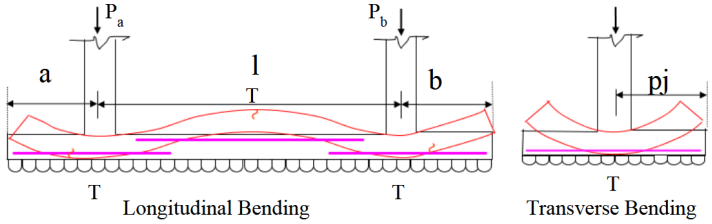
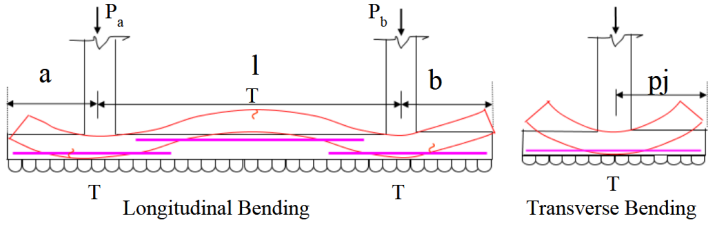
COMBINED FOOTING DESIGN REPORT

Element: Combined Footing 001

Design Code: BS EN 1992-1-1:2004 | Date: 28 October 2026

REFERENCE	CALCULATIONS	OUTPUT
§6.4.2 Loading Conditions	**SERVICE LOAD**  **Left column** bc = 300.0 mm, hc = 300.0 mm Unfactored dead load G_k = 1000.0 kN Unfactored live load Q_k = 200.0 kN $N_{s,left}$ = 1.0 × 1000.0 + 1.0 × 200.0 = 1200 kN **Right column** bc = 400.0 mm, hc = 400.0 mm Unfactored dead load G_k = 1400.0 kN Unfactored live load Q_k = 300.0 kN $N_{s,right}$ = 1.0 × 1400.0 + 1.0 × 300.0 = 1700 kN Total service load N_s = 1200 + 1700 = 2900 kN	**$N_{s,left}$ = 1200 kN** **$N_{s,right}$ = 1700 kN** **Total N_s = 2900 kN**
§6.5 Footing Size	**SIZING AT S.L.S** Soil bearing pressure q_s = 300.0 kN/m² Footing depth h = 850.0 mm Unit weight of concrete γ_c = 25.0 kN/m³ $q_{s,net} = q_s - \gamma_c h = 300.0 - 25.0 \times \frac{850.0}{1000} = 278.8 kN/m^2$ $A_{req} = \frac{N_s}{q_{s,net}} = \frac{2900}{278.8} = 10.4 m^2$ Indicative proportions for a rectangular footing (L = 2B): $L = 2\sqrt{\frac{A_{req}}{2}} = 4.56 m$ $B = \sqrt{\frac{A_{req}}{2}} = 2.28 m$ Provided L = 4600.0 mm, B = 2300.0 mm → A_{prov} = 10.58 m² Since A_{prov} = 10.58 m² > A_{req} = 10.4 m² → OK	**A_{req} = 10.4 m²** **A_{prov} = 10.58 m²** **Status: OK**

REFERENCE	CALCULATIONS	OUTPUT
§6.4.2 Footing Disposition	**FOOTING DISPOSITION**  **Centroid of loads – moments about the centre line of the right column** Centre-to-centre distance b = 3000.0 mm $\bar{x} = \frac{N_{s,left} \times b}{N_s} = \frac{1200 \times 3000.0}{2900} = 1241mm$ The base is centred on the resultant of the column loads: $a = \frac{L}{2} - (b - \bar{x}) = \frac{4600.0}{2} - (3000.0 - 1241) = 541mm$ $c = \frac{L}{2} - \bar{x} = \frac{4600.0}{2} - 1241 = 1059mm$	**$\bar{x}$ = 1241 mm** **a (left) = 541 mm** **c (right) = 1059 mm**
§6.4.3 Ultimate Analysis	**ULTIMATE LIMIT STATE** $N_{Ed} = 1.35G_k + 1.5Q_k$ $N_{Ed,left}$ = 1.35 × 1000.0 + 1.5 × 200.0 = 1650 kN $N_{Ed,right}$ = 1.35 × 1400.0 + 1.5 × 300.0 = 2340 kN Total N_{Ed} = 1650 + 2340 = 3990 kN $q_u = \frac{N_{Ed}}{A_{prov}} = \frac{3990}{10.58} = 377.1kN/m^2$	**N_{Ed} = 3990 kN** **q_u = 377.1 kN/m²**
§9.2.1.1 Longitudinal Reinforcement	**LONGITUDINAL REINFORCEMENT** **From analysis (inverted-beam method), moment at mid-span between the columns** M_{Ed} (total over B) = 679 kN·m $M_{Ed,m} = \frac{M_{Ed}}{B} = \frac{679}{2300.0/1000} = 295.22kN \cdot m/m$ Cover c_c = 50.0 mm; φ = 20.0 mm $d = h - c_c - \frac{\phi}{2} = 850.0 - 50.0 - \frac{20.0}{2} = 790mm$ f_{ck} = 30.0 N/mm², f_{yk} = 500.0 N/mm², design strip b = 1000 mm; no moment redistribution, k_{bal} = 0.167 $k = \frac{M}{bd^2 f_{ck}} = \frac{295.22 \times 10^6}{1000 \times 790^2 \times 30.0} = 0.016$ Since k = 0.016 < k_{bal} = 0.167 → no compression reinforcement required $\frac{z}{d} = 0.5 + \sqrt{0.25 - \frac{k}{1.134}} = 0.986$ z = 0.986 × 790 = 779 mm; z_{lim} = 0.95d = 750 mm → z = 750 mm **Reinforcement (B1)** $A_{s,req} = \frac{M \times 10^6}{0.87 f_{yk} z} = \frac{295.22 \times 10^6}{0.87 \times 500.0 \times 750} = 904mm^2/m$ $f_{ctm} = 0.3 f_{ck}^{2/3} = 2.9N/mm^2$ $A_{s,min}$ = max(0.26 f_{ctm}/f_{yk}·b·d, 0.0013 b d) = max(1190, 1027) = N/A mm²/m $A_{s,req}$ = max(N/A, 904) = N/A mm²/m Spacing S = 150.0 mm $A_{s,prov} = \pi\left(\frac{\phi}{2}\right)^2 \times \frac{1000}{S} = \pi\left(\frac{20.0}{2}\right)^2 \times \frac{1000}{150.0} = 2094mm^2/m$ Number of bars across B: B/S = 2300.0/150.0 → 16	**$M_{Ed,m}$ = 295.22 kN·m/m** **k = 0.016 < k_bal ✓** **$A_{s,req}$ = 1190 mm²/m** **$A_{s,prov}$ = 2094 mm²/m** **Status: OK** **f_s = 133.85 N/mm²** **S_{max} = 300 mm** **S_{prov} = 150.0 mm** **Crack control: OK**

REFERENCE	CALCULATIONS	OUTPUT

LONGITUDINAL REINFORCEMENT *(continued)*

$A_{s,prov,total} = 9.0 \times \pi(\frac{20.0}{2})^2 = 2827mm^2 (required 2737mm^2)$

Provided: 9.0 H20.0 @ 150.0 mm c/c (B1) & (T1)

Check: per metre ≥, total area OK → OK

SERVICEABILITY LIMIT STATE (SLS): CRACK WIDTH / SPACING VERIFICATION

Table 7.2N Maximum bar diameters ϕ^*_s for crack control[1]

Steel stress[2] [MPa]	Maximum bar size [mm] w_k= 0,4 mm	w_k= 0,3 mm	w_k= 0,2 mm
160	40	32	25
200	32	25	16
240	20	16	12
280	16	12	8
320	12	10	6
360	10	8	5
400	8	6	4
450	6	5	-

Table 7.3N Maximum bar spacing for crack control[1]

Steel stress[2] [MPa]	Maximum bar spacing [mm] w_k=0,4 mm	w_k=0,3 mm	w_k=0,2 mm
160	300	300	200
200	300	250	150
240	250	200	100
280	200	150	50
320	150	100	-
360	100	50	-

Steel stress under service load

$f_s = 310 \times \frac{500}{f_{yk}} \times \frac{A_{s,req}}{A_{s,prov}} = 310 \times \frac{500}{500.0} \times \frac{904}{2094} = 133.85 N/mm^2$

Maximum allowable spacing (EC2 Table 7.3N)

Stress thresholds: [160, 200, 240, 280, 320, 360] MPa

Spacing limits: [300, 250, 200, 150, 100, 50] mm

Interpolated for σ_s = 133.85 N/mm² → $S_{max,table}$ = 300 mm

Detailing limit (EC2 9.3.1.1(3)): min(3h, 400) = min(3 × 850.0, 400) = 400 mm

S_{max} = min(300, 400) = 300 mm

Provided spacing S = 150.0 mm, which is ≤ S_{max} = 300 mm

LONGITUDINAL REINFORCEMENT *(continued)*

PASS: Provided bar spacing is adequate for crack control limit (wk = 0.3mm)

REFERENCE	CALCULATIONS	OUTPUT
§9.2.1.1 Transverse Reinforcement	**TRANSVERSE REINFORCEMENT** **Transverse bending (per metre of length)** Moment from the clear projection beyond each column face (larger of the two governs): $L_{proj} = \max\left(\frac{B-h_{c,L}}{2}, \frac{B-h_{c,R}}{2}\right) = \max\left(\frac{2300.0-300.0}{2}, \frac{2300.0-400.0}{2}\right)$ $M_{Ed} = q_u \frac{L_{proj}^2}{2} = 188.56 kN \cdot m/m$ ϕ_{trans} = 16.0 mm $d = h - c_c - \phi_{long} - \frac{\phi_{trans}}{2} = 850.0 - 50.0 - 20.0 - \frac{16.0}{2} = 772 mm$ f_{ck} = 30.0 N/mm², f_{yk} = 500.0 N/mm², design strip b = 1000 mm; no moment redistribution, k_{bal} = 0.167 $k = \frac{M}{bd^2 f_{ck}} = \frac{188.56 \times 10^6}{1000 \times 772^2 \times 30.0} = 0.011$ Since k = 0.011 < k_{bal} = 0.167 → no compression reinforcement required $\frac{z}{d} = 0.5 + \sqrt{0.25 - \frac{k}{1.134}} = 0.991$ z = 0.991 × 772 = 765 mm; z_{lim} = 0.95d = 733 mm → z = 733 mm **Reinforcement (B2)** $A_{s,req} = \frac{M \times 10^6}{0.87 f_{yk} z} = \frac{188.56 \times 10^6}{0.87 \times 500.0 \times 733} = 591 mm^2/m$ $f_{ctm} = 0.3 f_{ck}^{2/3} = 2.9 N/mm^2$ $A_{s,min}$ = max(0.26 f_{ctm}/f_{yk}·b·d, 0.0013 b d) = max(1163, 1004) = 1163 mm²/m $A_{s,req}$ = max(1163, 591) = 1163 mm²/m Spacing S = 150.0 mm	**M_{Ed} = 188.56 kN·m/m** **k = 0.011 < k_bal ✓** **$A_{s,req}$ = 1163 mm²/m** **$A_{s,prov}$ = 1340 mm²/m** **Status: OK** **f_s = 136.69 N/mm²** **S_{max} = 300 mm** **S_{prov} = 150.0 mm** **Crack control: OK**

REFERENCE	CALCULATIONS	OUTPUT
	TRANSVERSE REINFORCEMENT *(continued)*	

$$A_{s,prov} = \pi\left(\frac{\phi}{2}\right)^2 \times \frac{1000}{S} = \pi\left(\frac{16.0}{2}\right)^2 \times \frac{1000}{150.0} = 1340 mm^2/m$$

Provided: H16.0 @ 150.0 mm c/c (B2) & (T2)

Place at closer centres under the columns, where transverse moments are higher.

Check: 1340 ≥ 1163 mm²/m → OK

SERVICEABILITY LIMIT STATE (SLS): CRACK WIDTH / SPACING VERIFICATION

Table 7.2N Maximum bar diameters ϕ^*_s for crack control[1]

Steel stress[2] [MPa]	Maximum bar size [mm] w_k= 0,4 mm	w_k= 0,3 mm	w_k= 0,2 mm
160	40	32	25
200	32	25	16
240	20	16	12
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320	12	10	6
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400	8	6	4
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160	300	300	200
200	300	250	150
240	250	200	100
280	200	150	50
320	150	100	-
360	100	50	-

Steel stress under service load

$$f_s = 310 \times \frac{500}{f_{yk}} \times \frac{A_{s,req}}{A_{s,prov}} = 310 \times \frac{500}{500.0} \times \frac{591}{1340} = 136.69 N/mm^2$$

Maximum allowable spacing (EC2 Table 7.3N)

Stress thresholds: [160, 200, 240, 280, 320, 360] MPa

Spacing limits: [300, 250, 200, 150, 100, 50] mm

Interpolated for σ_s = 136.69 N/mm² → $S_{max,table}$ = 300 mm

Detailing limit (EC2 9.3.1.1(3)): min(3h, 400) = min(3 × 850.0, 400) = 400 mm

TRANSVERSE REINFORCEMENT *(continued)*

S_{max} = min(300, 400) = 300 mm

Provided spacing S = 150.0 mm, which is ≤ S_{max} = 300 mm

PASS: Provided bar spacing is adequate for crack control limit (wk = 0.3mm)

§6.2.2 Shear – Face (left)	**FACE SHEAR – LEFT COLUMN**	**$V_{Rd,max}$ = 4948 kN**
	Mean effective depth d_{avg} = 781 mm	**β N_{Ed} = 2310 kN**
	$u = 2(b_c + h_c) = 2(300.0 + 300.0) = 1200.0 mm$	**Status: OK**
	$V_{Rd,max} = 0.5 u d \left[0.6\left(1 - \frac{f_{ck}}{250}\right)\right] \frac{f_{ck}}{1.5} = 4948 kN$	
	β N_{Ed} = 1.4 × 1650 = 2310 kN	
	Since $V_{Rd,max}$ = 4948 kN ≥ β N_{Ed} = 2310 kN → OK	

REFERENCE	CALCULATIONS	OUTPUT
§6.2.2 Shear – Face (right)	**FACE SHEAR – RIGHT COLUMN** Mean effective depth d_{avg} = 781 mm $u = 2(b_c + h_c) = 2(400.0 + 400.0) = 1600.0mm$ $V_{Rd,max} = 0.5ud\left[0.6\left(1 - \frac{f_{ck}}{250}\right)\right]\frac{f_{ck}}{1.5} = 6598kN$ β N_{Ed} = 1.4 × 2340 = 3276 kN Since $V_{Rd,max}$ = 6598 kN ≥ β N_{Ed} = 3276 kN → OK	**$V_{Rd,max}$ = 6598 kN** **β N_{Ed} = 3276 kN** **Status: OK**
§6.2.2 Shear – Direct	**DIRECT (ONE-WAY) SHEAR RESISTANCE** Longitudinal effective depth d_{long} = 790 mm $k = 1 + \sqrt{\frac{200}{790}} = 1.5 \quad k = \min(1.5, 2.0) = 1.5$ $\rho_1 = \frac{A_{s,prov}}{1000d} = \frac{2094}{1000 \times 790} = 0.00265$ $v_{Rd,c} = 0.12k(100\rho_1 f_{ck})^{1/3} = 0.36N/mm^2, \quad v_{min} = 0.353N/mm^2$ $v_{Rd,c}$ = max(0.36, 0.353) = 0.36 N/mm² $V_{Rd} = v_{Rd,c}Bd = 0.36 \times 2300.0 \times 790 \times 10^{-3} = 654.22kN$	**V_{Rd} = 654.22 kN**
§6.2.2 Shear – Direct (left)	**DIRECT SHEAR – LEFT COLUMN** V_{Ed} from analysis = 1180.0 kN is the shear at the column centreline; the critical section is (b_c/2 + d) from it. $V_{Ed} = V - q_u B\left(\frac{b_c}{2} + d\right) = 1180.0 - 377.1 \times 2300.0 \times 940 \times 10^{-3} = 364.65kN$ Since V_{Ed} = 364.65 kN > V_{Rd} = 654.22 kN → OK	**V_{Ed} = 364.65 kN** **V_{Rd} = 654.22 kN** **Status: OK**
§6.2.2 Shear – Direct (right)	**DIRECT SHEAR – RIGHT COLUMN** V_{Ed} from analysis = 1420.0 kN is the shear at the column centreline; the critical section is (b_c/2 + d) from it. $V_{Ed} = V - q_u B\left(\frac{b_c}{2} + d\right) = 1420.0 - 377.1 \times 2300.0 \times 990 \times 10^{-3} = 561.28kN$ Since V_{Ed} = 561.28 kN > V_{Rd} = 654.22 kN → OK	**V_{Ed} = 561.28 kN** **V_{Rd} = 654.22 kN** **Status: OK**
§6.4.4 Shear – Punching V_Rd,c	**PUNCHING SHEAR RESISTANCE (COMMON)** Mean effective depth d_{avg} = 781 mm $k = 1 + \sqrt{\frac{200}{781}} = 1.51 \quad k = \min(1.51, 2.0) = 1.51$ $\rho_l = \sqrt{\rho_{l,long}\rho_{l,trans}} = \sqrt{0.00265 \times 0.00174} = 0.00215 \quad \rho_l = \min(0.00215, 0.02) = 0.00215$ $v_{Rd,c} = 0.12k(100\rho_l f_{ck})^{1/3} = 0.336N/mm^2, \quad v_{min} = 0.354N/mm^2$ $v_{Rd,c}$ = max(0.354, 0.336) = 0.354 N/mm²	**k = 1.51** **ρ_l = 0.00215** **$v_{Rd,c}$ = 0.354 N/mm²**
§6.4.4 Shear – Punching (left)	**PUNCHING SHEAR – LEFT COLUMN** Control distance 2d = 1562 mm; column case: **Restrained (3+ edges)** (3 side(s) closer than 2d to a footing edge) Control perimeter 2d from the column face is cut by the footing edge on 3 side(s); the reduced perimeter and area are used. Full control perimeter $u_{1,basic}$ = 11014.3 mm, $A_{p,basic}$ = 9629396 mm² Effective (clipped to the footing) u_1 = 2470.6 mm, A_p = 4952759 mm² $V_{Ed,crit} = q_u A_p = 377.1 \times 4952759 \times 10^{-6} = 1867.82kN$ $V_{Ed,punch} = N_{Ed} - V_{Ed,crit} = 1650 - 1867.82 = -217.82kN$ Upward soil pressure inside the control perimeter exceeds the column load – punching is not critical. $v_{Rd,c}$ = 0.354 N/mm² **No Shear reinforcement required**	**v_{Ed} = 0 N/mm²** **$v_{Rd,c}$ = 0.354 N/mm²** **Status: No Shear reinforcement required**

REFERENCE	CALCULATIONS	OUTPUT
§6.4.4 Shear – Punching (right)	**PUNCHING SHEAR – RIGHT COLUMN** Control distance 2d = 1562 mm; column case: **Restrained (3+ edges)** (3 side(s) closer than 2d to a footing edge) Control perimeter 2d from the column face is cut by the footing edge on 3 side(s); the reduced perimeter and area are used. Full control perimeter $u_{1,basic}$ = 11414.3 mm, $A_{p,basic}$ = 10324196 mm² Effective (clipped to the footing) u_1 = 2442.4 mm, A_p = 6293351 mm² $V_{Ed,crit} = q_u A_p = 377.1 \times 6293351 \times 10^{-6} = 2373.39kN$ $V_{Ed,punch} = N_{Ed} - V_{Ed,crit} = 2340 - 2373.39 = -33.39kN$ Upward soil pressure inside the control perimeter exceeds the column load – punching is not critical. $v_{Rd,c}$ = 0.354 N/mm² **No Shear reinforcement required**	**v_{Ed} = 0 N/mm²** **$v_{Rd,c}$ = 0.354 N/mm²** **Status: No Shear reinforcement required**