FARRELL
DESIGN-BUILD

Calculation Submittal

Job Name	550 Gateway Hotel
Job Number	C17-501
System Type	Drill Displacement Pile
Submittal Date	August 29, 2017
Project Address	550 Gateway Blvd South San Francisco, CA
Customer Name	Vijay Patel
Customer Company	Southern Hospitality Services, LLC
Customer Address	2834 El Camino Real Redwood City, CA 94061

Submittal Prepared by: Adam Innocent, EIT
Project Engineer

Submittal Reviewed by: Mitchell Deacon, MS, PE
Engineering Manager

Submittal Reviewed by: Tom Farrell, MS, CE, GE
President

2017Aug29

Calculation Overview

Drill Displacement Pile Method of Support

The Drill Displacement Pile (DDP) system is a full displacement, well-defined, pressure grout, structural pile, deep foundation. DDP provide well-defined, steel-reinforced, concrete piles with reliable, high capacity support of heavy foundation loads. DDPs are installed using a displacement drill to compact soil in the ground, resulting in higher capacity and low spoils. The large cavity expansion effect of the DDP displaced soil produces higher strength. DDP strength and reliability are also enhanced by the pressure grout effect during construction. DDP construction produces low noise and no vibrations. DDPs are used the same as a driven pile; to support heavy structures on soft and weak soil at deeper more competent soil or on bedrock. DDPs provide reliable, strong, deep foundation support for heavy loads with reduced settlement.

System Properties and Performance

The DDP system has been selected to:

1) Provide increased bearing capacity.
2) Limit total and differential static settlement.
3) Reduce post-liquefaction settlement.

Table 1. System Properties Summary	
Target Drill Depth:	60 feet or refusal
Neat Diameter:	16 inches

Table Notes:

1) Drill depth is estimated from the historic elevation/rough grade working pad. Refer to the civil drawings for elevations.
2) Refusal criteria is less than 6-inch downward penetration within 30 seconds during drilling.

Table 2. Capacity Summary	
Allowable Bearing Capacity (ASD):	310 kips per DDP
Allowable Uplift Capacity (ASD):	65 kips per DDP

Table Notes:

3) Allowable capacities may be increased by ⅓ for wind and/or seismic transient loading if ASD alternative basic load combinations (CBC 1605.3.2) are used.
4) Lateral loads are resisted by friction at the bottom of the foundation and passive resistance. Refer to the geotechnical report for lateral capacities.
5) The allowable bearing and uplift capacities will be verified by full-scale bearing and uplift load tests.
6) Load testing program: 100% of the design load and up to 200% of the design load will be applied to a DDP in accordance with the DDP specification and construction drawings.

Table 3. Estimated Settlements Summary		
Settlement Type	**Vertical Settlement**	**Differential Settlement**
Static Settlement	Less than 1 inch	Less than ½ inch over 30 feet
Post-Seismic Settlement	None Expected at DDP-supported foundations. Refer to Geotechnical Report for settlement in areas outside DDP-supported foundations.	

Table Notes:

1) The pile foundation system is not designed to mitigate slab settlement potential. Settlement may be greater in slab areas than settlements at pile-supported foundations.
2) Differential settlement may be greater between adjacent buildings than the estimated values.
3) Liquefaction settlement above the bottom of the element elevation is not considered for post - seismic settlement. Refer to the geotechnical report for liquefaction settlement analysis.

References

Table 4. References				
Primary Design Documents	**Description**	**Document By**	**Date Received**	**Document Date**
DDP	*Drill Displacement Pile Drawings*	Farrell Design-Build	--	2017AUG29
Structural	*Foundation Loads*	HCP Engineering	2017JUL24	2017JUL24
	Additional Foundation Loads		2017AUG10	2017AUG10
	Revised Foundation Loads		2017AUG28	2017AUG28
	Foundation CAD Background		2017AUG23	--
	Structural Drawings		2017AUG17	2017AUG15
	Structural/Geotechnical Outstanding Issues – 550 Gateway Boulevard		2017MAY05	2016JUN14
Geotechnical	*Final Report Geotechnical Study – Proposed Hotel – P16-122*	GEC	2017MAY05	2016FEB12
	Downdrag Criteria Email		2017JUL14	2017JUL14
Civil	*Preliminary Civil Drawings*	Bellecci & Associates	2017JUN25	2017JUN16

Limitations

DDP-supported foundations will not mitigate expansion of subgrade soil. DDPs will not resist slab heaving deformations, which can cause floor slab damage.

Farrell based the DDP layout on information provided by Customer, the SEOR, and the GEOR. If the existing construction and soil conditions are not consistent with this information, engineering and construction changes may be required. If any site or soil conditions have changed from what is presented in this document or the referenced documents, Farrell must be asked to review the changed conditions and make the appropriate modifications where necessary.

This Design-Build Submittal is the private and proprietary property of Farrell Design-Build Inc. The owner and contractor are granted a limited use license to this document for purposes of structural foundation design, contract documents, and agency submittals. Farrell's design and engineering work are expressly provided and conditioned on Farrell installing the design work. Under no circumstance shall this Design-Build Submittal be provided to any other contractor to perform the designed work contained herein.

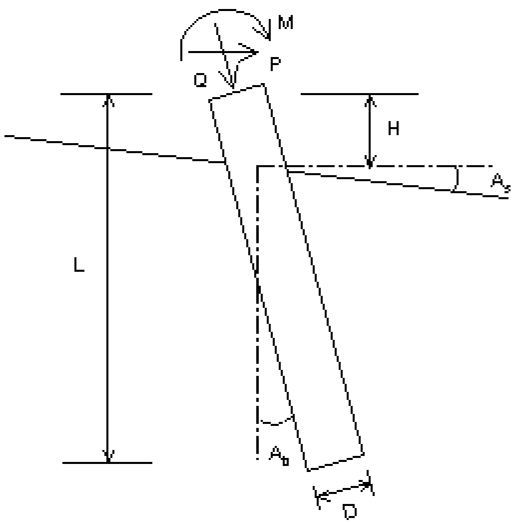
Attachment 1

Farrell Calculations

1) Capacity Calculations
   a) Boring Correlation Capacity (AllPile)
2) Settlement Calculations
   a) Settlement Analysis (Settle3D)
3) Pile Structural Calculations
   a) Cage Design Calculations

VERTICAL ANALYSIS

Figure 1



Drilled Pile (dia <=24 in. or 61 cm)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

(with Load Factor)
Vertical Load, Q= 310.0 -kp
Shear Load, P= 0.0 -kp
Moment, M= 0.0 -kp-f

Profile:
Pile Length, L= 60.0 -ft
Top Height, H= 0 -ft
Slope Angle, As= 0
Batter Angle, Ab= 0

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	125.0	34	0.5	976.5	0.53	23
5	125.0	29	0.25	179.3	1.08	7
10	125.0	37	.5	2406.2	0.33	49
15	125.0	36	.5	1705.8	0.40	36
20	62.6	33	.75	761.0	0.59	19
30	62.6	33	1	554.4	0.68	15
35	62.6	33	1	814.1	0.57	20
40	62.6	37	1	2092.6	0.36	43
45	62.6	35	1	1367.1	0.45	30
60	62.6	42	0	189.1	94.01	58

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	16	201.1	50.3	3217.0	3000	0.209
60.0						

Vertical Capacity:
Weight above Ground= 0.00 Total Weight= 9.06-kp *Soil Weight is not included
Side Resistance (Down)= 367.834-kp Side Resistance (Up)= 275.742-kp
Tip Resistance (Down)= 465.064-kp Tip Resistance (Up)= 0.000-kp
Total Ultimate Capacity (Down) Qult= 832.899-kp Total Ultimate Capacity (Up)= 284.804-kp
Total Allowable Capacity (Down) Qallow= 416.449-kp Total Allowable Capacity (Up) Qallow= 192.890-kp
OK! Qallow > Q

Settlement Calculation:
At Q= 310.00-kp Settlement= 0.29279-in
At Xallow= 1.00-in Qallow= 610.42810-kp

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

CivilTech Software

550 Gateway Hotel, SSF
B-1

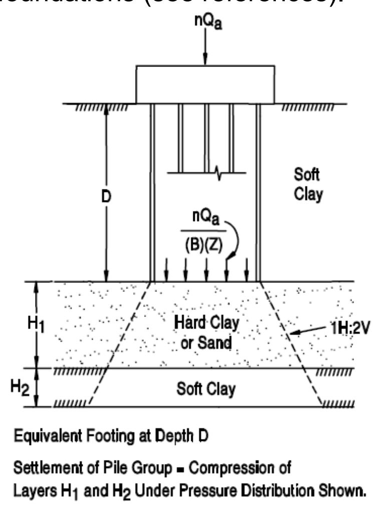
BORING CORRELATION CAPACITY (ALLPILE)

Settlement Calculations

Approach

End-Bearing Method

1) Model unimproved soil properties in Settle3D using constrained modulus (M). Ground improvement effects are conservatively omitted.
2) Estimate lower zones settlement by applying full structural foundation loads at the bottom of the DDP as shown in the figure below. This approach is based on established methods used to estimate settlement of piled foundations (see references).



Source: FHWA GEC 8 2007, page 101.

Summary

Estimated total static settlement is determined by summing the following terms:

Static Settlement = Lower Zone Settlement (Settle3D) +

1) Estimated lower zone settlement ≈ 0.89 inch

► ***Total Static Settlement ≤ 1 inch***

References

1) Brown, D.A., Dapp, S.D., Thompson, W.R., Lazarte, C.A., 2007, Design and Construction of Continuous Flight Auger Piles, FHWA-HIF-07-03 GEC No. 8.
2) McCarthy, David F. Essentials of Soil Mechanics and Foundations: Basic Geotechnics, 7th Edition
3) Settle3D v4.009 by RocScience.

Parts

1) Settlement Analysis Parameters (Settle3D)
2) Settlement Analysis Plan View (Settle3D)

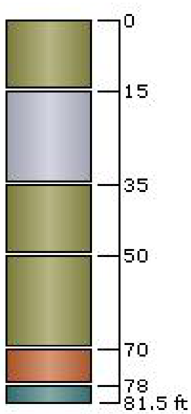
Settlement Analysis Parameters (Settle3D)

Project Settings

Project Title	550 Gateway Blvd Hotel
Author	AI
Company	Farrell Design-Build
Stress Computation Method	Vertical Ratio (2:1)
Use settlement cutoff	
Load/Insitu vertical stress ratio	0.05

Soil Layers

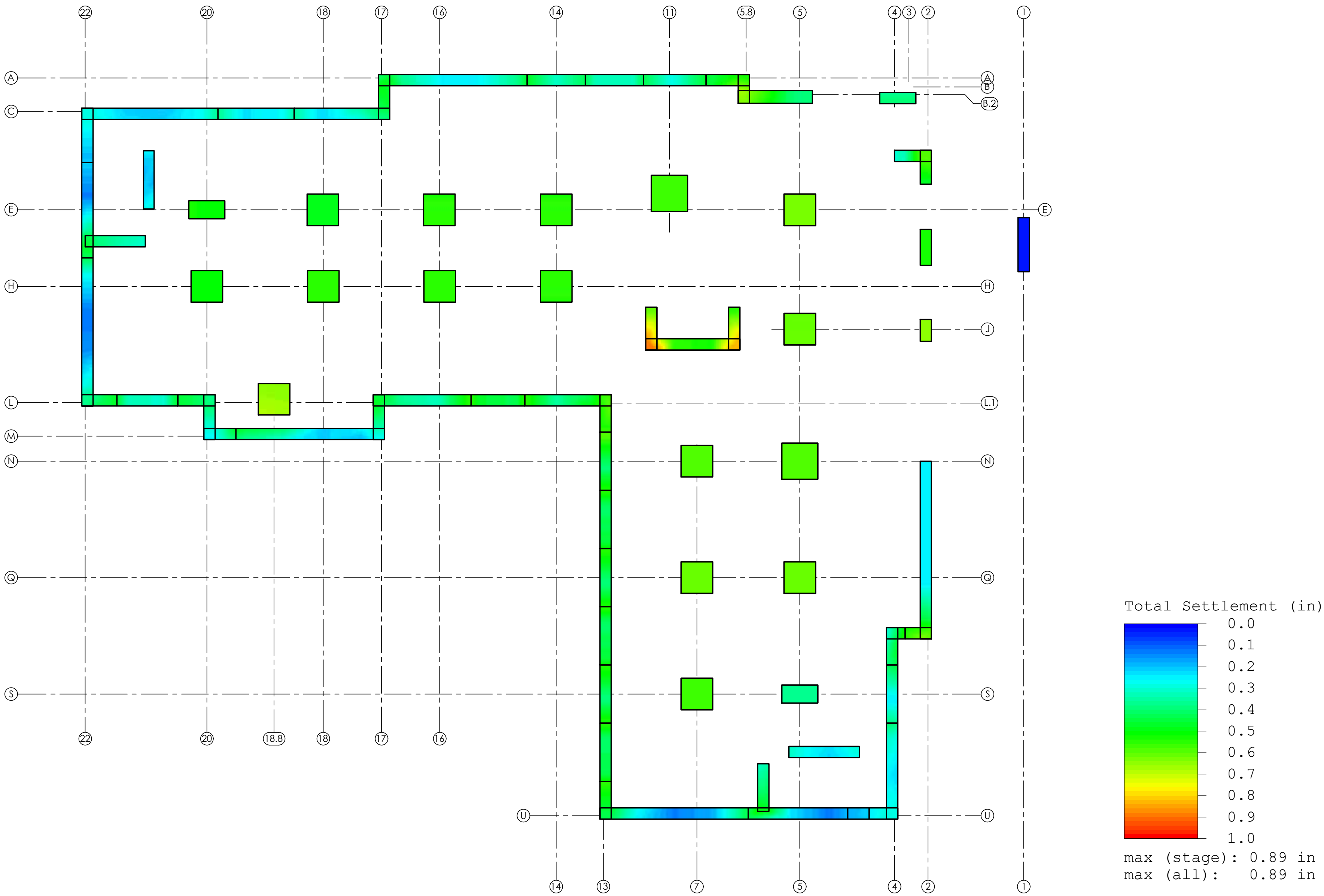
Layer #	Type	Thickness [ft]	Depth [ft]
1	M2000	15	0
2	M1250	20	15
3	M2000	15	35
4	M2000	20	50
5	M750	8	70
6	M3000	3.5	78



Soil Properties

Property	M750	M1250	M2000	M3000
Color				
Immediate Settlement	Enabled	Enabled	Enabled	Enabled
Es [ksf]	750	1250	2000	3000

Settlement Analysis Plan View (Settle3D)



Drill Displacement Pile Structural Calculations

August 28, 2017

The following pile cage structural calculations are based on the California Building Code 2016 and Building Code Requirements for Structural Concrete (ACI 318-14), structural loads provided by HCP Engineering and geotechnical report by GEC.

Basic Design Parameters

1) Concrete Compressive Strength: $f_c' = 4.5$ ksi
2) Rebar Yield Strength: $f_y = 60$ ksi
3) Nominal Pile Diameter: $D_p = 16$ in
4) Design Pile Length: $L_p = 60$ ft
5) Seismic Design Category: D
6) Site Class: D

Minimum Longitudinal Reinforcement

Reference: 2016 CBC 1810.3.9.4.2

Minimum of 4 bars with a reinforcement ratio of 0.005.

$$A_{s,\min} = A_g \cdot \rho_{\min} = \left(\pi \cdot 16^2/2\right) \cdot (0.005) = 1.01 \text{ in}$$

6-#6 rebar: $A_s = 6 \times 0.44 \text{ in}^2 + 1.27 \text{ in}^2 = 3.92 \text{ in}^2 \geq 1.01 \text{ in}^2$

► ***Use 6-#6 longitudinal rebars***

Minimum reinforced length must be the greatest of the following:

1) ½ the element length (30.0 ft)
2) 10 feet
3) 3 times the least element dimension (4.0 ft) *(i.e. 3 times the smallest pile diameter)*
4) The distance from the top of the element to the point where the cracking moment exceeds the required moment strength (N/A)
   a) Cracking Moment: $\phi M_n = 3\sqrt{f'_c} S_m$ = 6.74 kip · ft

► ***Use rebars within the top 30 feet of the cage***

Minimum Transverse Reinforcement

Reference: 2016 CBC 1810.3.9.4.2.1; ACI 318-14 18.7.5.3

Transverse reinforcement must be closed ties or spirals; #3 for up to 20-inch-diameter elements or #4 for larger-diameter elements.

► ***Use #3 continuous circular ties***

Within 3 times the least element dimension (4.0 ft + 0.25 ft embedment), transverse reinforcement spacing must not exceed the smallest of:

1) ¼ the least element dimension (4.0 in)

2) 6 times the diameter of the smallest longitudinal bar (4.5 in)
3) $s = 4 + (14 - h_x)/3$; where h_x may be taken to be the tie or spiral diameter (8.54 in)

Spacing must not exceed 6 inches and need not be less than 4 inches.

The volumetric ratio of spiral or circular hoop reinforcement, $\rho_s = 4(D_{ch} - d_{b,v})A_v/(D_{ch}^2 s) = 4(10-0.75)0.11/(10\times 1.5) = 0.027$, must comply with both of the following if $P_u = 310kips \le 0.3A_g f_c' = 271kips$ and $f_c' = 4{,}500 \le 10{,}000$ psi :

1) $\rho_s \ge \frac{1}{2}\left[0.12\frac{f_c'}{f_{yt}}\right]$

2) $\rho_s \ge \frac{1}{2}\left[0.45\left(\frac{A_g}{A_{ch}} - 1\right)\frac{f_c'}{f_{yt}}\right]$

However, if $P_u = 310kips > 0.3A_g f_c' = 0.3\times 201\times 4{,}500 = 271kips$ or $f_c' = 4{,}500 > 10{,}000$ psi , then the volumetric ratio must also comply with the following:

3) $\rho_s \ge \frac{1}{2}\left[0.35k_f\frac{P_u}{f_{yt}A_{ch}}\right] = \frac{1}{2}\left[0.35\times 0.4\frac{310}{60\times 79}\right] = .00458$, where $k_f = \frac{f_c'}{25{,}000} + 0.6 = 0.78 \ge 1.0$

► ***Use 1.5-inch spacing within the top 4.25 feet of the cage (includes embedment)***

Outside the tighter-spaced transverse reinforcement, next to the pile cap, the spacing must not exceed the smallest of the following:

1) 12 longitudinal bar diameters (9.0 in)
2) ½ of the least element dimension (8.0 in)
3) 12 inches

► ***Use 8-inch maximum spacing within the remainder of the cage***

Concrete Column Axial Compressive & Tensile Strength

Calculated at 4:38 PM on August 28, 2017 by Mitchell Deacon

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Column Axial Strength			
$P_{n,max}$	0.80	unitless	$0.80P_o$ for ties; $0.85P_o$ for spirals [ACI 318-14 Table 4.2.1]
f'_c	4,500	psi	Concrete compressive strength [ACI 318-14 19.2.1]
f_y	60,000	psi	Yield strength for nonprestressed reinforcement
D_{col}	16	in	Diameter of concrete column
A_g	201.1	in²	Gross area of the cross section
No. of Long't Bars	6	unitless	Number of longitudinal reinforcing bars
Long't Bar Size	#6	unitless	ASTM A615 standard reinforcing bar size
Center Bar?	No	unitless	Center bar used or not?
Center Bar Size		unitless	ASTM standard reinforcing bar size
A_{st}	2.64	in²	Area of longitudinal reinforcement
ρ	0.013	unitless	Reinforcement ratio
$\phi_{compression}$	0.65	unitless	Strength reduction factor; 0.65 for tied; 0.75 for spiral [ACI 318-14 21.2.1]
$\phi_{tension}$	0.90	unitless	Strength reduction factor; 0.90 for both tied and spiral [ACI 318-14 21.2.1]
P_o	**917.4**	**kips**	Nominal axial strength at zero eccentricity [ACI 318-14 22.4.2.2]
P_n	**733.9**	**kips**	Nominal axial compressive strength [ACI 318-14 22.4.2.1]
ϕP_n	**477.0**	**kips**	Factored axial compressive strength
P_{nt}	**158.4**	**kips**	Nominal axial tensile strength [ACI 318-14 22.4.3.1]
ϕP_{nt}	**142.6**	**kips**	Factored axial tensile strength

Note: This calculation is only valid for nonprestressed members.

Concrete Column Shear Strength

Calculated at 16:38 on August 28, 2017 by Mitchell Deacon

Column Shear Strength			
D	16	in	*Diameter of concrete column*
λ	1.0	unitless	*Lightweight concrete modification factor [ACI 318-14 19.2.4.2]*
f'_c	4,500	psi	*Concrete compressive strength [ACI 318-14 19.2.1]*
b_w	16.0	in	*Width of concrete member (same as diameter) [ACI 318-14 22.5.2.2]*
d	12.8	in	*Depth of concrete member (0.8 times the diameter) [ACI 318-14 22.5.2.2]*
N_u	5.3	kips	*Factored axial force normal to the cross-section [ACI 318-14 22.5.6.1, 22.5.7.1]*
A_g	201	in²	*Gross area of the cross section*
A_v	0.22	in²	*Area of shear reinforcement [ACI 318-14 22.5.10.5.6]*
f_{yt}	60,000	psi	*Transverse reinforcement yield strength*
s	1.5	in	*Center-to-center transverse reinforcement spacing*
ϕ	0.75	unitless	*Strength reduction factor [ACI 318-14 21.2.1]*
V_c	**27.8**	**kips**	*Shear strength provided by concrete [ACI 318-14 22.5.6.1]*
V_s	**112.6**	**kips**	*Shear strength provided by transverse steel reinforcement [ACI 318-14 22.5.10.5.3]*
V_n	**140.5**	**kips**	*Nominal one-way shear strength [ACI 318-14-22.5.1.1]*
ϕV_n	**105.4**	**kips**	*Factored one-way shear strength*

Note: This calculation is only valid for nonprestressed members.

Concrete Column Shear Strength

Calculated at 16:38 on August 28, 2017 by Mitchell Deacon

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Column Shear Strength			
D	16	in	*Diameter of concrete column*
λ	1.0	unitless	*Lightweight concrete modification factor [ACI 318-14 19.2.4.2]*
f'_c	4,500	psi	*Concrete compressive strength [ACI 318-14 19.2.1]*
b_w	16.0	in	*Width of concrete member (same as diameter) [ACI 318-14 22.5.2.2]*
d	12.8	in	*Depth of concrete member (0.8 times the diameter) [ACI 318-14 22.5.2.2]*
N_u	5.3	kips	*Factored axial force normal to the cross-section [ACI 318-14 22.5.6.1, 22.5.7.1]*
A_g	201	in²	*Gross area of the cross section*
A_v	0.22	in²	*Area of shear reinforcement [ACI 318-14 22.5.10.5.6]*
f_{yt}	60,000	psi	*Transverse reinforcement yield strength*
s	8.0	in	*Center-to-center transverse reinforcement spacing*
ϕ	0.75	unitless	*Strength reduction factor [ACI 318-14 21.2.1]*
$\boldsymbol{V_c}$	**27.8**	**kips**	*Shear strength provided by concrete [ACI 318-14 22.5.6.1]*
$\boldsymbol{V_s}$	**21.1**	**kips**	*Shear strength provided by transverse steel reinforcement [ACI 318-14 22.5.10.5.3]*
$\boldsymbol{V_n}$	**49.0**	**kips**	*Nominal one-way shear strength [ACI 318-14-22.5.1.1]*
$\boldsymbol{\phi V_n}$	**36.7**	**kips**	*Factored one-way shear strength*

Note: This calculation is only valid for nonprestressed members.

Transverse Reinforcement Volumetric Ratio Check

Calculated at 16:38 on August 28, 2017 by Mitchell Deacon

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Volumetric Ratio Check			
Site Class	D	unitless	
P_u	310.0	kips	*Factored axial force normal to the cross-section*
D_{pile}	16	in	*Diameter of concrete pier*
c_c	3.0	in	*Clear cover of reinforcement [2016 CBC 1808.8.2]*
A_g	201	in²	*Gross area of the cross section*
A_{ch}	79	in²	*Cross-sectional area within outside edges of transverse reinforcement*
f'_c	4,500	psi	*Concrete compressive strength [ACI 318-14 19.2.1]*
f_{yt}	60,000	psi	*Transverse reinforcement yield strength*
k_f	1.0	unitless	*Concrete strength factor [ACI 318-14 18.7.5.4]*
Bar size	#3	unitless	*Bar size of transverse reinforcement*
$d_{b,v}$	0.375	in	*Transverse bar size diameter*
$A_{b,v}$	0.11	in²	*Transverse bar cross-sectional area*
s	1.50	in	*Center-to-center transverse reinforcement spacing*
ρ_s	**0.030**	unitless	*Volumetric ratio of transverse reinf. to confined concrete*
$\rho_{s,min}$	**0.026**	unitless	*Min. vol. ratio of trans. reinf. to confined concrete [2016 CBC 1810.3.9.4.2; ACI 318-14 18.7.5.4]*

Note: This calculation is only valid for nonprestressed members.

Development Length for Deformed Reinforcing Bars

Last updated at 4:49 PM on August 28, 2017 by Mitchell Deacon

Development Lengths			
f_y	60,000	psi	*Non-prestressed steel reinforcement yield strength*
f'_c	4,500	psi	*Concrete compressive strength*
Bar Size	#6	unitless	*Reinforcing bar size*
d_b	0.75	in	*Reinforcing bar diameter*
ψ_t	1.0	unitless	*Casting position modification factor [ACI 318-14 25.4.2.4]*
ψ_e	1.0	in	*Epoxy coating modification factor [ACI 318-14 25.4.2.4]*
ψ_r	1.0	unitless	*Confining reinforcement modification factor [ACI 318-14 25.4.9.3]*
λ	1.0	unitless	*Lightweight concrete modification factor [ACI 318-14 25.4.2.4]*
$l_{d,tension}$	**26.8**	**in**	*Development length for deformed bars in tension [ACI 318-14 25.4.2]*
$l_{d,headed}$	**10.7**	**in**	*Development length for headed deformed bars in tension [ACI 318-14 25.4.4]*
$l_{d,compression}$	**13.5**	**in**	*Development length for deformed bars in compression [ACI 318-14 25.4.9]*

Development Length for Deformed Reinforcing Bars

Last updated at 4:49 PM on August 28, 2017 by Mitchell Deacon

Development Lengths			
f_y	60,000	psi	*Non-prestressed steel reinforcement yield strength*
f'_c	4,500	psi	*Concrete compressive strength*
Bar Size	#9	unitless	*Reinforcing bar size*
d_b	1.13	in	*Reinforcing bar diameter*
ψ_t	1.0	unitless	*Casting position modification factor [ACI 318-14 25.4.2.4]*
ψ_e	1.0	in	*Epoxy coating modification factor [ACI 318-14 25.4.2.4]*
ψ_r	1.0	unitless	*Confining reinforcement modification factor [ACI 318-14 25.4.9.3]*
λ	1.0	unitless	*Lightweight concrete modification factor [ACI 318-14 25.4.2.4]*
$l_{d,tension}$	**50.4**	**in**	*Development length for deformed bars in tension [ACI 318-14 25.4.2]*
$l_{d,headed}$	**16.1**	**in**	*Development length for headed deformed bars in tension [ACI 318-14 25.4.4]*
$l_{d,compression}$	**20.3**	**in**	*Development length for deformed bars in compression [ACI 318-14 25.4.9]*

Attachment 2

System Specifications

1) DDP Specification 31 63 16

SECTION 31 63 16

DRILL DISPLACEMENT PILE

PART 1 - GENERAL

1.01 SCOPE OF WORK

A. Section 31 63 16 includes all material, layout, and construction for the Drill Displacement Pile (DDP) system to meet the performance criteria defined in this specification.

B. The GeoContractor shall provide all equipment, material, labor, and supervision to design and install DDPs to meet the performance criteria defined for the project. Design shall rely upon information presented in the contract documents, geotechnical report, and Contract Drawings.

C. DDP ground improvement is a low-noise, full-displacement structure pile method used for controlled compaction, densification, stiffening, strengthening of loose and soft soil, and uplift resistance. This method comprises of injecting grout into a compatible soil mass to achieve controlled compaction, densification, cementation, and increased strength of the soil mass by displacing the soil mass, replacing the displaced soil with grout, and wet-setting a steel reinforcement cage. The steel reinforcement cage is connected into the foundation for uplift resistance.

D. Related sections, including drawings and general provisions of the contract (general conditions and supplementary general conditions and Division 1 Specification sections), apply to this section.

1.02 REFERENCES

A. Geotechnical Report for the site.

B. California Building Code (CBC), Title 24 Part 2, Volume 1 and 2 (Latest Edition).

C. Design and Construction of Continuous Flight Auger Piles, FHWA-HIF-07-03 GEC No. 8.

D. ASTM A615 Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement.

E. ASTM C31 Standard Practice for Making and Curing Concrete Test Specimens in the Field.

F. ASTM C33 Standard Specification for Concrete Aggregates.

G. ASTM C94 Specification for Ready-Mixed Concrete.

H. ASTM C150 Standard Specification for Portland Cement.

I. ASTM C494 Standard Specification for Chemical Admixtures for Concrete.

J. ASTM C618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete.

K. ASTM C937 Standard Specification for Grout Fluidifier for Preplaced-Aggregate Concrete.

L. ASTM D3689 Standard Test Methods for Deep Foundations Under Static Axial Tensile Load.

1.03 DEFINITIONS

A. Grout: a well-defined, controlled, composite material composed of aggregate, sand, cement, fly-ash, water, and admixtures. Grout can be concrete (with coarse aggregate) for the purpose of DDPs.

B. Drill Displacement Pile (DDP): a deep foundation pile method of installing grout under pressure in a displaced cavity and installing vertical steel reinforcing (“rebar” or “rebar cage”) to provide structural strength and stiffness to resist forces at the foundation. The system includes steel reinforcing, vertical dowels, spacers, centralizers, and grout.

C. Testing Agency: the special inspector and/or material testing company selected and retained by the Owner. The Geotechnical Engineer of Record (GEOR) commonly acts as the Testing Agency for DDP work.

D. GeoContractor: the specialist subcontractor responsible for the design, construction, and performance of DDPs outlined in these specifications. Farrell Design-Build Companies Inc. of Placerville, CA is the GeoContractor for this work.

1.04 SUBMITTALS

A. The GeoContractor shall submit the following documents for the Engineer's approval:

1) DDP design or shop drawings including, at minimum, a DDP layout drawing referencing the structural plans including a numbering system capable of identifying each individual DDP

2) DDP design report, prepared and sealed by a California-licensed Professional Engineer, with construction methods and materials that will be utilized to install the DDPs.

3) DDC installation record provided to the GEOR for each DDP not later than 1 week after installation is completed.

4) Load test report, prepared and sealed by a California-licensed Professional Engineer, with a description of the installation equipment, installation records, load test data, analysis of the test data, and recommended allowable design bearing pressure and tension capacity based on load test results.

5) Grout field sampling and lab tests shall be performed by the GEOR or Testing Agency.

6) Full-size drawing showing the as-built locations, diameters, and depths of all completed DDPs, submitted upon acceptance of the work performed.

1.05 QUALITY ASSURANCE

A. The DDP work shall be performed by a GeoContractor and shall be performed by skilled workmen thoroughly experienced in the necessary crafts. The GeoContractor's crew shall include a quality control (QC) inspector to observe installation operations and prepare the installation records.

B. The GEOR and/or Testing Agency shall perform inspection and testing in accordance with the governing code and perform the following:

1) Submittal review for conformance with the requirements of this section.

2) Continuous DDP installation monitoring for conformance with requirements.

3) Documentation of each DDP installed, including as-built DDP locations.

C. The presence of the GEOR and/or Testing Agency shall in no way relieve the GeoContractor of its obligation to perform the DDP installation in accordance with the contract drawings and these specifications.

D. The GEOR or Testing Agency shall perform material testing of the grout including but not limited to:

1) Slump Tests

2) Grout sample preparation and testing per ASTM methods. A minimum of one set of samples shall be obtained for every 100 cubic yards placed or at least once a day.

   a. One set of samples shall consist of 8 test cylinders. The test cylinders shall be 6×12 inches.
   b. The break schedule shall be:
      1. 1 test cylinder tested at 7 days
      2. 3 test cylinders tested at 28 days
      3. 3 test cylinders tested at 56 days
      4. 1 test cylinder held in reserve
   c. It is important that the samples be handled with care to achieve correct test results.

E. The GeoContractor shall calibrate the pump volume per stroke:

1) Once per day for the first 3 days of the project, then once per week thereafter.

2) Where a different ready mix supplier or pump equipment is used.

F. The GeoContractor shall stake the center of the DDP with a horizontal control accuracy 0.05 feet of maximum variance from true center.

1.06 DDP SYSTEM REQUIREMENTS

A. The DDP system shall be constructed by the drill-displacement, bottom-feed pumped method through a hollow auger with placement by wet stabbing steel reinforcing into fresh grout.

B. The reinforcing steel shall be placed into the fluid grout within 30 minutes after the auger is removed from the ground.

C. Construction of the DDP system shall be in accordance with this specification and the contract drawings, unless otherwise approved by the GeoContractor.

PART 2 - PRODUCTS

2.01 EQUIPMENT

A. The DDP system shall be constructed with pile equipment must meeting the following minimum requirements:

1) Drill rig torque = 125 kip-ft
2) Drill Rig downward crowd = 30 kips.
3) Grout pump volume rating = 50 cubic feet per hour
4) Grout line pumping pressure = 40 bars

2.02 GROUT

A. Grout shall be a flowable mixture of cement, pozzolan, coarse and fine aggregate, admixtures, and water which has been mixed in accordance with ASTM C94.

B. Grout shall be batched either by a ready mix concrete plant and delivered to the WORK by means of standard transit mixing trucks or an onsite mixing system. The mixture shall produce a flowable material.

C. The actual mix proportion and slump shall be as determined by the approved mix design.

D. Grout Properties:

1) Density shall be between 100 pcf and 145 pcf.
2) Slump shall be 6 to 11 inches.
3) Compressive strength at 28 days shall be in accordance with the approved drawings.

E. The following grout composition parameters shall be within the indicated limits and as necessary to produce the indicated compressive strengths.

1) Mix proportions shall be approved by the GEOR.
2) Cement: Cement shall be Type II in accordance with the requirements of ASTM C150.
3) Pozzolan: Pozzolan shall be Type F in accordance with the requirements of ASTM C618.
4) Aggregate: Aggregate shall consist of a well graded mixture of crushed rock, soil, or sand with a maximum size aggregate of ¾ inch. 100% shall pass the ¾-inch sieve.
5) Admixtures: Air entrainment may be added as approved by the GeoContractor not to exceed 10% and as required in ASTM C260. Retarding admixture may be added as approved by the GeoContractor not to exceed a retarding time of 8 hours and as required in ASTM C494.
6) Grout Fluidifier: Grout fluidifier shall conform to ASTM C937, except that expansion shall not exceed 4%. The fluidifier shall be a compound possessing characteristics which will increase the flowability of the mixture, assist in the dispersal of cement grains, and neutralize the setting shrinkage of the high-strength cement mortar.
7) Water: Water shall be clean and free from objectionable quantities of silt and clay, organic matter, alkali, salts, and other impurities.

2.03 REINFORCING STEEL

A. Steel materials: Steel rebar cages shall be furnished complete with all accessories, and shall be a standard product of a company regularly engaged in their manufacture.

B. Corrosion Protection System: The DDP steel assembly shall be isolated from all footing rebar and steel. If necessary, the uplift anchorage in the footing shall be covered with plastic tape or other method for isolating the steel from the footing rebar and steel.

2.04 ANCHOR ASSEMBLY

A. Unless otherwise directed, the GeoContractor shall select the type of steel anchor assembly to be used for tension in the DDP.

B. Anchors shall be handled and stored in a manner as to avoid damage. A light coating of rust on the steel is acceptable. If heavy corrosion or pitting is observed, the GeoContractor shall reject the affected steel.

C. GeoContractor shall supply bearing plate and hardware for anchor assembly (where applicable). Cutting and installation of bearing plate and hardware shall be performed by the General Contractor.

PART 3 - EXECUTION

3.01 GENERAL

A. The GeoContractor shall determine the type and method of DDP treatment and construction construction procedures, the specific equipment to be used, and the size and spacing of the DDPs. Such procedures and related information shall be subject to review by the GEOR during the submittal phase.

B. Horizontal tolerance: All DDPs shall be located within 3 inches of the plan positions shown on the approved shop drawings, unless otherwise approved by the GeoContractor.

C. Vertical Tolerance: All DDPs shall be plumb within 2 degrees of vertical, which is about 1 inch, horizontal in 28 inches, vertical.

3.02 DDP CONSTRUCTION

A. A pre-drill hole may be drilled below the bottom of the footing or slab prior to constructing the DDP.

B. Grout shall be delivered into each DDP by pumping. The grout pump shall be a positive displacement pump of an approved design. The pump discharge capacity shall be calibrated in strokes per cubic foot or revolutions per cubic foot by a method approved by the GeoContractor. Oil or other rust inhibitors shall be removed from the mixing drums and pressure grout pumps prior to mixing and pumping.

C. The volume of grout per linear foot of the DDP shall be not less than the neat volume. All volume measurements shall be made in the presence of the GEOR or the Testing Agency.

D. DDP installation and pressure injection shall continue without interruption.

1) Upon reaching the design depth or bottom of each DDP, the displacement tool shall be rotated a minimum of 6 turns to compact drill spoil at the bottom.
2) The tool shall be raised 12 inches and the drill stem and bottom shall be charged with grout prior DDP installation to begin the bottom pressure bulb.
3) After installation of the bottom pressure bulb, the tool shall be withdrawn at a rate to maintain a minimum average grout pumped replacement as shown on the approved drawings.
4) Pressurized pumping may be stopped at a depth as noted on the quality control documentation or after the adjacent ground heaves more than 0.5 feet.

E. Adjacent DDPs

1) Adjacent DDP within 10 feet, center-to-center, shall not be installed within 18 hours of each other.
2) Within footings, DDPs adjacent within 12 feet, center-to-center, shall not be installed within 12 hours of each other without the approval of the GeoContractor's engineer.

F. Grout shall be directed in place to ensure that voids, crevices, and pockets are filled with grout. Care shall be taken to avoid over-consolidation of the material separating the large and fine aggregate.

G. Grout shall be continuously placed against undisturbed in-situ earth material under pressure unless otherwise approved by the Engineer.

H. Where an unforeseen obstruction is encountered below the ground, the GeoContractor shall be informed immediately. Should any obstruction be encountered during installation of DDP work, the General Contractor shall be responsible for removing such obstruction or the DDP shall be relocated or abandoned as approved by the GeoContractor.

I. Centralizers shall be used to maintain the required grout cover. Centralizers shall be fabricated from plastic or material which is non-detrimental to the steel anchorage. Wood shall not be used. The centralizer shall be able to support the anchorage in the drill hole and position the bar so a minimum 3-inch cover is provided and shall permit grout to freely flow around the bar.

J. The finished DDP element shall be "post-drilled" to establish the final top elevation of the DDP.

3.03 QUALITY CONTROL TESTING

A. DDP Inspections

1) All DDP operations shall be performed under the observation of the GEOR or Testing Agency and in accordance with CBC (current edition) Section 18.
2) All DDP load test results shall be submitted to the GEOR for review and approval
3) Monitoring and logging of pile operations shall be done by the GeoContractor's QC inspector.
4) The GeoContractor shall provide access to the GEOR or Testing Agency to observe the work and take samples, measurements, and test as necessary for quality assurance purposes.
5) Compressive strength shall be determined by laboratory compression tests conforming to ASTM standards.

B. DDP Load Test

1) A load test shall be performed to verify the parameter values selected for design. The DDP load test shall be of the type and installed in a manner specified herein. The location of the DDP load test shall be coordinated with the GEOR. ASTM D1143 Procedure A shall be used as a guide to establish load increments, load duration, and load decrements except that the maximum load shall be 200% of the design maximum load on the pile and the load increments will be 5% of the design load.
2) The load test shall be performed as shown on the approved plans.
3) A seating load equal to 5% of the total load shall be applied prior to application of load increments.
4) The load test results shall be evaluated by the 90% Hansen criteria.

C. Construction Records: The GeoContractor shall keep written, daily records of the DDP installation completed and shall submit signed copies of the records to the General Contractor and GEOR within 1 week after installation is completed. The records shall show:

1) Identification number and date of installation.
2) DDP drill tool diameter.
3) Total drill depth.
4) Volume of grout placed (in cubic feet).
5) DDP pump pressures (where applicable),
6) Concrete truck ticket ID associated with the DDP.
7) Added reinforcement (if required).
8) Documentation of obstructions, placement delays, unusual ground conditions, or unusual occurrences observed during the DDP installation.

3.04 UTILITIES PROTECTION AND IDENTIFICATION

A. The Owner's Representative shall identify any and all underground utilities prior to drill rig mobilization.

3.05 DDP PROTECTION

A. DDPs shall be protected from running water, rain, freezing or other conditions that could damage the material or dowels.

B. No equipment, traffic, or backfill shall be allowed on the DDP until the surface of the DDP is able to withstand a 20 psi load without displacement or damage. If necessary, the General Contractor shall provide steel trench plates that span the work area impacted by traffic until the DDP has reached the required strength.

PART 4 - MEASUREMENT AND PAYMENT

A. The amount of completed and accepted DDP work shall be paid for at the contract sum price per job and/or adjusted for price per linear foot required by the contract. This price shall be full compensation for design and for furnishing all materials, and for all labor, equipment, tools, and incidentals necessary to complete the work.

END OF SECTION