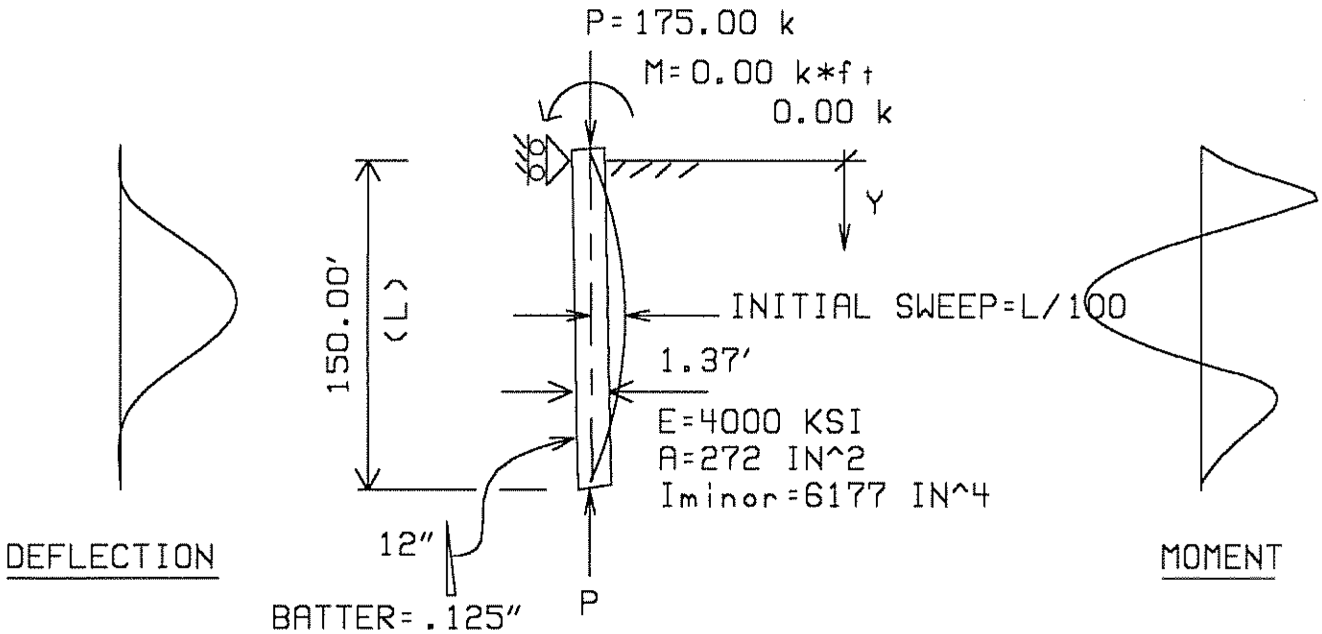
FIRM:DesignCalcs, Inc. JOB NO.123 SHEET NO: 1
MADE BY:KJH DATE:10-07-2014 CHECKED BY: DATE:
TITLE:Example PILEBUCL calculation

PILE BUCKLING ANALYSIS:



Theory:

The following program performs a non-linear analysis of an end bearing pile. No skin friction is assumed. The pile is modeled as a 51 node finite element model with lateral springs, as explained on the following sheet.

The user has input an initial imperfection in pile straightness based on an initial tolerance of,

X_0 = 12*150.00 ft/100 = 18.000 inch at mid-depth

The initial location of each of the nodes is assumed to be in the shape of a sin wave,

$X = Batter*Y + X_0 * Sin(\pi*Y/L)$

The solution is iterated to account for P effects using the "Newton-Raphson Method" (refer to "Stability Design of Steel Frames by Chen and Lui", p. 187). 20 iterations are used.

DESIGNER NOTE: This program does not check stresses in the pile. Please verify pile capacity using appropriate M-P strength curves.

PILE BUCKLING ANALYSIS:

Theory (Cont'd)

The program models the soil as a series of springs. Spring constants are based on the concept of a subgrade modulus. The choice of spring spring constant is derived using a method suggested by J.E. Bowles ("Foundation Analysis and Design", 1988):

Assuming that for a spread footing the soil displaces vertically by roughly 1 inch at qult,

ks1 = 12 * qult (kcf)

For piles, due to the substantial side shear resistance, the horizontal stiffness is approximately double the vertical stiffness:

ks=2*ks1 = 24 * qult (kcf) (p. 772)

(1) For sand, the program uses the spread footing bearing capacity equation,

$$q_{ult} = \text{Effective Soil Weight} * y * Nq$$

where Nq is derived from the Terzaghi bearing capacity equation,

$$Nq = a^2 / [2(\cos(45+\varphi/2))^2] \quad \text{(p. 188)}$$
$$a = e^{((.75*\pi - \varphi/2)*\tan(\varphi))}$$

q_{ult} in sand is limited to the following value determined by Meyerhof:

$$q_{ult(max)} = Nq * \tan(\varphi) \quad \text{(p. 741)}$$

The maximum pile lateral pressure for sand is Pmax = $3 * \sigma_v * K_p$
where σ_v = Effective Soil Weight * y
K_p = passive pressure coeff. = $\tan^2(45 + \varphi/2)$

(2) For clay, the program uses a commonly used expression for ultimate bearing pressure,

qult=3 * qu, for shallow footings (p. 201)
where qu=unconfined compressive strength

The maximum pile lateral pressure for clay, Pmax = 9*c = 9*qu/2 = 4.5 * qu

FIRM:DesignCalcs, Inc. JOB NO.123 SHEET NO: 3
MADE BY:KJH DATE:10-06-2014 CHECKED BY: DATE:
TITLE:Example PILEBUCL calculation

PILE BUCKLING ANALYSIS:

Number of soil layers= 5

```
Layer| From  | To    | Calculation
 No. | Y(ft) | Y(ft) |
------|-------|-------|--------------------------------------
  1  |   0.00|  12.50| Submerged dense sand
     |       |       | Dry Wt.=  .100 kcf, Sat. Wt.= .120 kcf
     |       |       | Sand can become submerged.
     |       |       | Submerged Wt.=  .058 kcf
     |       |       |  = 38.000 deg., Nq=  61.55
     |       |       | qult=  3.545 * y <  48.084 ksf
     |       |       | ks   = 24*qult = 85.080 * y < %1154.027 kcf
------|-------|-------|--------------------------------------
  2  |  12.50|  25.00| Submerged medium sand
     |       |       | Dry Wt.=  .100 kcf, Sat. Wt.= .120 kcf
     |       |       | Sand can become submerged.
     |       |       | Submerged Wt.=  .058 kcf
     |       |       |  = 33.000 deg., Nq=  32.23
     |       |       | qult=  1.856 * y <  20.930 ksf
     |       |       | ks   = 24*qult = 44.554 * y < 502.323 kcf
------|-------|-------|--------------------------------------
  3  |  25.00|  33.50| Very Soft clay
     |       |       | qu=   .250 ksf
     |       |       | qult= 3*   .250 =   .750 ksf
     |       |       | ks   = 24*qult = 18.000 kcf
------|-------|-------|--------------------------------------
  4  |  33.50| 101.50| Very Soft clay
     |       |       | qu=  0.000 ksf
     |       |       | qult= 3*  0.000 =  0.000 ksf
     |       |       | ks   = 24*qult =  0.000 kcf
------|-------|-------|--------------------------------------
  5  | 101.50| 153.50| Soft clay
     |       |       | qu=   .750 ksf
     |       |       | qult= 3*   .750 =  2.250 ksf
     |       |       | ks   = 24*qult = 54.000 kcf
```

PILE BUCKLING ANALYSIS:

SUMMARY OF ANALYSIS RESULTS FOR 20 ITERATIONS:

Iteration	P (k)	Pile Deflection at mid-depth (in)	Max. Moment (k*ft)	at Depth (ft)
1	8.75	0.056	1.91	24.00
2	17.50	.128	4.23	24.00
3	26.25	.209	6.71	24.00
4	35.00	.300	9.28	24.00
5	43.75	.399	11.94	24.00
6	52.50	.507	14.67	24.00
7	61.25	.623	17.49	24.00
8	70.00	.746	20.40	24.00
9	78.75	.878	23.40	24.00
10	87.50	1.017	26.50	24.00
11	96.25	1.165	29.71	24.00
12	105.00	1.322	33.02	24.00
13	113.75	1.486	36.46	24.00
14	122.50	1.660	40.02	24.00
15	131.25	1.842	43.71	24.00
16	140.00	2.034	47.55	24.00
17	148.75	2.241	51.62	24.00
18	157.50	2.456	55.84	24.00
19	166.25	2.687	60.31	24.00
20	175.00	2.938	65.17	24.00

PILE BUCKLING ANALYSIS:

DETAILED RESULTS FOR P= 175.0 k AFTER 20 ITERATIONS:

Depth Y (ft)	Spring Constant (k/in)	Lateral Disp. (in)	Moment (k')	Shear (k)	Pressure (ksf)	Pressure Limit (ksf)
0.03	0.00	0.00	0.0	0.0	0.000	0.000
3.03	87.42	-0.01	5.9	1.0	-.381	2.179
6.03	174.84	-0.03	12.2	2.0	-1.362	4.358
9.03	262.26	-0.03	20.0	2.3	-2.437	6.538
12.03	349.68	-0.03	30.3	3.0	-2.668	8.717
15.03	172.05	-0.00	42.7	3.7	-.210	8.792
18.03	172.05	0.04	54.7	4.0	2.028	10.551
21.03	172.05	.14	63.5	3.4	5.710	12.309
24.03	172.05	.26	65.2	1.7	11.052	14.068
27.02	6.16	.43	54.0	-1.6	.648	1.125
30.02	6.16	.63	42.3	-3.8	.951	1.125
33.02	5.36	.86	29.7	-4.0	1.230	1.125
36.01	0.00	1.11	16.3	-4.3	0.000	0.000
39.01	0.00	1.37	3.5	-4.3	0.000	0.000
42.01	0.00	1.63	-8.7	-4.1	0.000	0.000
45.00	0.00	1.88	-19.9	-3.9	0.000	0.000
48.00	0.00	2.13	-30.2	-3.5	0.000	0.000
51.00	0.00	2.35	-39.3	-3.2	0.000	0.000
53.99	0.00	2.55	-47.2	-2.8	0.000	0.000
56.99	0.00	2.72	-53.7	-2.4	0.000	0.000
59.99	0.00	2.85	-58.8	-1.9	0.000	0.000
62.99	0.00	2.95	-62.4	-1.4	0.000	0.000
65.99	0.00	3.01	-64.5	-.9	0.000	0.000
68.99	0.00	3.03	-65.0	-.4	0.000	0.000
71.99	0.00	3.00	-63.9	0.0	0.000	0.000
74.99	0.00	2.94	-61.3	.6	0.000	0.000
77.99	0.00	2.84	-57.1	1.1	0.000	0.000
80.99	0.00	2.70	-51.3	1.6	0.000	0.000
83.99	0.00	2.53	-44.1	2.1	0.000	0.000
86.99	0.00	2.33	-35.5	2.6	0.000	0.000
89.99	0.00	2.11	-25.6	3.1	0.000	0.000
92.99	0.00	1.87	-14.6	3.5	0.000	0.000
96.00	0.00	1.62	-2.4	3.9	0.000	0.000
99.00	0.00	1.37	10.7	4.2	0.000	0.000
102.00	12.24	1.13	24.7	4.5	3.740	3.375
105.00	15.29	.91	34.7	4.0	3.751	3.375
108.00	18.50	.70	40.7	2.7	3.165	3.375
111.00	18.50	.52	43.2	1.4	2.361	3.375
114.00	18.50	.37	42.9	.4	1.678	3.375

PILE BUCKLING ANALYSIS:

DETAILED RESULTS FOR P= 175.0 k AFTER 20 ITERATIONS (Cont'd):

Depth Y (ft)	Spring Constant (k/in)	Lateral Disp. (in)	Moment (k')	Shear (k)	Pressure (ksf)	Pressure Limit (ksf)
117.00	18.50	.25	40.6	-.4	1.117	3.375
120.00	18.50	.15	37.1	-1.0	.671	3.375
123.00	18.50	0.07	32.8	-1.3	.330	3.375
126.00	18.50	0.01	28.2	-1.5	0.082	3.375
129.00	18.50	-0.01	23.6	-1.5	-0.084	3.375
132.00	18.50	-0.04	19.2	-1.5	-.184	3.375
135.00	18.50	-0.05	15.1	-1.4	-.229	3.375
138.00	18.50	-0.05	11.5	-1.3	-.231	3.375
141.00	18.50	-0.04	8.2	-1.2	-.200	3.375
144.00	18.50	-0.03	5.2	-1.0	-.146	3.375
147.00	18.50	-.02	2.6	-.9	-0.076	3.375
150.00	9.25	0.00	-0.0	-.9	0.000	3.375