mm}^2/\text{m}$$

Area of shear reinforcement required

$$A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 338 \text{ mm}^2/\text{m}$$

Shear reinforcement provided

$$2 \times 10\phi \text{ legs} @ 200 \text{ c/c}$$

Area of shear reinforcement provided

$$A_{sv,prov} = 713 \text{ mm}^2/\text{m}$$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2) $S_{vl,max} = d / 2 = 224.6 \text{ mm}$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

Zone 2

Effective depth of long. reinf. used for shear zone

$$d = 449 \text{ mm}$$

Size effect factor (cl. 22.5.5.1.3)

$$\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$$

Area of longitudinal reinforcement

$$A_{st} = 507 \text{ mm}^2$$

Ratio of longitudinal reinforcement

$$\rho_w = A_{st} / (b \times d) = 0.004$$

Concrete shear strength (Table 22.5.5.1)

$$\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 46.7 \text{ kN}$$

Design shear force within zone

$$V_u = 68.2 \text{ kN}$$

Reinf. shear strength required (eqn. 22.5.1.1)

$$\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 21.5 \text{ kN}$$

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Area of design shear reinf. req'd (eqn. 22.5.8.5.3) $A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 154 \text{ mm}^2/\text{m}$

Area of shear reinforcement required $A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 250 \text{ mm}^2/\text{m}$

Shear reinforcement provided $2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

Area of shear reinforcement provided $A_{sv,prov} = 713 \text{ mm}^2/\text{m}$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2) $s_{vl,max} = d / 2 = 224.6 \text{ mm}$

PASS - longitudinal spacing of stirrups is less than the maximum allowable

Zone 3

Effective depth of long. reinf. used for shear zone $d = 449 \text{ mm}$

Size effect factor (cl. 22.5.5.1.3) $\lambda_s = \min(\sqrt{2 / (1 + (d / 1 \text{ in}) / 10)}, 1.0) = 0.85$

Area of longitudinal reinforcement $A_{st} = 253 \text{ mm}^2$

Ratio of longitudinal reinforcement $\rho_w = A_{st} / (b \times d) = 0.002$

Concrete shear strength (Table 22.5.5.1) $\phi V_c = \phi_s \times \min(8 \times \lambda \times (\rho_w)^{1/3}, 5 \times \lambda) \times \sqrt{(f'_c \times 1 \text{ psi})} \times b \times d = 37.1 \text{ kN}$

Design shear force at 449mm from support $V_u = 64.0 \text{ kN}$

Reinf. shear strength required (eqn. 22.5.1.1) $\phi V_s = \max(V_u - \phi V_c, 0 \text{ kips}) = 26.9 \text{ kN}$

Area of design shear reinf. req'd (eqn. 22.5.8.5.3) $A_{sv,des} = \phi V_s / (\phi_s \times \min(f_y, 60000 \text{ psi}) \times d) = 193 \text{ mm}^2/\text{m}$

Area of shear reinforcement required $A_{sv,req} = \max(A_{sv,min}, A_{sv,des}) = 250 \text{ mm}^2/\text{m}$

Shear reinforcement provided $2 \times 10\phi \text{ legs @ } 200 \text{ c/c}$

Area of shear reinforcement provided $A_{sv,prov} = 713 \text{ mm}^2/\text{m}$

PASS - Area of shear reinforcement provided exceeds area of shear reinforcement required

Maximum longitudinal spacing (Table 9.7.6.2.2) $s_{vl,max} = d / 2 = 224.6 \text{ mm}$

PASS - longitudinal spacing of stirrups is less than the maximum allowable