Combined Footing Verification Example

Reference: Reinforced Concrete – Mechanics and Design, 5th Edition, by Wright and MacGregor, Prentice Hall, 2009. Example 15-4.

A combined footing supports an 24-in x 16-in exterior column carrying a service dead load of 200 kips and a service live load of 150 kips, plus a 24-in square interior column carrying service loads of 300 kips dead and 225 live. The distance between the columns is 20-ft center to center. The allowable soil bearing pressure is 5000 psi at a depth of 4-ft below the finished floor. The density of the fill above the footing is 120 pcf. Design the footing assuming f'c = 3 ksi and fy = 60 ksi.

The resultant of the column loads is located at a distance:

(8 x 350 + 248 x 525) / (350 + 525) = 152" from the exterior face of the exterior column.

- Try a combined footing 25'-4" long x 8'-0" wide x 3'-4" thick. The factored net pressure is:

q_{nu} = (1.2 x (200 + 300) + 1.6 x (150 + 225)) / (25.33 x 8) = 5.92 ksf

Max. shear at CL of ext. column = 5.92 x 8 x 0.67 – 1.2 x 200 – 1.6 x 150 = 448 kips

Max. shear at CL of int. column = 5.92 x 8 x 4.67 – 1.2 x 300 – 1.6 x 225 = 499 kips

Distance of zero shear from CL of ext. column = 20 / (448 + 499) * 448 = 9.45 ft

Maximum bending moment = 5.92 * 8 * 0.67^2 / 2 – 448 * 9.45 / 2 = 2106 k-ft

- Check punching shear at interior column.

The critical perimeter is a square with sides 24 + 36.5 = 60.5"

V_u = 1.2 x 300 + 1.6 * 225 – 5.92 * $(60.5 / 12)^2$ = 569 kips

ϕV_c = 0.75 x 4 √3000 x 60.5 x 4 x 36.5 = 1451 kips > V_u , Ratio = 0.40 OK

- Check punching shear at exterior column.

The critical perimeter is three sided 24 + 36.5 + 2(16 + 36.5/2) = 129"

V_u = 1.2 x 200 + 1.6 * 150 – 5.92 * (24 + 36.5)(16 + 36.5/2) / 144 = 395 kips

ϕV_c = 0.75 x 4 √3000 x 129 x 36.5 = 774 kips > V_u , Ratio = 0.52 OK

- Check one-way shear in the longitudinal direction at distance d from the interior column face.

V_u = 499 – 5.92 * 8 * (12 + 36.5) / 12 = 308 kips

ϕV_c = 0.75 x 2 √3000 x 96 x 36.5 = 286 kips < V_u , Ratio = 1.08 NG

Either use min additional shear reinforcement or increase f'c to 3.5 ksi.

- Design flexural reinforcement in the longitudinal direction.

M_u = 2106 k-ft. Try 19 #8 bars at top (A_s = 15.0 in^2)

a = 15.0 x 60 / (0.85 x 3 x 96) = 3.67 in (tension controlled)

ϕM_n = 0.9 x 15.0 x 60 (37.5 – 3.67/2) / 12 = 2408 k-ft > M_u , Ratio = 0.87 OK

Use 15 #8 bars at bottom (A_s = 11.9 in^2)

- Check the development of top bars.

The clear spacing exceeds $2d_b$ and the clear cover exceeds d_b, therefore

L_d = 1.3 x 60000/(20 √3000) d_b = 1.3 x 54.8 x 1" = 71.2" OK

- Design the transverse bars.

The factored interior load is 1.2 x 300 + 1.6 x 225 = 720 kips

This is balanced by a net upward force of 720 / 8' = 90 k/ft

M_u = 90 x 3^2 /2 = 405 k-ft. Try 9 #8 thansverse bars at bottom (A_s = 7.11 in^2)

- Design the column-footing joint.

The allowable bearing on the interior footing is 0.85 x 0.65 x 3 x 24^2 x 2 = 1909 kips

The allowable bearing on the base of the column is 0.85 x 0.65 x 3 x 24^2 = 955 kips > P_u = 720 kips OK

Area of dowels minimum = 0.005 x 24^2 = 2.88 in^2 (controls)

Use 8 #6 dowels. Extend dowels 25" into column.

ASDIP Foundation 2.5.6 **COMBINED FOOTING DESIGN** *www.asdipsoft.com*

GEOMETRY

	Exterior	Interior		
Column to Column Distance		20.00	ft	
Column Length (X)	16.0	24.0	in	
Column Width (Z)	24.0	24.0	in	
Edge Distance (X)	0.67	4.66	ft	OK
Footing Width (Z)	8.00	8.00	ft	
Footing Thickness	40.0		in	OK
Soil Cover	0.67		ft	
Pedestal Height	N. A.			

SOIL PRESSURES (Comb: D+L)

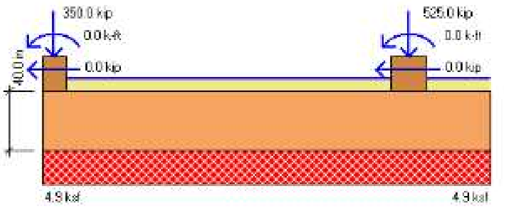
	Exterior	Interior		
Gross Allow. Soil Pressure		5.00	ksf	
Overburden Pressure		0.58	ksf	
Reaction Force		992.1	kip	
Reaction Eccentricity		0.00	ft	
Ftg. Area in Contact with Soil		100.0	%	
Bearing Pressure	4.89	4.90	ksf	
Bearing Ratio	0.98	0.98		OK

APPLIED LOADS

- Exterior Col.	Dead	Live	RLive	Snow	Wind	Seismic	
Axial Force P	200.0	150.0	0.0	0.0	0.0	0.0	kip
Moment about Z Mz	0.0	0.0	0.0	0.0	0.0	0.0	k-ft
Shear Force Vx	0.0	0.0	0.0	0.0	0.0	0.0	kip
- Interior Col.	**Dead**	**Live**	**RLive**	**Snow**	**Wind**	**Seismic**	
Axial Force P	300.0	225.0	0.0	0.0	0.0	0.0	kip
Moment about Z Mz	0.0	0.0	0.0	0.0	0.0	0.0	k-ft
Shear Force Vx	0.0	0.0	0.0	0.0	0.0	0.0	kip

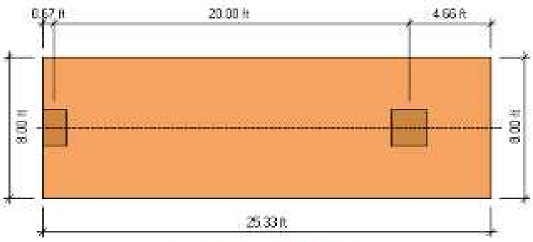
MATERIALS

	Columns	Footing	
Concrete f'c	4.0	3.0	ksi
Reinf. Steel fy	60.0	60.0	ksi
Soil Cover Density		120.0	pcf



SLIDING (Comb. 0.6D+1W)

Footing-Soil Friction Coeff.	0.45		
Passive Pressure Coeff. Kp	2.77		
Friction Force at Base	166.6	kip	
Passive Force @ Ftg	20.7	kip	
Horiz. Resisting Force	187.3	kip	
Horiz. Sliding Force	0.0	kip	
Sliding Safety Factor	99.99 > 1.5		OK



DESIGN CODES

Concrete Design	ACI 318-08
Load Combinations	ASCE 7-05

1

ASDIP Foundation 2.5.6 **COMBINED FOOTING DESIGN** *www.asdipsoft.com*

OVERTURNING CALCULATIONS (Comb: 0.6D+1W)

OVERTURNING

- About Z-Z	Force kip	Arm ft	Moment k-ft
Ext. Moment Mz ...	0.0	0.0	0.0
Ext. Shear Vx	0.0	3.33	0.0
Int. Moment Mz	0.0	0.0	0.0
Int. Shear Vx	0.0	3.33	0.0
Rh =	0.0	OTM =	0.0

Arm of Vertical Resultant .... 12.66 ft

Overturning Safety Factor .. 99.99 > 1.5 OK

RESISTING

- About Z-Z	Force kip	Arm ft	Moment k-ft
Soil Cover	9.5	12.67	119.7
Footing Weight ...	60.8	12.67	769.9
Ext. Column	0.0	24.66	0.0
Int. Column	0.0	4.66	0.0
Ext. Axial P	120.0	24.66	2959.2
Int. Axial P	180.0	4.66	838.8
Rv =	370.2	RM =	4687.7

FOOTING AT EXTERIOR COL.

- One-way Shear (Comb: 1.2D+1.6L+0.5S)

	- Side	+ Side	
Under-strength ϕ Factor	0.75		
One-way Shear Vux ...	0.0	101.3	kip
Shear Strength ϕVcx ..	283.9	283.9	kip
Max. One-way Shear Ratio Vu/ϕVc ..	0.36	OK	

- Punching Shear (Comb: 1.2D+1.6L+0.5S)

Unbalanced Moment Factor γvx ...	0.33	
Punching Shear due to Axial	85.9	psi
Punching Shear due to Mz	0.0	psi
Punching Shear Stress Vu	85.9	psi
Effective Perimeter bo	128.1	in
Average Effective Depth d	36.0	in
Punching Shear Strength ϕVc ..	164.3	psi
Punching Shear Ratio Vu/ϕVc	0.52	OK

- Transv. Flexure (Comb: 1.2D+1.6L+0.5S)

Under-strength ϕ Factor 0.90

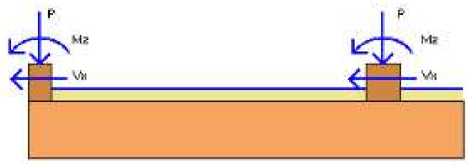
Footing Effective Length .... 5.00 ft

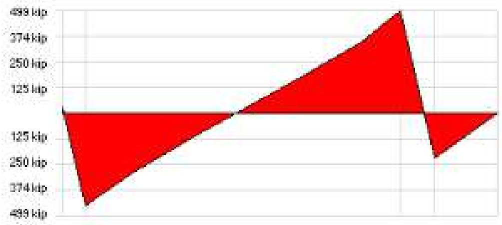
Use 6 #6 Bars Parallel to Z (Top) , d = 36.6 in

Use 6 #8 Bars Parallel to Z (Bot) , d = 35.5 in

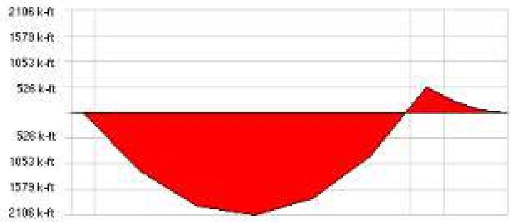
Bottom Steel Min. Area Ratio .... 0.91 OK

	Top	Bot	
Bending Moment Mux ..	0.0	284.1	k-ft
Bending Strength ϕMnx	428.9	737.3	k-ft
Max. Bending Ratio Mux/ϕMnx	0.39	OK	
Top Z-Bars Develop. Length Ratio .	0.00	OK	
Bot Z-Bars Develop. Length Ratio ..	0.37	OK	





SHEAR DIAGRAM (Comb. 1.2D+1.6L+0.5S)



MOMENT DIAGRAM (Comb. 1.2D+1.6L+0.5S)

2

FOOTING AT INTERIOR COL.

- One-way Shear (Comb: 1.2D+1.6L+0.5S)

Under-strength ϕ Factor 0.75

	- Side	+ Side		
One-way Shear Vux ...	309.4	31.3	kip	
Shear Strength ϕVcx ..	283.9	283.9	kip	
Max. One-way Shear Ratio Vu/ϕVc ..		1.09		NG

- Punching Shear (Comb: 1.2D+1.6L+0.5S)

Unbalanced Moment Factor ϒvx ...	0.40		
Punching Shear due to Axial	65.9	psi	
Punching Shear due to Mz	0.0	psi	
Punching Shear Stress Vu	65.9	psi	
Effective Perimeter bo	240.0	in	
Average Effective Depth d	36.0	in	
Punching Shear Strength ϕVc ..	164.3	psi	
Punching Shear Ratio Vu/ϕVc	0.40		OK

- Transv. Flexure (Comb: 1.2D+1.6L+0.5S)

Under-strength ϕ Factor 0.90

Footing Effective Length .... 8.00 ft

Use 6 #6 Bars Parallel to Z (Top) , d = 36.6 in

Use 9 #8 Bars Parallel to Z (Bot) , d = 35.5 in

Bottom Steel Min. Area Ratio .... 0.97 OK

	Top	Bot		
Bending Moment Mux ..	0.0	390.9	k-ft	
Bending Strength ϕMnx	431.2	1107.9	k-ft	
Max. Bending Ratio Mux/ϕMnx		0.35		OK
Top Z-Bars Develop. Length Ratio .		0.00		OK
Bot Z-Bars Develop. Length Ratio ..		0.34		OK

LONGITUDINAL REINF.

- Long. Flexure (Comb: 1.2D+1.6L+0.5S)

Use 19 #8 Bars Parallel to X (Top) , d = 37.5 in

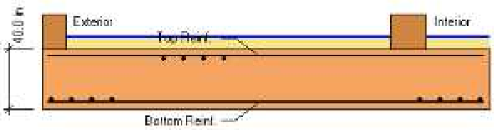
Use 15 #8 Bars Parallel to X (Bot) , d = 36.5 in

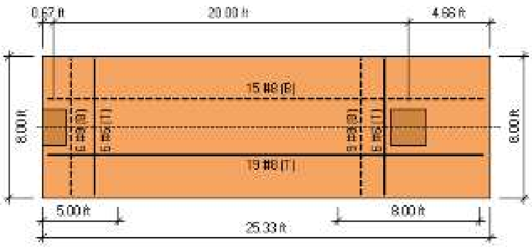
	Top	Bot	
Min. Steel Area Ratio ...	0.80	0.48	OK
Bending Moment Muz ..	2105.5	514.9	k-ft
Bending Strength ϕMnz	2408.3	1868.7	k-ft
Max. Bending Ratio Muz/ϕMnz		0.87	OK
Ext. Bot X-Bars Dev. Length Ratio .		0.06	OK
Int. Bot X-Bars Dev. Length Ratio ...		0.22	OK

LOAD TRANSFER (Comb: 1.2D+1.6L+0.5S)

Bearing Under-strength ϕ Factor 0.65

	Ext.	Int.		
Compressive Stress Pu	1.3	1.3	ksi	
Column Bearing ϕPn	2.6	2.4	ksi	OK
Footing Bearing ϕPn	2.0	3.6	ksi	OK
Shear Force Vu	**0.0**	**0.0**	kip	
Shear Friction ϕVn	95.0	95.0	kip	OK
Dowel Steel Area As	**3.52**	**3.52**	in2	
Min. Steel Area As min ..	1.92	2.88	in2	OK
Dev. Length Ratio at Col.	0.47	0.47		OK
Dev. Length Ratio at Ftg.	0.27	0.27		OK





UPLIFT CALCS (Comb: 0.6D+0.7E)

Uplift Force P	0.0	kip	
Pedestals Selfweight	0.0	kip	
Footing Selfweight	60.8	kip	
Soil Cover Weight	9.5	kip	
Downward Force W	370.2	kip	
Uplift Safety Factor	99.99	> 1.0	OK

3