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TITLE:Testing against IDOT spreadsheet for HP10x57 with 220 k

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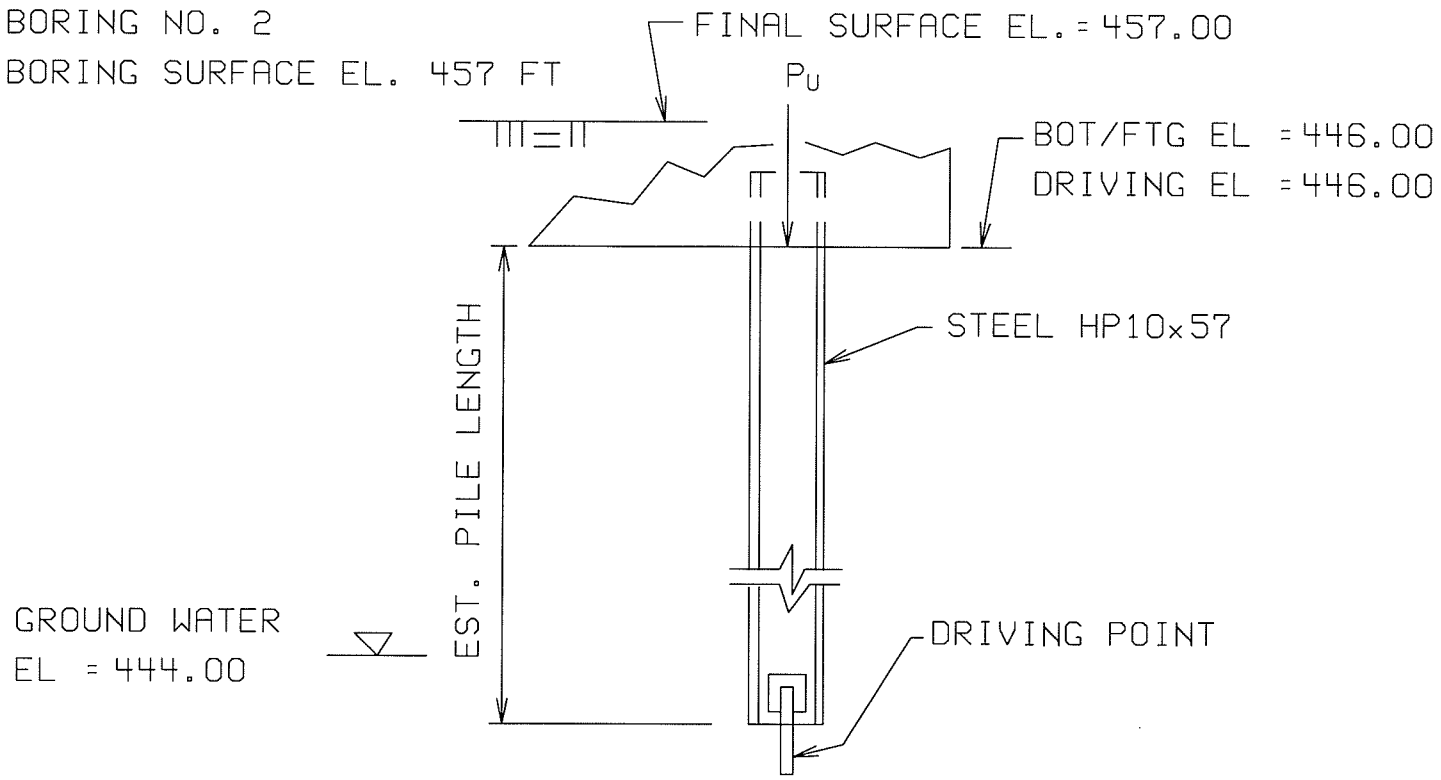
PILE CAPACITY CALCULATION:



DESIGN DATA:

Design Specification: AASHTO LRFD Specification (LRFD), using the Illinois Department of Transportation (IDOT) Modified Static Method Design Guide

Factored Pile Loading, Pu = 220.0 k

Load Factors to be applied to downdrag (per IDOT Design Guide):

Cohesive soil layers, λ_p = 1.40

Granular soil layers, λ_p = 1.05

Resistance Factor, φ_G = .55 (per IDOT Design Guide)

Hammer Efficiency, ER = 73 %

SOIL DATA:

Layer No.	From Elev. (ft)	To Elev. (ft)	Soil Classification (using IDOT terminology)	SPT N (blows/ft)	Qu (tsf)	Dry Wt (pcf)	Sat Wt (pcf)
1	457.00	441.50	Fine Sand	2		101	110
2	441.50	439.00	Cohesive Soil			1	121
3	439.00	436.50	Hard Till	30		131	133
4	436.50	434.00	Fine Sand	10		118	123
5	434.00	424.00	Cohesive Soil			2	132
6	424.00	421.50	Fine Sand	10		118	123
7	421.50	411.50	Cohesive Soil			1	118
8	411.50	409.00	Very Fine Silty Sand	15		122	126
9	409.00	406.50	Clean Medium to Coarse Sand	5		110	117
10	406.50	401.50	Cohesive Soil			2	129

PILE CAPACITY CALCULATION:

SOIL DATA (Cont'd):

Layer No.	From Elev. (ft)	To Elev. (ft)	Soil Classification (using IDOT terminology)	SPT N (blows /ft)	Qu (tsf)	Dry Wt (pcf)	Sat Wt (pcf)
11	401.50	399.00	Cohesive Soil	20	3.50	136	136
12	399.00	396.50	Cohesive Soil			1	121
13	396.50	389.00	Cohesive Soil			2	129
14	387.50	385.50	Rock: Limestone			125	125

PILE CAPACITY CALCULATION:

EXPLANATION OF THEORY:

This program uses the theory presented in the IDOT "Design Guide AGMU Memo 10.2-Geotechnical Pile Design". A static analysis prediction method is used to determine pile resistance, based on soil resistance curves developed by IDOT over 40 years and an extensive research study at Univ. of Illinois.

The ultimate pile resistance is determined as,

$R_n = [R_p \text{ (tip resistance)} + R_s \text{ (skin resistance)}] * I_G$

The pile tip resistance, R_s, for displacement piles is computed using a tip stress, q_p, as

$R_p = F_p * q_p * A_p$

where

F_p = tip resistance correction (0.758 for granular, 1 for cohesive soils)
q_p = nominal unit tip resistance
A_p = cross-sectional end area

The skin resistance, R_s, will be determined by subdividing the pile into 1 foot increments. The skin friction, q_s, will be computed in each increment. The total friction is the summation of all increments,

$R_s = F_s * \Sigma\ q_s * A_{sa} * 1 \text{ foot}$

where

F_s = side resistance correction (0.75g for granular, 1.174 for cohesive soils)
q_s = nominal unit side resistance
A_{sa} = effective surface area of the pile per foot

I_G = Bias Factor Ratio = 1.04

The maximum resistance of the pile cannot exceed a force, $R_{N,Max}$, that will cause damage to the pile.

Referring to IDOT's method, for STEEL HP10x57,

$A_{p(unplugged)}$ = .117 s.f./ft
$A_{p(plugged)}$ = .708 s.f./ft
$A_{sa(unplugged)}$ = 4.883 s.f./ft
$A_{sa(plugged)}$ = 3.365 s.f./ft

$R_{N,MAX}$ = 454.0 k

The factored bearing resistance of the pile (to be compared to the LRFD Factored Load), is

$R_R = \varphi_G * R_n$ (LRFD Eq. 10.7.2.8.6a-1)

PILE CAPACITY CALCULATION:

EXPLANATION OF THEORY (Cont'd):

Nominal Tip Resistance (q_p):

For Granular Soils,

$q_p = 0.8 * N1_{60} * D_b /D <= q_l$ (ksf) (LRFD Eq. 10.7.3.8.6g-1)

where

$N1_{60} = [0.77\log_{10}(40/\sigma_{v'})] * N_{60}$ (LRFD Eq. 10.4.6.2.4-1)

D = pile diameter or width
= 10.000 inch = .833 ft

D_b = depth of penetration into soil (ft)

N_{60} = SPT blow count corrected for 60% hammer efficiency
= (ER/60%) * N (LRFD Eq. 10.4.6.2.4-2)
where
ER = hammer efficiency = 73 %
N = uncorrected SPT blow count (blows/ft)

$N1_{60}$ = SPT blow count corrected for overburden

$\sigma_{v'}$ = effective vertical soil pressure
= σ_0 (total stress) - υ_{w0} (pore water pressure)

q_l = $8*N1_{60}$ (sands)
= $6*N1_{60}$ (nonplastic silt)

For Cohesive Soils,

$q_p = 9*Qu$ (ksf) (similar to LRFD Eq. 10.7.3.8.6e-1)

where Qu = unconfined compressive strength (tsf)

For Rock,

For shale and sandstone, q_p = 3888 ksf

For limestone and dolemite, q_p = 5184 ksf

Nominal Side Resistance (q_s):

For Hard Till:

$q_s = 0.07 * N1_{60}$ ($N1_{60} < 30$)

$q_s = 0.00136 * N1_{60}^2 - 0.00888 * N1_{60} + 1.13$ ($30 < N1_{60}$)

For Very Fine Silty Sand:

$q_s = 0.1 * N1_{60}$ ($N1_{60} < 30$)

$q_s = 42.58 * e^{Exponent}$ ($30 < N1_{60} < 74$)

where

Exponent = $[(N1_{60} - 175.05)^2 /-7944]$

$q_s = 0.297 * N1_{60} - 10.2$ ($74 < N1_{60}$)

For Fine Sand:

$q_s = 0.1 * N1_{60}$ ($N1_{60} < 30$)

$q_s = 0.3256 * N1_{60} + (182 / N1_{60}) - 12.51$ ($30 < N1_{60} < 66$)

$q_s = 0.329 * N1_{60} - 9.91$ ($66 < N1_{60}$)

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PILE CAPACITY CALCULATION:

EXPLANATION OF THEORY (Cont'd):

For Medium Sand:

$q_s = 0.117 * N1_{60}$ $(N1_{60} < 24)$

$q_s = 0.00404 * N1_{60}^2 - 0.0697 * N1_{60} + 2.13$ $(24 < N1_{60} < 55)$

$q_s = 0.356 * N1_{60} - 9.1$ $(55 < N1_{60})$

For Clean Medium to Coarse Sand:

$q_s = 0.128 * N1_{60}$ $(N1_{60} < 24)$

$q_s = 0.00468 * N1_{60}^2 - 0.0693 * N1_{60} + 2.05$ $(24 < N1_{60} < 50)$

$q_s = 0.394 * N1_{60} - 9.42$ $(50 < N1_{60})$

For Sandy Gravel:

$q_s = 0.15 * N1_{60}$ $(N1_{60} < 20)$

$q_s = 0.00861 * N1_{60}^2 - 0.271 * N1_{60} + 3.91$ $(20 < N1_{60} < 40)$

$q_s = 0.6 * N1_{60} - 15$ $(40 < N1_{60})$

For Cohesive Soils:

$q_s = -Qu^3 / 2500 - 0.177 * Qu^2 + 1.09 * Qu$ $(Qu < 1.5)$

$q_s = 0.0495 * Qu^3 - 0.347 * Qu^2 + 1.278 * Qu - 0.068$ $(1.5 < Qu < 2)$

$q_s = 0.47 * Qu + 0.555$ $(2 < Qu < 4.5)$

$q_s = 2.67$ $(4.5 < Qu)$

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PILE CAPACITY CALCULATION:

COMPUTE SIDE RESISTANCE:

Elev.	Layer No.	For Granular Soils σ_0	u_{w0}	σ'_0	$N1_{60}$	Qu (tsf)	qs (ksf)	Fs* Asa (sf)	Side Resis. (k)	DownDrag λ_p *DD (k)
(Surface El 457.00)										
456.00	1									
455.00	1									
454.00	1									
453.00	1									
452.00	1									
451.00	1									
450.00	1									
449.00	1									
448.00	1									
447.00	1									
446.00	1									
(Footing El 446.00)										
445.00	1	1.21	0.00	1.21	2.8		.28	1.01	.3	
(Ground Water El 444.00)										
444.00	1	1.32	0.00	1.32	2.8		.28	1.01	.3	
443.00	1	1.43	0.06	1.37	2.7		.27	1.01	.3	
442.00	1	1.54	.12	1.42	2.7		.27	1.01	.3	
441.00	2					1.0	.91	5.05	4.6	
440.00	2					1.0	.91	5.05	4.6	
439.00	2					1.0	.91	5.05	4.6	
438.00	3	2.04	.37	1.66	38.8		2.83	1.01	2.9	
437.00	3	2.17	.44	1.73	38.3		2.79	1.01	2.8	
436.00	4	2.29	.50	1.79	12.6		1.26	1.01	1.3	
435.00	4	2.42	.56	1.86	12.5		1.25	1.01	1.3	
434.00	4	2.54	.62	1.92	12.4		1.24	1.01	1.2	
433.00	5					2.5	1.73	5.05	8.7	
432.00	5					2.5	1.73	5.05	8.7	
431.00	5					2.5	1.73	5.05	8.7	
430.00	5					2.5	1.73	5.05	8.7	
429.00	5					2.5	1.73	5.05	8.7	
428.00	5					2.5	1.73	5.05	8.7	
427.00	5					2.5	1.73	5.05	8.7	
426.00	5					2.5	1.73	5.05	8.7	
425.00	5					2.5	1.73	5.05	8.7	
424.00	5					2.5	1.73	5.05	8.7	
423.00	6	3.98	1.31	2.67	11.0		1.10	1.01	1.1	
422.00	6	4.11	1.37	2.73	10.9		1.09	1.01	1.1	
421.00	7					.8	.76	5.05	3.8	

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PILE CAPACITY CALCULATION:

COMPUTE SIDE RESISTANCE (Cont'd):

Elev.	Layer No.	For Granular Soils				Qu	qs	Fs* Asa	Side Resis.	DownDrag λ_p *DD
		σ_0	u_{w0}	σ'_0	$N1_{60}$	(tsf)	(ksf)	(sf)	(k)	(k)
420.00	7					.8	.76	5.05	3.8	
419.00	7					.8	.76	5.05	3.8	
418.00	7					.8	.76	5.05	3.8	
417.00	7					.8	.76	5.05	3.8	
416.00	7					.8	.76	5.05	3.8	
415.00	7					.8	.76	5.05	3.8	
414.00	7					.8	.76	5.05	3.8	
413.00	7					.8	.76	5.05	3.8	
412.00	7					.8	.76	5.05	3.8	
411.00	8	5.41	2.06	3.35	15.1		1.51	1.01	1.5	
410.00	8	5.54	2.12	3.42	15.0		1.50	1.01	1.5	
409.00	8	5.66	2.18	3.48	14.9		1.49	1.01	1.5	
408.00	9	5.78	2.25	3.53	4.9		.63	1.01	.6	
407.00	9	5.90	2.31	3.59	4.9		.63	1.01	.6	
406.00	10					2.0	1.50	5.05	7.5	
405.00	10					2.0	1.50	5.05	7.5	
404.00	10					2.0	1.50	5.05	7.5	
403.00	10					2.0	1.50	5.05	7.5	
402.00	10					2.0	1.50	5.05	7.5	
401.00	11					3.5	2.20	5.05	11.1	
400.00	11					3.5	2.20	5.05	11.1	
399.00	11					3.5	2.20	5.05	11.1	
398.00	12					1.0	.91	5.05	4.6	
397.00	12					1.0	.91	5.05	4.6	
396.00	13					2.0	1.50	5.05	7.5	
395.00	13					2.0	1.50	5.05	7.5	
394.00	13					2.0	1.50	5.05	7.5	
393.00	13					2.0	1.50	5.05	7.5	
392.00	13					2.0	1.50	5.05	7.5	
391.00	13					2.0	1.50	5.05	7.5	
390.00	13					2.0	1.50	5.05	7.5	
389.00	13					2.0	1.50	5.05	7.5	
388.00	14					0.0	24.00	3.37	80.8	

Total Side Resistance = 379.4 k

Factored Pile Load = 220.0 k
Factored Downdrag Load = 0.0 k

Total Factored Load = 220.0 k

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PILE CAPACITY CALCULATION:

COMPUTE TIP RESISTANCE:
Fp*Ap = .117 s.f.
qp = 240.0 ksf
Total Tip Resistance = 240.0 ksf * .12 s.f. = 28.1 k

NOMINAL PILE RESISTANCE FOR THIS LOAD CASE (R_N):
R_N = (379.4 k + 28.1 k)*1.04
= 423.8 k (GOVERNS) < $R_{N,MAX}$ = 454.0 k for this pile

FACTORED RESISTANCE AVAILABLE (R_F):
R_F = R_N *φ G
= 423.8 k * (.55) = 233.1 k > 220.0 k (OK)

ESTIMATED REQUIRED PILE LENGTH:
Footing Elev = 446.00 ft
Pile Tip Elev = 388.00 ft

--> Estimated Required Pile Length = 58.00 ft
(not including portion embedded in the footing)

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PILE CAPACITY CALCULATION:

COMPUTE NOMINAL REQUIRED RESISTANCE DURING DRIVING:

In the previous analysis, the pile length required to support the loads was calculated based on eventual conditions that may include the effects of downdrag, scour and liquifaction. During the pile installation these effects will not exist, therefore we need to determine the forces due to side resistance without these effects.

The "Nominal Required Bearing" represents the resistance that the pile will experience during driving. This value is used in the field to determine the required pile length based on driving characteristics.

COMPUTE SIDE RESISTANCE DURING DRIVING:

Elev.	Layer No.	For Granular Soils				Qu	qs	Fs* Asa	Side Resistance
		σ_0	u_{w0}	σ'_0	$N1_{60}$	(tsf)	(ksf)	(sf)	(k)
(Driving El 446.00)									
445.00	1	.10	0.00	.10	4.9		.49	1.01	.5
(Ground Water El 444.00)									
444.00	1	.21	0.00	.21	4.3		.43	1.01	.4
443.00	1	.32	0.06	.26	4.1		.41	1.01	.4
442.00	1	.43	.12	.31	4.0		.40	1.01	.4
441.00	2					1.0	.91	5.05	4.6
440.00	2					1.0	.91	5.05	4.6
439.00	2					1.0	.91	5.05	4.6
438.00	3	.93	.37	.55	52.3		4.38	1.01	4.4
437.00	3	1.06	.44	.62	50.8		4.19	1.01	4.2
436.00	4	1.18	.50	.68	16.6		1.66	1.01	1.7
435.00	4	1.31	.56	.74	16.2		1.62	1.01	1.6
434.00	4	1.43	.62	.81	15.9		1.59	1.01	1.6
433.00	5					2.5	1.73	5.05	8.7
432.00	5					2.5	1.73	5.05	8.7
431.00	5					2.5	1.73	5.05	8.7
430.00	5					2.5	1.73	5.05	8.7
429.00	5					2.5	1.73	5.05	8.7
428.00	5					2.5	1.73	5.05	8.7
427.00	5					2.5	1.73	5.05	8.7
426.00	5					2.5	1.73	5.05	8.7
425.00	5					2.5	1.73	5.05	8.7
424.00	5					2.5	1.73	5.05	8.7
423.00	6	2.87	1.31	1.56	13.2		1.32	1.01	1.3
422.00	6	2.99	1.37	1.62	13.0		1.30	1.01	1.3

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PILE CAPACITY CALCULATION:

COMPUTE SIDE RESISTANCE DURING DRIVING (Cont'd):

Elev.	Layer No.	For Granular Soils				Qu	qs	Asa	Side Resistance
		σ_0	u_{w0}	σ'_0	$N1_{60}$	(tsf)	(ksf)	(sf)	(k)
421.00	7					.8	.76	5.05	3.8
420.00	7					.8	.76	5.05	3.8
419.00	7					.8	.76	5.05	3.8
418.00	7					.8	.76	5.05	3.8
417.00	7					.8	.76	5.05	3.8
416.00	7					.8	.76	5.05	3.8
415.00	7					.8	.76	5.05	3.8
414.00	7					.8	.76	5.05	3.8
413.00	7					.8	.76	5.05	3.8
412.00	7					.8	.76	5.05	3.8
411.00	8	4.30	2.06	2.24	17.6		1.76	1.01	1.8
410.00	8	4.43	2.12	2.31	17.4		1.74	1.01	1.8
409.00	8	4.55	2.18	2.37	17.2		1.72	1.01	1.7
408.00	9	4.67	2.25	2.42	5.7		.73	1.01	.7
407.00	9	4.79	2.31	2.48	5.7		.72	1.01	.7
406.00	10					2.0	1.50	5.05	7.5
405.00	10					2.0	1.50	5.05	7.5
404.00	10					2.0	1.50	5.05	7.5
403.00	10					2.0	1.50	5.05	7.5
402.00	10					2.0	1.50	5.05	7.5
401.00	11					3.5	2.20	5.05	11.1
400.00	11					3.5	2.20	5.05	11.1
399.00	11					3.5	2.20	5.05	11.1
398.00	12					1.0	.91	5.05	4.6
397.00	12					1.0	.91	5.05	4.6
396.00	13					2.0	1.50	5.05	7.5
395.00	13					2.0	1.50	5.05	7.5
394.00	13					2.0	1.50	5.05	7.5
393.00	13					2.0	1.50	5.05	7.5
392.00	13					2.0	1.50	5.05	7.5
391.00	13					2.0	1.50	5.05	7.5
390.00	13					2.0	1.50	5.05	7.5
389.00	13					2.0	1.50	5.05	7.5
388.00	14					0.0	24.00	3.37	80.8

Total Side Resistance During Driving = 385.5 k
Tip Resistance = 28.1 k
Rn = 413.6 k
< $R_{N,MAX}$ = 454.0 k

--> Nominal Required Resistance During Driving = 413.6 k