FIRE TRAINING EQUIPMENT

CONCRETE FOUNDATION CALCULATIONS

WESCO MODEL WS-2 CUSTOM
22'X16'X25' TOWER SIMULATOR
FOR

NICEVILLE, FL

DESIGN CODE: FBC 2020

DESIGN LOADS TAKEN FROM STRUCTURAL CALCULATIONS
BASED ON THE INFORMATION SHOWN BELOW

ROOF LIVE LOAD: 100 psf
FLOOR LIVE LOAD: 100 psf
WIND LOAD: 131 mph, EXP C; Risk Cat. I
SEISMIC DESIGN CAT: A
SITE CLASS: D

Steven Westra
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Date: 2023.01.18 12:11:09-06'00'

STEVEN P. WESTRA
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NO. 56328
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PROFESSIONAL ENGINEER
JAN 18 2022

PREPARED BY: DWK
DATE: 01/11/2023
ORDER NUMBER: FTE-816 / 267183

WS-2

LOAD CASE	COLUMN	SHEAR (KIPS)	DOWNWARD (KIPS)	UPLIFT (KIPS)
WIND	A1,A2,B1,B2	6.17	5.73	14.39
DEAD	A1,A2,B1,B2	0.98	6.56	0.00
LIVE	A1,A2,B1,B2	3.51	24.36	0.00
SEISMIC	A1,A2,B1,B2	0.40	0.88	0.88

Reactions shown above are individual load cases with a load factor of one (no reductions). These reactions are based on FBC 2020 with a 131 mph; exp C wind and a seismic category A. Please also note that these reactions are based on the fire training simulator show on the Fire Facilities drawing dated or revised on 08/05/2022

CAST IN PLACE "HEADED" ANCHOR BOLT DESIGN

Columns - WS-2 (tower)

GENERAL INFORMATION - DATA ENTRY

NUMBER OF ANCHORS IN BASE PLATE $n := 4$

BOLT TYPE - F1554 (GRADE 36)

ULIMATE TENSILE STRENGTH $f_{ut} := 60000psi$

BOLT DIAMETER $d_o := 0.75in$

BOLT EMBEDMENT LENGTH $h_{ef} := 10.5in$

NUMBER OF THREADS PER INCH $n_t := 10.5$

BEARING AREA OF HEAD $A_b := 0.654in^2$

DEPTH OF SLAB/PIER $h := 18in$

EDGE DISTANCES/SPACING

$c_{minx} := 4.75in$ $spacing_x := 4.5in$

$c_{miny} := 5.5in$ $spacing_y := 5in$

PIER/4EDGES (1=yes, 2=no) $P := 2$ $h_{ef} := h_{ef} - 6in$ $h_{ef} = 4.5 \cdot in$

RIGIDLY WELDED (1=yes, 2=no) $RW := 2$

CONCRETE STRENGTH $f_c := 3000psi$

REBAR SIZE @ ANCHOR & EDGE OF CONC (<#4BAR,ψ=1; >=#4BAR,ψ=1.2 &w/stirup space<=4"ψ=1.4) - (D6.2.7) $\psi_c := 1.2$

MODERATE OR HIGH SEISMIC RISK W/O ANCHOR REINFORCEMENT? (D3.3.4.4 / 17.2.3.4.4) (1=yes, 2=no) $R := 2$

Hef BETWEEN OR EQUAL TO 11 IN AND 25 (1=yes, 2=no) $EF := if(11in < h_{ef} \le 25in, 1, 2)$ $EF = 2$

LOAD SUMMARY

SHEAR - UNFACTORED LOADS IN MOST CONSERVATIVE DIRECTION PER COLUMN

$V_d := 0.98k$

$V_l := 3.51k$

$V_w := 6.17k$

$V_{seis} := 0.4k$

TENSION - UNFACTORED LOADS PER COLUMN-UPLIFT MUST BE A NEGATIVE VALUE - (D3.2)

$P_d := 6.56k$

$P_l := 24.36k$

$P_w := -14.39k$

$P_{seis} := -0.88k$

SHEAR - FACTORED PER BOLT - (D3.2)

$U_{v1} := \frac{(1.2 \cdot V_d + 1.6 \cdot V_l)}{n}$ $U_{v1} = 1.698 \cdot k$

$U_{v2} := \frac{(1.2 \cdot V_d + 0.5 \cdot V_l + 1.0 \cdot V_w)}{n}$ $U_{v2} = 2.275 \cdot k$

$U_{v3} := \frac{(.9 \cdot V_d + 1.0 \cdot V_w)}{n}$ $U_{v3} = 1.763 \cdot k$

$U_{v4} := \frac{(1.2 \cdot V_d + 1.0 \cdot V_{seis} + .5 \cdot V_l)}{n}$ $U_{v4} = 0.833 \cdot k$

$U_{v5} := \frac{(.9 \cdot V_d + 1.0 \cdot V_{seis})}{n}$ $U_{v5} = 0.321 \cdot k$

$U_{vmax} := max(U_{v1}, U_{v2}, U_{v3}, U_{v4}, U_{v5})$ $U_{vmax} = 2.275 \cdot k$

TENSION - FACTORED PER BOLT - (D3.2)

$U_{p1} := \frac{(1.2 \cdot P_d + 1.6 \cdot P_l)}{n}$ $U_{p1} = 11.712 \cdot k$

$U_{p2} := \frac{(1.2 \cdot P_d + 0.5 \cdot P_l + 1.0 \cdot P_w)}{n}$ $U_{p2} = 1.415 \cdot k$

$U_{p3} := \frac{(.9 \cdot P_d + 1.0 \cdot P_w)}{n}$ $U_{p3} = -2.122 \cdot k$

$U_{p4} := \frac{(1.2 \cdot P_d + 1.0 \cdot P_{seis} + .5 \cdot P_l)}{n}$ $U_{p4} = 4.793 \cdot k$

$U_{p5} := \frac{(.9 \cdot P_d + 1.0 \cdot P_{seis})}{n}$ $U_{p5} = 1.256 \cdot k$

$U_{pmax} := min(U_{p1}, U_{p2}, U_{p3}, U_{p4}, U_{p5}, 0k)$ $U_{pmax} = -2.122 \cdot k$

STEEL STRENGTH OF FASTENER

$A_{se} := \frac{\pi}{4} \cdot \left(d_o - \frac{.9743in}{n_t}\right)^2$ $A_{se} = 0.339 \cdot in^2$

D5.2.1

Tension - (D5.1 - EQ D-2)

$\phi_t := .75$ $N_s := n \cdot A_{se} \cdot f_{ut}$ $N_s = 81.416 \cdot k$

$\phi N_s := \phi_t \cdot N_s$ $\phi N_s = 61.062 \cdot k$

$codecheck := if\left(\left|U_{pmax}\right| \le \phi N_s, "OK", "NOT\ OK"\right)$ $codecheck = "OK"$

Shear - (D6.1 - EQ D-29)

$\phi_s := .65$ $V_s := n \cdot (0.6) A_{se} \cdot f_{ut}$ $V_s = 48.849 \cdot k$

$\phi V_s := \phi_s \cdot V_s$ $\phi V_s = 31.752 \cdot k$

$codecheck := if\left(U_{vmax} \le \phi V_s, "OK", "NOT\ OK"\right)$ $codecheck = "OK"$

CONCRETE BREAKOUT STRENGTH OF FASTENERS IN TENSION (D5.2)

$c_{max} := max(c_{miny}, c_{minx})$ $c_{max} = 5.5 \cdot in$ $\phi := .75$

$c_{min} := min(c_{minx}, c_{miny})$ $c_{min} = 4.75 \cdot in$

$h'_{ef} := if\left(c_{max} \le 1.5 \cdot h_{ef}, \frac{c_{max}}{1.5}, h_{ef}\right)$ $h'_{ef} := if\left(P = 1, h'_{ef}, h_{ef}\right)$ $h'_{ef} = 4.5 \cdot in$

$c_{minx} := min(c_{minx}, 1.5 \cdot h_{ef})$ $c_{minx} = 4.75 \cdot in$ $s_x := min(spacing_x, 3 \cdot h_{ef})$ $s_x = 4.5 \cdot in$

$c_{miny} := min(c_{miny}, 1.5 \cdot h_{ef})$ $c_{miny} = 5.5 \cdot in$ $s_y := min(spacing_y, 3 \cdot h_{ef})$ $s_y = 5 \cdot in$

$A_{nc} := if\left[P = 2, (1.5 \cdot h_{ef} + s_x + c_{minx}) \cdot (1.5 \cdot h_{ef} + s_y + c_{miny}), (s_x + 2 \cdot c_{minx}) \cdot (s_y + 2 \cdot c_{miny})\right]$ $A_{nc} = 276 \cdot in^2$ fig RD5.2.1

$A_{nco} := 9 \cdot h'^2_{ef}$ $A_{nco} = 182.25 \cdot in^2$

$A_{nc} := min(A_{nc}, n \cdot A_{nco})$ $A_{nc} = 276 \cdot in^2$

$k_1 := 24 in^{-.5} \cdot 1lbf^{.5}$ $k_{ef} := 16 in^{-.67} \cdot 1lbf^{.5}$

$N_b := k_1 \cdot \sqrt{f_c} \cdot h'^{1.5}_{ef}$ $N_b = 12.548 \cdot k$ D5.2.2 - EQ D-6

$EFN_b := k_{ef} \cdot \sqrt{f_c} \cdot h'^{1.67}_{ef}$ $EFN_b = 10.803 \cdot k$ D5.2.2 - EQ D-7

$N_b := if\left(EF = 1, min(N_b, EFN_b), N_b\right)$ $N_b = 12.548 \cdot k$

$\psi_{ec} := 1.0$ D5.2.4 - EQ D-8
not eccentrically loaded

$\psi_{ed} := if\left(c_{min} \ge 1.5 \cdot h'_{ef}, 1, 0.7 + 0.3 \cdot \frac{c_{min}}{1.5 \cdot h'_{ef}}\right)$ $\psi_{ed} = 0.91$ D5.2.5 - EQ D-10

$\psi_{cn} := 1.0$ D5.2.6 - assumed cracking

$N_{cbg} := \frac{A_{nc}}{A_{nco}} \cdot \psi_{ec} \cdot \psi_{ed} \cdot \psi_{cn} \cdot N_b$ $N_{cbg} = 17.314 \cdot k$ for a group of fasteners
D5.2.1 - EQ D-4

$\phi N_{cbg} := if\left(R = 1, .75 \cdot \phi \cdot N_{cbg}, \phi \cdot N_{cbg}\right)$ $\phi N_{cbg} = 12.986 \cdot k$

$codecheck := if\left(\left|U_{pmax}\right| \le \phi N_{cbg}, "OK", "NOT\ OK"\right)$ $codecheck = "OK"$

PULL OUT STRENGTH OF FASTENER IN TENSION (D5.3)

$\psi_{cp} := 1.0$ — D5.3.6 - assumed cracking

$N_{pn} := \psi_{cp} \cdot 8 \cdot f_c \cdot A_b$ — $N_{pn} = 15.696 \cdot k$ — D5.3.1 - EQ D-13

$\phi N_{pn} := \text{if}(R = 1, .75 \cdot \phi \cdot N_{pn}, \phi \cdot N_{pn})$ — $\phi N_{pn} = 11.772 \cdot k$

$\text{codecheck} := \text{if}(|U_{pmax}| \le \phi N_{pn}, \text{"OK"}, \text{"NOT OK"})$ — codecheck = "OK"

CONCRETE SIDE FACE BLOW OUT STRENGTH OF FASTENERS IN TENSION (D5.4)

$N_{sb} := 160 \cdot \left(\frac{lbf^{.5}}{in}\right) \cdot c_{min} \cdot \sqrt{A_b} \cdot \sqrt{f_c}$ — $N_{sb} = 33.664 \cdot k$ — D5.4.1 - EQ D-16

$N_{sbg} := \text{if}\left[c_{min} < .4 \cdot h'_{ef}, \left(1 + \frac{\min(6 \cdot c_{min}, spacing_x, spacing_y)}{6 \cdot c_{min}}\right) \cdot N_{sb}, N_{pn}\right]$ — $N_{sbg} = 15.696 \cdot k$ — D5.4.2 - EQ D-17

$\phi N_{sbg} := \text{if}(R = 1, .75 \cdot \phi \cdot N_{sbg}, \phi \cdot N_{sbg})$ — $\phi N_{sbg} = 11.772 \cdot k$

$\text{codecheck} := \text{if}(|U_{pmax}| \le \phi N_{sbg}, \text{"OK"}, \text{"NOT OK"})$ — codecheck = "OK"

CONCRETE BREAKOUT STRENGTH OF FASTENER IN SHEAR (D6.2)

$c_{a1x} := \text{if}(RW = 1, c_{minx} + spacing_x, c_{minx})$ — $c_{a1x} = 4.75 \cdot in$

$c_{a1y} := \text{if}(RW = 1, c_{miny} + spacing_y, c_{miny})$ — $c_{a1y} = 5.5 \cdot in$

$c_{a2x} := \min(c_{miny}, 1.5 \cdot c_{a1x})$ — $c_{a2x} = 5.5 \cdot in$

$c_{a2y} := \min(c_{minx}, 1.5 \cdot c_{a1y})$ — $c_{a2y} = 4.75 \cdot in$

$c_{a3x} := \text{if}(P = 1, c_{a2x}, 1.5 \cdot c_{a1x})$ — $c_{a3x} = 7.125 \cdot in$

$c_{a3y} := \text{if}(P = 1, c_{a2y}, 1.5 \cdot c_{a1y})$ — $c_{a3y} = 8.25 \cdot in$

$h_x := \min(h, 1.5 \cdot c_{a1x})$ — $h_x = 7.125 \cdot in$

$h_y := \min(h, 1.5 \cdot c_{a1y})$ — $h_y = 8.25 \cdot in$

$spacing_x = 4.5 \cdot in$ — $spacing_y = 5 \cdot in$

D6.2.2 - EQ D-32

$A_{vcox} := 4.5 \cdot c_{a1x}^2$ — $A_{vcox} = 101.5 \cdot in^2$

$A_{vcoy} := 4.5 \cdot c_{a1y}^2$ — $A_{vcoy} = 136.1 \cdot in^2$

$A_{vcx} := \text{if}[RW = 1, 2 \cdot (1.5 \cdot c_{a1x}) + \min(3 \cdot c_{a1x}, s_x), 2(1.5 \cdot c_{a1x})] \cdot h_x$

$A_{vcy} := \text{if}[RW = 1, 2 \cdot (1.5 \cdot c_{a1y}) + \min(3 \cdot c_{a1y}, s_y), 2(1.5 \cdot c_{a1y})] \cdot h_y$

fig RD6.2.1

$A_{vcx} = 101.5 \cdot in^2$ — $A_{vcy} = 136.1 \cdot in^2$

$V_{bx} := \min\left[9 \cdot \sqrt{f_c} \cdot c_{a1x}^{1.5} \cdot \left(\frac{lbf}{in}\right)^{.5}, \text{if}(RW = 1, 8, 7) \cdot \left[\left(\frac{\min(h_{ef}, 8 \cdot d_o)}{d_o}\right)^{.2} \cdot \sqrt{d_o} \cdot \sqrt{f_c} \cdot c_{a1x}^{1.5}\right] \cdot \left(\frac{lbf^{.5}}{in}\right)\right]$ — $V_{bx} = 4.919 \cdot k$

D6.2.2, 3 - EQ D-33, 34, 35

$V_{by} := \min\left[9 \cdot \sqrt{f_c} \cdot c_{a1y}^{1.5} \cdot \left(\frac{lbf}{in}\right)^{.5}, \text{if}(RW = 1, 8, 7) \cdot \left[\left(\frac{\min(h_{ef}, 8 \cdot d_o)}{d_o}\right)^{.2} \cdot \sqrt{d_o} \cdot \sqrt{f_c} \cdot c_{a1y}^{1.5}\right] \cdot \left(\frac{lbf^{.5}}{in}\right)\right]$ — $V_{by} = 6.129 \cdot k$

D6.2.2, 3 - EQ D-33, 34, 35

$\psi_{edvx} := \min\left(1, .7 + .3 \cdot \frac{c_{a2x}}{1.5 \cdot c_{a1x}}\right)$ — $\psi_{edvx} = 0.9$

$\psi_{edvy} := \min\left(1, .7 + .3 \cdot \frac{c_{a2y}}{1.5 \cdot c_{a1y}}\right)$ — $\psi_{edvy} = 0.87$

D6.2.6 - EQ D-37,38

$\psi_{ecv} := 1.0$ — D6.2.5 - EQ D-36 not eccentrically loaded

$\psi_c = 1.2$ — D6.2.7 - See Above

D6.2.1 - EQ D-31

$V_{cbgx} := \frac{A_{vcx}}{A_{vcox}} \cdot \psi_{ecv} \cdot \psi_{edvx} \cdot \psi_c \cdot V_{bx}$ — $V_{cbgx} = 5.499 \cdot k$

$V_{cbgy} := \frac{A_{vcy}}{A_{vcoy}} \cdot \psi_{ecv} \cdot \psi_{edvx} \cdot \psi_c \cdot V_{by}$ — $V_{cbgy} = 6.851 \cdot k$

$\phi V_{cbgx} := \phi \cdot V_{cbgx}$ — $\phi V_{cbgx} = 4.124 \cdot k$

$\phi V_{cbgy} := \phi \cdot V_{cbgy}$ — $\phi V_{cbgy} = 5.138 \cdot k$

$\text{codecheckX} := \text{if}(U_{vmax} \le \phi V_{cbgx}, \text{"OK"}, \text{"NOT OK"})$ — codecheckX = "OK"

$\text{codecheckY} := \text{if}(U_{vmax} \le \phi V_{cbgy}, \text{"OK"}, \text{"NOT OK"})$ — codecheckY = "OK"

CONCRETE PRYOUT STRENGTH OF FASTENER IN SHEAR (D6.3)

$k_{cp} := \text{if}(h_{ef} < 2.5in, 1, 2)$ $\quad k_{cp} = 2$

$N_{cbg} = 17.314 \cdot k$

$V_{cp} := k_{cp} \cdot N_{cbg}$ $\quad V_{cp} = 34.628 \cdot k$ $\quad$ D6.3.1 - EQ D-41

$\phi V_{cp} := \phi \cdot V_{cp}$ $\quad \phi V_{cp} = 25.971 \cdot k$

codecheck := if$(U_{vmax} \le \phi V_{cp}$, "OK" , "NOT OK"$)$ $\quad$ codecheck = "OK"

COMBINATION OF TENSILE AND SHEAR FORCES

$\phi N_n := \min(\phi N_s, \phi N_{cbg}, \phi N_{pn}, \phi N_{sbg})$ $\quad \phi N_n = 11.772 \cdot k$

$\phi V_n := \min(\phi V_s, \phi V_{cbgx}, \phi V_{cbgy}, \phi V_{cp})$ $\quad \phi V_n = 4.124 \cdot k$

SOLUTION1 := if$(U_{vmax} \le .2 \cdot \phi V_n$, "FULL TENSION ALLOWED" , "COMBINATION REQUIRED"$)$

SOLUTION1 = "COMBINATION REQUIRED"

SOLUTION2 := if$(\left|U_{pmax}\right| \le .2 \cdot \phi N_n$, "FULL SHEAR ALLOWED" , "COMBINATION REQUIRED"$)$

SOLUTION2 = "FULL SHEAR ALLOWED"

COMBINATION

$$Check := \frac{\left|U_{pmax}\right|}{\phi N_n} + \frac{U_{vmax}}{\phi V_n} = 0.732$$

D7.3 - EQ D-42

codecheck := if (Check ≤ 1.2, "OK" , "NOT OK") $\quad$ codecheck = "OK"

MAT FOUNDATION DESIGN

Order No:	FTE - 816 / 267183
Job Description:	Wesco Model WS-2
Location:	Niceville, FL
Completed By:	DWK
Date:	January 11, 2023

I. Determine Plan Dimension of Footing/Mat Foundation

GENERAL INFORMATION - DATA ENTRY

Allowable Bearing Soil Pressure $q_{all} := 1500psf$

Weight Of Concrete Per Cubic Foot $w_c := 150pcf$

Length Of Footing (Most Conservative) $L := 22ft$

Width Of Footing $B := 16ft$

Factor Of Safety $FS_{min} := 2$

Depth Of Footing (Assume On 1st Run) $h := 1.5 \cdot ft$

Unfactored Column Reactions (enter all values as positive) $DL := 6.56k$ $LL := 24.36k$ $WL_D := 5.73k$ $WL_U := 14.39k$ $SL := 0.88k$

Moment Arm For Overturning Moment $x_1 := 20.833ft$

Moment Arm For Resisting Moment $x_2 := \frac{L}{2}$ $x_2 = 11\,ft$

Linear stud loads or column loads (1 or 2) $Load_{type} := 2$

Worst Case ASD loads per column Gravity (Down) $P_d = 30.92 \cdot k$ Uplift $P_u = 4.7 \cdot k$

A. Allow For The Self Weight Of The Footing (No Soil Above Footing)

$q_{net} := q_{all} - [w_c \cdot (h - 3in)]$ $q_{net} = 1312.5 \cdot psf$

B. Determine The Centroid Of The Load

(To Insure The Length And Width Of The Footing Will Provide / Produce A Uniform Bearing Pressure)

1. See 2 - 12 In Structural Eng. Reference Manual For Non-Symmetric Column Placements
2. The Columns Are Symmetrically Placed - Therefore Uniform Loads Are Present

C. Dimension Required For Footing

$L = 22\,ft$

$B_{min} := \frac{2P_d}{q_{net} \cdot L}$ $B_{min} = 2.142\,ft$ Minimum Req'd $B_{max} := 3ft$ (max width available for linear loads)

$B_{min} := if(Load_{type} = 1, B_{max}, B_{min})$ $B_{min} = 2.142\,ft$ $Ceil(B_{min}, ft) = 3\,ft$

$\frac{B}{2} = 8\,ft$ $CodeCheck := if\left(Ceil(B_{min}, ft) \geq \frac{B}{2}, "NOT OK", "OK"\right)$ $CodeCheck = "OK"$

D. Check Overturning Moment

Thickness Of Slab - Actual Thickness Used — T

Thickness Of Slab - Calculated — T_o

Resisting Moment — $B := \text{if}\left(Load_{type} = 1, B_{max}, \frac{2B}{3}\right)$ $B = 10.667\,ft$

$M_r := L \cdot B \cdot T_o \cdot w_c \cdot x_2$

Resisting Moment W/O Thickness — $M_{rwot} := L \cdot B \cdot w_c \cdot x_2$ $M_{rwot} = 387.2 \cdot k$

Overturning Moment — $M_o := x_1 \cdot P_u$ $M_o = 97.9 \cdot k \cdot ft$

Factor Of Safety — $FS := \frac{M_r}{M_o}$ $FS := \frac{M_{rwot} \cdot T_o}{M_o}$

Thickness Of Slab — $T_o := \frac{M_o \cdot FS_{min}}{M_{rwot}}$ $T_o = 0.51\,ft$ $T := 1.5ft$

E. Diagrams and Design Forces

GENERAL INFORMATION - DATA ENTRY

Length Of Base Plate — $P_L := 12in$

Width Of Base Plate — $P_W := 7in$

Length Base Plate Is Away From Edge — $P_{eL} := 3.5in$

Width Base Plate Is Away From Edge — $P_{eW} := 4.5in$

Strength Of Concrete — $f_c := 3000psi$

Resistance Factor For Shear — $\phi := 0.75 \frac{\sqrt{lbf}}{in}$

Resistance Factor For Flexure — $\phi_f := 0.9$

Minimum Yield Stress — $f_y := 60000psi$ $\rho := .0018$

Theoretical beam/strip width — $B_{beam} := 5ft$

Available — $\text{if}\left(Load_{type} = 1, B, .5B\right) = 5.333\,ft$

Minimum — $B_{min} = 2.142\,ft$

Distance From Top Of Foundation To Rebar — $d := T - 3in$ $d = 15 \cdot in$

Worst Case LRFD loads per column — Gravity (Down) $P_{ud} = 46.85 \cdot k$ Uplift $P_{uu} = 8.49 \cdot k$

Worst Case Distributed Loads — $w_d := \frac{2P_{ud}}{L}$ $w_d = 4.259 \cdot \frac{k}{ft}$ $w_u := \frac{2P_{uu}}{L}$ $w_u = 0.771 \cdot \frac{k}{ft}$

E. Diagrams and Design Forces (continued)

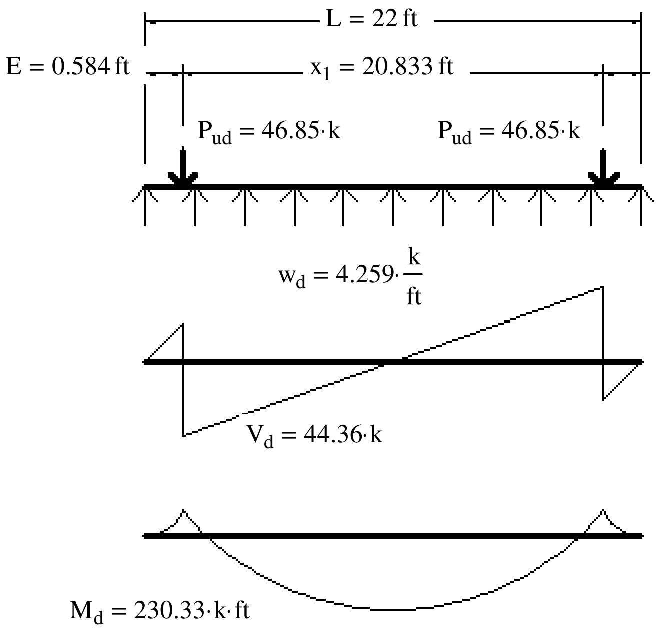
Distance Between Columns $x_1 := \text{if}(\text{Load}_{type} = 1, L, x_1)$ $x_1 = 20.833\,\text{ft}$

Edge Distance of Columns $E := \text{if}[\text{Load}_{type} = 1, 0 \cdot \text{ft}, .5 \cdot (L - x_1)]$ $E = 0.584\,\text{ft}$

1. Distance from Edge (for Linear Loading)
2. Distance from Center Line (for Columns)

$D := \text{if}(\text{Load}_{type} = 1, d + P_W, d + .5P_W)$ $D = 1.542\,\text{ft}$

Gravity (Downward)



Max Shear $V_d := .5 \cdot (w_d \cdot x_1)$

Shear at D from Column

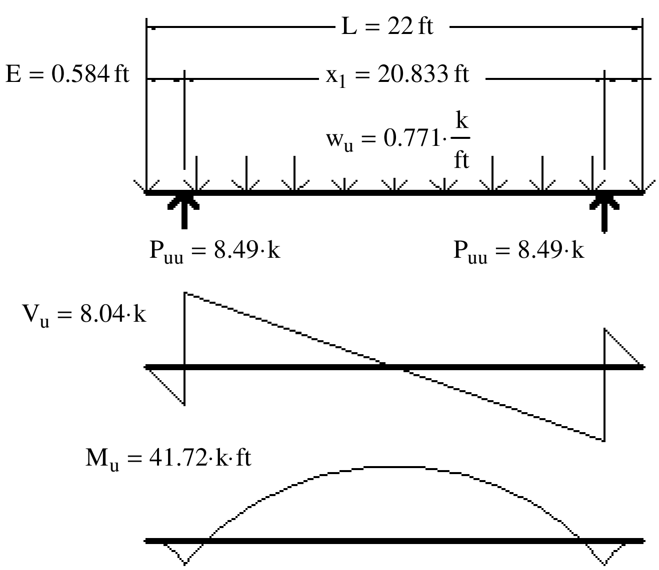
$$V_{ud} := \frac{(.5x_1 - D) \cdot V_d}{.5 \cdot x_1} \qquad V_{ud} = 37.8 \cdot k$$

Max Moment

$$M_d := \frac{x_1^2 \cdot w_d}{8} - \frac{E^2 \cdot w_d}{2}$$

$$M_d = 230.33 \cdot k \cdot ft$$

Uplift



Max Shear $V_u := .5 \cdot (w_u \cdot x_1)$

Shear at D from Column

$$V_{uu} := \frac{(.5x_1 - D) \cdot V_u}{.5 \cdot x_1} \qquad V_{uu} = 6.85 \cdot k$$

Max Moment

$$M_u := \frac{x_1^2 \cdot w_u}{8} - \frac{E^2 \cdot w_u}{2}$$

$$M_u = 41.72 \cdot k \cdot ft$$

Maximum Shear at D away from column $V_u := \max(V_{ud}, V_{uu})$ $V_u = 37.797 \cdot k$

Max Moment (Downward) $M_d = 230.328 \cdot k \cdot ft$ Max Moment (Uplift) $M_u = 41.721 \cdot k \cdot ft$

II. Check One Way Shear

A. Design Check For One Way Shear

Factored Shear Strength Provided By Concrete
(Calculated by Shear And Moment Diagrams above)
(Vu At d Away From Face Of Column/Base Plate)

$V_u = 37.797 \cdot k$

Nominal Shear Strength Provided By Concrete

$V_c := 2 \cdot \sqrt{f_c} \cdot B_{beam} \cdot d$

$V_c = 8215.8 \cdot ft \cdot lbf^{.5}$

$\phi \cdot V_c = 73.9 \cdot k$

$CodeCheck := if(\phi \cdot V_c \geq V_u, "OK", "NOT OK")$

$CodeCheck = "OK"$

III. Check Two Way Shear

A. Design Check For Two Way Shear

$V_u = 37.797 \cdot k$

$.5d = 7.5 \cdot in$

$P_{eW} := if(P_{eW} < .5d, P_{eW}, .5d)$ $P_{eW} = 4.5 \cdot in$

$P_{eL} := if(P_{eL} < .5d, P_{eL}, .5d)$ $P_{eL} = 3.5 \cdot in$

Length Of Critical Per. $b_o := (.5d + P_L + P_{eL}) + (.5d + P_W + P_{eW})$ $b_o = 42 \cdot in$

$V_u := (1.5 \cdot P_d) - (q_{net} \cdot 1.5) \cdot (.5d + P_L + P_{eL}) \cdot (.5d + P_W + P_{eW})$ $V_u = 40.4 \cdot k$

$P_L := \frac{P_L}{P_W}$ $P_L = 1.714$ $P_L := if(P_L < 2, 2, P_L)$ $P_L = 2$

$V_{c1} := \left(2 + \frac{4}{P_L}\right) \cdot \sqrt{f_c} \cdot b_o \cdot d$ $V_{c1} = 11502.2 \cdot ft \cdot lbf^{.5}$

$V_{c2} := 4 \cdot \sqrt{f_c} b_o \cdot d$ $V_{c2} = 11502.2 \cdot ft \cdot lbf^{.5}$

$V_c := if(V_{c1} > V_{c2}, V_{c2}, V_{c1})$ $V_c = 11502.2 \cdot ft \cdot lbf^{.5}$

$\phi \cdot V_c = 103.52 \cdot k$

$CodeCheck := if(\phi \cdot V_c \geq V_u, "OK", "NOT OK")$ $CodeCheck = "OK"$

IV. Design For Flexure Reinforcement (Downward Forces)

$$Ast_{reqd} := \left[\frac{\frac{M_d}{\phi_f}}{f_y \cdot \left(d - \frac{a}{2}\right)}\right]$$

Maximum Moment $M_d = 230.328 \cdot k \cdot ft$

$a := 2in$

$d := T - a$ $d = 16 \cdot in$

$Ast_{reqd} = 3.66 \cdot in^2$

$Ast_{min} := \rho \cdot B_{beam} \cdot T$ $Ast_{min} = 1.94 \cdot in^2$

$Ast_{reqd} := if\left(Ast_{reqd} > Ast_{min}, Ast_{reqd}, Ast_{min}\right)$ $Ast_{reqd} = 3.66 \cdot in^2$

Pick Steel That Meet Requirements (Top Steel)

Rebar Size (max #11 bar) $Bar := 6$ Strip Size $B_{beam} = 5\ ft$

Rebar Spacing
(must divide evenly into strip size) $Spacing := 6in$

$$Ast := \frac{B_{beam}}{Spacing} \cdot \begin{cases} \pi \cdot (.5 \cdot 1.41 \cdot in)^2 & \text{if } Bar = 11 \\ \pi \cdot (.5 \cdot 1.27 \cdot in)^2 & \text{if } Bar = 10 \\ \pi \cdot [(.5 \cdot 1.128) \cdot in]^2 & \text{if } Bar = 9 \\ \pi \cdot \left(.5 \frac{Bar \cdot in}{8}\right)^2 & \text{if } Bar \le 8 \end{cases}$$

$Ast = 4.42 \cdot in^2$

$CodeCheck := if\left(Ast > Ast_{reqd}, \text{"OK"}, \text{"NOT OK"}\right)$ $CodeCheck = \text{"OK"}$

$\phi M_n := \phi_f \cdot Ast \cdot f_y \cdot \left(d - \frac{a}{2}\right)$ $\phi M_n = 298.21 \cdot k \cdot ft$

$CodeCheck := if\left(\phi M_n > M_d, \text{"OK"}, \text{"NOT OK"}\right)$ $CodeCheck = \text{"OK"}$

V. Design For Flexure Reinforcement (Uplift)

Maximum Moment $M_u = 41.721 \cdot k \cdot ft$

$$Ast_{reqd} := \left[\frac{\frac{M_u}{\phi_f}}{f_y \cdot \left(d - \frac{a}{2} \right)} \right]$$

$a := 3in$

$d := T - a$ $\quad d = 15 \cdot in$

$Ast_{reqd} = 0.64 \cdot in^2$

$Ast_{min} := \rho \cdot B_{beam} \cdot T$ $\quad Ast_{min} = 1.94 \cdot in^2$

$Ast_{reqd} := if\left(Ast_{reqd} > Ast_{min}, Ast_{reqd}, Ast_{min}\right)$ $\quad Ast_{reqd} = 1.94 \cdot in^2$

Pick Steel That Meet Requirements (Bottom Steel)

Rebar Size (max #11 bar) $Bar := 4$ Strip Size $B_{beam} = 5\ ft$

Rebar Spacing
(must divide evenly into strip size) $Spacing := 6in$

$$Ast := \frac{B_{beam}}{Spacing} \cdot \begin{cases} \pi \cdot (.5 \cdot 1.41 \cdot in)^2 & \text{if } Bar = 11 \\ \pi \cdot (.5 \cdot 1.27 \cdot in)^2 & \text{if } Bar = 10 \\ \pi \cdot [(.5 \cdot 1.128) \cdot in]^2 & \text{if } Bar = 9 \\ \pi \cdot \left(.5 \frac{Bar \cdot in}{8} \right)^2 & \text{if } Bar \le 8 \end{cases}$$

$Ast = 1.96 \cdot in^2$

$CodeCheck := if\left(Ast > Ast_{reqd}, "OK", "NOT OK"\right)$ $\quad CodeCheck = "OK"$

$\phi M_n := \phi_f \cdot Ast \cdot f_y \cdot \left(d - \frac{a}{2} \right)$ $\quad \phi M_n = 119.3 \cdot k \cdot ft$

$CodeCheck := if\left(\phi M_n > M_u, "OK", "NOT OK"\right)$ $\quad CodeCheck = "OK"$

VI. Transverse Reinforcement

Less Critical Therefore Use Same As Longitudinal Because Mat Is Limited In Size

GRADE BEAM DESIGN - ANNEX

Order No:	FTE-816
Job Description:	WS-2
Location:	Niceville, FL
Completed By:	DWK
Date:	January 11, 2023

GENERAL INFORMATION - DATA ENTRY

Unfactored Load W/ Floor Slab Load	$P := 1.25\,\frac{k}{ft}$	
Unfactored Load W/O Floor Slab Load	$P_{ult} := 1k$	
Soil Bearing Pressure	$q_{all} := 1500psf$	
Strength Of Concrete	$f_c := 3000psi$	
Resistance Factor (Shear)	$\phi_s := 0.75\cdot\frac{\sqrt{lbf}}{in}$	
Resistance Factor (Bending)	$\phi_b := 0.90$	
Minimum Yield Stress	$f_y := 60000psi$	
Depth Of Footing (Assume On 1st Run)	$D := 1.5ft$	
Depth To Reinforcement	$d := D - 3in$	$d = 15\cdot in$
Area of Steel (Insert Value Calculated At The End Of The Sheet To Check Codes)	$A_{st} := .88in^2$	

STEP 1: Find Footing Width

Width Of Footing

$$B := \frac{P\cdot 1.6}{q_{all}} \qquad B = 16\cdot in \qquad B := 24in$$

STEP 2: Reinforcement Ratio

$$X_1 := 0.85 - \left(0.05\cdot\frac{f_c - 4000psi}{1000psi}\right) \qquad X_1 = 0.9 \qquad X_2 := 0.85$$

$$\beta_1 := \text{if}\left(f_c \le 4000psi, X_2, X_1\right) \qquad \beta_1 = 0.85$$

$$\beta_1 := \text{if}\left(\beta_1 \ge 0.65, \beta_1, .65\right) \qquad \beta_1 = 0.85$$

Reinforcement Ratio $\rho := \frac{A_{st}}{B \cdot d}$ $\rho = 0.0024$

$$\rho_{balanced} := \left(\frac{0.85 \cdot \beta_1 \cdot f_c}{f_y}\right) \cdot \left(\frac{87000psi}{87000psi + f_y}\right) \qquad \rho_{balanced} = 0.021$$

$$X_3 := \rho_{balanced} \cdot 0.75 \qquad X_3 = 0.016$$

$$CodeCheck := if(X_3 \geq \rho, \text{"OK"}, \text{"NOT BALANCED"}) \qquad CodeCheck = \text{"OK"}$$

$$X_4 := \frac{200 \cdot psi}{f_y} \qquad X_4 = 0.0033$$

$$CodeCheck := if(X_4 \leq \rho, \text{"OK"}, \text{"NOT BALANCED"}) \qquad CodeCheck = \text{"NOT BALANCED"}$$

OK because cont. supported

STEP 3: Check Wide-Beam Shear (Transverse Reinforced For Shear)

$$q_{ult} := \frac{P_{ult} \cdot 1.6}{B} \qquad q_{ult} = 800 \cdot \frac{lbf}{ft}$$

Length Of Wall $L := 1ft$

$$V_u := q_{ult} \cdot L \qquad V_u = 800 \cdot lbf$$

$$v_a := \frac{V_u}{L \cdot d} \qquad v_a = 4.444 \cdot psi$$

$$V_a := 2 \cdot \phi_s \cdot \sqrt{f_c} \qquad V_a = 82.16 \cdot psi$$

$$CodeCheck := if(V_a > v_a, \text{"OK"}, \text{"NOT OK"}) \qquad CodeCheck = \text{"OK"}$$

STEP 4: Required Reinforcement For Transverse Bending

$$M_u := \left[\phi_b \cdot A_s \cdot f_y \cdot \left(d - \frac{a \cdot A_s}{2}\right)\right]$$ expands to $$\frac{-\left(A_s^2 \cdot a \cdot \phi_b \cdot f_y\right)}{2} + A_s \cdot d \cdot \phi_b \cdot f_y - M_u := 0$$

Moment Arm $L_1 := 12in$

Ultimate Moment $M_u := q_{ult} \cdot \left(\frac{L_1^2}{2}\right)$ $M_u = 4800 \cdot lbf \cdot in$

Coefficient For a Value $a := \left(\frac{f_y}{0.85 \cdot f_c \cdot B}\right)$ $a = 0.98 \cdot \frac{1}{in}$

Coefficients For Equation To Solve For As

$X_1 := \frac{-a \cdot \phi_b \cdot f_y}{2}$ $X_2 := d \cdot \phi_b \cdot f_y$ $X_3 := -M_u$

$X_1 = -26471 \cdot \frac{lbf}{in^3}$ $X_2 = 810000 \cdot \frac{lbf}{in}$ $X_3 = -4800 \cdot lbf \cdot in$

$a := \frac{X_1}{X_1}$ $b := \frac{X_2}{X_1}$ $c := \frac{X_3}{X_1}$

$a = 1$ $b = -0.212\,ft^2$ $c = 8.745 \times 10^{-6}\,ft^4$

$a \cdot A_s^2 + b \cdot A_s + c := 0$

$A_{s1} := \frac{-b + \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a}$ $A_{s1} = 30.5941 \cdot in^2$

$A_{s2} := \frac{-b - \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a}$ $A_{s2} = 0.0059 \cdot in^2$

Choose The Reasonable Answer $As := 0.0059in^2$

Use (-) # - As=-.---

STEP 5: Check For Temperature & Shrinkage For Steel

$\rho_{min} := 0.0018$

$A_s := \rho_{min} \cdot d \cdot B$ $A_s = 0.648 \cdot in^2$

Use (2) # 6 As=0.88

Check Spacing Requirements Per 7.12.2.2

Spacing Every 18"

STEP 6: Select Longitudinal Steel

Base On The Reinforcement Ratio Of The Beam See Step #2 But A Continually Supported Beam So Therefore Use ρmin From Step 5 ρmin=0.0018 Which Governs Because There Is No Moment

Therefore Use (2) # 6 T&B As=1.72

GRADE BEAM DESIGN - FIRE ESCAPE

Order No:	FTE-816
Job Description:	WS-2
Location:	Niceville, FL
Completed By:	DWK
Date:	January 11, 2023

GENERAL INFORMATION - DATA ENTRY

Unfactored Load W/ Floor Slab Load — $P := 2\frac{k}{ft}$

Unfactored Load W/O Floor Slab Load — $P_{ult} := 1k$

Soil Bearing Pressure — $q_{all} := 1500psf$

Strength Of Concrete — $f_c := 3000psi$

Resistance Factor (Shear) — $\phi_s := 0.75\cdot\frac{\sqrt{lbf}}{in}$

Resistance Factor (Bending) — $\phi_b := 0.90$

Minimum Yield Stress — $f_y := 60000psi$

Depth Of Footing (Assume On 1st Run) — $D := 2ft$

Depth To Reinforcement — $d := D - 3in$ $\quad d = 21\cdot in$

Area of Steel (Insert Value Calculated At The End Of The Sheet To Check Codes) — $A_{st} := 1.84in^2$

STEP 1: Find Footing Width

Width Of Footing $\quad B := \frac{P\cdot 1.6}{q_{all}} \quad B = 25.6\cdot in \quad B := 48in$

STEP 2: Reinforcement Ratio

$$X_1 := 0.85 - \left(0.05\cdot\frac{f_c - 4000psi}{1000psi}\right) \quad X_1 = 0.9 \quad X_2 := 0.85$$

$$\beta_1 := if\left(f_c \le 4000psi, X_2, X_1\right) \quad \beta_1 = 0.85$$

$$\beta_1 := if\left(\beta_1 \ge 0.65, \beta_1, .65\right) \quad \beta_1 = 0.85$$

Reinforcement Ratio $\rho := \frac{A_{st}}{B \cdot d}$ $\rho = 0.0018$

$\rho_{balanced} := \left(\frac{0.85 \cdot \beta_1 \cdot f_c}{f_y}\right) \cdot \left(\frac{87000psi}{87000psi + f_y}\right)$ $\rho_{balanced} = 0.021$

$X_3 := \rho_{balanced} \cdot 0.75$ $X_3 = 0.016$

$CodeCheck := if\left(X_3 \geq \rho, "OK", "NOT BALANCED"\right)$ $CodeCheck = "OK"$

$X_4 := \frac{200 \cdot psi}{f_y}$ $X_4 = 0.0033$

$CodeCheck := if\left(X_4 \leq \rho, "OK", "NOT BALANCED"\right)$ $CodeCheck = "NOT BALANCED"$

OK because cont. supported

STEP 3: Check Wide-Beam Shear (Transverse Reinforced For Shear)

$q_{ult} := \frac{P_{ult} \cdot 1.6}{B}$ $q_{ult} = 400 \cdot \frac{lbf}{ft}$

Length Of Wall $L := 1ft$

$V_u := q_{ult} \cdot L$ $V_u = 400 \cdot lbf$

$v_a := \frac{V_u}{L \cdot d}$ $v_a = 1.587 \cdot psi$

$V_a := 2 \cdot \phi_s \cdot \sqrt{f_c}$ $V_a = 82.16 \cdot psi$

$CodeCheck := if\left(V_a > v_a, "OK", "NOT OK"\right)$ $CodeCheck = "OK"$

STEP 4: Required Reinforcement For Transverse Bending

$M_u := \left[\phi_b \cdot A_s \cdot f_y \cdot \left(d - \frac{a \cdot A_s}{2}\right)\right]$ expands to $\frac{-\left(A_s^2 \cdot a \cdot \phi_b \cdot f_y\right)}{2} + A_s \cdot d \cdot \phi_b \cdot f_y - M_u := 0$

Moment Arm $L_1 := 12in$

Ultimate Moment $M_u := q_{ult} \cdot \left(\frac{L_1^2}{2}\right)$ $M_u = 2400 \cdot lbf \cdot in$

Coefficient For a Value $a := \left(\frac{f_y}{0.85 \cdot f_c \cdot B}\right)$ $a = 0.49 \cdot \frac{1}{in}$

Coefficients For Equation To Solve For As

$X_1 := \frac{-a \cdot \phi_b \cdot f_y}{2}$ $X_2 := d \cdot \phi_b \cdot f_y$ $X_3 := -M_u$

$X_1 = -13235 \cdot \frac{lbf}{in^3}$ $X_2 = 1134000 \cdot \frac{lbf}{in}$ $X_3 = -2400 \cdot lbf \cdot in$

$a := \frac{X_1}{X_1}$ $b := \frac{X_2}{X_1}$ $c := \frac{X_3}{X_1}$

$a = 1$ $b = -0.595\, ft^2$ $c = 8.745 \times 10^{-6}\, ft^4$

$a \cdot A_s^2 + b \cdot A_s + c := 0$

$A_{s1} := \frac{-b + \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a}$ $A_{s1} = 85.6779 \cdot in^2$

$A_{s2} := \frac{-b - \sqrt{b^2 - 4 \cdot a \cdot c}}{2 \cdot a}$ $A_{s2} = 0.0021 \cdot in^2$

Choose The Reasonable Answer $As := 0.0021 in^2$

Use (-) # - As=-.---

STEP 5: Check For Temperature & Shrinkage For Steel

$\rho_{min} := 0.0018$

$A_s := \rho_{min} \cdot d \cdot B$ $A_s = 1.814 \cdot in^2$

Use (6) # 5 As=1.84

Check Spacing Requirements Per 7.12.2.2

Spacing Every 8"

STEP 6: Select Longitudinal Steel

Base On The Reinforcement Ratio Of The Beam See Step #2 But A Continually Supported Beam So Therefore Use ρmin From Step 5 ρmin=0.0018 Which Governs Because There Is No Moment

Therefore Use (6) # 5 T&B As=3.68