MacLean™
POWER SYSTEMS

EXCALIBUR HIGH CAPACITY PILES

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DYLAN ROBINSON, P.E.

EXCALIBUR HIGH CAPACITY PILES

- Communication Breakdown
- Product Overview
- Design Methodology
- Installation Procedure

COMMUNICATION BREAKDOWN

- Request for a foundation pile comes in
- Send information to MPS sales person and myself
  - Geotechnical report (boring log)
  - Pile loading information
  - Foundation plans/details
- I will review and provide a product recommendation and quote

- For finer points of installation, may require conference call with necessary parties and PW at my discretion

EXCALIBUR PRODUCT OVERVIEW

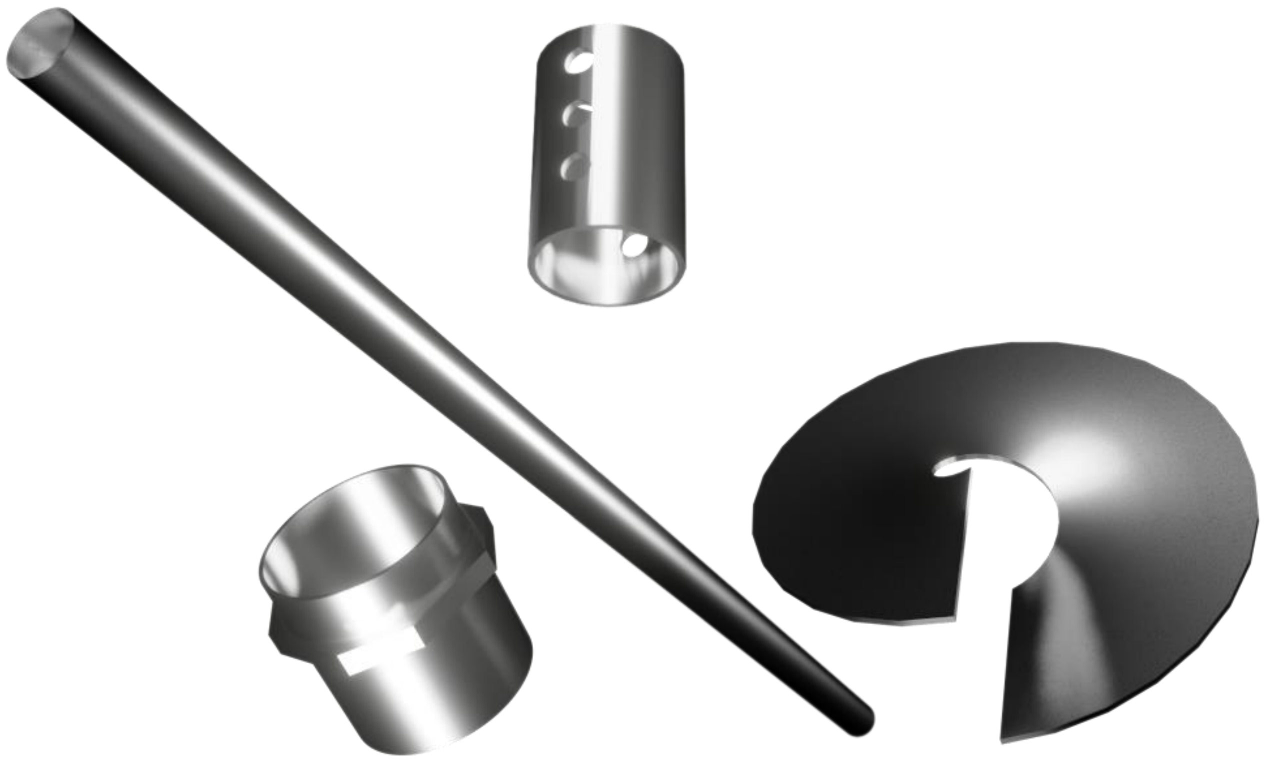
- Displacement Pile
  - Steel pile that is torqued into the soil
  - Multiple driver plates
  - Capacity estimated by measuring torque and applying a torque factor
  - Develops the majority of its axial resistance through end bearing on driver plates

EXCALIBUR PRODUCT OVERVIEW

- Pressure Grouted Pile (DDM)
  - Steel pile that is torqued into the soil and encased in grout
  - Single driver plate
  - Grout delivered through ID of the pile as it is advanced in the soil
  - Capacity is determined by the length and diameter of the grout column
  - Develops the majority of its axial resistance through skin friction

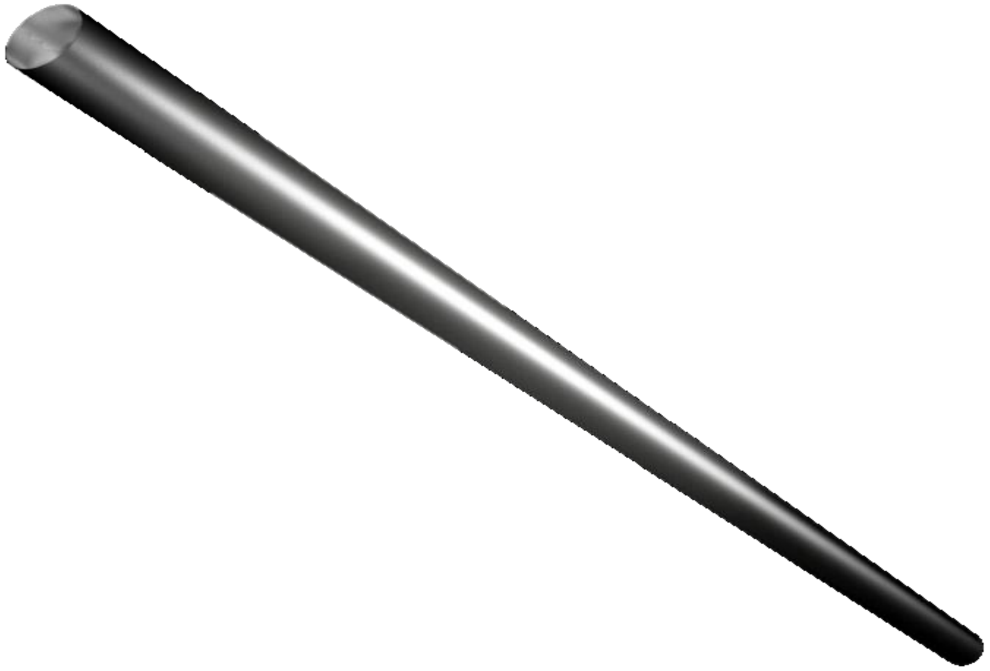
PRODUCT OVERVIEW

- Shaft
- Couplings
- Driver plate(s)
- Grout
- Termination



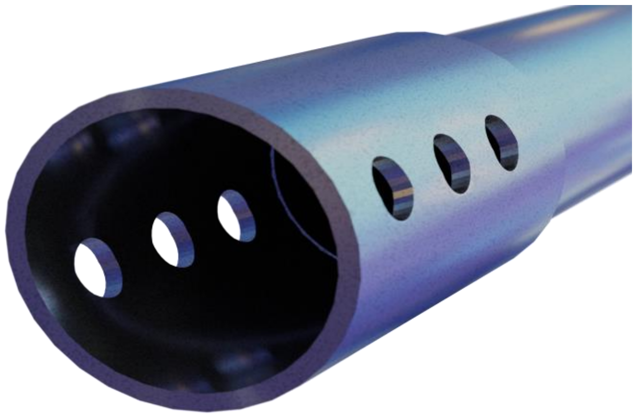
SHAFT

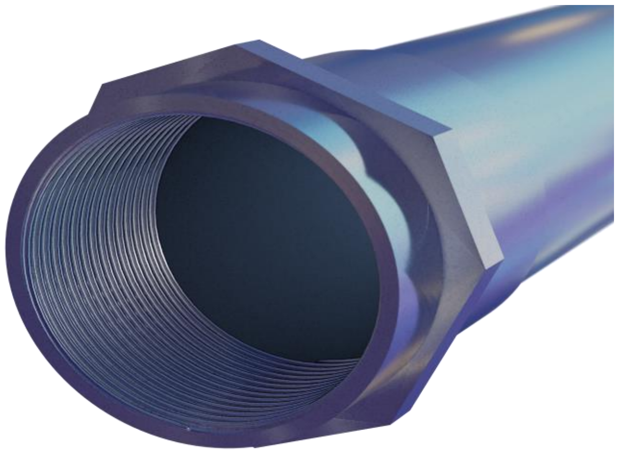
- 4.5” to >9.625” OD pipe
- 10’ – 40’ lengths
- 80 ksi yield strength
- Seamless pipe
- Displaces soil
- No vibrations
- Galvanizing available



COUPLINGS

- Bolted
- Threaded





DRIVER PLATE(S)

- 8” – 30” diameter
- ½” – ¾” thick
- 6” pitch
- Help to advance to the pile
- Create annulus for grout column
- End bearing

GROUT

- Neat grout mix
- 4,000 psi min yield
- Delivered through ID of pile during installation
- Able to control bonded length

TERMINATIONS

- Stationary bolted top plates
- Adjustable top plates
- Nelson studs

CAPACITY CHART – DISPLACEMENT PILES

Catalog Number	Pipe Dimensions (in)	Ultimate Axial Capacity (kips)*	Ultimate Torque Rating (ft-lb)*	Kt factor (ft^{-1})
H45/T45	4.5 x 0.290	184	35,000	6
H55/T55	5.5 x 0.415	318	65,000	5
H70/T70	7 x 0.408	406	122,000	4
H76/T76	7.625 x 0.500	537	150,000	3.9
H96/T96	9.625 x 0.545	746	250,000	3.1

*Ratings vary based on coupler configuration, grade of steel

H – bolted couplers

T – threaded couplers

TORQUE TO CAPACITY EXAMPLE

7” OD pile, Kt = 4

- Pile installed to 45’
- Average torque over final 3’
  - 18,000 ft-lbs

18,000 ft-lbs x 4 ft^{-1} = 72,000 lbs

4.5” OD pile, Kt = 6

- Pile installed to 30’
- Average torque over final 3’
  - 25,000 ft-lbs

25,000 ft-lbs x 6 ft^{-1} = 150,000 lbs

Installation torque is a direct measurement of the soil’s shear strength that the plates are embedding into

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CAPACITY CHART – PRESSURE GROUTED PILES (DDM)

Catalog Number	Pipe Dimensions (in)	Ultimate Torque Rating (ft-lb)*	Grout Column Diameter (in)*	Grout Take (yd^3 per ft)	Ultimate Compression (kips)*	Ultimate Tension (kips)*
G45/W45	4.5 x 0.290	35,000	16	0.05	428	169
G55/W55	5.5 x 0.415	65,000	18	0.07	607	292
G70/W70	7 x 0.408	122,000	20	0.08	764	372
G76/W76	7.625 x 0.500	150,000	22	0.1	958	492
G96/W96	9.625 x 0.545	250,000	24	0.11	1,230	684

*Ratings vary based on coupler configuration, grade of steel, grout

G – bolted couplers

W – threaded couplers

APPLICATIONS

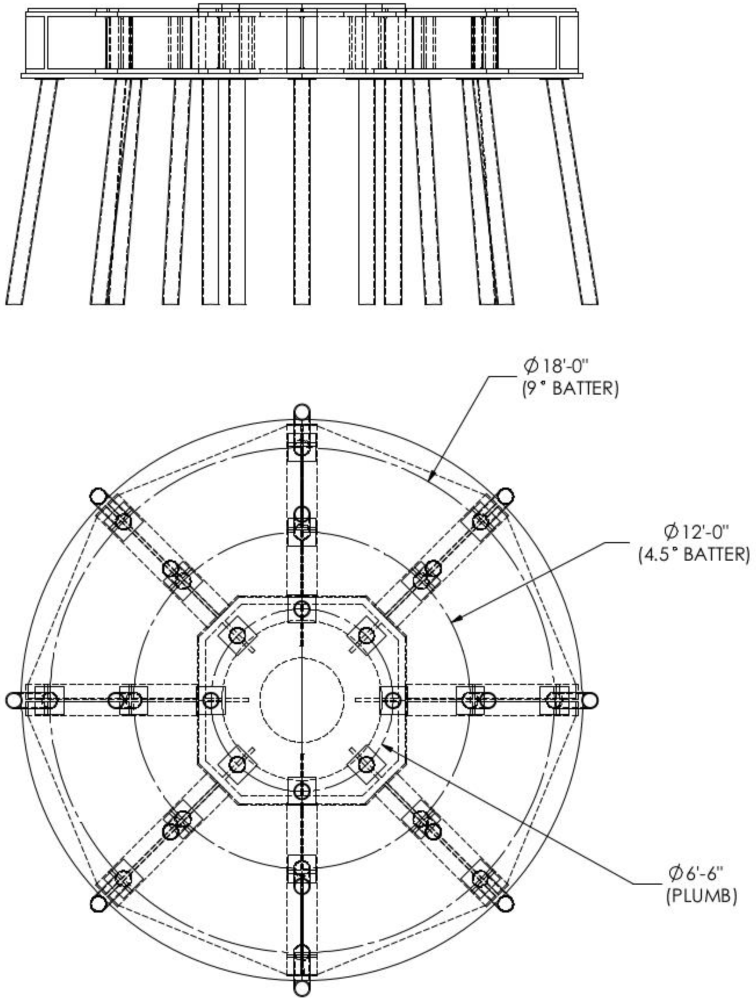
- Bridge abutments
- Commercial building foundation
- High axial and/or lateral loads
- Areas with poor upper soil layers
- Contaminated soils

APPLICATIONS

- Multi-Story new build
- Storage tanks/silos
- Towers
- Substations

- Sound walls
- Commercial building remediation
- Tiebacks/bulkheads

PILE SIZE = 7.00 X .432 WALL
PILE MAT'L: L80
TOTAL PILES: 24



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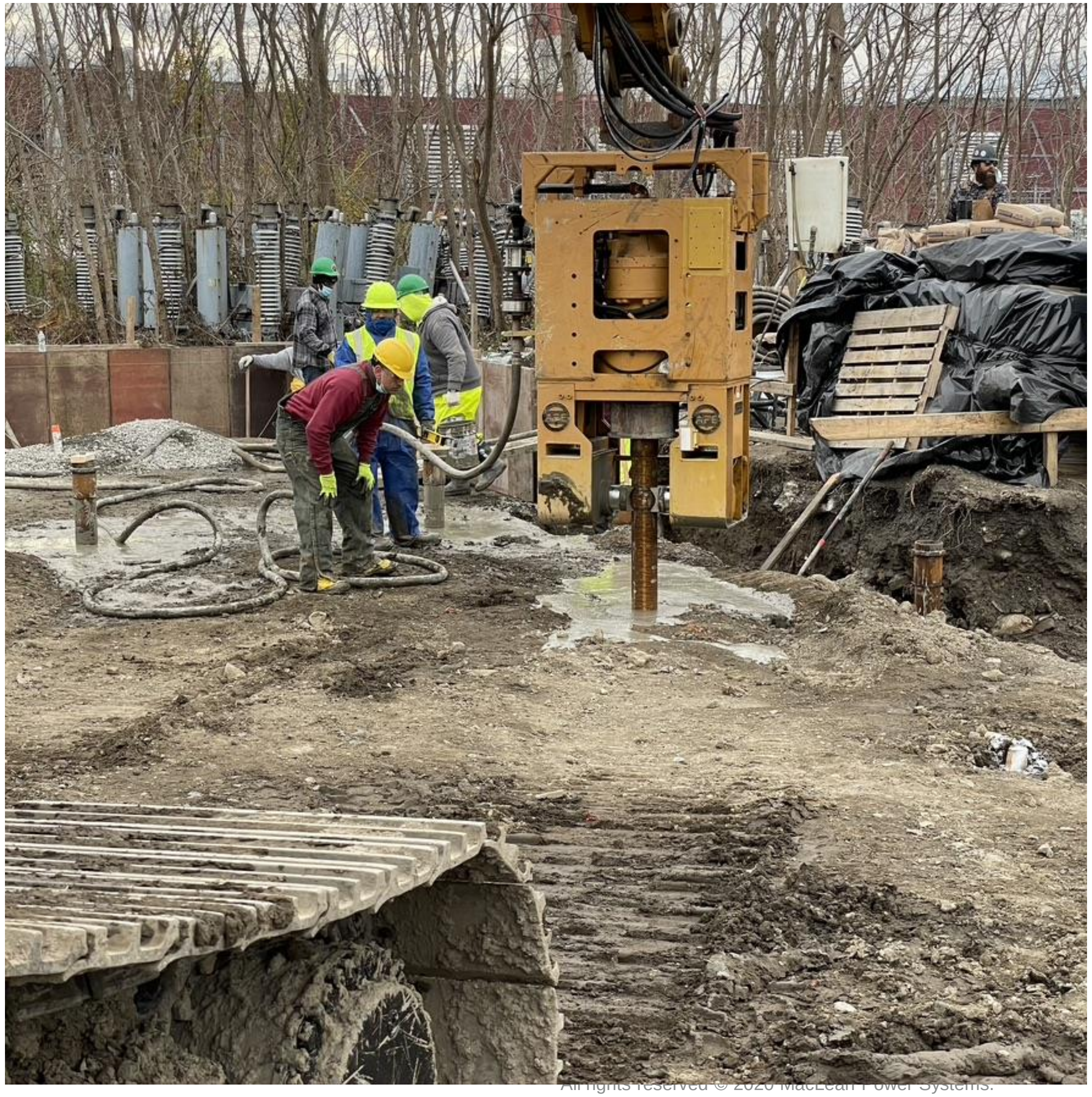
HIGH CAPACITY PILE CASE STUDIES

- Louisiana
- 115 kV Substation
- 5.5” x 0.415” Grouted piles
- 35’ deep with 16” grout column
- Very soft clay and silt
- 70 kips compression
- 7 kips lateral, 140 ft-kips moment

- New York
- 20,000 Gallon Dielectric Fluid Tank
- 5.5” x 0.415” Grouted piles
- 25’ deep with 12” grout column
- Very dense misc. fill in upper 20’ followed by very dense glacial till
- 80 kip compression, 40 kip uplift
- 0.3” deflection under load

NEW YORK



HIGH CAPACITY PILE CASE STUDY

- Louisiana
- 230 kV bus support
- 8.625” x 0.322” displacement pile
- 45’ depth with 14”, 16” driver plates
- Very soft clays
- 20 kip compression
- 10 kip lateral, 56 ft-kip moment

- Louisiana
- 230 kV substation
- 8.625” x 0.188” displacement pile
- 60’ depth with 14”, 16” driver plates
- Very soft clays
- 40 kip compression, 32 kip uplift
- 4 kip lateral

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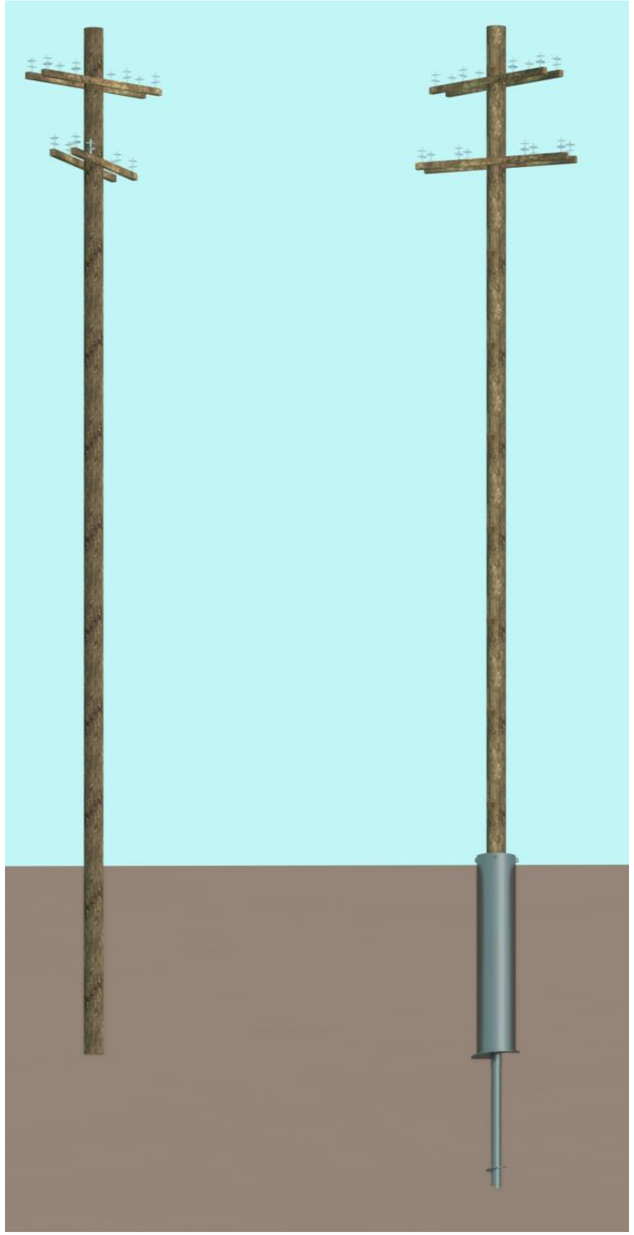

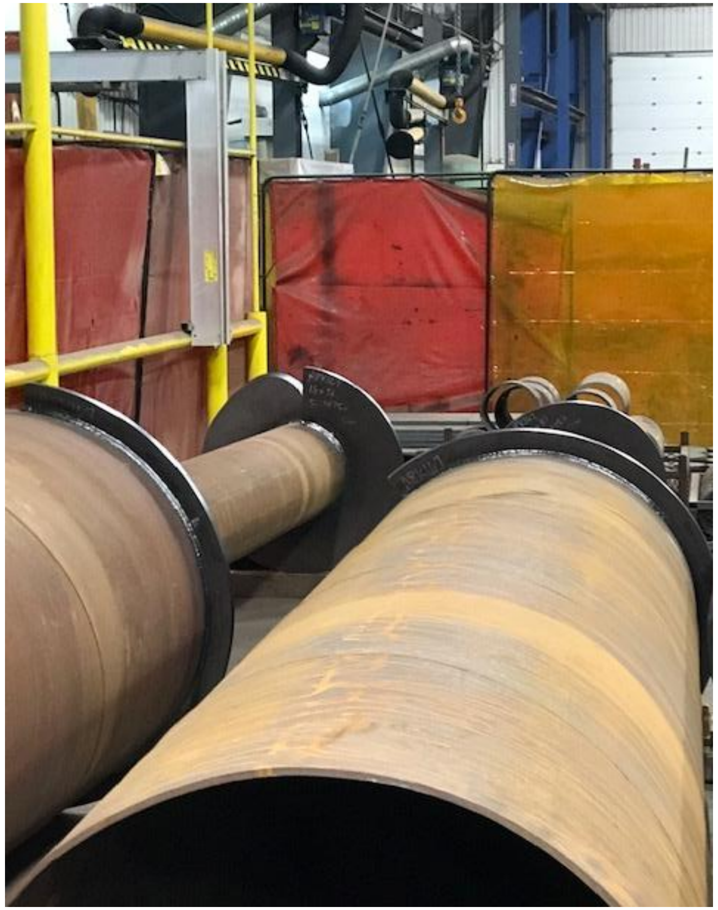

BUCKET PILE CASE STUDIES

- Galveston, TX
- 69 kV
- 7” pipe x 7’ lead section
- 18” driver plate
- 24” bucket x 9’
- Grouted
- 61 kip compression
- 4 kip shear, 180 ft-kip moment

- New Jersey rail crossing
- 69 kV
- 7.625” x 9’ lead section
- 14”, 16” double driver plate
- 30” x 13’ bucket section
- Concrete collar
- 55 kip compression, 13 kip uplift
- 8 kip shear, 310 ft-kip moment

Excalibur Bucket Pile Capacity Chart

Lead OD (in)	Bucket OD (in)	Soft Clay: Moment Resistance (ft-kips)	Soft Clay: Lateral Resistance (kips)	Medium Stiff Clay: Moment Resistance (ft-kips)	Medium Stiff Clay: Lateral Resistance (kips)	Loose Sand: Moment Resistance (ft-kips)	Loose Sand: Lateral Resistance (kips)
4.5	20	138.1	19.8	252.0	39.0	400.0	59.0
5.5	24	168.6	22.9	316.8	46.3	569.2	78.4
5.5	30	191.8	25.9	375.9	54.0	866.7	110.8
7	30	220.3	27.7	416.8	56.9	941.7	116.6
7	36	237.5	30.1	457.9	62.9	1,141.7	139.3
7.625	36	258.7	31.4	487.4	64.8	1,200.0	144.1
9.625	42	327.7	36.9	617.1	76.2	1,550.0	177.1
9.625	48	341.7	39.0	656.0	81.6	1,741.7	197.0

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DESIGN METHODOLOGY

- Allowable Stresses
    - Displacement pile
        - Helical pile – IBC
    - Pressure grouted pile (DDM)
        - Micropile – FHWA/IBC

- Geotechnical Capacity
    - Terzaghi's general bearing formula
    - Skin friction calculations
    - LPILE analysis

IBC – DISPLACEMENT PILE

1810.3.2.6 Allowable stresses.

The allowable stresses for materials used in deep foundation elements shall not exceed those specified in Table 1810.3.2.6.

TABLE 1810.3.2.6
ALLOWABLE STRESSES FOR MATERIALS USED IN DEEP FOUNDATION ELEMENTS

MATERIAL TYPE AND CONDITION	MAXIMUM ALLOWABLE STRESS[a]
1. Concrete or grout in compression[b] Cast-in-place with a permanent casing in accordance with Section 1810.3.2.7 Cast-in-place in a pipe, tube, other permanent casing or rock Cast-in-place without a permanent casing Precast nonprestressed Precast prestressed	$0.4\ f'_c$ $0.33\ f'_c$ $0.3 f'_c$ $0.33 f'_c$ $0.33 f'_c - 0.27\ f_{pc}$
2. Nonprestressed reinforcement in compression	$0.4\ f_y \leq 30{,}000$ psi
3. Steel in compression Cores within concrete-filled pipes or tubes Pipes, tubes or H-piles, where justified in accordance with Section 1810.3.2.8 Pipes or tubes for micropiles Other pipes, tubes or H-piles Helical piles	$0.5\ F_y \leq 32{,}000$ psi $0.5\ F_y \leq 32{,}000$ psi $0.4\ F_y \leq 32{,}000$ psi $0.35\ F_y \leq 16{,}000$ psi $0.6\ F_y \leq 0.5\ F_u$
4. Nonprestressed reinforcement in tension Within micropiles Other conditions	$0.6\ f_y$ $0.5\ f_y \leq 24{,}000$ psi
5. Steel in tension Pipes, tubes or H-piles, where justified in accordance with Section 1810.3.2.8 Other pipes, tubes or H-piles Helical piles	$0.5 F_y \leq 32{,}000$ psi $0.35\ F_y \leq 16{,}000$ psi $0.6\ F_y \leq 0.5\ F_u$
6. Timber	In accordance with the ANSI/AWC NDS

a. f'_c is the specified compressive strength of the concrete or grout; f_{pc} is the compressive stress on the gross concrete section due to effective prestress forces only; f_y is the specified yield strength of reinforcement; F_y is the specified minimum yield stress of steel; F_u is the specified minimum tensile stress of structural steel.

b. The stresses specified apply to the gross cross-sectional area within the concrete surface. Where a temporary or permanent casing is used, the inside face of the casing shall be considered to be the concrete surface.

IBC – PRESSURE GROUTED PILE (DDM)

1810.3.2.6 Allowable stresses.

The allowable stresses for materials used in deep foundation elements shall not exceed those specified in Table 1810.3.2.6.

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2. Nonprestressed reinforcement in compression	$0.4 f_y \leq 30{,}000$ psi
3. Steel in compression Cores within concrete-filled pipes or tubes Pipes, tubes or H-piles, where justified in accordance with Section 1810.3.2.8 Pipes or tubes for micropiles Other pipes, tubes or H-piles Helical piles	 $0.5 F_y \leq 32{,}000$ psi $0.5 F_y \leq 32{,}000$ psi $0.4 F_y \leq 32{,}000$ psi $0.35 F_y \leq 16{,}000$ psi $0.6 F_y \leq 0.5 F_u$
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6. Timber	In accordance with the ANSI/AWC NDS

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b. The stresses specified apply to the gross cross-sectional area within the concrete surface. Where a temporary or permanent casing is used, the inside face of the casing shall be considered to be the concrete surface.

PRESSURE GROUTED PILE (DDM) – FHWA NHI-05-039

(FHWA Equation 5-1)

$$P_{allcomp} = 0.47 * f_{yshaft} * A_s + 0.4 * f_c' * (A_{ginside} + A_{goutside} * r_{outside})$$

(FHWA Equation 5-2)

$$P_{t-allowable} = 0.55 * f_y * A_s$$

GEOTECHNICAL CALCULATIONS

- Terzaghi's general bearing formula

$$Q_{ult} = A_{plate}(cN_c + \ q'N_q + 0.5\gamma' BN_\gamma)$$

- Skin friction formulas

$$Q_s = 0.6 * \pi * D_s * f_s * L_f$$

$$Cohesive\ Soils: f_s = \alpha * c$$

$$Noncohesive\ Soils: f_s = \beta * \sigma'_v$$

- FHWA skin friction formula

$$P_{G-allowable} = \frac{\alpha_{bond}}{FS} * \pi * D_b * L_b$$

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BOND STRENGTHS

- Type B – pressure grouted
- Most effective in areas with medium dense to dense sand and gravel

Table 5-3 FHWA NHI-05-039

Soil / Rock Description	Grout-to-Ground Bond Ultimate Strengths, kPa (psi)			
	Type A	Type B	Type C	Type D
Silt & Clay (some sand) (soft, medium plastic)	35-70 (5-10)	35-95 (5-14)	50-120 (5-17.5)	50-145 (5-21)
Silt & Clay (some sand) (stiff, dense to very dense)	50-120 (5-17.5)	70-190 (10-27.5)	95-190 (14-27.5)	95-190 (14-27.5)
Sand (some silt) (fine, loose-medium dense)	70-145 (10-21)	70-190 (10-27.5)	95-190 (14-27.5)	95- 240 (14-35)
Sand (some silt, gravel) (fine-coarse, med.-very dense)	95-215 (14-31)	120-360 (17.5-52)	145-360 (21-52)	145-385 (21-56)
Gravel (some sand) (medium-very dense)	95-265 (14-38.5)	120-360 (17.5-52)	145-360 (21-52)	145-385 (21-56)
Glacial Till (silt, sand, gravel) (medium-very dense, cemented)	95-190 (14-27.5)	95-310 (14-45)	120-310 (17.5-45)	120-335 (17.5-48.5)
Soft Shales (fresh-moderate fracturing, little to no weathering)	205-550 (30-80)	N/A	N/A	N/A
Slates and Hard Shales (fresh-moderate fracturing, little to no weathering)	515-1,380 (75-200)	N/A	N/A	N/A
Limestone (fresh-moderate fracturing, little to no weathering)	1,035-2,070 (150-300)	N/A	N/A	N/A
Sandstone (fresh-moderate fracturing, little to no weathering)	520-1,725 (75.5-250)	N/A	N/A	N/A
Granite and Basalt (fresh-moderate fracturing, little to no weathering)	1,380-4,200 (200-609)	N/A	N/A	N/A

Type A: Gravity grout only
Type B: Pressure grouted through the casing during casing withdrawal
Type C: Primary grout placed under gravity head, then one phase of secondary "global" pressure grouting
Type D: Primary grout placed under gravity head, then one or more phases of secondary "global" pressure grouting

ADDITIONAL CALCULATION

- Davisson Failure Deformation
  - Estimate pile deflection during load test
- Flexural capacity
  - Verify allowable axial and moment capacities of shaft are sufficient
- Buckling capacity
  - Verify pile will not buckle in areas with low consistency (N<5) soils
- Ensoft's LPILE
  - Program used to determine lateral capacity and pile head deflection

PRODUCT RECOMMENDATION PACKET

- Summarizes assumptions and mechanical/geotechnical inputs
- Shows calculations and code references

EXCALIBUR™ MacLean™ POWER SYSTEMS

March 4, 2021

Joe Engineer
Project Engineer
Engineer Services Corp.
2122 Lincoln Way
Ames, IA 50014
(468) 385-6691

Dear Joe,

Per your request we have evaluated our displacement pile product line in terms of the soils boring information provided to our office on the Big Deal High Capacity project. The boring log provided and used for geotechnical pile capacity estimates is referenced as B-1 based on soils data obtained on 03/04/2020. Soil strength parameters used in this pile capacity estimation were taken from *Table 5-3. Soil Parameters for Micropile Lateral Capacity*.

For this pile capacity estimation our final product modeled was a 5.5" (0.415" wall) steel shaft with a 14" driver plate to form a 12" diameter grout column around the central steel shaft. This was found to be an economic option given the soil design parameters provided to us.

The following summary page will outline all pertinent inputs and calculations. Calculations can be found in the appendix.

A load test is recommended to confirm the axial load capacity shown on the following summary reports.

Please contact our office if you have any questions.

With regards,

Dylan Robinson, P.E.

Project Engineer
MacLean Power Systems
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Steel Calculation Summary

Inputs				
OD	Pipe Outer Diameter	5.5	inches	
t	Pipe Wall Thickness	0.415	inches	
ID	Pipe Inner Diameter	4.67	inches	
A_s	Pipe Area	6.63	$inches^2$	
Z	Plastic Section Modulus	10.75	$inches^3$	
I	Moment of Inertia	46.07	$inches^4$	
f_y	Yield Strength	80	ksi	

	Calculations			Formulas	Reference
V_n	Nominal Shear	159.1	kips	$V_n = F_{cr}*A_g/2$	AISC G6 Round HSS
V_a	Allowable Shear	95	kips	$V_a = V_n/\Omega$	Ω = 1.67 - AISC Chapter G
$P_{c\text{-}allowable}$	Allowable Compression	249	kips	$P_{c\text{-}allowable} = 0.47*f_y*A_s$	FHWA Equation 5-1
$P_{t\text{-}allowable}$	Allowable Tension	292	kips	$P_{t\text{-}allowable} = 0.55*f_y*A_s$	FHWA Equation 5-2
M_n	Nominal Moment	860	kip-ft	$M_n = F_y*Z$	AISC F8 Round HSS
M_a	Allowable Moment	515.2	kip-ft	$M_a = M_n/\Omega$	Ω = 1.67 - AISC Chapter F

Composite Calculation Summary

Inputs			
f'_c	Compressive Strength of Concrete (28 days)	4	ksi
OD_g	Design Grout Column Diameter	10	inches
$r_{outside}$	Reduction Factor for Grout Column Diameter	0.7	

	Calculations			Formulas
E_c	Mod of Elasticity Concrete	3605	ksi	$E_c = 57000*f'_c{}^{0.5}$
$A_{ginside}$	Area Grout Inside Pipe	17	$inches^2$	$A_{ginside} = pi*ID^2/4$
$A_{goutside}$	Area Grout Outer Column	231	$inches^2$	$A_{goutside} = pi*(OD_g{}^2 - OD^2)/4$
$P_{allcomp}$	Allowable Compressive Strength of Composite	535	kips	$P_{allcomp}$ = 0.47*fy*As + 0.4*f'c*(Aginside + Agoutside*routside)

Geotechnical Calculation Summary

Inputs			
	Soil Boring ID	B-1	
	Pile Tip Depth	30	ft

	Calculations			Formulas	
Q_{ult}	End Bearing Capacity	127.8	kips	$Q_{ult} = A_{plate}*(c*N_c + q*N_q)$	Terzaghi (1943)
$P_{G\text{-}allowable}$	Skin Friction/Tension Resistance	79.2	kips	$P_{G\text{-}allowable} = \alpha_{bond}*L_b*OD_g*\pi/FS$	FHWA-NHI-05-039
Q_T	Compression Resistance	207.0	kips	$Q_T = Q_{ult} + P_{G\text{-}allowable}$	

Note: All values, calculations and recommendations should be considered estimates based on information provided at time of request. All recommendation provided should be reviewed and accepted by the project engineer of record. Calculations are based on applicable building codes and industry standards.

Deformation Calculator for Load Testing

E_{steel}	29000000	psi	
f'_c	4000	psi	
E_c	3604997	psi	$57{,}000*f'^{0.5}_c$
n	0.12431		E_g/E_s
max load, P	160	kips	
pile length, L	30	feet	

Calculations

										1	2	3	4
			Steel Area			Equivalent Grout Diameter	Driver Plate Diameter	Interior Grout Area	Exterior Grout Area	AE_{comp} (steel basis)	Theoretical Elastic Compression	Davisson Offset	Davisson "Failure" Deformation at Load
OD	t	ID	A_s	f_y	f'_c		D_{plate}	$A_{ginside}$	$A_{goutside}$				
inches	inches	inches	In^2	ksi	ksi	inches	inches	In^2	In^2	pounds	inches	inches	inches
4.5	0.29	3.92	3.84	80	4	10	14	12	63	380540091	0.15	0.27	0.42
5.5	0.415	4.67	6.63	80	4	10	14	17	55	451495101	0.13	0.27	0.39
7	0.408	6.184	8.45	80	4	10	14	30	40	497708982	0.12	0.27	0.38
9.625	0.545	8.535	15.55	80	4	9	12	57	-9	624143021	0.09	0.25	0.34

Calculations

1. $A_s*E_s + (A_{ginside} + A_{goutside})*n*E_s$
2. $P*L/(E*A)$
3. $0.15 + D_{plate}/120$
4. calculations 2 + 3

Flexural Strength Check

P_r	120	Required axial load (kips)
P_c	535	Axial strength of the material (kips)
M_r	355	Required flexural strength (in-kips)
M_c	515	Flexural strength of the material (in-kips)

Calculations	1	2	3
	P_r/P_c ratio	if ≥ 0.2; $P_r/P_c + (8/9)*(M_r/M_c)$	if < 0.2; $P_r/(2*P_c) + M_r/M_c$
	0.22	0.837	N/A

Calculations

1 AISC 360 axial strength ratio
2 Check to verify resulting value is ≤ 1 — AISC 360 equation H1-1a
3 Check to verify resulting value is ≤ 1 — AISC 360 equation H1-1ab

Buckling Check

OD	5.5	inches
t	0.415	inches
ID	4.67	inches
f_y	80	ksi
A_S	6.63	in^2
moment of inertia, I	21.57	in^4
radius of gyration, r	1.80	inches
E_{steel}	29000	ksi
unsupported length, L	8	feet
f'_c	4	ksi
A_g	60	in^2

Calculations		4	5		6	7	8	9	10
	Soil Type	Soil Elastic Constant	Soil Elastic Constant Limit	check if $E_s > E_s^{LIMIT}$	Critical Buckling Load	Slenderness Ratio		Allowable Stress	Allowable Compressive Load
	Fine Sand - Loose	E_s	E_s^{LIMIT}		P_{cr}	K*L/r	C_c	F_a	$P_{c\text{-}allowable}$
		ksf	ksf		kips			ksi	kips
		160	129.51	buckling does not need to be considered	N/A	N/A	N/A	#VALUE!	N/A

Calculations

4 FHWA NHI-05-039 Table 5-12 or 5-13
5 $L/((4*I/A_s^2)*(E_s/f_y^2))$ — FHWA NHI-05-039 equation 5-29
6 $\pi^2*E_{steel}*I/L^2 + E_s*L^2/\pi^2$ — FHWA NHI-05-039 equation 5-28
7 K assumed equal to 1.0 per FHWA NHI-05-039 Section 5.6
8 ratio of steel material properties per FHWA NHI-08-039 section 5.21.2
9 if $K*L/r \le C_c$, $F_a = f_y/FS*(1-((K*L/r)^2/(2*C_c^2)))$ else, $F_a = \pi^2*E_{steel}/(FS*(K*L/r)^2)$ — FHWA NHI-05-039 equation 5-31 and 5-32 — FS = factor of safety = 2.12 per Table 10.32.1A AASHTO (2002)
10 $P_{c\text{-}allowable} = (0.4*f'_c \cdot A_g+0.47*f_y \cdot A_s)*F_a/(0.47*f_y)$ — FHWA NHI-05-039 equation 5-30

Allowable Load

Steel Calculations

								1	2	3	4	5	6
			Steel Area					Nominal Shear	Allowable Shear	Allowable Compression	Allowable Tension	Nominal Moment	Allowable Moment
OD	t	ID	A_s	Z	I	f_y	C_v	V_n	V_a	$P_{c\text{-allowable}}$	$P_{t\text{-allowable}}$	M_n	M_a
inches	inches	inches	in^2	in^3	in^4	ksi		kips	kips	kips	kips	in-kip	in-kip
4.5	0.29	3.92	3.84	5.15	8.54	80	1.0	92.1	55.1	144	169	412	246.6
5.5	0.415	4.67	6.63	10.75	21.57	80	1.0	159.1	95.3	249	292	860	515.2
7	0.408	6.184	8.45	17.75	46.07	80	1.0	202.8	121.4	318	372	1420	850.4
7.625	0.500	6.625	11.19	25.42	71.37	80	1.0	268.6	160.8	421	492	169	101.5
9.625	0.545	8.535	15.55	44.99	160.80	80	1.0	373.1	223.4	585	684	300	179.6

Composite (Steel+Grout) Calculations

										7	8	9
			Steel Area			Equivalent Grout Diameter	Interior Grout Area	Exterior Grout Area	Reduction Factor for Exterior Area	Check % of steel	Composite Allowable Compression	Composite Allowable Moment
OD	t	ID	A_s	f'_c	E_c		$A_{ginside}$	$A_{goutside}$	$r_{outside}$		$P_{allcomp}$	
inches	inches	inches	in^2	ksi	ksi	inches	in^2	in^2			kips	in-kip
4.5	0.29	3.92	3.84	4	3605	16	12	185	0.7	1.9%	371	246.6
5.5	0.415	4.67	6.63	4	3605	18	17	231	0.7	2.6%	535	515.2
7	0.408	6.184	8.45	4	3605	20	30	276	0.7	2.7%	675	850.4
7.625	0.5	6.625	11.19	4	3605	22	34	334	0.7	2.9%	851	101.5
9.625	0.545	8.535	15.55	4	3605	24	57	380	0.7	3.4%	1101	179.6

Calculations

1 $0.6*F_y*A_s/2$ — AISC G6 Round HSS

2 V_n/Ω — $\Omega = 1.67$ — AISC Chapter G

3 $0.47*f_y*A_s$ — FHWA Equation 5-1

4 For tension, ignore grout $F_{at} = 0.55*F_y$ — FHWA Equation 5-2

5 f_y*Z — AISC F8 Round HSS

6 M_n/Ω — $\Omega = 1.67$ — AISC Chapter F

7 Cross-sectional area of steel must be a minimum of 1% of total composite cross section; conservatively ignore reduction factor

8 $P_{allcomp} = 0.47*f_y*A_s + 0.4*f'_c*(A_{ginside} + A_{goutside}*r_{outside})$ — FHWA Equation 5-1

9 The flexural strength of a composite concrete/steel member is assumed to be the same as the steel member alone

Allowable per FHWA-NHI-05-039

Excludes potential strength reduction at joints

Geotechnical Information

Est Grout Column Diameter (inch)	12	Perimeter (inch)	37.7	Perimeter (foot)	3.1
Pile Tip Diameter (inch)	14	Area ($inch^2$)	153.9	Area ($foot^2$)	1.1

Soil Boring ID B-1

Groundwater Table 10 feet Groundwater Unit Weight γ_w 62.4 lb/ft^3

Calculations

Soil Strata (feet)		Strata Depth	1 Soil Description	2 SPT N	3 Soil Condition	4 Unit Weight γ	5 Effective Unit weight γ'	6 Effective Confining Stress - Bottom σ'_{vb}	7 Effective Confining Stress - Mid Layer σ'_{vm}	8 Cohesion S_u	9 Friction Angle ϕ'	10 Type B Bond Strength Soil Type	11 Type B Ultimate Bond Strength α	Factor of Safety FS	12 Type B Allowable Bond Strength	13 Skin Friction Resistance
Beginning	End	feet		blows/foot		lb/ft^3	lb/ft^3	lb/ft^2	lb/ft^2	lb/ft^2	degrees		lb/in^2		lb/in^2	kips
0	10	10	cohesionless	34	Dense	132	132	1320.0	660.0	0	39.2	FILL - neglect	0	2	0	0.00
10	20	10	cohesionless	45	Dense	137.5	75.1	2071.0	1695.5	0	43.2	FILL - neglect	0	2	0	0.00
20	30	10	cohesionless	45	Dense	137.5	75.1	2822.0	2446.5	0	43.2	SP, SW-SM	35	2	17.5	79.17

Calculations

					14	15	16	17, 18, 19		
Pile Tip Depth	30	cohesionless	26	Dense	N_c	N_q	σ'_{vb}	Q_{ult} End Bearing	127.82	kips
					0	42.37	2822.0	$P_{G\text{-}allowable}$ Skin Friction/Tension Resistance	79.17	kips
								Q_T Compression Resistance	206.99	kips

Calculations

1 Input cohesive or cohesionless
2 Input field SPT N; whole number between 0 and 50
3 Soil condition for cohesionless soils; Loose if SPT N < 15, Dense otherwise
4 γ per Bowles (1996)
5 $\gamma' = \gamma - \gamma_w$
6 σ'_{vb} calculated as γ'*Strata Depth
7 σ'_{vm} taken as the average confining stress acting on a given soil strata
8 S_u calculated as SPT N*125 or manually entered
9 ϕ' per Bowles (1996) or manually entered
10 Input Type B micropile bond strength
11 Ultimate Bond Strength is the average bond strength based on input soil type
12 Allowable Bond Strength calculated as Ultimate Bond Strength/Factor of Safety
13 Skin Friction Resistance calculated per FHWA-NHI-05-039 as α*Strata Depth*Perimeter/FS
14 For cohesive soils, $N_c = 9$
15 For cohesionless soils, N_q per Terzaghi (1943) reduced by 0.6 for long term applications
16 σ'_{vb} taken as the effective confining stress at the pile tip
17 End bearing calculated using Terzaghi's general bearing formula
18 Compression Resistance taken as End Bearing + Skin Friction Resistance
19 Tension Resistance = Skin Friction Resistance

INSTALLATION PROCEDURE – DISPLACEMENT

1. Attach the hydraulic drive head to the Excalibur lead section and align pile tip at specified pile location.

2. Advance the lead section into the ground while maintaining steady torque.

3. Sufficient crowd shall be applied to the pile throughout the entire installation process to ensure 6 inches of advancement per revolution.

4. Document installation torque every 1 to 3 feet during installation and at pile termination using the MPS Excalibur Displacement Pile Installation Record provided. Pile capacity is estimated using installation torque and shaft specific torque factor (K_t).

5. Where extensions are required, stop the drive head and remove from lead section. Attach the hydraulic drive head to the Excalibur extension section. Attach the extension section to the lead section with specified hardware or by threading sections together and continue installation. Add extensions as required to reach design depth.

6. If dense soils or obstructions are encountered and the pile will not advance, reverse the pile 24 inches and re-advance. Repeat 3 to 5 times while measuring how much the pile advances each time. Do not exceed maximum specified torque of the shaft. If the pile will not advance, then pre-auguring may be required to reach design depth (Confer with Engineer of Record).

7. If the pile is terminated above the pile cut-off elevation, cut the pile using an appropriate method such as a band saw or torch.

8. Install steel pile cap or termination.

- Key Points:
  - Record and monitor torque and depth

INSTALLATION PROCEDURE – PRESSURE GROUTED PILE (DDM)

1. Attach the hydraulic drive head to the Excalibur lead section and align pile tip at specified pile location.

2. Advance the lead section approximately 12 inches below ground and begin grouting (350 psi maximum). If there is a planned unbonded zone, maintain minimal grout flow until specified start to bonded zone is reached.

3. Record grout take during entire installation of each pile using the Excalibur Grouted Displacement Pile Installation Record. A grout flow meter can be utilized to increase grout volume measurement accuracy.

4. Grout shall be pumped continuously to fill the annulus created by the Excalibur's displacement plate.

5. Sufficient crowd shall be applied to the pile throughout the entire installation process to ensure 6 inches of advancement per revolution.

6. Document installation torque every 1 to 3 feet during installation and at pile termination using the MPS Excalibur Displacement Pile Installation Record provided. Pile capacity is not determined by installation torque and data is used as reference only.

7. Where extensions are required, stop the drive head and remove from lead section. Attach the hydraulic drive head to the Excalibur extension section. Attach the extension section to the lead section with specified hardware or by threading sections together and continue installation. Add extensions as required to reach design depth.

8. If dense soils or obstructions are encountered and the pile will not advance, reverse the pile 24 inches and re-advance. Repeat 3 to 5 times while measuring how much the pile advances each time. Do not exceed maximum specified torque of the shaft. If the pile will not advance, then pre-auguring may be required to reach design depth (Confer with Engineer of Record).

9. If the pile is terminated above the pile cut-off elevation, cut the pile using an appropriate method such as a band saw or torch.

10. Upon completion of the pile installation, ensure that the grout level is brought to the top of pile (inside and outside of the steel pipe shaft).

11. Install steel pile cap or termination.

- Key points:
  - Record and monitor grout take and pressure

INSTALLATION PROCEDURE

MPS Excalibur Displacement Pile Installation Record

EXCALIBUR

Installation Contractor
Project
Pile Number
Nearest Boring
Location
Observer
Pressure:Torque Conversion ft-lb/psi

Date
Start Time
Finish Time

Project No.
Ground Elevation
Cutoff Elevation

Installation Summary

Depth (ft)	Pressure Out (psi)	Back Pressure (psi)	Pressure Reading (psi)	Torque (ft-lb)	Grout Pump Strokes	Grout Volume (ft^3)	Grout Line Pressure (psi)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							

Pile Information	
Design Tip Depth (ft)	
Steel Shaft OD (in)	
Steel Shaft Thickness (in)	
Drive Plate Diameter (in)	
Drilling Information	
Drill Rig	
Drill Head	
Pile Installation	
Pre-drill Depth (ft)	
Stick-up at Completion (ft)	
Embedment Depth (ft)	
Torque at Final Depth (ft-lb)	
Plumbness N/S	
Plumbness E/W	
Grout Information	
Grout Mix	
Average 28 day UCS (psi)	
Pump Stroke to Volume Conversion	
Total Grout Volume (ft^3)	
In-ground Grout Volume (ft^3)	
Average Grouted Diameter (in)	
Installation Review	
Pile Meets Criteria?	Y/N
Per	
Reviewer	
Comments	

TYPICAL SITE LAYOUT

VOLUMETRIC MIX TRUCK

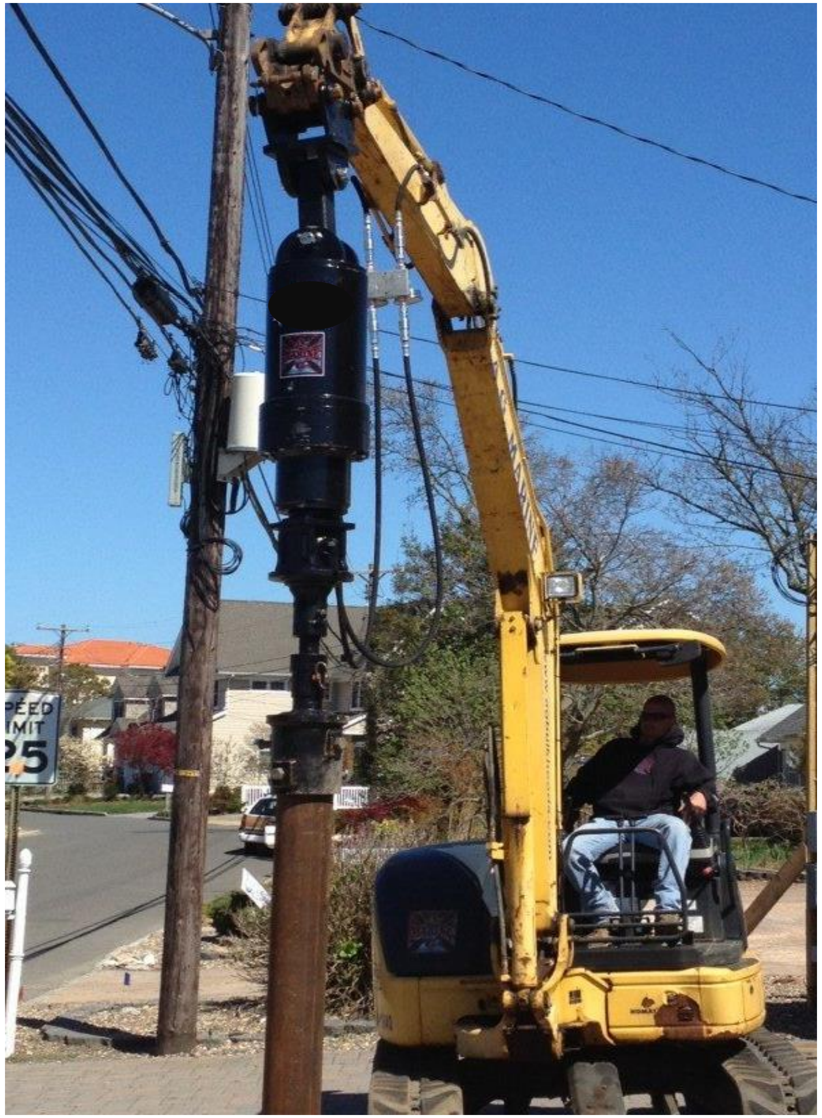
PILING INSTALL AND MATERIAL HANDLING EQUIPMENT

GROUT PUMP

PRESSURE GROUTED PILE INSTALLATION TOOLING

10 – 45 ton excavators most common

DISPLACEMENT PILE INSTALLATION EXAMPLES



ON-SITE LOAD VERIFICATION

- Static axial load test – ASTM D1143 & D3689
- Increase applied axial force to 200% design load
- Monitor deflection

ON-SITE LOAD VERIFICATION

- Static lateral load test – ASTM D3966-07
- Increase applied axial force to 200% design load
- Monitor deflection

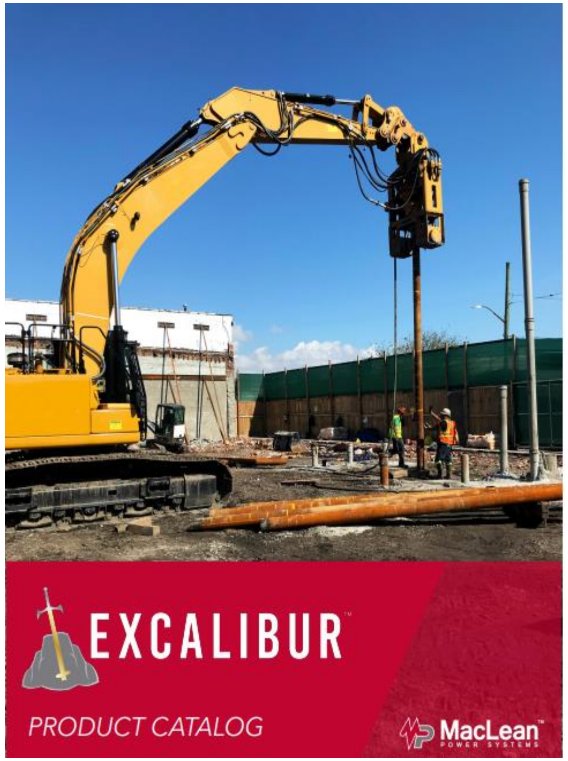
ON-SITE LOAD VERIFICATION

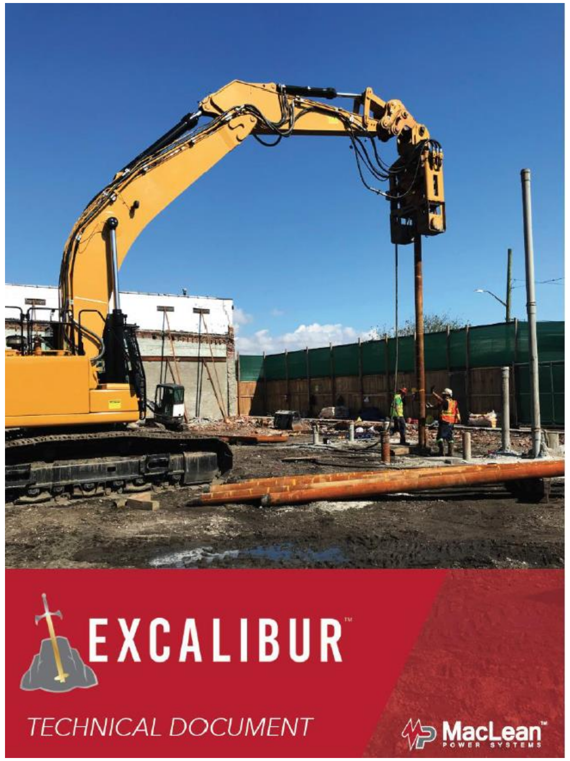
MPS Excalibur Displacment Pile Load Testing Record						
Load Test Schedule			Pile Head Deflection (in)			Notes
Load	Applied Load	Hold Time (minutes)	Record and Plot Total Movement (δ)	Record and Plot Residual Movement (δ_r)	Calculate Elastic Movement ($\delta_t - \delta_r = \delta_e$)	
AL		2.5				
Cycle 1	0.15DL	2.5	δ_1			
	0.30DL	2.5	δ_1			
	0.45DL	2.5	δ_{t1}			
	AL	1		δ_{r1}	$\delta_{t1} - \delta_{r1}$	
Cycle 2	0.15DL	1	δ_2			
	0.45DL	1	δ_2			
	0.60DL	2.5	δ_2			
	0.75DL	2.5	δ_2			
	0.90DL	2.5	δ_2			
	1.00DL	2.5	δ_{t2}			
	AL	1		δ_{r2}	$\delta_{t2} - \delta_{r2}$	
Cycle 3	0.15DL	1	δ_3			
	1.00DL	1	δ_3			
	1.15DL	2.5	δ_3			
	1.30DL		δ_3			
Hold load for at least 10 minutes while recording movement at specified times. If the total movement measured exceeds the specified maximum value then the load hold should be extended to a total of 60 minutes. Zero out movement reading for creep test.						
Cycle 3 cont'd	1.45DL	2.5	δ_{t3}			
	AL	1		δ_{r3}	$\delta_{t3} - \delta_{r3}$	
Cycle 4	0.15DL	1	δ_4			
	1.45DL	1	δ_4			
	1.60DL	1	δ_4			
	1.75DL	2.5	δ_4			
	1.90DL	2.5	δ_4			
	2.00DL	10	δ_4			
	1.50DL	5	δ_4			
	1.00DL	5	δ_4			
	0.50DL	5	δ_{t4}			
	AL	5		δ_{r4}	$\delta_{t4} - \delta_{r4}$	
Remove load and compare results to acceptance criteria						

AL = Alignment Load
DL = Design Load

QUESTIONS?

- drobinson@macleanpower.com
- 205-572-0856





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