D E S I G N   S H E E T

KE ASIA, INC.

Project	:	SMC SHORELINE PROTECTION DIKE ROAD PROJECT	Date	:	
Location	:	NAVOTAS METRO MANILA	Designed	:	
Item	:	BHE-29 P11	Checked	:	

The calculations presented herein are based on the recommendations of AASHTO LRFD Bridge Design Specifications (2012).

1. Pile Parameters

Pile Shape, $P_s := \text{"Circular"}$

Unit weight of concrete, $\gamma_c := 24.5 \frac{kN}{m^3}$

Pile Diameter, $D_1 := 2m$

Conc. Strength, $f'_c := 35MPa$

Pile Length, $P_L := 32m$

Pile Area, $A_p := \pi \cdot \frac{D_1^{\,2}}{4}$ $\quad A_p = 3.142\,m^2$

Circumference, $P := \pi \cdot D_1$ $\quad P = 6.283\,m$

Pile Head Elevation, $P_e := 1m$

2. Hammer Efficiency

Hammer Type, $H_T := 1$

1 = Coventional Drop Hammer using Rope and Cathead

2 = Automatic Trip Hammer

Hammer Efficiency, $H_e := \begin{cases} .6 & \text{if } H_T = 1 \\ .8 & \text{otherwise} \end{cases}$ *(AASHTO LRFD 2012 10.4.6.2.4)*

$H_e = 0.6$

3. Unit Side Resistance (q_{sr}) in Rock *(AASHTO LRFD 2012 10.8.3.5.4b)*

a. Soil Parameters

Uniaxial compressive strength of rock, $\mathbf{q_u}$ (kPa) *(obtained from unconfined compression tests)*

Atmospheric pressure, $p_a := 101.506kPa$

Rock Quality Designation, **RQD (%)**

Reduction factor based on RQD, $\mathbf{E_{RQD}}$ *(see Table 3.1 below for a list of values)*

Reduction factor to account for jointing in rock, $\boldsymbol{\alpha_E}$ *(see Table 3.2 below for a list of values)*

Table 3.1 Reduction factor based on RQD (after O'Neill and Reese, 1999)

RQD (%)	E_{RQD}	
	Closed Joint	Open Joint
100	1.00	0.60
70	0.70	0.10
50	0.15	0.10
20	0.05	0.05

Table 3.2 Estimation of α_E (after O'Neill and Reese, 1999)

E_{rqd}	α_E
1.00	1.00
0.50	0.80
0.30	0.70
0.10	0.55
0.05	0.45

Side resistance, q_{sr}, is given by:

$$q_{sr} = 0.65\alpha_E p_a (q_u / p_a)^{0.5} < \quad L_{sr} = 1.47 \times 10^4 \cdot \text{kPa}$$

where: L_{sr} = limiting value of side resistance

$= 7.8p_a(f'_c / p_a)^{0.5}$

4. Unit Tip Resistance (q_{pr}) in Rock *(AASHTO LRFD 2012 10.8.3.5.4c)*

For intact rocks (no compressible material within $2.0D_1$ of the drilled shaft), and the depth of the socket is greater than $1.5D_1$ *(after O'Neill and Reese, 1999)*, tip resistance is:

$$q_{pr} = 2.5\ q_u$$

For jointed rocks (random orientation) within $2.0D_1$ of the drilled shaft, tip resitance is:

$$q_{pr} = [s^{0.5} + (m\ s^{0.5} + s)^{0.5}]q_u$$

where: s, m = fractured rock mass parameters

(see Table 10.4.6.4-4 of AASHTO LRFD 2012)

5. Unit Side Resistance (q_{sc}) in Cohesive Soils *(AASHTO LRFD 2012 10.8.3.5.1b)*

$$q_{sc} = \alpha\ S_u$$

where: S_u = undrained shear strength (kPa)

α = adhesion factor

= 0.55 if $S_u/p_a \leq 1.5$

= 0.55 - 0.1 (S_u/p_a - 1.5) if $1.5 \leq S_u/p_a \leq 2.5$

The following portions of a drilled shaft should not be considered in side resistance calculation:

a. At least the top 1.5m of any shaft;

b. For straight shafts, the bottom length equal to $1.0D_1$;

c. Belled ends; and,

d. Distance above the belled end equal to $1.0D_1$.

6. Unit Tip Resistance (q_{pc}) in Cohesive Soils *(AASHTO LRFD 2012 10.8.3.5.1c)*

$$q_{pc} = N_c\ S_u \leq 3830.4 \text{ kPa}$$

where: S_u = undrained shear strength (kPa)

$N_c = 6[1+0.2(Z/D)] \leq 9$

Z = penetration of shaft (m)

D = diameter of shaft (m)

Note that if the soil within $2.0D_1$ of the tip has Su < 23.94kPa, Nc must be multiplied by 0.67.

7. Unit Side Resistance (q_{ss}) in Cohesionless Soils *(AASHTO LRFD 2012 10.8.3.5.2b)*

$$\mathbf{q_{ss} = \beta\sigma'_v \leq 191.52\ kPa} \quad \text{for } 0.25 \leq \beta \leq 1.2$$

where: σ'_v = vertical effective stress at soil layer mid-depth (kPa)

β = load transfer coefficient

= $1.5 - 0.135\sqrt{z}$ for sandy soils with $N_{60} \geq 15$

= $N_{60}/15\,(1.5 - 0.135\sqrt{z})$ for sandy and gravelly soils with $N_{60} < 15$

= $2.0 - 0.06(z)^{0.75}$ for gravelly soils with $N_{60} \geq 15$

z = depth below ground at mid-depth of the soil layer (m)

N_{60} = SPT blow count corrected for hammer efficiency

8. Unit Tip Resistance (q_{ps}) in Cohesionless Soils *(AASHTO LRFD 2012 10.8.3.5.2c)*

$$\mathbf{q_{ps} = 1.2N_{60} \leq 2872.8\ kPa} \quad \text{for } N_{60} \leq 50$$

$$\mathbf{q_{ps} = 0.59[N_{60}(p_a/\sigma'_v)]^{0.8}\sigma'_v} \quad \text{for } 50 < N_{60} \geq 100$$

9. Factored Resitance of Drilled Shafts (R_r) *(AASHTO LRFD 2012 10.8.3.5)*

$$\mathbf{R_r = \varphi R_p + \varphi R_s = \varphi_p q_p A + \varphi_s q_s A_s}$$

where: R_p = nominal shaft tip resitance (kN)

R_s = nominal shaft side resitance (kN)

ϕ_p = resistance factor for tip resistance

ϕ_s = resistance factor for shaft side resistance

A_s = area of shaft side resitance (m^2)

Table 9.1 Nominal Axial Compressive Resistance of Drilled Shafts

Soil / Condition		Tip Resistance Factor φ_p	Side Resistance Factor φ_s
Axial Compressive Resistance	Clay	0.40	0.45
	Sand	0.50	0.55
	Intermediate Geomaterial (IGM)	0.55	0.60
	Rock	0.50	0.50

Table 9.2 Uplift Resistance of Drilled Shafts

Soil / Condition		Resistance Factor, φ
Uplift Resistance	Clay	0.35
	Sand	0.45
	Rock	0.40

10. Side Resistance in Soil

Table 10.1 Soil Parameters

Layer Depth, d (m)	Soil Type, S_T	SPT N-Value, N_1	γ_s (kN/m^3)	RQD (%)	Comp. Strength of Rock q_u (kPa)	Undrained Shear Strength S_u (kPa)	Correlated coefficients		
							α_E	α	β
1.0	Sand	2	18.0	-	-	-	-	-	0.11
2.0	Sand	2	18.0	-	-	-	-	-	0.11
3.0	Clay	3	16.0	-	-	18	-	0.55	-
4.0	Sand	3	18.0	-	-	-	-	-	0.15
5.0	Sand	3	18.0	-	-	-	-	-	0.15
6.0	Clay	6	16.0	-	-	36	-	0.55	-
7.0	Sand	50	19.0	-	-	-	-	-	1.16
8.0	Sand	50	19.0	-	-	-	-	-	1.13
9.0	Sand	50	19.0	-	-	-	-	-	1.11
10.0	Sand	50	19.0	-	-	-	-	-	1.08
11.0	Sand	50	19.0	-	-	-	-	-	1.06
12.0	Sand	50	19.0	-	-	-	-	-	1.04
13.0	Sand	50	19.0	-	-	-	-	-	1.02
14.0	Sand	50	19.0	-	-	-	-	-	1.00
15.0	Sand	50	19.0	-	-	-	-	-	0.99
16.0	Sand	50	19.0	-	-	-	-	-	0.97
17.0	Sand	50	19.0	-	-	-	-	-	0.95
18.0	Sand	50	19.0	-	-	-	-	-	0.94
19.0	Sand	50	19.0	-	-	-	-	-	0.92
20.0	Sand	50	19.0	-	-	-	-	-	0.90
21.0	Sand	50	19.0	-	-	-	-	-	0.89
22.0	Sand	50	19.0	-	-	-	-	-	0.87
23.0	Sand	50	19.0	-	-	-	-	-	0.86
24.0	Sand	50	19.0	-	-	-	-	-	0.85
25.0	Sand	50	19.0	-	-	-	-	-	0.83
26.0	Sand	50	19.0	-	-	-	-	-	0.82
27.0	Sand	50	19.0	-	-	-	-	-	0.81
28.0	Sand	50	19.0	-	-	-	-	-	0.79
29.0	Sand	50	19.0	-	-	-	-	-	0.78
30.0	Sand	50	19.0	-	-	-	-	-	0.77
31.0	Sand	50	19.0	-	-	-	-	-	0.75
32.0	Sand	50	19.0	-	-	-	-	-	0.74
33.0	Sand	50	19.0	-	-	-	-	-	0.73

"-" means that the parameter has no relationship with the soil type in question.

Table 10.2 Side Resistance per Soil Layer

Layer Depth, d (m)	Soil Type, S_T	Corrected SPT N-Value, N_{60}	σ_v (kPa)	$\Sigma\sigma_v$ (kPa)	σ'_v (kPa)	Side Resistance		Factored Side Resistance
						q_s (kPa)	R_s (kN)	$\varphi_s R_s$ (kN)
1.0	Sand	1	18.00	18.00	9.00	0.00	0.00	0.00
2.0	Sand	1	18.00	36.00	22.10	0.00	0.00	0.00
3.0	Clay	2	16.00	52.00	29.29	0.00	0.00	0.00
4.0	Sand	2	18.00	70.00	36.48	5.46	34.31	18.87
5.0	Sand	2	18.00	88.00	44.67	6.50	40.87	22.48
6.0	Clay	4	16.00	104.00	51.86	19.80	124.41	55.98
7.0	Sand	30	19.00	123.00	59.55	68.82	432.43	237.84
8.0	Sand	30	19.00	142.00	68.74	77.69	488.14	268.48
9.0	Sand	30	19.00	161.00	77.93	86.22	541.72	297.94
10.0	Sand	30	19.00	180.00	87.12	94.42	593.28	326.31
11.0	Sand	30	19.00	199.00	96.31	102.33	642.95	353.62
12.0	Sand	30	19.00	218.00	105.50	109.95	690.81	379.95
13.0	Sand	30	19.00	237.00	114.69	117.29	736.95	405.32
14.0	Sand	30	19.00	256.00	123.88	124.37	781.43	429.78
15.0	Sand	30	19.00	275.00	133.07	131.19	824.31	453.37
16.0	Sand	30	19.00	294.00	142.26	137.77	865.66	476.11
17.0	Sand	30	19.00	313.00	151.45	144.12	905.53	498.04
18.0	Sand	30	19.00	332.00	160.64	150.23	943.95	519.17
19.0	Sand	30	19.00	351.00	169.83	156.13	980.98	539.54
20.0	Sand	30	19.00	370.00	179.02	161.80	1016.64	559.15
21.0	Sand	30	19.00	389.00	188.21	167.27	1050.98	578.04
22.0	Sand	30	19.00	408.00	197.40	172.53	1084.03	596.22
23.0	Sand	30	19.00	427.00	206.59	177.59	1115.82	613.70
24.0	Sand	30	19.00	446.00	215.78	182.45	1146.38	630.51
25.0	Sand	30	19.00	465.00	224.97	187.12	1175.72	646.65
26.0	Sand	30	19.00	484.00	234.16	191.52	1203.36	661.85
27.0	Sand	30	19.00	503.00	243.35	191.52	1203.36	661.85
28.0	Sand	30	19.00	522.00	252.54	191.52	1203.36	661.85
29.0	Sand	30	19.00	541.00	261.73	191.52	1203.36	661.85
30.0	Sand	30	19.00	560.00	270.92	191.52	1203.36	661.85
31.0	Sand	30	19.00	579.00	280.11	191.52	1203.36	661.85
32.0	Sand	30	19.00	598.00	289.30	191.52	1203.36	661.85
33.0	Sand	30	19.00	617.00	298.49	191.52	1203.36	661.85

Continued...

Layer Depth, d (m)	Soil Type, S_T	Corrected SPT N-Value, N_{60}	σ_v (kPa)	$\Sigma\sigma_v$ (kPa)	σ'_v (kPa)	Side Resistance		Factored Side Resistance
						q_s (kPa)	R_s (kN)	$\varphi_s R_s$ (kN)
						Total Side Resistance	25844.15 kN	14201.84 kN

11. Tip Resistance in Soil

Soil Type at Pile Tip, S_{tip} = "Sand"

Unit Tip Resistance, $q_p = 2872.8 \cdot kPa$

Pile Area, $A_p = 3.142 m^2$

Nominal Tip Resistance, $R_p = 9025.17 \cdot kN$

Factored Tip Resistance, $\varphi_{pR.p} = 4512.58 \cdot kN$

12. Combined Resistance in Drilled Shafts

12a. Pile Bearing Resistance

$\mathbf{R_u = R_p + R_s}$ *(under Extreme Event)*

$\mathbf{R_r = \varphi R_p + \varphi R_s}$ *(under Service I Condition)*

Load Condition	Resistance (kN)	Reaction (kN)	Remarks
Service I	18714.43	7543.31	***Safe!***
Extreme Event	34869.32	32854.32	***Safe!***

12b. Pile Uplift Resistance

$\mathbf{R_{up} = R_s}$ *(under Extreme Event)*

$\mathbf{\varphi R_{up} = \varphi R_s}$ *(under Seervice I Condition)*

Load Condition	Resistance (kN)	Reaction (kN)	Remarks
Service I	11617.43	0.00	***Safe!***
Extreme Event	25844.15	15076.87	***Safe!***