PILE FOOTING DESIGN

Number of load cases = $na := 5$ $n := 0..\ na - 1$ $As := 1$

Max load per pile (k) = $pmax := 110$

Strength of materials (psi) = $fc := 3$ $fy := 60$

Max cover for bars on bottom of ftg = $cover := 3$

Bar ddiameter for Preliminary calculations (in) = $bd := 1.0$ $stirrupd := bd$ $dcolbar := bd$

Max column dimension (in) = $columnd := 36$

Bend radius (in) = $bendrad := 1$

Unit weight of concrete (kcf) = $\lambda c := 0.150$

Long. column dimension (ft) = $DL := 3$

If column is round set DL = DT

Trans. column dimension (ft) = $DT := 3$

Is column round or square (1 for round 2 for square) $type := 2$

Applied loads (k*ft) =

SL := READPRN("sl_foot.prn") LD := READPRN("ld_foot.prn")

Service LD

$$SL = \begin{pmatrix} 983.5 & 1372 & 2505 \\ 1070 & 879.5 & 2928 \\ 925.9 & 538.6 & 1802 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

Load factor

$$LD = \begin{pmatrix} 1415 & 1165 & 3942 \\ 1300 & 932.7 & 3041 \\ 910.6 & 1579 & 537.9 \\ 1043 & 161.1 & 0 \\ 1300 & 1702 & 3331 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$P2 := LD^{\langle 0 \rangle}$ $P := SL^{\langle 0 \rangle}$

$MT2 := LD^{\langle 1 \rangle}$ $MT := SL^{\langle 1 \rangle}$

$ML2 := LD^{\langle 2 \rangle}$ $ML := SL^{\langle 2 \rangle}$

Approximate footing dimensions

Length and width: T is along the CL. of bent. First estimate using the max applied "P" load and divide it by the max allowable bearing pressure, and take the square root of it and add one.

The following formula will approximate the number of piles based on a perfectly square footing with a 1.5 ft edge distance and a 3 ft pile spacing. This formula is large, so I have hidden it. If you want to see the formula expand the area below. It is just an estimate anyway.

Estimated Number of rows and columns = (based on moment and axial) $p1 = 6$

Estimate based on Axial load and momnet = $est1 := p1 \cdot p1$ $est1 = 36$

Estimate based on pure axial = $est2 := \text{floor}\left(\frac{\max\left(SL^{\langle 0 \rangle}\right)}{pmax}\right) + 1$ $est2 = 10$

Controlling estimate = $est := \max(est1, est2)$ $est = 36$

Approx footing dimensions using 2.5 ft pile spacing and 1.5 corner disance = $p2 := (p1 - 1) \cdot 2.5 + 3$

APPROXIMATE LENGTH AND WIDTH (ft) = $p2 = 15.5$

Depth: The minimum depth shall be the larger of the (development length + 2*bd*cover) and the minimum embedment length

Development length (in) = $develop := 1200 \cdot \frac{bd}{\sqrt{(fc \cdot 1000)}} + 2 \cdot bd + cover$ $develop = 26.909$

Calculate the required depth based on punching shear of one pile in the corner that is loaded to its capacity.

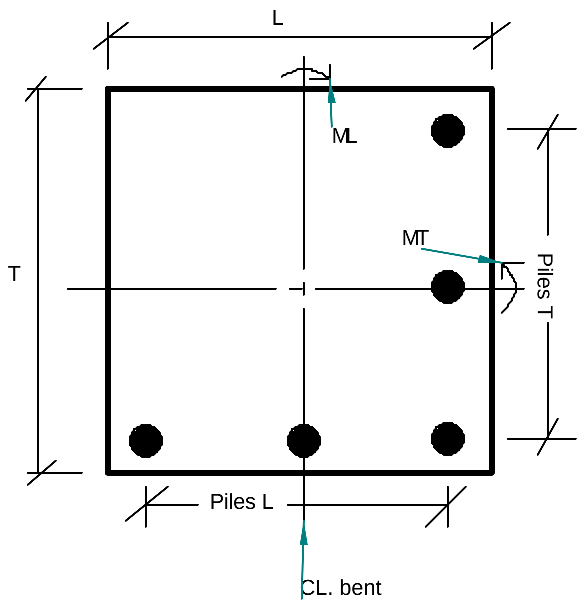
$$d1 := \begin{array}{l} \text{for } j \in 12..144 \\ \quad \begin{array}{|l} j1 \leftarrow j - 3 - 1.5 \\ j2 \leftarrow \left[18 + \left(\frac{j1}{2}\right)\right] \cdot 2 \\ j3 \leftarrow \frac{pmax \cdot 1000}{0.85 \cdot j2 \cdot j1} \\ j5 \leftarrow 1.8 \cdot \sqrt{fc \cdot 1000} \\ (\text{break}) \cdot (j4 \leftarrow j) \text{ if } j5 > j3 \\ \text{continue} \quad \text{otherwise} \end{array} \\ j \end{array}$$

$d1 = 27$

$\frac{d1}{12} = 2.25$

Footing Depth to use (ft) = $D := 5.0$

ACTUAL NUMBER OF PILES TO USE (INPUT BY USER)



Pile spacing = $s1 := 2.5$

Edge distance = $edge := 1.5$

Piles T = $piles\_T := 5$

Piles L = $piles\_L := 5$

Transverse Footing dimension (ft) =

$T := (piles\_T - 1) \cdot s1 + edge \cdot 2$ $T = 13$

Longitudinal Footing dimension (ft) =

$L := (piles\_L - 1) \cdot s1 + edge \cdot 2$ $L = 13$

Total number of piles = $piles := piles\_T \cdot piles\_L$

$piles = 25$

Additional P load due to footing

$Pa := \frac{L \cdot T \cdot D \cdot \lambda c}{piles}$ $Pa = 5.07$

Constants

$T = 13$ ft $L = 13$ ft $D = 5$ ft

Footing Area (ft^2) = $A := T \cdot L$ $A = 169$

Distance from Longitudinal footing axis to last pile (ft) = $CT := \frac{T}{2} - edge$ $CT = 5$

Distance from Transverse footing axis to last pile (ft) = $CL := \frac{L}{2} - edge$ $CL = 5$

Footing Inertia

Location of pile rows relative to Transverse axis

$a1 := \text{ceil}\left(\frac{piles\_L}{2}\right)$ $a1 = 3$ $n1 := 0..a1-1$

$a2_{n1} := \begin{vmatrix} n1 \cdot s1 + \frac{s1}{2} & \text{if } a1 = \frac{piles\_L}{2} \\ n1 \cdot s1 & \text{otherwise} \end{vmatrix}$ $a2 = \begin{pmatrix} 0 \\ 2.5 \\ 5 \end{pmatrix}$

Location of pile rows relative to Longitudinal axis

$b1 := \text{ceil}\left(\frac{piles\_T}{2}\right)$ $b1 = 3$ $n2 := 0..b1-1$

$b2_{n2} := \begin{vmatrix} n2 \cdot s1 + \frac{s1}{2} & \text{if } b1 = \frac{piles\_T}{2} \\ n2 \cdot s1 & \text{otherwise} \end{vmatrix}$ $b2 = \begin{pmatrix} 0 \\ 2.5 \\ 5 \end{pmatrix}$

Inertia used in transverse moment calculations =

$d2 := piles\_L \cdot 2 \cdot b2^2$ $d2 = \begin{pmatrix} 0 \\ 62.5 \\ 250 \end{pmatrix}$

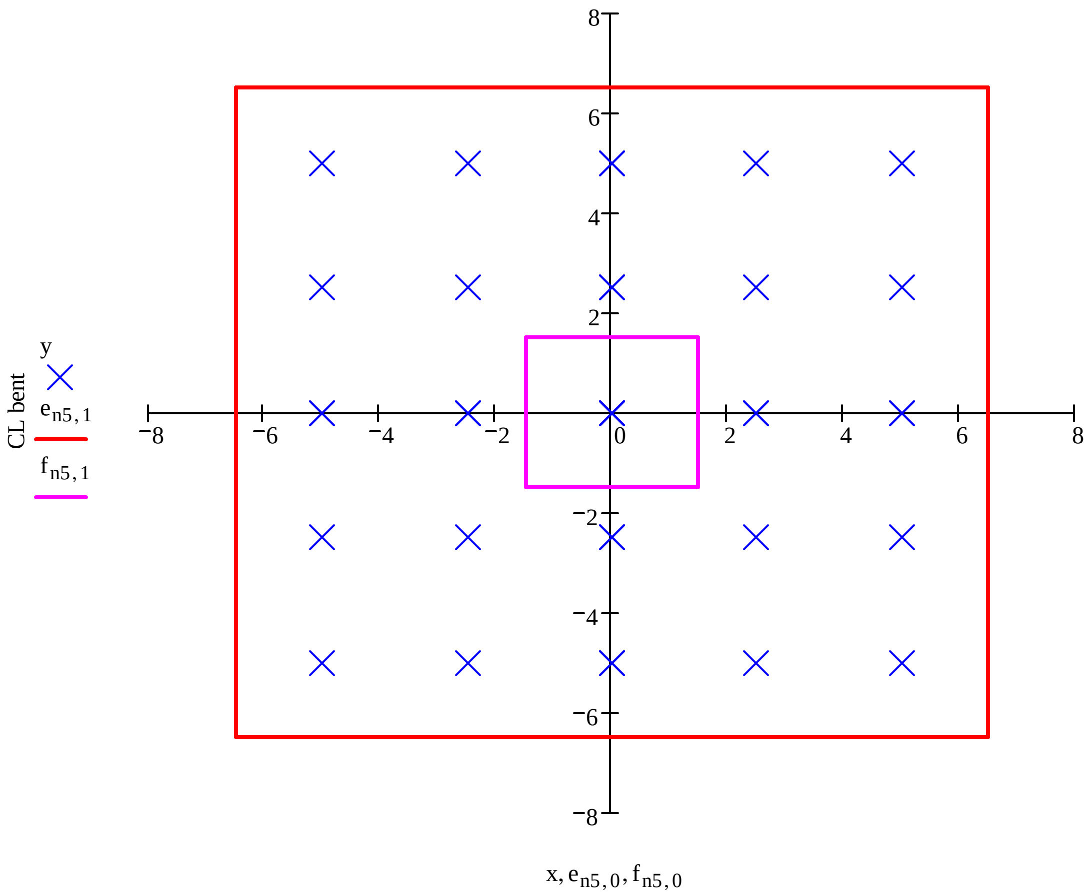
$IT := \sum_{n2} d2_{n2}$ $IT = 312.5$

Inertia used in longitudinal moment calculations =

$c2 := piles\_T \cdot 2 \cdot a2^2$ $c2 = \begin{pmatrix} 0 \\ 62.5 \\ 250 \end{pmatrix}$

$IL := \sum_{n1} c2_{n1}$ $IL = 312.5$

FOOTING DIAGRAM (NOT TO SCALE)



Pile Forces at the extreme corner piles

Max Pile (k) =

$$PmaxSL_n := \frac{P_n}{piles} + Pa + \frac{MT_n \cdot CT}{IT} + \frac{ML_n \cdot CL}{IL}$$

$$PmaxSL = \begin{pmatrix} 106.442 \\ 108.79 \\ 79.556 \\ 5.07 \\ 5.07 \end{pmatrix}$$

$$\max(PmaxSL) = 108.79$$

Min Pile (k) =

$$PminSL_n := \frac{P_n}{piles} + Pa - \frac{MT_n \cdot CT}{IT} - \frac{ML_n \cdot CL}{IL}$$

$$PminSL = \begin{pmatrix} -17.622 \\ -13.05 \\ 4.656 \\ 5.07 \\ 5.07 \end{pmatrix}$$

$$\min(PminSL) = -17.622$$

Negative ML corner (k) =

$$PnMLSL_n := \frac{P_n}{piles} + Pa + \frac{MT_n \cdot CT}{IT} - \frac{ML_n \cdot CL}{IL}$$

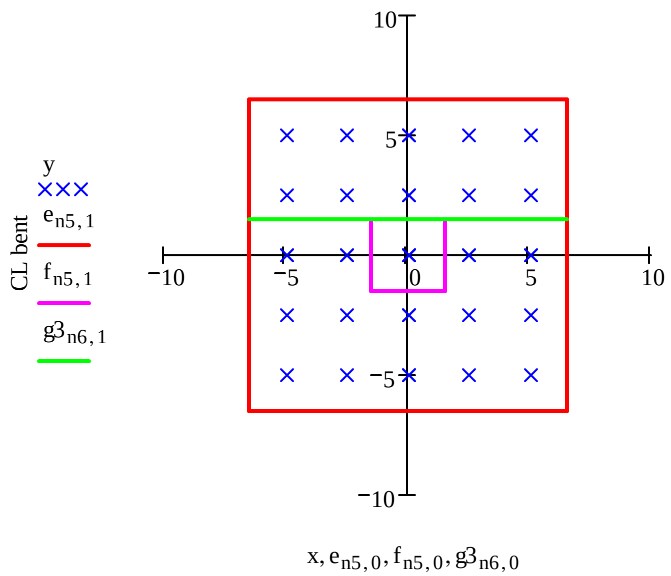
$$PnMLSL = \begin{pmatrix} 26.282 \\ 15.094 \\ 21.892 \\ 5.07 \\ 5.07 \end{pmatrix}$$

Negative MT corner (k) =

$$PnMTSL_n := \frac{P_n}{piles} + Pa - \frac{MT_n \cdot CT}{IT} + \frac{ML_n \cdot CL}{IL}$$

$$PnMTSL = \begin{pmatrix} 62.538 \\ 80.646 \\ 62.32 \\ 5.07 \\ 5.07 \end{pmatrix}$$

Transverse Moment Reinforcement



Number of rows of piles creating transverse moment =

$$m1 := \text{ceil}\left(\frac{\frac{T}{2} - edge - \frac{DT}{2}}{s1}\right) \qquad m1 = 2 \qquad m1a := 0 .. m1 - 1$$

Distance to each row of piles (ft) = (from f.f. column)

$$m2_{m1a} := \left| \begin{array}{l} \text{for } j \in 0 .. m1 - 1 \\ \quad j1_j \leftarrow \frac{T}{2} - edge - j \cdot s1 - \frac{DT}{2} \\ j1_{m1a} \end{array} \right. \qquad m2 = \begin{pmatrix} 3.5 \\ 1 \end{pmatrix}$$

P load on each row of piles (k) =

$$m3_{m1a,n} := \frac{P2_n}{piles} + Pa \cdot 1.25 + \frac{MT2_n \cdot \left(m2_{m1a} + \frac{DT}{2}\right)}{IT}$$

$$m3 = \begin{pmatrix} 81.578 & 73.261 & 68.025 & 50.635 & 85.57 \\ 72.257 & 65.799 & 55.393 & 49.346 & 71.953 \end{pmatrix}$$

Moment for each row (k*ft) = (include number of piles here)

$$m4_{m1a,n} := m3_{m1a,n} \cdot m2_{m1a} \cdot piles\_L$$

$$m4 = \begin{pmatrix} 1427.606 & 1282.062 & 1190.446 & 886.114 & 1497.466 \\ 361.287 & 328.995 & 276.967 & 246.731 & 359.767 \end{pmatrix}$$

Total moment in each row (k*ft) = $m5_n := \sum_{m1a} m4_{m1a,n}$ $m5 = \begin{pmatrix} 1788.894 \\ 1611.058 \\ 1467.414 \\ 1132.846 \\ 1857.234 \end{pmatrix}$

Effective depth (in) = $d := D \cdot 12 - cover - 1.5 \cdot bd - 12$ $d = 43.5$

Design moment is max of all cases (k*ft) = $MuT := max\left(m5^{\langle 0 \rangle}\right)$ $MuT = 1857.234$

$AsTa := 0$

Required area of steel (in^2) = $AsTa := root\left[0.9 \cdot AsTa \cdot fy \cdot \left(d - \frac{AsTa \cdot fy}{1.7 \cdot fc \cdot L \cdot 12}\right) - MuT \cdot 12, AsTa\right]$

$AsTa = 9.649$

Increase required by 4/3 to = take care of cracking $AsT := AsTa \cdot \frac{4}{3}$ $AsT = 12.866$

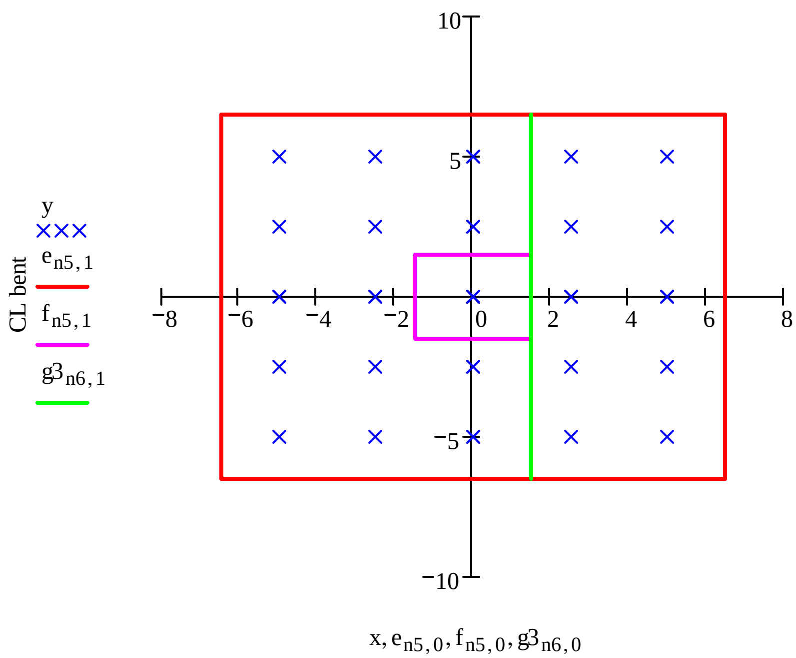
BAR PATTERN REQUIRMENTS $n8 := 0..6$

$barsT := \begin{pmatrix} 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \end{pmatrix}$ $AsoneT := \begin{pmatrix} 0.31 \\ 0.44 \\ 0.60 \\ 0.79 \\ 1.0 \\ 1.27 \\ 1.56 \end{pmatrix}$ $nbarsT_{n8} := floor\left(\frac{AsT}{AsoneT_{n8}}\right) + 1$ $SbarsT_{n8} := \frac{L \cdot 12 - 12}{nbarsT_{n8} - 1}$

Bar pattern for size of bars, number of bars, and relative spacing.

$barsT = \begin{pmatrix} 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \end{pmatrix}$ $nbarsT = \begin{pmatrix} 42 \\ 30 \\ 22 \\ 17 \\ 13 \\ 11 \\ 9 \end{pmatrix}$ $SbarsT = \begin{pmatrix} 3.512 \\ 4.966 \\ 6.857 \\ 9 \\ 12 \\ 14.4 \\ 18 \end{pmatrix}$

Longitudinal Moment Reinforcement



Number of rows of piles creating transverse moment = $p1 := \mathrm{ceil}\left(\dfrac{\frac{L}{2} - edge - \frac{DL}{2}}{s1}\right)$ $p1 = 2$ $p1a := 0..\, p1 - 1$

Distance to each row of piles (ft) = (from f.f. column)

$$p2_{p1a} := \left| \begin{array}{l} \text{for } j \in 0..\, p1-1 \\ \quad j1_j \leftarrow \frac{L}{2} - edge - j \cdot s1 - \frac{DL}{2} \\ j1_{p1a} \end{array} \right.$$

$$p2 = \begin{pmatrix} 3.5 \\ 1 \end{pmatrix}$$

P load on each row of piles (k) =

$$p3_{p1a,n} := \frac{P2_n}{piles} + Pa \cdot 1.25 + \frac{ML2_n \cdot \left(p2_{p1a} + \frac{DL}{2}\right)}{IL}$$

$$p3 = \begin{pmatrix} 126.01 & 106.993 & 51.368 & 48.057 & 111.633 \\ 94.474 & 82.665 & 47.065 & 48.057 & 84.986 \end{pmatrix}$$

Moment for each row (k*ft) = (include number of piles here)

$$p4_{p1a,n} := p3_{p1a,n} \cdot p2_{p1a} \cdot piles\_T$$

$$p4 = \begin{pmatrix} 2205.166 & 1872.386 & 898.938 & 841.006 & 1953.586 \\ 472.368 & 413.327 & 235.324 & 240.287 & 424.928 \end{pmatrix}$$

Total moment in each row (k*ft) = $p5_n := \sum_{p1a} p4_{p1a,n}$ $p5 = \begin{pmatrix} 2677.534 \\ 2285.714 \\ 1134.262 \\ 1081.294 \\ 2378.514 \end{pmatrix}$

Design moment is max of all cases (k*ft) = $MuL := max\left(p5^{\langle 0 \rangle}\right)$ $MuL = 2677.534$

$AsLa := 0$

Required area of steel (in^2) = $AsLa := root\left[0.9 \cdot AsLa \cdot fy \cdot \left(d - \frac{AsLa \cdot fy}{1.7 \cdot fc \cdot T \cdot 12}\right) - MuL \cdot 12, AsLa\right]$

$AsLa = 14.019$

Increase required by 4/3 =
to take care of cracking $AsL := AsLa \cdot \frac{4}{3}$ $AsL = 18.692$

BAR PATTERN REQUIRMENTS $n8 := 0..6$

$barsL := \begin{pmatrix} 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \end{pmatrix}$ $AsoneL := \begin{pmatrix} 0.31 \\ 0.44 \\ 0.60 \\ 0.79 \\ 1.0 \\ 1.27 \\ 1.56 \end{pmatrix}$ $nbarsL_{n8} := floor\left(\frac{AsL}{AsoneL_{n8}}\right) + 1$ $SbarsL_{n8} := \frac{T \cdot 12 - 12}{nbarsL_{n8} - 1}$

Bar pattern for size of bars,
number of bars, and
relative spacing.

$barsL = \begin{pmatrix} 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \end{pmatrix}$ $nbarsL = \begin{pmatrix} 61 \\ 43 \\ 32 \\ 24 \\ 19 \\ 15 \\ 12 \end{pmatrix}$ $SbarsL = \begin{pmatrix} 2.4 \\ 3.429 \\ 4.645 \\ 6.261 \\ 8 \\ 10.286 \\ 13.091 \end{pmatrix}$

Shear Checks

LRFD 5.13.3.6; In determining the shear resistance of slabs and footings in the vicinity of concentrated loads or reaction forces, the more critical of the following conditions shall govern:

1. One was action, with a critical section extending in a plane across the entire width and located at a distance taken as specified in LRFD 5.8.3.2
2. Two-way action, with a critical section perpendicular to the plane of the slab and located so that its perimeter, bo, is a minimum but not closer than 0.5dv to the perimeter of the concentrated load or reaction area.

LRFD 5.8.3.2 Critical section

The location of the critical section for shear shall be taken as the larger of 0.5dv*cotθ or dv from the internal face of support. Since this is a non-prestressed section the value of dv will always govern, I shall therefore use dv from the face of support.

LRFD 5.13.3.6.2 One way action

For one-was action, the shear resistance of the footing or slab shall satisfy the requirements specified in article 5.8.3.

LRFD 5.8.3.3 Shear capacity for one way action

If Vn < Vc no stirrups are required.

$$Vc = 0.0316\beta\cdot\sqrt{fc}\cdot bv\cdot dv$$

LRFD 5.13.3.6.3 Two-Way Action

For two-way action for sections without transverse reinforcement, the nominal shear resistance, Vn i Kip, of the concrete shall be taken as:

$$Vm = \left(0.063 + \frac{0.126}{\beta c}\right)\cdot\sqrt{fc}\cdot bo\cdot dv \le 0.126\cdot\sqrt{fc}\cdot bo\cdot dv$$

βc = ratio of long side to short side of the rectangle through wiich the concentrated load or reaction force is transmitted.
bo = the perimeter of the critical section
dv = effective shear depth

ONE WAY SHEAR: Check Longitudinal Line at d from face

Calculate "d" assuming no. 8 bars $dvL := d - \frac{AsL \cdot fy}{1.7 \cdot fc \cdot L \cdot 12}$ $dvL = 42.09$

Distance from CL. footing to edge of shear plane (ft) = $g1 := \frac{DT}{2} + \frac{dvL}{12}$ $g1 = 5.008$

Is the shear plane past the piles = (if YES then no adjustment is necessary, otherwise adjust)

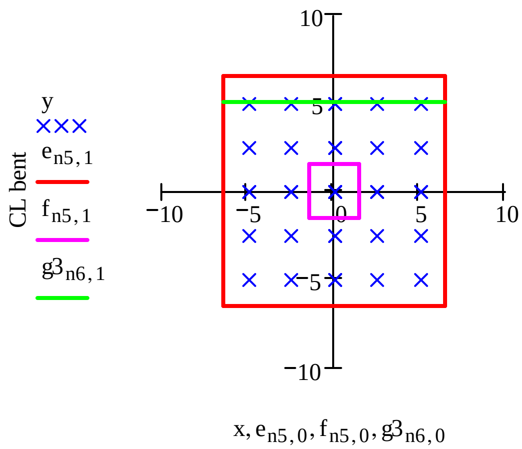
$$g2 := \begin{cases} \text{"YES"} & \text{if } g1 > \frac{T}{2} - edge \\ \text{"NO"} & \text{otherwise} \end{cases}$$

$g2 = \text{"YES"}$

If NO then suggested footing depth to take care of it

$$g4 := \begin{cases} \text{"OK"} & \text{if } g2 = \text{"YES"} \\ (CT - g1) + D & \text{otherwise} \end{cases}$$

$g4 = \text{"OK"}$



Allowable shear force = $VcL := 0.0316 \cdot 2 \cdot \sqrt{fc} \cdot L \cdot 12 \cdot dvL$

$VcL = 718.761$

Applied shear force (k) =

$$g5a_{n,n6} := \begin{array}{|l} j1_n \leftarrow 0 \\ j \leftarrow ceil\left(\frac{CT - g1}{2.5}\right) \\ \text{for } j2 \in 0..j-1 \\ \quad j1_{n,0} \leftarrow \left[\frac{P2_n}{piles} + Pa + \frac{MT2_n \cdot (CT - j2 \cdot s1)}{IT}\right] \cdot piles\_L \cdot g6a + j1_n \end{array}$$

$$g5a = \begin{pmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{pmatrix}$$

Check

$$g5_{n,n6} := \begin{cases} \text{"OK"} & \text{if } (g4 = \text{"OK"}) + (VcL > g5a_{n,n6}) \\ \text{"NG"} & \text{otherwise} \end{cases}$$

$$g5 = \begin{pmatrix} \text{"OK"} & \text{"OK"} \\ \text{"OK"} & \text{"OK"} \\ \text{"OK"} & \text{"OK"} \\ \text{"OK"} & \text{"OK"} \\ \text{"OK"} & \text{"OK"} \end{pmatrix}$$

ONE WAY SHEAR: Check Transverse Line at d from face

Calculate "d" assuming no. 8 bars $dvT := d - \frac{AsT \cdot fy}{1.7 \cdot fc \cdot T \cdot 12}$ $dvT = 42.53$

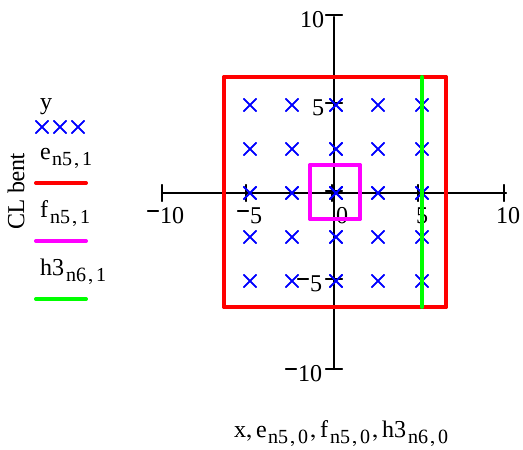
Distance from CL. footing to edge of shear plane (ft) = $h1 := \frac{DL}{2} + \frac{dvT}{12}$ $h1 = 5.044$

Is the shear plane past the piles = (if YES then no adjustment is necessary, otherwise adjust)

$h2 := \begin{cases} \text{"YES"} & \text{if } h1 > \frac{L}{2} - edge \\ \text{"NO"} & \text{otherwise} \end{cases}$ $h2 = \text{"YES"}$

If NO then suggested footing depth to take care of it

$h4 := \begin{cases} \text{"OK"} & \text{if } h2 = \text{"YES"} \\ (CL - h1) + D & \text{otherwise} \end{cases}$ $h4 = \text{"OK"}$



Allowable shear force = $VcT := 0.0316 \cdot 2 \cdot \sqrt{fc} \cdot L \cdot 12 \cdot dvT$

$VcT = 726.265$

Applied shear force (k) =

$$h5a_{n,n6} := \left| \begin{array}{l} j1_n \leftarrow 0 \\ j \leftarrow ceil\left(\frac{CL - h1}{2.5}\right) \\ \text{for } j2 \in 0..j-1 \\ \quad j1_{n,0} \leftarrow \left[\frac{P2_n}{piles} + Pa + \frac{ML2_n \cdot (CL - j2 \cdot s1)}{IL}\right] \cdot piles\_T \cdot h6a + j1_n \end{array} \right.$$

$$h5a = \begin{pmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{pmatrix}$$

Check

$$h5_{n,n6} := \begin{cases} \text{"OK"} & \text{if } (h4 = \text{"OK"}) + \left(VcT > h5a_{n,n6}\right) \\ \text{"NG"} & \text{otherwise} \end{cases}$$

$$h5 = \begin{pmatrix} \text{"OK"} & \text{"OK"} \\ \text{"OK"} & \text{"OK"} \\ \text{"OK"} & \text{"OK"} \\ \text{"OK"} & \text{"OK"} \\ \text{"OK"} & \text{"OK"} \end{pmatrix}$$

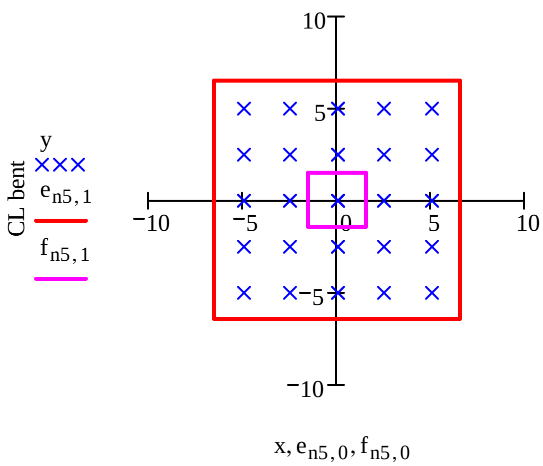
$n7 := 0..4 \cdot (a1 \cdot b1) - 1$

Two way shear at d/2

Effective shear depth to luse (in) = $dv := (dvL + dvT)\cdot 0.5$ $dv = 42.31$

Define shear plane (in) =
$$bo := \begin{cases} \left[\pi\cdot\left(DL\cdot 12 + \frac{dv}{2}\cdot 2\right)\right] & \text{if } type = 1 \\ (DL\cdot 12 + dv)\cdot 2 + (DT\cdot 12 + dv)\cdot 2 & \text{otherwise} \end{cases}$$
$bo = 313.24$

Number of piles outiste the shear plane = $k = 16$
(too see how this was determined
expand the area above)



Additional load per pile from self weight (k) = $Pa = 5.07$

Applied Shearing force (k) = $P\_2way_n := k\cdot\left(\frac{P2_n}{piles} + Pa\cdot 1.25\right)$

$$P\_2way = \begin{pmatrix} 1007 \\ 933.4 \\ 684.184 \\ 768.92 \\ 933.4 \end{pmatrix}$$

Allowable shear (k) =

$$Vc2 := \begin{vmatrix} \beta c \leftarrow \dfrac{\max\left(\begin{pmatrix} DL \\ DT \end{pmatrix}\right)}{\min\left(\begin{pmatrix} DL \\ DT \end{pmatrix}\right)} \\ j1 \leftarrow \left(0.063 + \dfrac{0.126}{\beta c}\right)\cdot\sqrt{fc}\cdot bo\cdot dv \\ j2 \leftarrow 0.126\cdot\sqrt{fc}\cdot bo\cdot dv \\ \min\left(\begin{pmatrix} j1 \\ j2 \end{pmatrix}\right) \end{vmatrix}$$

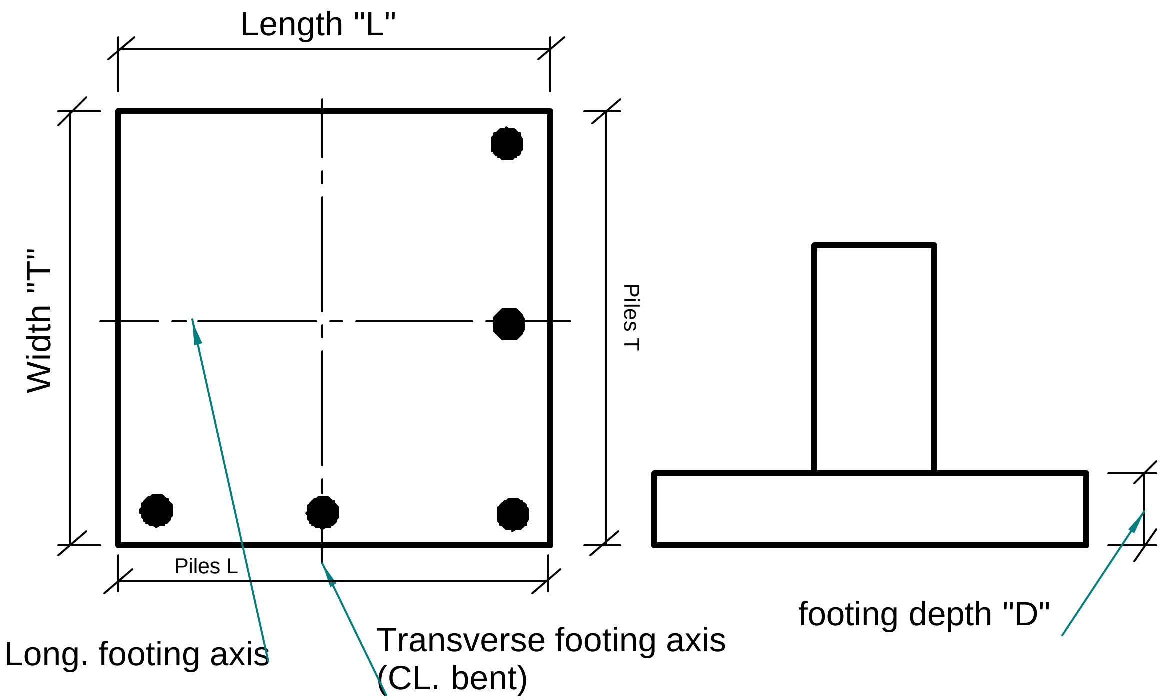
$Vc2 = 2892.358$

Check

$$vu\_2way_n := \begin{cases} \text{"OK"} & \text{if } P\_2way_n < Vc2 \\ \text{"NG"} & \text{otherwise} \end{cases}$$

$$vu\_2way = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \\ \text{"OK"} \\ \text{"OK"} \\ \text{"OK"} \end{pmatrix}$$

SUMMARY



$L = 13$

$T = 13$

$D = 5$

Required Reinforcing for theTransverse Moment

$$barsT = \begin{pmatrix} 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \end{pmatrix} \quad nbarsT = \begin{pmatrix} 42 \\ 30 \\ 22 \\ 17 \\ 13 \\ 11 \\ 9 \end{pmatrix} \quad SbarsT = \begin{pmatrix} 3.512 \\ 4.966 \\ 6.857 \\ 9 \\ 12 \\ 14.4 \\ 18 \end{pmatrix}$$

Required Reinforcing for the Longitudinal Moment

$$barsL = \begin{pmatrix} 5 \\ 6 \\ 7 \\ 8 \\ 9 \\ 10 \\ 11 \end{pmatrix} \quad nbarsL = \begin{pmatrix} 61 \\ 43 \\ 32 \\ 24 \\ 19 \\ 15 \\ 12 \end{pmatrix} \quad SbarsL = \begin{pmatrix} 2.4 \\ 3.429 \\ 4.645 \\ 6.261 \\ 8 \\ 10.286 \\ 13.091 \end{pmatrix}$$