United States Steel
Pittsburgh, Pennsylvania 15230

Sales Offices:

Atlanta	Los Angeles
Baltimore	Louisville
Birmingham	Memphis
Boston	Milwaukee
Buffalo	New Orleans
Charlotte	New York
Chicago	Philadelphia
Cincinnati	Pittsburgh
Cleveland	Portland (Oregon)
Dallas	Quad-Cities (Bettendorf, Iowa)
Denver	St. Louis
Detroit	St. Paul
Houston	Salt Lake City
Indianapolis	San Francisco
Jacksonville	Seattle
Kansas City	Tulsa

Tapered Steel Poles Caisson Foundation Design

Prepared for United States Steel

by Teng and Associates

United States Steel

NOTATION

C = cohesive strength of soil, pounds per square feet

D = diameter of caisson foundation, feet

F = lateral soil reaction at toe of caisson in granular soil, kips

H_1 = passive resistance of cohesive soil to lateral forces in upper portion of caisson, kips

H_2 = passive resistance of cohesive soil to lateral forces in bottom portion of caisson, kips

K_p = passive earth pressure coefficient

L = length of caisson embedment, feet

M = external moment at top of foundation from pole, kip feet

N = number of blows per foot from standard penetration test

P = external vertical load at top of caisson, kips

P_b = vertical bearing at caisson base, kips

P_f = vertical skin friction along perimeter of caisson, kips

Q = external lateral load at top of caisson, kips

Y_1 = length of upper portion of caisson in cohesive soil which resists lateral forces, feet

Y_2 = length of bottom portion of caisson in cohesive soil which resists lateral forces, feet

qu = unconfined compressive strength of soil, kips per square feet

γ = unit weight of soil, pounds per cubic feet

ϕ = angle of internal friction of soil, degree

TAPERED STEEL POLES CAISSON FOUNDATION DESIGN

The market for tapered steel poles which support transmission lines is increasing at a rapid rate. The narrow right-of-way requirements, the ease of erection, and the fact that the pole, when finished with the proper color, blends into any background, are among the many advantages of pole structures.

The design of the foundation for a single pole with one end embedded in the ground and subjected to lateral loads has been a subject which has received a considerable amount of attention. The pole foundation is not only subjected to axial forces, but to bending moments and lateral forces as well. However, the effects of the axial force on the foundation is usually secondary compared to the effects of the bending moments.

U. S. Steel is presenting the enclosed tables as a guide to designing caisson foundations for tapered steel poles that carry transmission lines. The analysis of the foundation reactions is based on the theory presented by Bengt B. Broms in the *Journal* of the Soil Mechanics and Foundations Division of the Proceedings of the American Society of Civil Engineers.* Teng and Associates has adapted the Broms' method of analysis to caisson design, and the enclosed tables are presented with the following assumptions and limitations:

1. The foundation is embedded in a soil mass which is homogenous and isotropic.
2. The cohesive strength of clay is taken to be equal to one-half of its unconfined compressive strength.
3. The plane of bending of the pole and foundation are in the same plane as the loads.
4. Broms' assumptions for the distribution of the soil reactions at ultimate load for foundations in granular and cohesive soils are applicable. These are shown in Figures 1 and 2.
5. The effect of the vertical load is ignored.
6. The bending moments at the top of the foundation shown in the table is dependent upon the magnitude and the height of the applied lateral force. It is assumed that the lateral force is applied fifty feet above grade. Using these tables for poles, where the applied lateral force is higher than fifty feet, yields conservative results.
7. At ultimate load, the bending moment, due to lateral loadings, at any section of the foundation is equal to or less than the ultimate resisting moment at that section.
8. Only circular reinforced concrete foundations with reinforcing bars arranged in a circular pattern are considered. The ultimate strength is based on Eq. 19-11 of the ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318-63).

* *Proceedings 3835, Volume 90, SM2, March 1964, pp. 27-63 and Proceedings 3909, Volume 90, SM3, May 1964, pp. 123-156.*

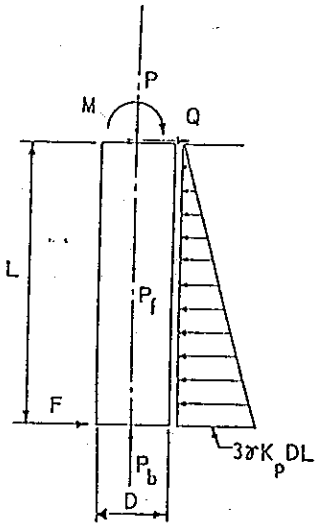

Fig. 1.0. Foundation in Granular Soil

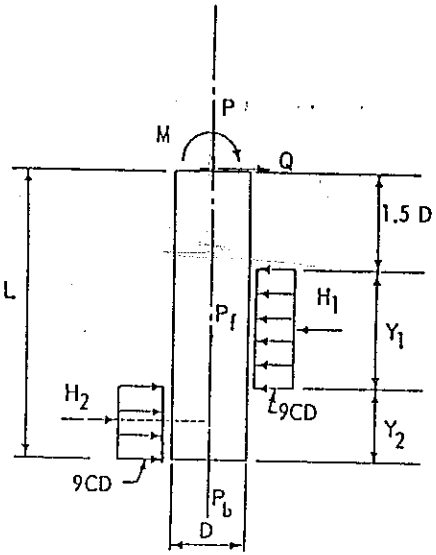

Fig. 2. Foundation in Cohesive Soil

9. An overload factor must be assigned to the transmission line force to establish design loads.

The tables are limited to concrete having an ultimate compressive strength, $f'_c = 3{,}000$ psi, and reinforcing steel having a specified minimum yield point, $f_y = 60{,}000$ psi. The values of the soil constants ϕ or qu may be determined by laboratory test of soil samples or may be estimated if the results of a standard penetration test on the soil in situ is available.

1. Angle of internal friction Phi, ϕ, (degree) of course grained soil. This may be estimated for clear sand as

$$\phi = 28.5° + \frac{N}{4}$$

where

N = number of blows per foot of a 140-pound hammer falling 30 inches onto a 2" O.D. split spoon sampler. (Standard Penetration Test)

Phi, ϕ, may also be obtained from Figures 3 or 4.

The relationship between the in-place unit weight of soil, γ, and the angle of internal friction, ϕ, shown in the enclosed tables for granular soils is based upon the following values:

ϕ (degrees)	26	30	34	38
γ (lb/cu ft)	95	105	115	125

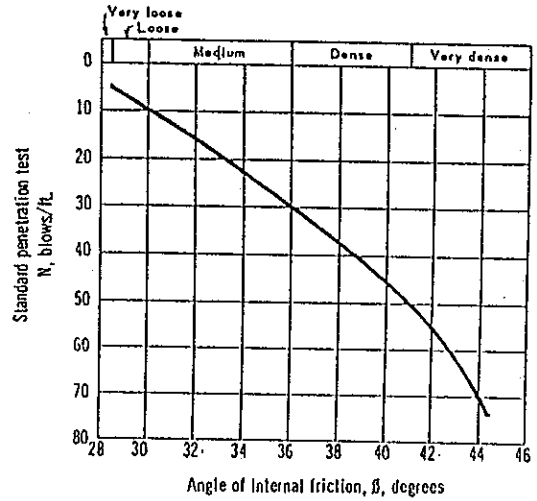

Fig. 3. N vs. ϕ values
(Peak, Hansen and Thornburn, *Foundation Engineering*)

Compactness	Very loose	Loose	Medium	Dense	Very dense
Relative density	0 15%	35%	65%	85%	100%
Standard penetration test, N = no. of blows per foot	0 4	10	30	50	
Ø (degrees)*	28	30	36	41	
Unit weight, pcf					
moist	<100	95-125	110-130	110-140	>130
submerged	< 60	55-65	60-70	65-85	> 75

* Increase 5 degrees for soils containing less than 5% fine sand or silt.

Fig. 4. N vs. Ø values
(Teng, W.C. *Foundation Design*, 1962)

2. The unconfined compressive strength of cohesive soils, qu, should be obtained by laboratory tests, but an approximate value may be estimated from the relationship:

$$qu = \frac{N}{4} \text{ (qu in kips per sq. ft.)}$$

or be obtained from Figure 5.

Consistency	Very soft	Soft	Medium	Stiff	Very stiff	Hard
qu = unconfined compression strength, kips per square ft.	0 0.50	1.00	2.00	4.00	8.00	
Standard penetration test, N = no. of blows per ft.	0 2	4	8	16	32	
Unit weight, pcf (saturated)	100-120		110-130	120-140		130+
Identification characteristics	Exudes from between fingers when squeezed in hand	Molded by light finger pressure	Molded by strong finger pressure	Indented by thumb	Indented by thumb nail	Difficult to indent by thumb nail

Fig. 5. N vs. qu values
(Teng, W.C. *Foundation Design*, 1962)

3. The bending moment at ground surfaces in kip-feet is determined by taking the estimated transmission line force times its distance to the top of the foundation. Since ultimate design is used, an appropriate overload factor must be applied to the transmission line force when using the tables.

4. The caisson diameter is determined by the equipment available, costs, and overturning force.

Example Problems

1. Granular Soil

Given: phi = Ø = 34°
pole height = 80 feet
line force = 20 kips
overload factor = 1.5

Solution:
moment at ground = 1.5 (20 x 80) = 2400 kip - ft
from tables that follow, using a 48 inch diameter caisson
length of embedment = 15.71 feet
area of steel = 44.60 sq. in.
theoretical cutoff point for 1/2 of the reinforcing steel = 12.91 ft.
volume of concrete = 7.31 cu. yd.

2. Cohesive Soil

Given: unconfined compression (qu) = 2 kips per sq. ft.
pole height = 60 feet
line force = 30 kips
overload factor = 2

Solution:
moment at ground = 2 (30 x 60) = 3600 kip - ft
from tables that follow, using a 60 inch diameter caisson
length of embedment = 28.42 feet
area of steel = 55.97 sq. in.
theoretical cutoff point for 1/2 of the reinforcing steel = 18.76 ft.
volume of concrete = 20.66 cu. yd.

POLE FOUNDATION IN GRANULAR SOIL

MINIMUM POLE HEIGHT = 50 FEET.
DIA. STEEL REINF = DIA. CAISSON − 10 IN. , ULTIMATE DESIGN f'_c = 3.0 KSI , f_y = 60 KSI

CAISSON DIAMETER (IN.)	MOMENT AT GROUND (KIP-FT.)	ANG. OF INT. FRICTION ϕ (DEG.)	LENGTH OF EMBEDMENT (FT.)	AREA OF STEEL (SQ. IN.)	POINT OF CUTOFF (FT.)*	VOLUME OF CONCRETE (CU. YDS.)
24	100	26.0	7.80	4.87	6.32	.91
		30.0	7.13	4.85	5.77	.83
		34.0	6.53	4.84	5.28	.76
		38.0	5.97	4.83	4.82	.70
	200	26.0	9.95	9.82	8.10	1.16
		30.0	9.09	9.79	7.38	1.06
		34.0	8.31	9.75	6.74	.97
		38.0	7.60	9.73	6.16	.88
	300	26.0	11.49	14.83	9.38	1.34
		30.0	10.48	14.77	8.54	1.22
		34.0	9.58	14.71	7.79	1.11
		38.0	8.76	14.66	7.11	1.02
	400	26.0	12.73	19.89	10.41	1.48
		30.0	11.61	19.79	9.48	1.35
		34.0	10.60	19.70	8.64	1.23
		38.0	9.69	19.62	7.88	1.13
	500	26.0	13.79	24.99	11.30	1.60
		30.0	12.57	24.84	10.28	1.46
		34.0	11.48	24.72	9.37	1.34
		38.0	10.48	24.61	8.54	1.22
	600	26.0	14.73	30.12	12.08	1.71
		30.0	13.42	29.93	10.99	1.56
		34.0	12.25	29.77	10.01	1.42
		38.0	11.18	29.62	9.12	1.30
30	400	26.0	11.76	13.86	9.60	2.14
		30.0	10.73	13.80	8.74	1.95
		34.0	9.80	13.74	7.97	1.78
		38.0	8.96	13.69	7.27	1.63
	500	26.0	12.73	17.40	10.41	2.31
		30.0	11.61	17.31	9.48	2.11
		34.0	10.60	17.24	8.64	1.93
		38.0	9.69	17.17	7.88	1.76
	600	26.0	13.59	20.97	11.13	2.47
		30.0	12.39	20.85	10.13	2.25
		34.0	11.31	20.75	9.23	2.06
		38.0	10.33	20.66	8.41	1.88
	700	26.0	14.36	24.55	11.78	2.61
		30.0	13.09	24.41	10.71	2.38
		34.0	11.95	24.28	9.76	2.17
		38.0	10.91	24.16	8.89	1.98
	800	26.0	15.07	28.16	12.37	2.74
		30.0	13.73	27.98	11.25	2.50
		34.0	12.53	27.82	10.25	2.28
		38.0	11.44	27.68	9.33	2.08
	900	26.0	15.73	31.78	12.92	2.86
		30.0	14.33	31.56	11.75	2.60
		34.0	13.07	31.38	10.70	2.38
		38.0	11.93	31.21	9.74	2.17

*DISTANCE FROM GROUND SURFACE TO THEORETICAL CUTOFF POINT OF ONE-HALF STEEL AREA.

POLE FOUNDATION IN GRANULAR SOIL

MINIMUM POLE HEIGHT = 50 FEET.
DIA. STEEL REINF = DIA. CAISSON − 10 IN. , ULTIMATE DESIGN f'_c = 3.0 KSI , f_y = 60 KSI

CAISSON DIAMETER (IN.)	MOMENT AT GROUND (KIP-FT.)	ANG. OF INT. FRICTION ϕ (DEG.)	LENGTH OF EMBEDMENT (FT.)	AREA OF STEEL (SQ. IN.)	POINT OF CUTOFF (FT.)*	VOLUME OF CONCRETE (CU. YDS.)
36	700	26.0	13.45	18.81	11.01	3.52
		30.0	12.27	18.70	10.02	3.21
		34.0	11.20	18.61	9.13	2.93
		38.0	10.23	18.53	8.33	2.68
	800	26.0	14.11	21.56	11.57	3.69
		30.0	12.86	21.43	10.52	3.37
		34.0	11.74	21.32	9.59	3.07
		38.0	10.72	21.23	8.74	2.81
	900	26.0	14.73	24.33	12.08	3.86
		30.0	13.42	24.17	10.99	3.51
		34.0	12.25	24.04	10.01	3.21
		38.0	11.18	23.93	9.12	2.93
	1000	26.0	15.30	27.10	12.56	4.00
		30.0	13.94	26.93	11.42	3.65
		34.0	12.72	26.77	10.40	3.33
		38.0	11.61	26.64	9.47	3.04
	1200	26.0	16.34	32.69	13.44	4.28
		30.0	14.88	32.46	12.21	3.90
		34.0	13.57	32.26	11.12	3.55
		38.0	12.39	32.08	10.12	3.24
	1400	26.0	17.28	38.32	14.23	4.52
		30.0	15.74	38.03	12.93	4.12
		34.0	14.35	37.77	11.76	3.76
		38.0	13.09	37.55	10.71	3.43
42	1000	26.0	14.47	21.93	11.86	5.16
		30.0	13.19	21.80	10.79	4.70
		34.0	12.04	21.68	9.83	4.29
		38.0	10.99	21.58	8.96	3.92
	1200	26.0	15.45	26.45	12.69	5.51
		30.0	14.08	26.27	11.54	5.02
		34.0	12.85	26.12	10.51	4.58
		38.0	11.72	25.98	9.57	4.18
	1400	26.0	16.34	30.99	13.44	5.82
		30.0	14.88	30.77	12.21	5.30
		34.0	13.57	30.58	11.12	4.84
		38.0	12.39	30.41	10.12	4.41
	1600	26.0	17.15	35.56	14.12	6.11
		30.0	15.62	35.29	12.83	5.57
		34.0	14.24	35.06	11.67	5.07
		38.0	12.99	34.85	10.63	4.63
	1800	26.0	17.91	40.16	14.75	6.38
		30.0	16.30	39.84	13.40	5.81
		34.0	14.86	39.56	12.19	5.29
		38.0	13.55	39.31	11.10	4.83
	2000	26.0	18.61	44.78	15.35	6.63
		30.0	16.94	44.40	13.94	6.04
		34.0	15.44	44.07	12.68	5.50
		38.0	14.07	43.79	11.53	5.02

*DISTANCE FROM GROUND SURFACE TO THEORETICAL CUTOFF POINT OF ONE-HALF STEEL AREA.

POLE FOUNDATION IN GRANULAR SOIL

MINIMUM POLE HEIGHT = 50 FEET. ULTIMATE DESIGN
DIA. STEEL REINF = DIA. CAISSON − 10 IN. , f'_c = 3.0 KSI , f_y = 60 KSI

CAISSON DIAMETER (IN.)	MOMENT AT GROUND (KIP-FT.)	ANG. OF INT. FRICTION ϕ (DEG.)	LENGTH OF EMBEDMENT (FT.)	AREA OF STEEL (SQ. IN.)	POINT OF CUTOFF (FT.)*	VOLUME OF CONCRETE (CU. YDS.)
48	1600	26.0	16.34	29.82	13.44	7.61
		30.0	14.88	29.61	12.21	6.93
		34.0	13.57	29.43	11.12	6.32
		38.0	12.39	29.26	10.12	5.76
	1800	26.0	17.06	33.67	14.04	7.94
		30.0	15.53	33.42	12.75	7.23
		34.0	14.16	33.20	11.61	6.59
		38.0	12.92	33.00	10.57	6.01
	2000	26.0	17.72	37.54	14.60	8.25
		30.0	16.13	37.24	13.26	7.51
		34.0	14.71	36.98	12.07	6.85
		38.0	13.42	36.76	10.98	6.24
	2200	26.0	18.35	41.43	15.13	8.54
		30.0	16.70	41.08	13.74	7.77
		34.0	15.22	40.78	12.50	7.09
		38.0	13.88	40.52	11.37	6.46
	2400	26.0	18.95	45.33	15.63	8.82
		30.0	17.24	44.94	14.19	8.02
		34.0	15.71	44.60	12.91	7.31
		38.0	14.32	44.30	11.74	6.67
	2600	26.0	19.51	49.25	16.11	9.08
		30.0	17.75	48.81	14.62	8.26
		34.0	16.17	48.43	13.29	7.53
		38.0	14.74	48.09	12.09	6.86
54	2200	26.0	17.58	35.64	14.48	10.36
		30.0	16.00	35.36	13.15	9.43
		34.0	14.59	35.11	11.97	8.59
		38.0	13.31	34.90	10.89	7.84
	2400	26.0	18.15	38.99	14.96	10.69
		30.0	16.52	38.67	13.58	9.73
		34.0	15.06	38.39	12.36	8.87
		38.0	13.73	38.15	11.25	8.09
	2600	26.0	18.69	42.35	15.41	11.01
		30.0	17.00	41.99	13.99	10.02
		34.0	15.50	41.68	12.73	9.13
		38.0	14.13	41.41	11.58	8.32
	2800	26.0	19.20	45.73	15.85	11.31
		30.0	17.47	45.33	14.39	10.29
		34.0	15.92	44.98	13.08	9.38
		38.0	14.51	44.67	11.90	8.55
	3000	26.0	19.70	49.12	16.26	11.60
		30.0	17.92	48.68	14.76	10.55
		34.0	16.32	48.29	13.42	9.62
		38.0	14.88	47.95	12.21	8.76
	3200	26.0	20.17	52.53	16.67	11.88
		30.0	18.34	52.04	15.12	10.81
		34.0	16.71	51.61	13.75	9.84
		38.0	15.23	51.23	12.50	8.97

*DISTANCE FROM GROUND SURFACE TO THEORETICAL CUTOFF POINT OF ONE-HALF STEEL AREA.

POLE FOUNDATION IN GRANULAR SOIL

MINIMUM POLE HEIGHT = 50 FEET. ULTIMATE DESIGN
DIA. STEEL REINF = DIA. CAISSON − 10 IN. , f'_c = 3.0 KSI , f_y = 60 KSI

CAISSON DIAMETER (IN.)	MOMENT AT GROUND (KIP-FT.)	ANG. OF INT. FRICTION ϕ (DEG.)	LENGTH OF EMBEDMENT (FT.)	AREA OF STEEL (SQ. IN.)	POINT OF CUTOFF (FT.)*	VOLUME OF CONCRETE (CU. YDS.)
60	2800	26.0	18.47	40.09	15.23	13.44
		30.0	16.81	39.76	13.83	12.23
		34.0	15.32	39.47	12.58	11.14
		38.0	13.97	39.21	11.45	10.16
	3000	26.0	18.95	43.06	15.63	13.78
		30.0	17.24	42.69	14.19	12.54
		34.0	15.71	42.37	12.91	11.43
		38.0	14.32	42.08	11.74	10.42
	3200	26.0	19.40	46.04	16.02	14.11
		30.0	17.65	45.63	14.54	12.84
		34.0	16.08	45.28	13.22	11.70
		38.0	14.66	44.96	12.02	10.66
	3400	26.0	19.84	49.03	16.39	14.43
		30.0	18.05	48.58	14.87	13.12
		34.0	16.44	48.19	13.52	11.96
		38.0	14.99	47.85	12.30	10.90
	3600	26.0	20.26	52.03	16.74	14.74
		30.0	18.43	51.54	15.19	13.40
		34.0	16.79	51.11	13.81	12.21
		38.0	15.30	50.74	12.56	11.12
	3800	26.0	20.67	55.03	17.09	15.03
		30.0	18.80	54.50	15.50	13.67
		34.0	17.12	54.04	14.09	12.45
		38.0	15.60	53.64	12.81	11.34
72	3400	26.0	18.55	39.28	15.30	19.43
		30.0	16.89	38.95	13.89	17.68
		34.0	15.39	38.66	12.64	16.12
		38.0	14.03	38.41	11.50	14.69
	3600	26.0	18.95	41.67	15.63	19.84
		30.0	17.24	41.31	14.19	18.05
		34.0	15.71	41.00	12.91	16.45
		38.0	14.32	40.73	11.74	15.00
	3800	26.0	19.33	44.07	15.95	20.24
		30.0	17.58	43.68	14.48	18.41
		34.0	16.02	43.35	13.17	16.78
		38.0	14.61	43.05	11.98	15.29
	4000	26.0	19.70	46.48	16.26	20.63
		30.0	17.92	46.06	14.76	18.76
		34.0	16.32	45.70	13.42	17.09
		38.0	14.88	45.37	12.21	15.58
	4200	26.0	20.05	48.90	16.57	21.00
		30.0	18.24	48.44	15.03	19.10
		34.0	16.61	48.05	13.67	17.40
		38.0	15.14	47.70	12.43	15.86
	4400	26.0	20.40	51.32	16.86	21.36
		30.0	18.55	50.83	15.30	19.43
		34.0	16.90	50.41	13.90	17.70
		38.0	15.40	50.04	12.64	16.13

*DISTANCE FROM GROUND SURFACE TO THEORETICAL CUTOFF POINT OF ONE-HALF STEEL AREA.

POLE FOUNDATION IN COHESIVE SOIL

MINIMUM POLE HEIGHT = 50 FEET. ULTIMATE DESIGN
DIA. STEEL REINF = DIA. CAISSON − 10 IN. , f'_c = 3.0 KSI , f_y = 60 KSI

CAISSON DIAMETER (IN.)	MOMENT AT GROUND (KIP-FT.)	UNCONFINED COMPRESSION qu(KSF)	LENGTH OF EMBEDMENT (FT.)	AREA OF STEEL (SQ. IN.)	POINT OF CUTOFF (FT.)*	VOLUME OF CONCRETE (CU. YDS.)
24	100	.5	13.17	5.07	8.31	1.53
		1.0	10.09	5.06	6.66	1.17
		2.0	7.97	5.05	5.54	.93
		4.0	6.49	5.05	4.77	.75
	200	.5	17.67	10.18	10.78	2.06
		1.0	13.17	10.14	8.31	1.53
		2.0	10.09	10.12	6.66	1.17
		4.0	7.97	10.11	5.54	.93
	300	.5	21.25	15.33	12.79	2.47
		1.0	15.59	15.24	9.63	1.81
		2.0	11.75	15.19	7.54	1.37
		4.0	9.12	15.17	6.14	1.06
	400	.5	24.35	20.53	14.57	2.83
		1.0	17.67	20.36	10.78	2.06
		2.0	13.17	20.28	8.31	1.53
		4.0	10.09	20.23	6.66	1.17
	500	.5	27.15	25.77	16.19	3.16
		1.0	19.54	25.50	11.83	2.27
		2.0	14.44	25.37	9.00	1.68
		4.0	10.96	25.30	7.12	1.28
	600	.5	29.74	31.05	17.70	3.46
		1.0	21.25	30.67	12.79	2.47
		2.0	15.59	30.48	9.63	1.81
		4.0	11.75	30.38	7.54	1.37
30	400	.5	22.77	14.52	13.97	4.14
		1.0	16.87	14.43	10.66	3.07
		2.0	12.86	14.38	8.48	2.34
		4.0	10.12	14.36	7.02	1.84
	500	.5	25.24	18.21	15.38	4.59
		1.0	18.52	18.06	11.58	3.37
		2.0	13.99	17.99	9.09	2.54
		4.0	10.89	17.95	7.43	1.98
	600	.5	27.51	21.93	16.70	5.00
		1.0	20.04	21.71	12.43	3.64
		2.0	15.02	21.61	9.65	2.73
		4.0	11.60	21.55	7.81	2.11
	700	.5	29.64	25.66	17.94	5.39
		1.0	21.45	25.37	13.22	3.90
		2.0	15.97	25.23	10.17	2.90
		4.0	12.25	25.16	8.16	2.23
	800	.5	31.65	29.43	19.12	5.75
		1.0	22.77	29.05	13.97	4.14
		2.0	16.87	28.86	10.66	3.07
		4.0	12.86	28.76	8.48	2.34
	900	.5	33.57	33.21	20.26	6.10
		1.0	24.03	32.73	14.69	4.37
		2.0	17.71	32.49	11.13	3.22
		4.0	13.44	32.37	8.80	2.44

*DISTANCE FROM GROUND SURFACE TO THEORETICAL CUTOFF POINT OF ONE-HALF STEEL AREA.

POLE FOUNDATION IN COHESIVE SOIL

MINIMUM POLE HEIGHT = 50 FEET. ULTIMATE DESIGN
DIA. STEEL REINF = DIA. CAISSON − 10 IN. , f'_c = 3.0 KSI , f_y = 60 KSI

CAISSON DIAMETER (IN.)	MOMENT AT GROUND (KIP-FT.)	UNCONFINED COMPRESSION qu(KSF)	LENGTH OF EMBEDMENT (FT.)	AREA OF STEEL (SQ. IN.)	POINT OF CUTOFF (FT.)*	VOLUME OF CONCRETE (CU. YDS.)
36	700	.5	28.04	19.94	17.31	7.34
		1.0	20.64	19.75	13.09	5.40
		2.0	15.68	19.66	10.35	4.10
		4.0	12.29	19.61	8.52	3.22
	800	.5	29.85	22.85	18.36	7.81
		1.0	21.85	22.60	13.77	5.72
		2.0	16.49	22.48	10.79	4.32
		4.0	12.84	22.42	8.82	3.36
	900	.5	31.57	25.77	19.37	8.27
		1.0	22.99	25.46	14.41	6.02
		2.0	17.26	25.31	11.21	4.52
		4.0	13.37	25.23	9.10	3.50
	1000	.5	33.22	28.71	20.34	8.70
		1.0	24.07	28.33	15.03	6.30
		2.0	17.99	28.14	11.62	4.71
		4.0	13.87	28.04	9.37	3.63
	1200	.5	36.35	34.63	22.20	9.52
		1.0	26.12	34.09	16.20	6.84
		2.0	19.37	33.81	12.38	5.07
		4.0	14.81	33.68	9.88	3.88
	1400	.5	39.29	40.62	23.97	10.29
		1.0	28.04	39.87	17.31	7.34
		2.0	20.64	39.50	13.09	5.40
		4.0	15.68	39.31	10.35	4.10
42	1000	.5	31.75	23.55	19.77	11.31
		1.0	23.37	23.29	14.94	8.33
		2.0	17.76	23.15	11.82	6.33
		4.0	13.96	23.09	9.76	4.97
	1200	.5	34.61	28.39	21.45	12.33
		1.0	25.25	28.01	16.01	9.00
		2.0	19.03	27.82	12.52	6.78
		4.0	14.82	27.72	10.23	5.28
	1400	.5	37.28	33.27	23.05	13.29
		1.0	27.01	32.75	17.02	9.62
		2.0	20.21	32.49	13.17	7.20
		4.0	15.63	32.36	10.66	5.57
	1600	.5	39.83	38.19	24.57	14.19
		1.0	28.67	37.51	17.97	10.21
		2.0	21.32	37.17	13.79	7.60
		4.0	16.38	37.00	11.07	5.84
	1800	.5	42.26	43.15	26.04	15.06
		1.0	30.24	42.29	18.89	10.78
		2.0	22.37	41.87	14.38	7.97
		4.0	17.09	41.65	11.45	6.09
	2000	.5	44.60	48.16	27.46	15.89
		1.0	31.75	47.10	19.77	11.31
		2.0	23.37	46.57	14.94	8.33
		4.0	17.76	46.31	11.82	6.33

*DISTANCE FROM GROUND SURFACE TO THEORETICAL CUTOFF POINT OF ONE-HALF STEEL AREA.

POLE FOUNDATION IN COHESIVE SOIL

MINIMUM POLE HEIGHT = 50 FEET. ULTIMATE DESIGN
DIA. STEEL REINF = DIA. CAISSON − 10 IN. , f'_c = 3.0 KSI , f_y = 60 KSI

CAISSON DIAMETER (IN.)	MOMENT AT GROUND (KIP-FT.)	UNCONFINED COMPRESSION qu(KSF)	LENGTH OF EMBEDMENT (FT.)	AREA OF STEEL (SQ. IN.)	POINT OF CUTOFF (FT.)*	VOLUME OF CONCRETE (CU. YDS.)
48	1600	.5	38.22	32.44	23.89	17.79
		1.0	27.89	31.94	17.83	12.98
		2.0	21.06	31.69	13.97	9.80
		4.0	16.44	31.56	11.44	7.65
	1800	.5	40.46	36.63	25.23	18.83
		1.0	29.35	36.00	18.68	13.66
		2.0	22.03	35.68	14.52	10.25
		4.0	17.11	35.53	11.80	7.96
	2000	.5	42.62	40.86	26.53	19.83
		1.0	30.75	40.08	19.49	14.31
		2.0	22.97	39.69	15.04	10.69
		4.0	17.74	39.49	12.15	8.26
	2200	.5	44.70	45.12	27.79	20.80
		1.0	32.10	44.17	20.27	14.94
		2.0	23.86	43.70	15.54	11.10
		4.0	18.34	43.46	12.48	8.54
	2400	.5	46.71	49.40	29.02	21.74
		1.0	33.40	48.28	21.03	15.54
		2.0	24.72	47.72	16.03	11.50
		4.0	18.92	47.44	12.79	8.81
	2600	.5	48.67	53.72	30.22	22.65
		1.0	34.65	52.41	21.77	16.13
		2.0	25.55	51.75	16.50	11.89
		4.0	19.48	51.42	13.10	9.07
54	2200	.5	43.10	39.28	27.10	25.39
		1.0	31.34	38.56	20.13	18.46
		2.0	23.62	38.20	15.73	13.91
		4.0	18.42	38.01	12.86	10.85
	2400	.5	44.97	43.00	28.23	26.49
		1.0	32.56	42.13	20.84	19.18
		2.0	24.42	41.70	16.18	14.39
		4.0	18.97	41.49	13.16	11.17
	2600	.5	46.79	46.74	29.34	27.56
		1.0	33.73	45.72	21.53	19.87
		2.0	25.20	45.22	16.62	14.85
		4.0	19.50	44.97	13.44	11.49
	2800	.5	48.57	50.50	30.42	28.61
		1.0	34.87	49.32	22.19	20.54
		2.0	25.96	48.74	17.04	15.29
		4.0	20.01	48.44	13.72	11.79
	3000	.5	50.30	54.28	31.49	29.63
		1.0	35.98	52.94	22.85	21.20
		2.0	26.69	52.26	17.46	15.72
		4.0	20.50	51.93	14.00	12.08
	3200	.5	51.99	58.10	32.53	30.63
		1.0	37.07	56.56	23.49	21.83
		2.0	27.40	55.80	17.87	16.14
		4.0	20.98	55.41	14.26	12.36

*DISTANCE FROM GROUND SURFACE TO THEORETICAL CUTOFF POINT OF ONE-HALF STEEL AREA.

POLE FOUNDATION IN COHESIVE SOIL

MINIMUM POLE HEIGHT = 50 FEET. ULTIMATE DESIGN
DIA. STEEL REINF = DIA. CAISSON − 10 IN. , f'_c = 3.0 KSI , f_y = 60 KSI

CAISSON DIAMETER (IN.)	MOMENT AT GROUND (KIP-FT.)	UNCONFINED COMPRESSION qu(KSF)	LENGTH OF EMBEDMENT (FT.)	AREA OF STEEL (SQ. IN.)	POINT OF CUTOFF (FT.)*	VOLUME OF CONCRETE (CU. YDS.)
60	2800	.5	47.04	44.79	29.76	34.21
		1.0	34.17	43.86	22.08	24.85
		2.0	25.75	43.40	17.25	18.73
		4.0	20.12	43.17	14.12	14.63
	3000	.5	48.66	48.13	30.75	35.39
		1.0	35.22	47.07	22.69	25.61
		2.0	26.45	46.53	17.64	19.23
		4.0	20.59	46.27	14.38	14.97
	3200	.5	50.25	51.49	31.72	36.54
		1.0	36.24	50.28	23.29	26.35
		2.0	27.12	49.67	18.02	19.72
		4.0	21.04	49.37	14.63	15.30
	3400	.5	51.80	54.87	32.67	37.67
		1.0	37.23	53.50	23.88	27.08
		2.0	27.78	52.82	18.39	20.20
		4.0	21.48	52.48	14.87	15.62
	3600	.5	53.32	58.27	33.61	38.78
		1.0	38.20	56.74	24.45	27.78
		2.0	28.42	55.97	18.76	20.66
		4.0	21.91	55.58	15.11	15.93
	3800	.5	54.81	61.69	34.54	39.86
		1.0	39.16	59.98	25.02	28.48
		2.0	29.04	59.12	19.12	21.12
		4.0	22.33	58.69	15.34	16.24
72	3400	.5	49.24	44.98	31.64	51.57
		1.0	36.16	44.06	23.84	37.86
		2.0	27.59	43.60	18.92	28.89
		4.0	21.85	43.37	15.74	22.88
	3600	.5	50.60	47.74	32.47	52.99
		1.0	37.04	46.71	24.35	38.78
		2.0	28.17	46.19	19.25	29.50
		4.0	22.25	45.94	15.96	23.30
	3800	.5	51.94	50.52	33.28	54.39
		1.0	37.89	49.37	24.85	39.68
		2.0	28.74	48.79	19.57	30.10
		4.0	22.63	48.50	16.17	23.70
	4000	.5	53.25	53.30	34.09	55.76
		1.0	38.74	52.03	25.35	40.56
		2.0	29.30	51.39	19.89	30.68
		4.0	23.00	51.07	16.37	24.09
	4200	.5	54.54	56.10	34.88	57.11
		1.0	39.56	54.70	25.84	41.43
		2.0	29.84	53.99	20.20	31.25
		4.0	23.37	53.64	16.57	24.47
	4400	.5	55.81	58.91	35.66	58.44
		1.0	40.37	57.37	26.32	42.28
		2.0	30.38	56.60	20.50	31.81
		4.0	23.73	56.21	16.77	24.85

*DISTANCE FROM GROUND SURFACE TO THEORETICAL CUTOFF POINT OF ONE-HALF STEEL AREA.