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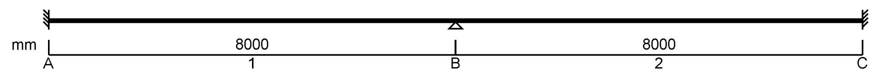
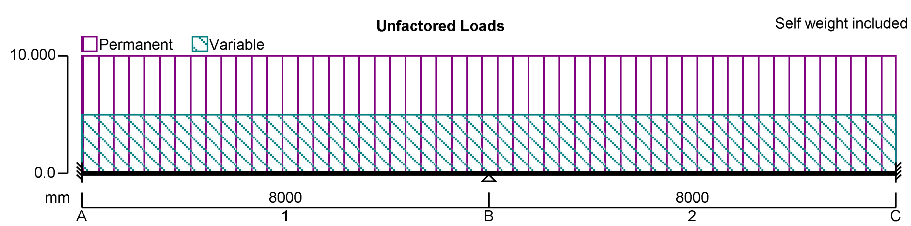
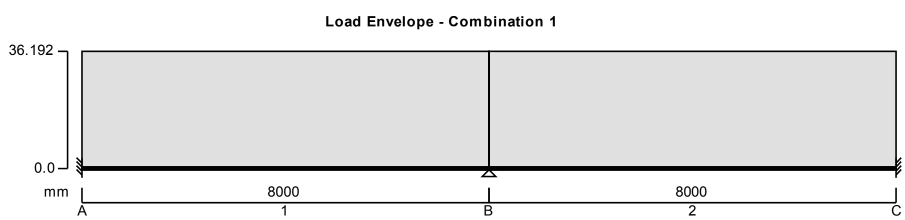
Project				Job Ref.	
RC Beam Analysis & Design Example (EN1992-1)					
Section				Sheet no./rev.	
Civil & Geotechnical Engineering				1	
Calc. by	Date	Chk'd by	Date	App'd by	Date
Dr.C.Sachpazis	23/04/2013	-			

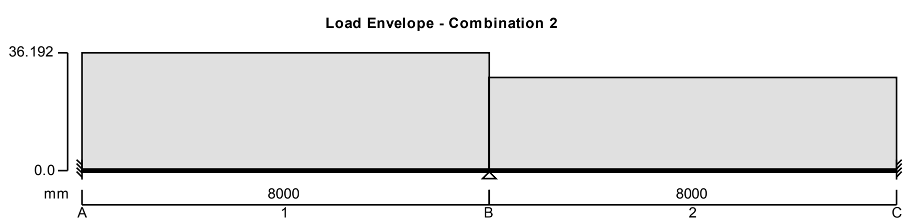
RC BEAM ANALYSIS & DESIGN (EN1992-1)

In accordance with recommended values









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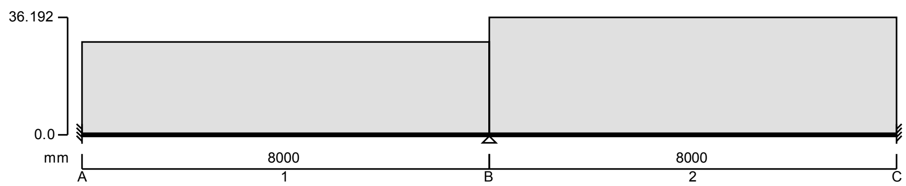
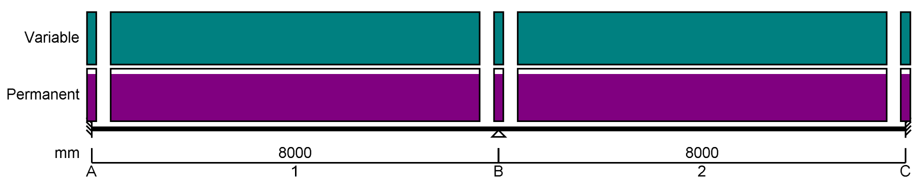
	Section Civil & Geotechnical Engineering			Sheet no./rev. 1	
	Calc. by Dr.C.Sachpazis	Date 23/04/2013	Chk'd by -	Date	App'd by	Date

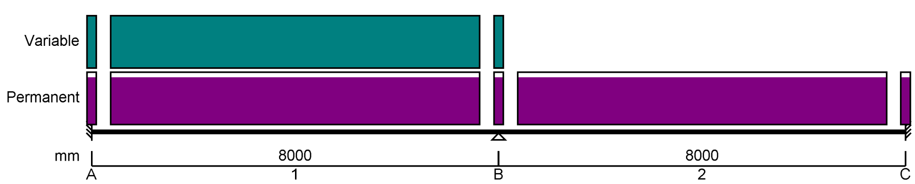
Load Envelope - Combination 3



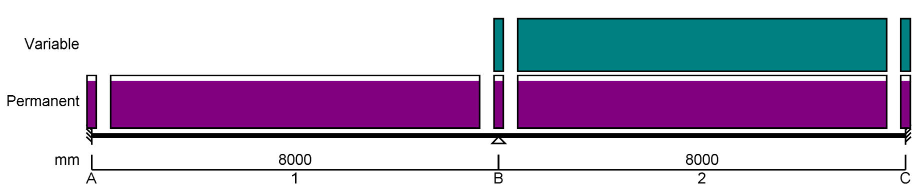
Load Combination 1 (shown in proportion)



Load Combination 2 (shown in proportion)



Load Combination 3 (shown in proportion)



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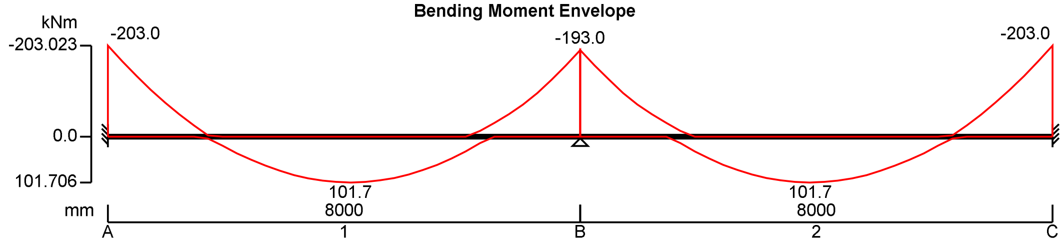
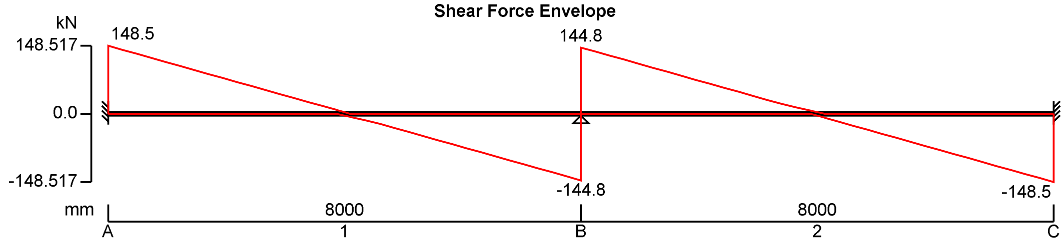
Bending Moment Envelope



Shear Force Envelope



Support conditions

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

Applied loading

Permanent self weight of beam × 1

Permanent full UDL 10 kN/m

Variable full UDL 5 kN/m

Load combinations

Load combination 1	Support A	Permanent × 1.35
		Variable × 1.50
	Span 1	Permanent × 1.35
		Variable × 1.50
	Support B	Permanent × 1.35
		Variable × 1.50
	Span 2	Permanent × 1.35
		Variable × 1.50
	Support C	Permanent × 1.35

		Variable × 1.50
Load combination 2	Support A	Permanent × 1.35
		Variable × 1.50
	Span 1	Permanent × 1.35
		Variable × 1.50
	Support B	Permanent × 1.35
		Variable × 1.50
	Span 2	Permanent × 1.35
		Variable × 0.00
	Support C	Permanent × 1.35
		Variable × 0.00
Load combination 3	Support A	Permanent × 1.35
		Variable × 0.00
	Span 1	Permanent × 1.35
		Variable × 0.00
	Support B	Permanent × 1.35
		Variable × 1.50
	Span 2	Permanent × 1.35
		Variable × 1.50
	Support C	Permanent × 1.35
		Variable × 1.50

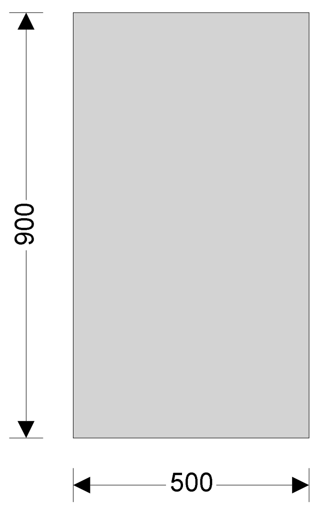
Analysis results

Maximum moment support A;	M_{A_max} = **-203** kNm;	M_{A_red} = **-203** kNm;
Maximum moment span 1 at 4104 mm;	M_{s1_max} = **102** kNm;	M_{s1_red} = **102** kNm;
Maximum moment support B;	M_{B_max} = **-193** kNm;	M_{B_red} = **-193** kNm;
Maximum moment span 2 at 3896 mm;	M_{s2_max} = **102** kNm;	M_{s2_red} = **102** kNm;
Maximum moment support C;	M_{C_max} = **-203** kNm;	M_{C_red} = **-203** kNm;
Maximum shear support A;	V_{A_max} = **149** kN;	V_{A_red} = **142** kN
Maximum shear support A span 1 at 843 mm;	$V_{A\_s1\_max}$ = **118** kN;	$V_{A\_s1\_red}$ = **118** kN
Maximum shear support B;	V_{B_max} = **-145** kN;	V_{B_red} = **-145** kN
Maximum shear support B span 1 at 7158 mm;	$V_{B\_s1\_max}$ = **-114** kN;	$V_{B\_s1\_red}$ = **-114** kN
Maximum shear support B span 2 at 843 mm;	$V_{B\_s2\_max}$ = **114** kN;	$V_{B\_s2\_red}$ = **114** kN
Maximum shear support C;	V_{C_max} = **-149** kN;	V_{C_red} = **-149** kN
Maximum shear support C span 2 at 7158 mm;	$V_{C\_s2\_max}$ = **-118** kN;	$V_{C\_s2\_red}$ = **-118** kN
Maximum reaction at support A;	R_A = **149** kN	
Unfactored permanent load reaction at support A;	$R_{A\_Permanent}$ = **85** kN	

Unfactored variable load reaction at support A; $R_{A\_Variable}$ = **20** kN
Maximum reaction at support B; R_B = **290** kN
Unfactored permanent load reaction at support B; $R_{B\_Permanent}$ = **170** kN
Unfactored variable load reaction at support B; $R_{B\_Variable}$ = **40** kN
Maximum reaction at support C; R_C = **149** kN
Unfactored permanent load reaction at support C; $R_{C\_Permanent}$ = **85** kN
Unfactored variable load reaction at support C; $R_{C\_Variable}$ = **20** kN

Rectangular section details

Section width; b = **500** mm
Section depth; h = **900** mm



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

Concrete strength class; **C40/50**
Characteristic compressive cylinder strength; f_{ck} = **40** N/mm^2
Characteristic compressive cube strength; $f_{ck,cube}$ = **50** N/mm^2
Mean value of compressive cylinder strength; $f_{cm} = f_{ck} + 8$ N/mm^2 = **48** N/mm^2
Mean value of axial tensile strength; $f_{ctm} = 0.3$ N/mm$^2 \times (f_{ck}/ 1$ N/mm$^2)^{2/3}$ = **3.5** N/mm^2
Secant modulus of elasticity of concrete; $E_{cm} = 22$ kN/mm$^2 \times [f_{cm}/10$ N/mm$^2]^{0.3}$ = **35220** N/mm^2
Partial factor for concrete (Table 2.1N); γ_C = **1.50**
Compressive strength coefficient (cl.3.1.6(1)); α_{cc} = **1.00**
Design compressive concrete strength (exp.3.15); $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C$ = **26.7** N/mm^2
Maximum aggregate size; h_{agg} = **20** mm

Reinforcement details

Characteristic yield strength of reinforcement; f_{yk} = **500** 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

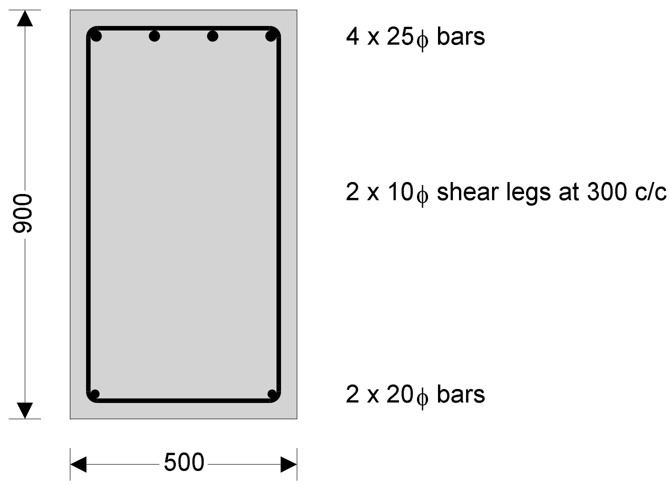
Nominal cover to reinforcement

Nominal cover to top reinforcement; c_{nom_t} = **35** mm

Nominal cover to bottom reinforcement; c_{nom_b} = **35** mm

Nominal cover to side reinforcement; c_{nom_s} = **35** mm

Support A



Rectangular section in flexure (Section 6.1)

Minimum moment factor (cl.9.2.1.2(1)); β_1 = **0.15**

Design bending moment; $M = \max(\text{abs}(M_{A\_red}), \beta_1 \times \text{abs}(M_{s1\_red}))$ = **203** kNm

Depth to tension reinforcement; $d = h - c_{nom\_t} - \phi_v - \phi_{top} / 2$ = **843** mm

Percentage redistribution; m_{rA} = **0** %

Redistribution ratio; $\delta = \min(1 - m_{rA}, 1)$ = **1.000**

$K = M / (b \times d^2 \times f_{ck})$ = **0.014**

$K' = 0.547 \times \delta - 0.137 \times \delta^2 - 0.214$ = **0.196**

K' > K - No compression reinforcement is required

Lever arm; $z = \min((d / 2) \times [1 + (1 - 3.53 \times K)^{0.5}], 0.95 \times d)$ = **800** mm

Depth of neutral axis; $x = 2.5 \times (d - z)$ = **105** mm

Area of tension reinforcement required; $A_{s,req} = M / (f_{yd} \times z)$ = **583** mm^2

Tension reinforcement provided; 4 × 25ϕ bars

Area of tension reinforcement provided; $A_{s,prov}$ = **1963** mm^2

Minimum area of reinforcement (exp.9.1N); $A_{s,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times b \times d$ = **769** mm^2

Maximum area of reinforcement (cl.9.2.1.1(3)); $A_{s,max} = 0.04 \times b \times h$ = **18000** mm^2

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

Minimum bottom reinforcement at supports

Minimum reinforcement factor (cl.9.2.1.4(1)); β_2 = **0.25**

Area of reinforcement to adjacent span; $A_{s,span}$ = **1963** mm^2

Minimum bottom reinforcement to support; $A_{s2,min} = \beta_2 \times A_{s,span}$ = **491** mm^2

Bottom reinforcement provided; 2 × 20ϕ bars

Area of bottom reinforcement provided; $A_{s2,prov}$ = **628** mm^2

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

Rectangular section in shear (Section 6.2)

Design shear force at support A; $V_{Ed,max} = abs(max(V_{A\_max}, V_{A\_red}))$ = **149** kN

Maximum design shear force (exp.6.9); $V_{Rd,max} = b \times z \times v_1 \times f_{cd} / (cot(\theta) + tan(\theta))$ = **1855** kN

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

Design shear force span 1 at 843 mm; $V_{Ed} = max(V_{A\_s1\_max}, V_{A\_s1\_red})$ = **118** kN

Design shear stress; $v_{Ed} = V_{Ed} / (b \times z)$ = **0.294** N/mm^2

Strength reduction factor (cl.6.2.3(3)); $v_1 = 0.6 \times [1 - f_{ck} / 250 \text{ N/mm}^2]$ = **0.504**

Compression chord coefficient (cl.6.2.3(3)); α_{cw} = **1.00**

Angle of concrete compression strut (cl.6.2.3);

$\theta = min(max(0.5 \times Asin[min(2 \times v_{Ed} / (\alpha_{cw} \times f_{cd} \times v_1),1)], 21.8 \text{ deg}), 45\text{deg})$ = **21.8** deg

Area of shear reinforcement required (exp.6.13); $A_{sv,req} = v_{Ed} \times b / (f_{yd} \times cot(\theta))$ = **135** mm^2/m

Shear reinforcement provided; 2 × 10ϕ legs at 300 c/c

Area of shear reinforcement provided; $A_{sv,prov}$ = **524** mm^2/m

Minimum area of shear reinforcement (exp.9.5N); $A_{sv,min} = 0.08 \text{ N/mm}^2 \times b \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / f_{yk}$ = **506** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (exp.9.6N); $s_{vl,max} = 0.75 \times d$ = **632** mm

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

Crack control (Section 7.3)

Maximum crack width; w_k = **0.3** mm

Mean value of concrete tensile strength; $f_{ct,eff} = f_{ctm}$ = **3.5** N/mm^2

Stress distribution coefficient; k_c = 0.4

Non-uniform self-equilibrating stress coefficient; k = min(max(1 + (300 mm - min(h, b)) × 0.35 / 500 mm, 0.65), 1) = **0.86**

Depth of tensile zone; $h_{cr} = h - x$ = **795** mm

Area of concrete in the tensile zone; $A_{ct} = h_{cr} \times b$ = **397344** mm^2

Adjusted maximum bar diameter (exp.7.6N); $\phi_{mod} = \phi_{top} \times (2.9 \text{ N/mm}^2 / f_{ct,eff}) \times 2 \times (h - d) / (k_c \times h_{cr})$ = **7** mm

Maximum adjusted bar diameter; ϕ_{max} = **32** mm

Tension bar spacing; $s_{bar} = (b - 2 \times (c_{nom\_s} + \phi_v) - \phi_{top}) / (N_{top} - 1)$ = **128** mm

Maximum tension bar spacing; s_{max} = **300** mm

Minimum allowable bar spacing; $s_{min} = max(\phi_{top}, h_{agg} + 5 \text{ mm}, 20 \text{ mm}) + \phi_{top}$ = **50** mm

Maximum stress permitted (Tables 7.2N & 7.3N); σ_s = **280** N/mm^2

Minimum area of reinforcement required (exp.7.1); $A_{sc,min} = k_c \times k \times f_{ct,eff} \times A_{ct} / \sigma_s$ = **1713** mm^2

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

PASS - Actual bar spacing exceeds minimum allowable

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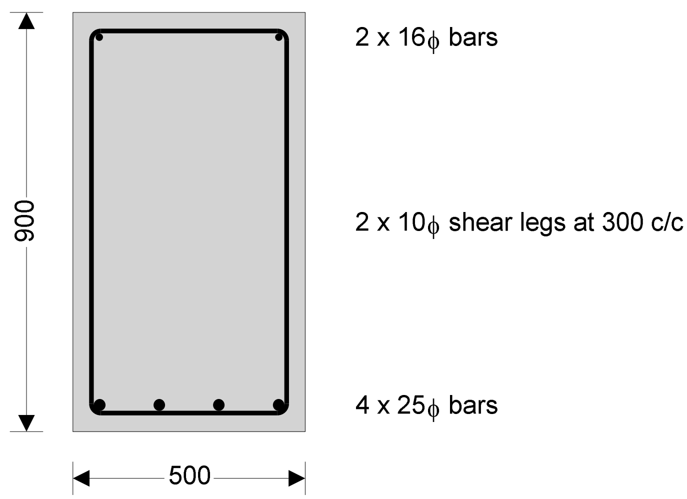
Mid span 1



Rectangular section in flexure (Section 6.1) - Positive midspan moment

Design bending moment; $M = abs(M_{s1\_red})$ = **102** kNm

Depth to tension reinforcement; $d = h - c_{nom\_b} - \phi_v - \phi_{bot} / 2$ = **843** mm

Percentage redistribution; $m_{rs1} = M_{s1\_red} / M_{s1\_max} - 1$ = **0** %

Redistribution ratio; $\delta = \min(1 - m_{rs1}, 1)$ = **1.000**

$K = M / (b \times d^2 \times f_{ck})$ = **0.007**

$K' = 0.547 \times \delta - 0.137 \times \delta^2 - 0.214$ = **0.196**

K' > K - No compression reinforcement is required

Lever arm; $z = \min((d / 2) \times [1 + (1 - 3.53 \times K)^{0.5}], 0.95 \times d)$ = **800** mm

Depth of neutral axis; $x = 2.5 \times (d - z)$ = **105** mm

Area of tension reinforcement required; $A_{s,req} = M / (f_{yd} \times z)$ = **292** mm^2

Tension reinforcement provided; $4 \times 25\phi$ bars

Area of tension reinforcement provided; $A_{s,prov}$ = **1963** mm^2

Minimum area of reinforcement (exp.9.1N); $A_{s,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times b \times d$ = **769** mm^2

Maximum area of reinforcement (cl.9.2.1.1(3)); $A_{s,max} = 0.04 \times b \times h$ = **18000** mm^2

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

Rectangular section in shear (Section 6.2)

Shear reinforcement provided; $2 \times 10\phi$ legs at 300 c/c

Area of shear reinforcement provided; $A_{sv,prov}$ = **524** mm^2/m

Minimum area of shear reinforcement (exp.9.5N); $A_{sv,min} = 0.08\ N/mm^2 \times b \times (f_{ck} / 1\ N/mm^2)^{0.5} / f_{yk}$ = **506** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (exp.9.6N); $s_{vl,max} = 0.75 \times d$ = **632** mm

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

Design shear resistance (assuming cot(θ) is 2.5); $V_{prov} = 2.5 \times A_{sv,prov} \times z \times f_{yd}$ = **455.5** kN

Shear links provided valid between 0 mm and 8000 mm with tension reinforcement of 1963 mm^2

Crack control (Section 7.3)

Maximum crack width; w_k = **0.3** mm

Mean value of concrete tensile strength; $f_{ct,eff} = f_{ctm}$ = **3.5** N/mm^2

Stress distribution coefficient; k_c = 0.4

Non-uniform self-equilibrating stress coefficient; k = min(max(1 + (300 mm - min(h, b)) × 0.35 / 500 mm, 0.65), 1) = **0.86**

Depth of tensile zone; h_{cr} = h - x = **795** mm

Area of concrete in the tensile zone; $A_{ct} = h_{cr} \times b$ = **397344** mm^2

Adjusted maximum bar diameter (exp.7.6N); $\phi_{mod} = \phi_{bot} \times (2.9\ N/mm^2 / f_{ct,eff}) \times 2 \times (h - d) / (k_c \times h_{cr})$ = **7** mm

Maximum adjusted bar diameter; ϕ_{max} = **32** mm

Tension bar spacing; $s_{bar} = (b - 2 \times (c_{nom\_s} + \phi_v) - \phi_{bot}) / (N_{bot} - 1)$ = **128** mm

Maximum tension bar spacing; s_{max} = **300** mm

Minimum allowable bar spacing; $s_{min} = \max(\phi_{bot}, h_{agg} + 5\ mm, 20\ mm) + \phi_{bot}$ = **50** mm

Maximum stress permitted (Tables 7.2N & 7.3N); σ_s = **280** N/mm^2

Minimum area of reinforcement required (exp.7.1); $A_{sc,min} = k_c \times k \times f_{ct,eff} \times A_{ct} / \sigma_s$ = **1713** mm^2

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

PASS - Actual bar spacing exceeds minimum allowable

Deflection control (Section 7.4)

Reference reinforcement ratio; $\rho_{m0} = (f_{ck} / 1\ N/mm^2)^{0.5} / 1000$ = **0.006**

Required tension reinforcement ratio; $\rho_m = A_{s,req} / (b \times d)$ = **0.001**

Required compression reinforcement ratio; $\rho'_m = A_{s2,req} / (b \times d)$ = **0.000**

Structural system factor (Table 7.4N); K_b = **1.3**

Basic allowable span to depth ratio (7.16a); $span\_to\_depth_{basic} = K_b \times [11 + 1.5 \times (f_{ck} / 1\ N/mm^2)^{0.5} \times \rho_{m0} / \rho_m + 3.2 \times (f_{ck} / 1\ N/mm^2)^{0.5} \times (\rho_{m0} / \rho_m - 1)^{1.5}]$ = **735.018**

Reinforcement factor (exp.7.17); $K_s = A_{s,prov} \times 500\ N/mm^2 / (A_{s,req} \times f_{yk})$ = **6.718**

Flange width factor; F1 = **1.000**

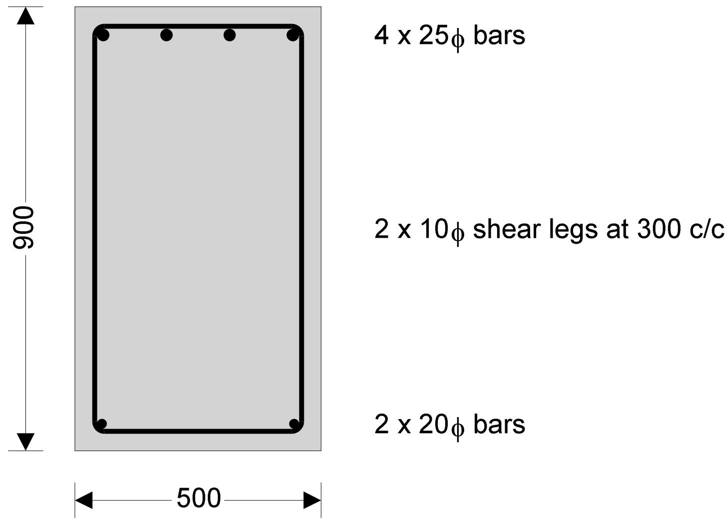
Long span supporting brittle partition factor; F2 = **1.000**

Allowable span to depth ratio; $span\_to\_depth_{allow} = span\_to\_depth_{basic} \times K_s \times F1 \times F2$ = **4937.972**

Actual span to depth ratio; $span\_to\_depth_{actual} = L_{s1} / d$ = **9.496**

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

<u>Support B</u>



Rectangular section in flexure (Section 6.1)

Design bending moment; $M = abs(M_{B\_red})$ = **193** kNm

Depth to tension reinforcement; $d = h - c_{nom\_t} - \phi_v - \phi_{top} / 2$ = **843** mm

Percentage redistribution; m_{rB} = **0** %

Redistribution ratio; $\delta = \min(1 - m_{rB}, 1)$ = **1.000**

$K = M / (b \times d^2 \times f_{ck})$ = **0.014**

$K' = 0.547 \times \delta - 0.137 \times \delta^2 - 0.214$ = **0.196**

K' > K - No compression reinforcement is required

Lever arm; $z = \min((d / 2) \times [1 + (1 - 3.53 \times K)^{0.5}], 0.95 \times d)$ = **800** mm

Depth of neutral axis; $x = 2.5 \times (d - z)$ = **105** mm

Area of tension reinforcement required; $A_{s,req} = M / (f_{yd} \times z)$ = **555** mm^2

Tension reinforcement provided; 4 × 25ϕ bars

Area of tension reinforcement provided; $A_{s,prov}$ = **1963** mm^2

Minimum area of reinforcement (exp.9.1N); $A_{s,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times b \times d$ = **769** mm^2

Maximum area of reinforcement (cl.9.2.1.1(3)); $A_{s,max} = 0.04 \times b \times h$ = **18000** mm^2

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

Rectangular section in shear (Section 6.2)

Design shear force at support B; $V_{Ed,max} = abs(\max(V_{B\_max}, V_{B\_red}))$ = **145** kN

Maximum design shear force (exp.6.9); $V_{Rd,max} = b \times z \times v_1 \times f_{cd} / (\cot(\theta) + \tan(\theta))$ = **1855** kN

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

Design shear force span 1 at 7158 mm; $V_{Ed} = abs(\min(V_{B\_s1\_max}, V_{B\_s1\_red}))$ = **114** kN

Design shear stress; $v_{Ed} = V_{Ed} / (b \times z)$ = **0.285** N/mm^2

Strength reduction factor (cl.6.2.3(3)); $v_1 = 0.6 \times [1 - f_{ck} / 250 N/mm^2]$ = **0.504**

Compression chord coefficient (cl.6.2.3(3)); α_{cw} = **1.00**

Angle of concrete compression strut (cl.6.2.3);

θ = min(max(0.5 × Asin[min(2 × v_{Ed} / (α_{cw} × f_{cd} × v_1),1)], 21.8 deg), 45deg) = **21.8** deg

Area of shear reinforcement required (exp.6.13); $A_{sv,req}$ = v_{Ed} × b / (f_{yd} × cot(θ)) = **131** mm^2/m

Shear reinforcement provided; 2 × 10ϕ legs at 300 c/c

Area of shear reinforcement provided; $A_{sv,prov}$ = **524** mm^2/m

Minimum area of shear reinforcement (exp.9.5N); $A_{sv,min}$ = 0.08 N/mm^2 × b × (f_{ck} / 1 N/mm^2)$^{0.5}$ / f_{yk} = **506** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (exp.9.6N); $s_{vl,max}$ = 0.75 × d = **632** mm

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

Design shear force span 2 at 843 mm; V_{Ed} = max($V_{B\_s2\_max}$, $V_{B\_s2\_red}$) = **114** kN

Design shear stress; v_{Ed} = V_{Ed} / (b × z) = **0.285** N/mm^2

Strength reduction factor (cl.6.2.3(3)); v_1 = 0.6 × [1 - f_{ck} / 250 N/mm^2] = **0.504**

Compression chord coefficient (cl.6.2.3(3)); α_{cw} = **1.00**

Angle of concrete compression strut (cl.6.2.3);

θ = min(max(0.5 × Asin[min(2 × v_{Ed} / (α_{cw} × f_{cd} × v_1),1)], 21.8 deg), 45deg) = **21.8** deg

Area of shear reinforcement required (exp.6.13); $A_{sv,req}$ = v_{Ed} × b / (f_{yd} × cot(θ)) = **131** mm^2/m

Shear reinforcement provided; 2 × 10ϕ legs at 300 c/c

Area of shear reinforcement provided; $A_{sv,prov}$ = **524** mm^2/m

Minimum area of shear reinforcement (exp.9.5N); $A_{sv,min}$ = 0.08 N/mm^2 × b × (f_{ck} / 1 N/mm^2)$^{0.5}$ / f_{yk} = **506** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (exp.9.6N); $s_{vl,max}$ = 0.75 × d = **632** mm

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

Crack control (Section 7.3)

Maximum crack width; w_k = **0.3** mm

Mean value of concrete tensile strength; $f_{ct,eff}$ = f_{ctm} = **3.5** N/mm^2

Stress distribution coefficient; k_c = 0.4

Non-uniform self-equilibrating stress coefficient; k = min(max(1 + (300 mm - min(h, b)) × 0.35 / 500 mm, 0.65), 1) = **0.86**

Depth of tensile zone; h_{cr} = h - x = **795** mm

Area of concrete in the tensile zone; A_{ct} = h_{cr} × b = **397344** mm^2

Adjusted maximum bar diameter (exp.7.6N); ϕ_{mod} = ϕ_{top} × (2.9 N/mm^2 / $f_{ct,eff}$) × 2 × (h - d) / (k_c × h_{cr}) = **7** mm

Maximum adjusted bar diameter; ϕ_{max} = **32** mm

Tension bar spacing; s_{bar} = (b - 2 × (c_{nom_s} + ϕ_v) - ϕ_{top}) / (N_{top} - 1) = **128** mm

Maximum tension bar spacing; s_{max} = **300** mm

Minimum allowable bar spacing; s_{min} = max(ϕ_{top}, h_{agg} + 5 mm, 20 mm) + ϕ_{top} = **50** mm

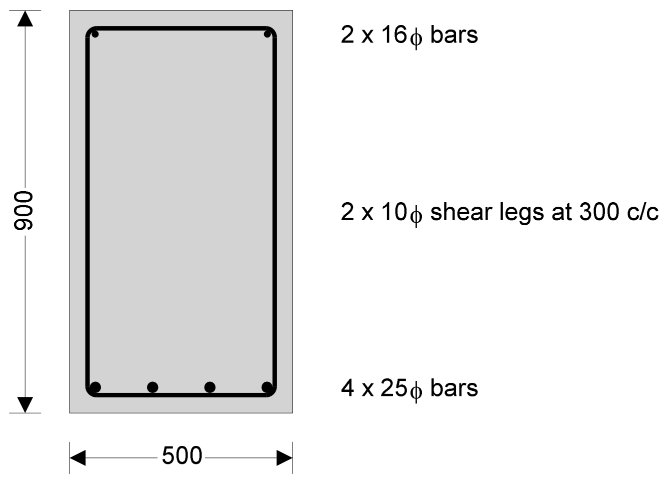
Maximum stress permitted (Tables 7.2N & 7.3N); σ_s = **280** N/mm^2

Minimum area of reinforcement required (exp.7.1); $A_{sc,min}$ = k_c × k × $f_{ct,eff}$ × A_{ct} / σ_s = **1713** mm^2

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

PASS - Actual bar spacing exceeds minimum allowable

Mid span 2



Rectangular section in flexure (Section 6.1) - Positive midspan moment

Design bending moment; $M = abs(M_{s2\_red}) = \mathbf{102}$ kNm

Depth to tension reinforcement; $d = h - c_{nom\_b} - \phi_v - \phi_{bot} / 2 = \mathbf{843}$ mm

Percentage redistribution; $m_{rs2} = M_{s2\_red} / M_{s2\_max} - 1 = \mathbf{0}$ %

Redistribution ratio; $\delta = \min(1 - m_{rs2}, 1) = \mathbf{1.000}$

$K = M / (b \times d^2 \times f_{ck}) = \mathbf{0.007}$

$K' = 0.547 \times \delta - 0.137 \times \delta^2 - 0.214 = \mathbf{0.196}$

K' > K - No compression reinforcement is required

Lever arm; $z = \min((d / 2) \times [1 + (1 - 3.53 \times K)^{0.5}], 0.95 \times d) =$ **800** mm

Depth of neutral axis; $x = 2.5 \times (d - z) = \mathbf{105}$ mm

Area of tension reinforcement required; $A_{s,req} = M / (f_{yd} \times z) = \mathbf{292}$ mm^2

Tension reinforcement provided; $4 \times 25\phi$ bars

Area of tension reinforcement provided; $A_{s,prov} = \mathbf{1963}$ mm^2

Minimum area of reinforcement (exp.9.1N); $A_{s,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times b \times d = \mathbf{769}$ mm^2

Maximum area of reinforcement (cl.9.2.1.1(3)); $A_{s,max} = 0.04 \times b \times h = \mathbf{18000}$ mm^2

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

Rectangular section in shear (Section 6.2)

Shear reinforcement provided; $2 \times 10\phi$ legs at 300 c/c

Area of shear reinforcement provided; $A_{sv,prov} = \mathbf{524}$ mm^2/m

Minimum area of shear reinforcement (exp.9.5N); $A_{sv,min} = 0.08\ N/mm^2 \times b \times (f_{ck} / 1\ N/mm^2)^{0.5} / f_{yk} =$ **506** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (exp.9.6N); $s_{vl,max}$ = 0.75 × d = **632** mm

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

Design shear resistance (assuming cot(θ) is 2.5); V_{prov} = 2.5 × $A_{sv,prov}$ × z × f_{yd} = **455.5** kN

Shear links provided valid between 0 mm and 8000 mm with tension reinforcement of 1963 mm²

Crack control (Section 7.3)

Maximum crack width; w_k = **0.3** mm

Mean value of concrete tensile strength; $f_{ct,eff}$ = f_{ctm} = **3.5** N/mm^2

Stress distribution coefficient; k_c = 0.4

Non-uniform self-equilibrating stress coefficient; k = min(max(1 + (300 mm - min(h, b)) × 0.35 / 500 mm, 0.65), 1) = **0.86**

Depth of tensile zone; h_{cr} = h - x = **795** mm

Area of concrete in the tensile zone; A_{ct} = h_{cr} × b = **397344** mm^2

Adjusted maximum bar diameter (exp.7.6N); ϕ_{mod} = ϕ_{bot} × (2.9 N/mm^2 / $f_{ct,eff}$) × 2 × (h - d) / (k_c × h_{cr}) = **7** mm

Maximum adjusted bar diameter; ϕ_{max} = **32** mm

Tension bar spacing; s_{bar} = (b - 2 × (c_{nom_s} + ϕ_v) - ϕ_{bot}) / (N_{bot} - 1) = **128** mm

Maximum tension bar spacing; s_{max} = **300** mm

Minimum allowable bar spacing; s_{min} = max(ϕ_{bot}, h_{agg} + 5 mm, 20 mm) + ϕ_{bot} = **50** mm

Maximum stress permitted (Tables 7.2N & 7.3N); σ_s = **280** N/mm^2

Minimum area of reinforcement required (exp.7.1); $A_{sc,min}$ = k_c × k × $f_{ct,eff}$ × A_{ct} / σ_s = **1713** mm^2

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

PASS - Actual bar spacing exceeds minimum allowable

Deflection control (Section 7.4)

Reference reinforcement ratio; ρ_{m0} = (f_{ck} / 1 N/mm^2)$^{0.5}$ / 1000 = **0.006**

Required tension reinforcement ratio; ρ_m = $A_{s,req}$ / (b × d) = **0.001**

Required compression reinforcement ratio; ρ'_m = $A_{s2,req}$ / (b × d) = **0.000**

Structural system factor (Table 7.4N); K_b = **1.3**

Basic allowable span to depth ratio (7.16a); $span\_to\_depth_{basic}$ = K_b × [11 + 1.5 × (f_{ck} / 1 N/mm^2)$^{0.5}$ × ρ_{m0} / ρ_m + 3.2 × (f_{ck} / 1 N/mm^2)$^{0.5}$ × (ρ_{m0} / ρ_m - 1)$^{1.5}$] = **735.018**

Reinforcement factor (exp.7.17); K_s = $A_{s,prov}$ × 500 N/mm^2 / ($A_{s,req}$ × f_{yk}) = **6.718**

Flange width factor; F1 = **1.000**

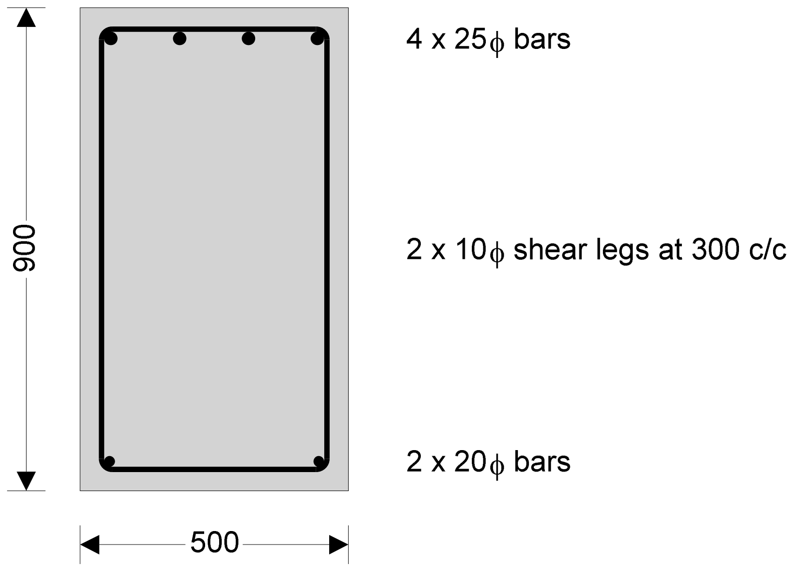
Long span supporting brittle partition factor; F2 = **1.000**

Allowable span to depth ratio; $span\_to\_depth_{allow}$ = $span\_to\_depth_{basic}$ × K_s × F1 × F2 = **4937.972**

Actual span to depth ratio; $span\_to\_depth_{actual}$ = L_{s2} / d = **9.496**

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

Support C



Rectangular section in flexure (Section 6.1)

Minimum moment factor (cl.9.2.1.2(1)); β_1 = **0.15**

Design bending moment; M = max(abs(M_{C_red}), $\beta_1 \times$ abs(M_{s2_red})) = **203** kNm

Depth to tension reinforcement; $d = h - c_{nom\_t} - \phi_v - \phi_{top} / 2$ = **843** mm

Percentage redistribution; m_{rC} = **0** %

Redistribution ratio; $\delta = \min(1 - m_{rC}, 1)$ = **1.000**

$K = M / (b \times d^2 \times f_{ck})$ = **0.014**

$K' = 0.547 \times \delta - 0.137 \times \delta^2 - 0.214$ = **0.196**

K' > K - No compression reinforcement is required

Lever arm; $z = \min((d / 2) \times [1 + (1 - 3.53 \times K)^{0.5}], 0.95 \times d)$ =
800 mm

Depth of neutral axis; $x = 2.5 \times (d - z)$ = **105** mm

Area of tension reinforcement required; $A_{s,req} = M / (f_{yd} \times z)$ = **583** mm^2

Tension reinforcement provided; 4 × 25ϕ bars

Area of tension reinforcement provided; $A_{s,prov}$ = **1963** mm^2

Minimum area of reinforcement (exp.9.1N); $A_{s,min} = \max(0.26 \times f_{ctm} / f_{yk}, 0.0013) \times b \times d$ = **769** mm^2

Maximum area of reinforcement (cl.9.2.1.1(3)); $A_{s,max} = 0.04 \times b \times h$ = **18000** mm^2

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

Minimum bottom reinforcement at supports

Minimum reinforcement factor (cl.9.2.1.4(1)); β_2 = **0.25**

Area of reinforcement to adjacent span; $A_{s,span}$ = **1963** mm^2

Minimum bottom reinforcement to support; $A_{s2,min} = \beta_2 \times A_{s,span}$ = **491** mm^2

Bottom reinforcement provided; 2 × 20ϕ bars

Area of bottom reinforcement provided; $A_{s2,prov}$ = **628** mm^2

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

Rectangular section in shear (Section 6.2)

Design shear force at support C; $V_{Ed,max}$ = abs(max(V_{C_max}, V_{C_red})) = **149** kN

Maximum design shear force (exp.6.9); $V_{Rd,max} = b \times z \times v_1 \times f_{cd} / (\cot(\theta) + \tan(\theta))$ = **1855** kN

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

Design shear force span 2 at 7158 mm; V_{Ed} = abs(min($V_{C\_s2\_max}$, $V_{C\_s2\_red}$)) = **118** kN

Design shear stress; $v_{Ed} = V_{Ed} / (b \times z)$ = **0.294** N/mm^2

Strength reduction factor (cl.6.2.3(3)); $v_1 = 0.6 \times [1 - f_{ck} / 250\text{ N/mm}^2]$ = **0.504**

Compression chord coefficient (cl.6.2.3(3)); α_{cw} = **1.00**

Angle of concrete compression strut (cl.6.2.3);

θ = min(max(0.5 × Asin[min(2 × v_{Ed} / (α_{cw} × f_{cd} × v_1),1)], 21.8 deg), 45deg) = **21.8** deg

Area of shear reinforcement required (exp.6.13); $A_{sv,req} = v_{Ed} \times b / (f_{yd} \times \cot(\theta))$ = **135** mm^2/m

Shear reinforcement provided; 2 × 10ϕ legs at 300 c/c

Area of shear reinforcement provided; $A_{sv,prov}$ = **524** mm^2/m

Minimum area of shear reinforcement (exp.9.5N); $A_{sv,min} = 0.08\text{ N/mm}^2 \times b \times (f_{ck} / 1\text{ N/mm}^2)^{0.5} / f_{yk}$ = **506** mm^2/m

PASS - Area of shear reinforcement provided exceeds minimum required

Maximum longitudinal spacing (exp.9.6N); $s_{vl,max} = 0.75 \times d$ = **632** mm

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

Crack control (Section 7.3)

Maximum crack width; w_k = **0.3** mm

Mean value of concrete tensile strength; $f_{ct,eff} = f_{ctm}$ = **3.5** N/mm^2

Stress distribution coefficient; k_c = 0.4

Non-uniform self-equilibrating stress coefficient; k = min(max(1 + (300 mm - min(h, b)) × 0.35 / 500 mm, 0.65), 1) = **0.86**

Depth of tensile zone; $h_{cr} = h - x$ = **795** mm

Area of concrete in the tensile zone; $A_{ct} = h_{cr} \times b$ = **397344** mm^2

Adjusted maximum bar diameter (exp.7.6N); $\phi_{mod} = \phi_{top} \times (2.9\text{ N/mm}^2 / f_{ct,eff}) \times 2 \times (h - d) / (k_c \times h_{cr})$ = **7** mm

Maximum adjusted bar diameter; ϕ_{max} = **32** mm

Tension bar spacing; $s_{bar} = (b - 2 \times (c_{nom\_s} + \phi_v) - \phi_{top}) / (N_{top} - 1)$ = **128** mm

Maximum tension bar spacing; s_{max} = **300** mm

Minimum allowable bar spacing; s_{min} = max(ϕ_{top}, h_{agg} + 5 mm, 20 mm) + ϕ_{top} = **50** mm

Maximum stress permitted (Tables 7.2N & 7.3N); σ_s = **280** N/mm^2

Minimum area of reinforcement required (exp.7.1); $A_{sc,min} = k_c \times k \times f_{ct,eff} \times A_{ct} / \sigma_s$ = **1713** mm^2

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

PASS - Actual bar spacing exceeds minimum allowable