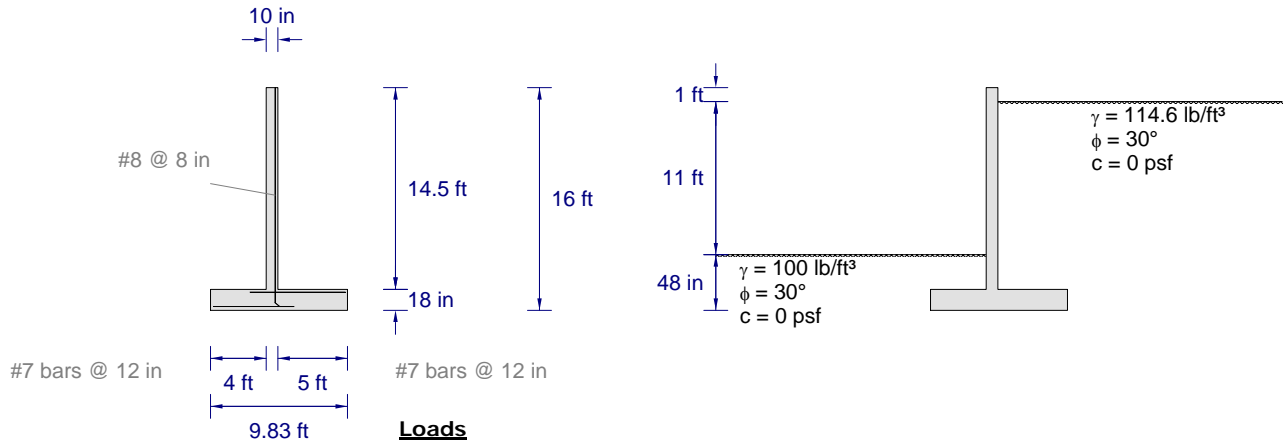


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Wall

General

Burial Depth	4 ft
Material	
Rebar Fy	60 ksi
Concrete F'c	3 ksi
Unit Weight	150 lb/ft³
Footing	
Footing Thickness	18 in
Heel Length	5 ft
Toe Length	4 ft
Heel Bar Size	#7
Heel Bar Spacing	12 in
Hook Heel Bars Downward	No
Heel Bar Ld	2 ft
Heel Bar Cover	2 in
Toe Bars Hook Into Stem	No
Toe Bar Size	#7
Toe Bar Spacing	12 in
Toe Bar Ld	2 ft
Toe Bar Cover	3 in
Key	
Has Key	No

General

Stem Type	Single / Tapered
Bars Developed @ Top	No
Has Lateral Support (Restrained Wo Extension Above Backfill)	1 ft

Geometry

Stem Top Thickness	10 in
Tapered	No
Bar Cover	2 in

Reinforcement

Dowel Bar Size	#8
Dowel Bar Spacing	8 in
Bars are Centered	No
Dowel Bar Embedment	Hook into Heel
Has Lapped Bars	No
Cutoff Alternate Bars	No

Loads

Backfill

Retained Height	11 ft
Slope	0°
Gamma (weight)	114.6 lb/ft³
Use Equiv. Fluid Pressure (EFP)	No
Analysis Type	Rankine
Phi (friction angle)	30°
Cohesion	0 psf
Has Water in Backfill	No

Passive Pressure @ Toe

Calculation Method	Rankine
Phi (friction angle)	30°
Cohesion	0 psf
Gamma (weight)	100 lb/ft³
Apply Only to Key	No
Overburden Depth To Ignore	1 ft

Surcharge (Uniform)

Surcharge Type	None
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Surcharge (Line/Strip)

Type	None
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Axial Load

Apply Axial Load On Stem	No
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Lateral Load

Apply Lateral Pressure To Stem	No
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Seismic Loading

Has Backfill Seismic Load	No
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Assumptions

Restrained Against Sliding	No
Neglect Bearing @ Heel	Yes
Use Vert. Comp. for OT	No
Use Vert. Comp. for Sliding	No
Use Vert. Comp. for Bearing	Yes
Use Surcharge for Sliding & OT	Yes
Use Surcharge for Bearing	Yes
Neglect soil over toe	No
Neglect Backfill Wt. for Coulomb	No
Factor Soil Wt as Dead	Yes
Use Passive Force for OT	Yes
Assume Pressure to Top	Yes

Geotechnical

Friction Coefficient	0.35
Wall Friction Angle	25°

Stability Criteria

Required F.S. for Overturning	1.50
Required F.S. for Sliding	1.50
Allowable Bearing Pressure	3000 psf
Req'd Bearing Location	Middle third

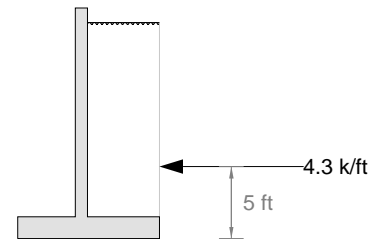
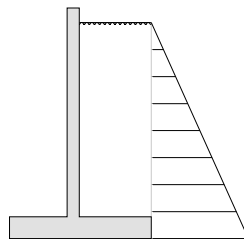
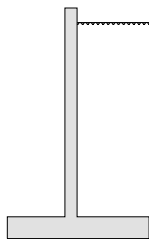
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Load Combinations Checked

	Stem Base Mu:	Stem Pos Mu:	Stem Base Vu:	Heel Mu:	Heel Vu:	Toe Mu:	Toe Vu:
1.4D	0 ft-k/ft	0 ft-k/ft	0 k/ft	0 ft-k/ft	1.03 ft-k/ft	0 ft-k/ft	0.44 ft-k/ft
1.2D + 1.6H	25.06 ft-k/ft	-0 ft-k/ft	5.57 k/ft	25.06 ft-k/ft	0.89 ft-k/ft	13.17 ft-k/ft	0.38 ft-k/ft
1.2D	0 ft-k/ft	0 ft-k/ft	0 k/ft	0 ft-k/ft	0.89 ft-k/ft	0 ft-k/ft	0.38 ft-k/ft
0.9D + 1.6H	25.06 ft-k/ft	-0 ft-k/ft	5.57 k/ft	19.94 ft-k/ft	0.66 ft-k/ft	9.88 ft-k/ft	0.29 ft-k/ft

Force Calculations

Backfill Pressure

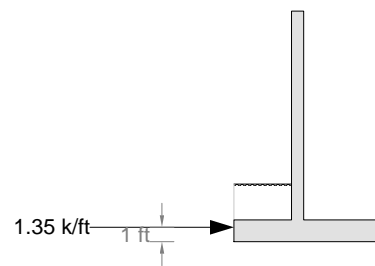
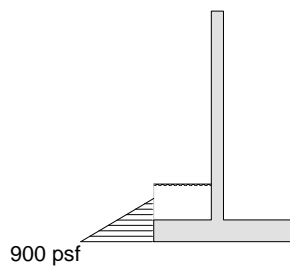
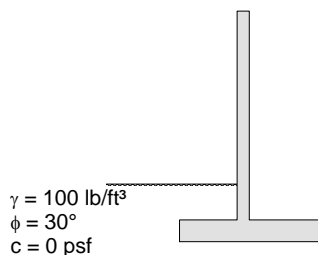


$$K_a = \tan^2 \left[45^\circ - \frac{\phi}{2} \right] = \tan^2 \left[45^\circ - \frac{30^\circ}{2} \right] = 0.33$$

$$\sigma_a = \gamma H K_a - 2c \sqrt{K_a} = (114.6 \text{ lb/ft}^3)(15 \text{ ft}) 0.33 - 2(0 \text{ psf}) \sqrt{0.33} = 573 \text{ psf}$$

$$P_a = \frac{1}{2} H \sigma_a = \frac{1}{2} (15 \text{ ft}) (573 \text{ psf}) = 4.3 \text{ k/ft} \quad \text{Location} = \frac{H}{3} = \frac{15 \text{ ft}}{3} = 5 \text{ ft}$$

Passive Pressure @ Toe



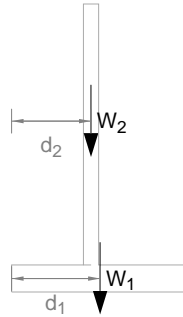
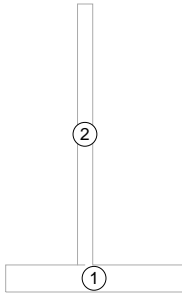
$$K_p = \tan^2 \left[45^\circ + \frac{\phi}{2} \right] = \tan^2 \left[45^\circ + \frac{30^\circ}{2} \right] = 3.00$$

$$\sigma_p = \gamma d_b K_p + 2c \sqrt{K_p} = (100 \text{ lb/ft}^3)(3 \text{ ft}) 3.00 + 2(0 \text{ psf}) \sqrt{3.00} = 900 \text{ psf}$$

$$P_p = \frac{1}{2} (H_{\text{press}}) \sigma_p = \frac{1}{2} (3 \text{ ft}) (900 \text{ psf}) = 1.35 \text{ k/ft} \quad \text{Location} = \frac{H_{\text{press}}}{3} - H_{\text{key}} = \frac{3 \text{ ft}}{3} - 0 \text{ ft} = 1 \text{ ft}$$

Force Calculations

Wall Weights



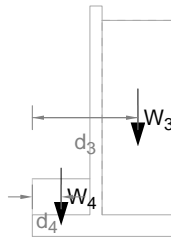
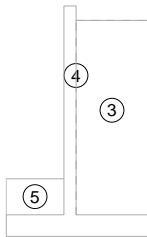
$$W_1 = \gamma_1 A_1 = (150 \text{ lb/ft}^3)(14.75 \text{ ft}^2) = 2.21 \text{ k/ft}$$

$$W_2 = \gamma_2 A_2 = (150 \text{ lb/ft}^3)(12.08 \text{ ft}^2) = 1.81 \text{ k/ft}$$

$$d_1 = 4.92 \text{ ft}$$

$$d_2 = 4.42 \text{ ft}$$

Backfill Weights



$$W_3 = \gamma_3 A_3 = (114.6 \text{ lb/ft}^3)(67.5 \text{ ft}^2) = 7.74 \text{ k/ft}$$

$$W_4 = \gamma_4 A_4 = (100 \text{ lb/ft}^3)(10 \text{ ft}^2) = 1 \text{ k/ft}$$

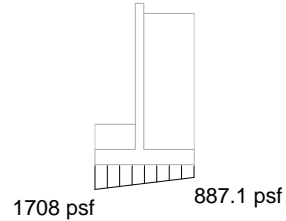
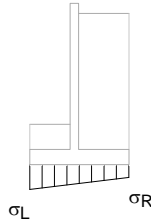
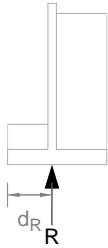
$$d_3 = 7.33 \text{ ft}$$

$$d_4 = 2 \text{ ft}$$

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Force Calculations

Bearing Pressure



$$\begin{aligned}
 R &= W_1 + W_2 + W_3 + W_4 + P_{av} \\
 &= 2.21 \text{ k/ft} + 1.81 \text{ k/ft} + 7.74 \text{ k/ft} + 1 \text{ k/ft} + 0 \text{ k/ft} \\
 &= 12.76 \text{ k/ft} \quad (100.0\% \text{ dead}, 0.0\% \text{ live}, 0.0\% \text{ earth})
 \end{aligned}$$

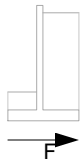
$$\begin{aligned}
 M &= W_1d_1 + W_2d_2 + W_3d_3 + W_4d_4 + P_{av}b_f - P_{ah}\frac{H}{3} \\
 &= (4.92 \text{ ft})(2.21 \text{ k/ft}) + (4.42 \text{ ft})(1.81 \text{ k/ft}) + (7.33 \text{ ft})(7.74 \text{ k/ft}) + (2 \text{ ft})(1 \text{ k/ft}) + (0 \text{ k/ft})(9.83 \text{ ft}) - (4.3 \text{ k/ft})\frac{15 \text{ ft}}{3} \\
 &= 56.12 \text{ ft-k/ft}
 \end{aligned}$$

$$d_R = \frac{M}{R} = \frac{56.12 \text{ ft-k/ft}}{12.76 \text{ k/ft}} = 4.4 \text{ ft}$$

$$\sigma_L = \frac{R}{L} \left[1 + 3 \left(1 - 2 \frac{d_R}{L} \right) \right] = \frac{12.76 \text{ k/ft}}{9.83 \text{ ft}} \left[1 + 3 \left(1 - 2 \frac{4.4 \text{ ft}}{9.83 \text{ ft}} \right) \right] = 1708 \text{ psf}$$

$$\sigma_R = \frac{R}{L} \left[1 - 3 \left(1 - 2 \frac{d_R}{L} \right) \right] = \frac{12.76 \text{ k/ft}}{9.83 \text{ ft}} \left[1 - 3 \left(1 - 2 \frac{4.4 \text{ ft}}{9.83 \text{ ft}} \right) \right] = 887.1 \text{ psf}$$

Friction Force



$$F = \mu R = (0.35)(12.76 \text{ k/ft}) = 4.47 \text{ k/ft}$$

Note: Bearing resultant used here was decreased by 0 k/ft to remove vertical backfill component effect.
(prevent vertical backfill component from contributing to sliding resistance)

Stability Checks

Overturning Check

Overturning Moments

	Force	Distance	Moment
Backfill pressure	4.3 k/ft	5 ft	21.49 ft-k/ft
			Total: 21.49 ft-k/ft

Resisting Moments

	Force	Distance	Moment
W1 (footing)	2.21 k/ft	4.92 ft	10.88 ft-k/ft
W2 (stem)	1.81 k/ft	4.42 ft	8.01 ft-k/ft
W3 (soil)	7.74 k/ft	7.33 ft	56.73 ft-k/ft
W4 (soil)	1 k/ft	2 ft	2 ft-k/ft
Passive pressure @ toe	1.35 k/ft	1 ft	1.35 ft-k/ft
			Total: 78.96 ft-k/ft

$$F.S. = \frac{RM}{OTM} = \frac{78.96 \text{ ft-k/ft}}{21.49 \text{ ft-k/ft}} = 3.675 \text{ (OK)}$$

Sliding Check

Sliding Force(s)

Backfill lateral pressure	4.3 k/ft
Total:	4.3 k/ft

Resisting Force(s)

Passive pressure @ toe	1.35 k/ft
Friction	4.47 k/ft
Total:	5.82 k/ft

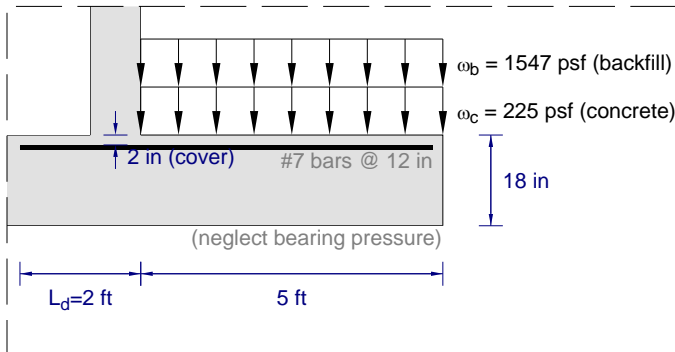
$$F.S. = \frac{RF}{SF} = \frac{5.82 \text{ k/ft}}{4.3 \text{ k/ft}} = 1.353 \text{ (fails)}$$

Bearing Capacity Check

Max bearing pressure < allowable (1708 psf < 3000 psf), bearing OK

Resultant is within middle third (OK)

Heel Check



Min Reinforcement Check

Not needed: capacity 1/3 greater than req'd: $\frac{\phi M_n}{M_u} = \frac{40.43 \text{ ft}\cdot\text{k}/\text{ft}}{25.06 \text{ ft}\cdot\text{k}/\text{ft}} = 1.613$ ✓

Design Forces

Controlling combination: 1.2D + 1.6H

$$M_u = 1.20 \frac{1}{2} \omega_c L^2 + 1.20 \frac{1}{2} \omega_b L^2 = 1.20 \frac{1}{2} (225 \text{ psf}) (5 \text{ ft})^2 + 1.20 \frac{1}{2} (1547 \text{ psf}) (5 \text{ ft})^2 = 26.58 \text{ ft}\cdot\text{k}/\text{ft}$$

$$M_u \text{ @ stem base} = 25.06 \text{ ft}\cdot\text{k}/\text{ft} < 26.58 \text{ ft}\cdot\text{k}/\text{ft} \quad \therefore \text{heel } M_u \text{ taken as } 25.06 \text{ ft}\cdot\text{k}/\text{ft}$$

$$V_u = 1.20 \omega_c L + 1.20 \omega_b L = 1.20 (225 \text{ psf}) (5 \text{ ft}) + 1.20 (1547 \text{ psf}) (5 \text{ ft}) = 10.63 \text{ k}/\text{ft}$$

Shear Check

$$\phi V_n = \phi [2 \text{ sqrt}(f_c)] d = (0.75) [2 \text{ sqrt}(3000 \text{ psi})] (15.56 \text{ in}) = 15.34 \text{ k}/\text{ft} \quad \phi V_n > V_u \quad \checkmark$$

Min Tensile Strain Check

$$\text{Extreme tensile strain} = 0.0307 > 0.004 \quad \checkmark$$

Flexure Check

$$\phi M_n = \phi A_s F_y (d - a/2) = 0.90 (0.6 \text{ in}^2/\text{ft}) (60 \text{ ksi}) [15.56 \text{ in} - (1.18 \text{ in})/2] = 40.43 \text{ ft}\cdot\text{k}/\text{ft} \quad \phi M_n > M_u \quad \checkmark$$

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Heel Check

Development

$$\frac{L_d}{d_b} = \frac{3}{40} \frac{f_y}{\sqrt{f_c}} \frac{\alpha\beta\gamma\lambda}{\left[\frac{c + K_{tr}}{d_b}\right]} = \frac{3}{40} \frac{60000 \text{ psi}}{\sqrt{3000 \text{ psi}}} \frac{(1.3)(1.0)(1.0)(1.0)}{2.50} = 42.72$$

$$\text{where: } \frac{c + K_{tr}}{d_b} = \frac{2.44 \text{ in} + 0}{0.875 \text{ in}} = 2.79 > 2.5 \therefore \text{ use } 2.5$$

where: $\alpha = 1.3$ (>12" fresh concrete below) $\beta = 1.0$ (bars not coated) $\gamma = 1.0$ (bar size > #6) $\lambda = 1.0$ (normal wt concrete)

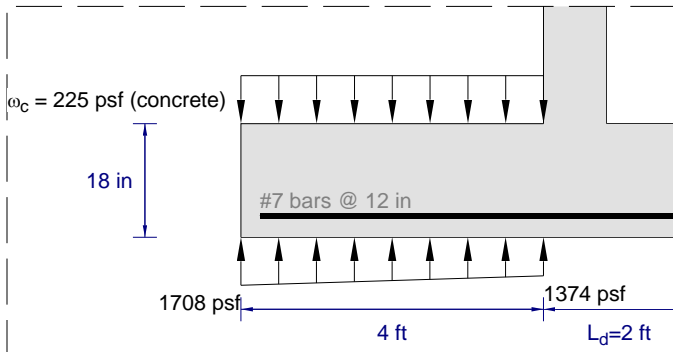
$K_{tr} = 0$ (no transverse reinforcement) $c = 2.44 \text{ in}$ (lesser of bar ctr to outer edge or half of ctr- to ctr spacing)

$$L_d = \frac{L_d}{d_b} d_b = (42.72)(0.875 \text{ in}) = 37.38 \text{ in}$$

Excess reinforcement reduction of 12.2.5: $62.0\% L_d = 62.0\% (37.38 \text{ in}) = 23.17 \text{ in}$

Required $L_d = 23.17 \text{ in} \leq$ Actual L_d (24 in) ✓

Toe Check



Min Reinforcement Check

Not needed: capacity 1/3 greater than req'd: $\frac{\phi M_n}{M_u} = \frac{37.73 \text{ ft}\cdot\text{k}/\text{ft}}{13.17 \text{ ft}\cdot\text{k}/\text{ft}} = 2.865$ ✓

Design Forces

Controlling combination: 1.2D + 1.6H

Bearing load factor: take weighted average of factors from all sources based on contribution (see bearing calcs):

$$100.0\% (1.20 - \text{Dead}) + 0.0\% (0.00 - \text{Live}) + 0.0\% (1.60 - \text{Earth}) = 1.20$$

$$\begin{aligned} M_u &= -1.20 \left[\frac{1}{2} \omega_c L^2 \right] + 1.20 \left[\frac{1}{2} \omega_{br} L^2 + \frac{1}{3} (\omega_{bl} - \omega_{br}) L^2 \right] \\ &= -1.20 \left[\frac{1}{2} (225 \text{ psf}) (4 \text{ ft})^2 \right] + 1.20 \left[\frac{1}{2} (1374 \text{ psf}) (4 \text{ ft})^2 + \frac{1}{3} (1708 \text{ psf} - 1374 \text{ psf}) (4 \text{ ft})^2 \right] \\ &= 13.17 \text{ ft}\cdot\text{k}/\text{ft} \end{aligned}$$

M_u @ stem base = 25.06 ft-k/ft > 13.17 ft-k/ft (does not control for toe)

$$V_u = -1.20 \omega_c L + 1.20 [\omega_{br} L + (\omega_{bl} - \omega_{br}) L/2] = -1.20 (225 \text{ psf}) (2.79 \text{ ft}) + 1.20 [(1476 \text{ psf}) (2.79 \text{ ft}) + (1708 \text{ psf} - 1476 \text{ psf}) (2.79 \text{ ft})/2] = 4.57 \text{ k}/\text{ft}$$

(taken @ 'd' from the base of the stem: d = 14.56 in, bearing pressure @ d = 1476 psf)

Shear Check

$$\phi V_n = \phi [2 \text{ sqrt}(f'_c)] d = (0.75) [2 \text{ sqrt}(3000 \text{ psi})] (14.56 \text{ in}) = 14.36 \text{ k}/\text{ft} \quad \phi V_n > V_u \quad \checkmark$$

Min Tensile Strain Check

Extreme tensile strain = 0.0286 > 0.004 ✓

Flexure Check

$$\phi M_n = \phi A_s F_y (d - a/2) = 0.90 (0.6 \text{ in}^2/\text{ft}) (60 \text{ ksi}) [14.56 \text{ in} - (1.18 \text{ in})/2] = 37.73 \text{ ft}\cdot\text{k}/\text{ft} \quad \phi M_n > M_u \quad \checkmark$$

Toe Check

Development

$$\frac{L_d}{d_b} = \frac{3}{40} \frac{f_y}{\sqrt{f_c}} \frac{\alpha\beta\gamma\lambda}{\left[\frac{c+K_{tr}}{d_b}\right]} = \frac{3}{40} \frac{60000 \text{ psi}}{\sqrt{3000 \text{ psi}}} \frac{(1.0)(1.0)(1.0)(1.0)}{2.50} = 32.86$$

$$\text{where: } \frac{c+K_{tr}}{d_b} = \frac{3.44 \text{ in} + 0}{0.875 \text{ in}} = 3.93 > 2.5 \therefore \text{ use } 2.5$$

where: $\alpha = 1.0$ (≤ 12 " fresh concrete below) $\beta = 1.0$ (bars not coated) $\gamma = 1.0$ (bar size $> \#6$) $\lambda = 1.0$ (normal wt concrete)

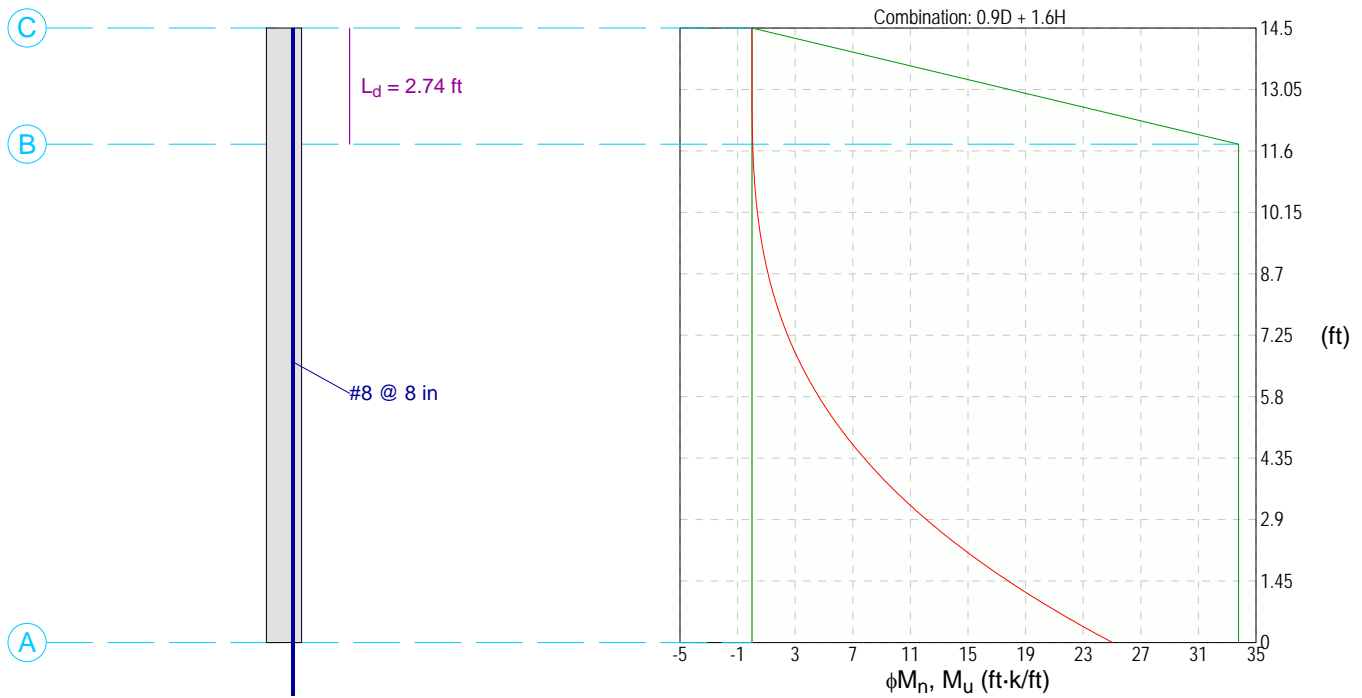
$K_{tr} = 0$ (no transverse reinforcement) $c = 3.44 \text{ in}$ (lesser of bar ctr to outer edge or half of ctr- to ctr spacing)

$$L_d = \frac{L_d}{d_b} d_b = (32.86)(0.875 \text{ in}) = 28.76 \text{ in}$$

Excess reinforcement reduction of 12.2.5: $34.9\% L_d = 34.9\% (28.76 \text{ in}) = 10.04 \text{ in}$

Required $L_d = 10.04 \text{ in} \leq$ Actual L_d (24 in) ✓

Stem Check



Negative Moment Capacity @ A

$$\frac{A_s}{b} = \frac{0.79 \text{ in}^2}{8 \text{ in}} = 1.185 \text{ in}^2/\text{ft}$$

$$d = t_h - \text{cover} - \frac{d_b}{2} = 10 \text{ in} - 2 \text{ in} - \frac{1 \text{ in}}{2} = 7.5 \text{ in}$$

$$\phi M_n = \phi A_s F_y (d - a/2) = 0.90 (1.185 \text{ in}^2/\text{ft}) (60 \text{ ksi}) [7.5 \text{ in} - (2.32 \text{ in})/2] = 33.8 \text{ ft}\cdot\text{k/ft}$$

Negative Moment Capacity @ E

$$\frac{A_s}{b} = \frac{0.79 \text{ in}^2}{8 \text{ in}} = 1.185 \text{ in}^2/\text{ft}$$

$$d = t_h - \text{cover} - \frac{d_b}{2} = 10 \text{ in} - 2 \text{ in} - \frac{1 \text{ in}}{2} = 7.5 \text{ in}$$

$$\phi M_n = \phi A_s F_y (d - a/2) = 0.90 (1.185 \text{ in}^2/\text{ft}) (60 \text{ ksi}) [7.5 \text{ in} - (2.32 \text{ in})/2] = 33.8 \text{ ft}\cdot\text{k/ft}$$

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Stem Check

Development length from C to B (#8 @ 8 in)

$$\frac{L_d}{d_b} = \frac{3}{40} \frac{f_y}{\sqrt{f_c}} \frac{\alpha\beta\gamma\lambda}{\left[\frac{c+K_{tr}}{d_b}\right]} = \frac{3}{40} \frac{60000 \text{ psi}}{\sqrt{3000 \text{ psi}}} \frac{(1.0)(1.0)(1.0)(1.0)}{2.50} = 32.86$$

where: $\frac{c+K_{tr}}{d_b} = \frac{2.5 \text{ in} + 0}{1 \text{ in}} = 2.50 \leq 2.5$

where: $\alpha = 1.0$ (≤ 12 " fresh concrete below) $\beta = 1.0$ (bars not coated) $\gamma = 1.0$ (bar size $> \#6$) $\lambda = 1.0$ (normal wt concrete)

$K_{tr} = 0$ (no transverse reinforcement) $c = 2.5$ in (lesser of bar ctr to outer edge or half of ctr- to ctr spacing)

$$L_d = \frac{L_d}{d_b} d_b = (32.86)(1 \text{ in}) = 32.86 \text{ in}$$

Shear checks

@ base: $V_u = 5.57 \text{ k/ft}$ $\phi V_n = \phi [2 \sqrt{f_c}] d = (0.75) [2 \sqrt{3000 \text{ psi}}] (7.5 \text{ in}) = 7.39 \text{ k/ft}$ $\phi V_n > V_u$ ✓

@ 174 in: $V_u = 0 \text{ k/ft}$ $\phi V_n = \phi [2 \sqrt{f_c}] d = (0.75) [2 \sqrt{3000 \text{ psi}}] (7.5 \text{ in}) = 7.39 \text{ k/ft}$ $\phi V_n > V_u$ ✓

Development of bars into footing

#8 bars @ 8 in: Developed by 90° hook

$$L_{dh} = (0.02\beta\lambda f_y / \sqrt{f_c}) d_b = (0.02)(1.0)(1.0)(60 \text{ ksi}) / \sqrt{3 \text{ ksi}} (1 \text{ in}) = 21.91 \text{ in}$$

$$L_{dh} = 0.7(21.91 \text{ in}) = 15.34 \text{ in} \quad (\text{reduction allowed by ACI 12.5.3})$$

$$\text{Excess reinforcement reduction of } 12.5\% (d): 74.2\% L_d = 74.2\% (15.34 \text{ in}) = 11.37 \text{ in}$$

Actual L_{dh} (15 in) \geq required L_{dh} (11.37 in) ✓

Minimum extension = $12d_b = 12(1 \text{ in}) = 12 \text{ in} \leq 12 \text{ in}$ (actual extension) ✓

Minimum inside bend diameter = $6d_b = 6(1 \text{ in}) = 6 \text{ in} \leq 8 \text{ in}$ (actual diameter) ✓

Check Minimum Steel

At 0 in:

Check not needed: capacity 1/3 greater than req'd: $\frac{\phi M_n}{M_u} = \frac{33.8 \text{ ft}\cdot\text{k/ft}}{25.06 \text{ ft}\cdot\text{k/ft}} = 1.349$ ✓

Check Min Tensile Strain

At 0 in:

Extreme tensile strain = 0.0052 $>$ 0.004 ✓