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1. OVERVIEW

This Part D contains the existing information. The documents are provided for the information only. The Contractor shall further verify by themselves for the correctness of the data. The Contractor shall not claim PTT for any impacts (Cost & Time) due to the data of PTT.

During Engineering & Construction phrases, the Contractor shall find the existing data at PTT's library by themselves. If the Contractor need information more than existing data in the library, the Contractor shall verify the data by their own cost (such as contact supplier, vendors, engineering firms or consultant firm).

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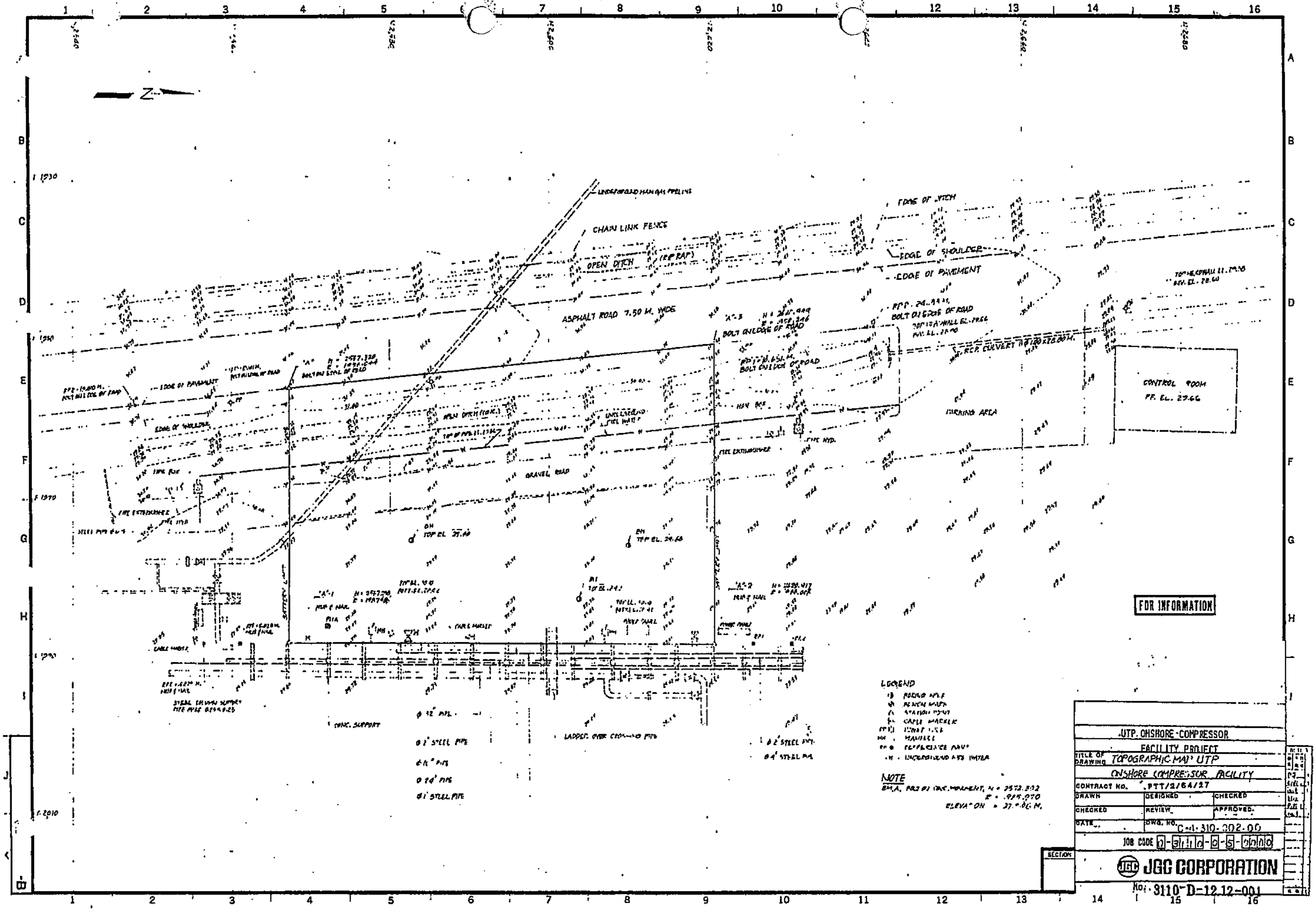
No.	DRAWINGS NO.	DESCRIPTION	REMARK
1	C-4-310-002-00	AS-BUILT DRAWING FOR UTP ONSHORE COMPRESSOR_TOPOGRAPGIC MAP_EXISTING	
2	3110-C-13.20-003	CALCULATION SHEETS FOR GAS TURBINE-COMPRESSOR FOUNDATION	
3	3110-C-13.20-003	CALCULATION SHEETS FOR PILE BEARING CAPACITY	
4	SP C-9304.07-0010-003	PRECONSTRUCTION SURVEYS REPORT (TOPOGRAPHIC SURVEY & SOIL INVESTIGATION) EXISTING	



UTP. ONSHORE COMPRESSOR
FACILITY PROJECT

TITLE OF DRAWING	TOPOGRAPHIC MAP UTP ONSHORE COMPRESSOR FACILITY	
CONTRACT NO.	PTT/2/64/27	
DRAWN	DESIGNED	CHECKED
CHECKED	REVIEW	APPROVED
DATE	DWG. NO. C-1-310-202-00	

JOB CODE 0-3110-0-5-0000

SECTION

JGC CORPORATION

No. 3110-D-12.12-001

JGC CORPORATION

3110-C-1320-003 6

SHEET 1 OF 30

DATE 16 - Nov - '84

PREP'D	S.Ooi
CHK'D	S. Kasuga
APP'D	T. Kawai

SP-F-310-05-06

CALCULATION SHEETS

FOR

FOUNDATION OF C-201, C-202, C-203, C-204.

AS BUILT

UNION 10-13 TIE-IN PIPELINE PROJECT

ONSHORE COMPRESSOR FACILITY

PETROLEUM AUTHORITY OF THAILAND

配付先		
新	本社	4
客	现场	
PJ		1
DQ FLD		2
JGC 现		1
JGC FLD		1

REV.	DATE	PREP'D	APP'D	PAGE	DESCRIPTION
0	16Nov-'84	S.Ooi	T-Kawai	ALL	1st ISSUED FOR REVIEW
1	19-DEC-'84	S.Ooi	T-Kawai	22,23, 25~27	REV. OF CONCRETE DESIGN STRENGTH
2	28-DEC-'84	S.Ooi	T-Kawai	P.6~16	REV. OF FOUNDATION SHAPE AND THERMAL LOAD
3	7-JAN-'85	S.Ooi	T-Kawai	P.25,26,27,30	REV. OF PC WIRE DIA. AND NUMBER
4	31-JAN-'85	S.Ooi	T-Kawai	P.6, 10~15 27, 28	INCREASE PILE AND REV. OF PILE BEARING CAPACITY
5	7-MAR-'85	S.Ooi	T-Kawai	P.6, 10~15 27, 28	REV. OF NUMBER OF PILE
6	13-AUG-'86	S.Ooi	T-Kawai	ALL	ISSUED FOR AS BUILT

JGC CORPORATION
(NIKKI KABUSHIKI KAISHA)

SHEET NO. 2/

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CONTENTS

§1. GENERAL

1.1 Design Standard

Reinforced concrete foundations shall be in accordance with ACI 318-77; " Building code requirements for reinforced concrete "

1.2 Materials

a) Concrete

$fc' = 210 Kg/cm^2$ for general foundations

b) Reinforcing Bars

$fy = 2800 Kg/cm^2$ for general foundations and tie bars for heavy equipment foundations

c) Soil Bearing Capacity Unit:ton/m2

B Df	B < 1.5m	B ≧ 1.5m
Df < 1m	6	10
Df ≥ 1m	13	15

The above figures may be increased by one-third (33%) for the load combinations B, C, D and E.

1.3 Unit weight of Materials

Concrete : 2.4 ton/m^3

Soil : 1.7 ton/m^3

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1.4 Load Components and Combinations

(1) Load Componentnets

The following load components shall be considered

a ——— Weight of foundation proper

p ——— Piping Weight

ee ——— Empty equipment weight

(e_r)

e_o ——— Operating (normal) fluids weight

e_t ——— Test fluids weight

L ——— Live load on plat form

W ——— Wind load

j ——— Bundle pulling load (H/E only)

t ——— Thermal force

V ——— Vibratory load

e_r ——— Erection equipment weight

i ——— Impact load

F ——— Friction load

(2) Load Combinations

The following load combinations shall be considered for verification of stabilities

Load Combinations	Formula
A	a + ee + L + e_o + P + t + (V) + F
B	a + ee + L + e_o + P + t + W + (V)
C	a + ee + L + e_t + P
D	a + ee + L + P + j + (i)
E	a + e_r + W

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The following load combinations shall be considered for calculation of stresses.

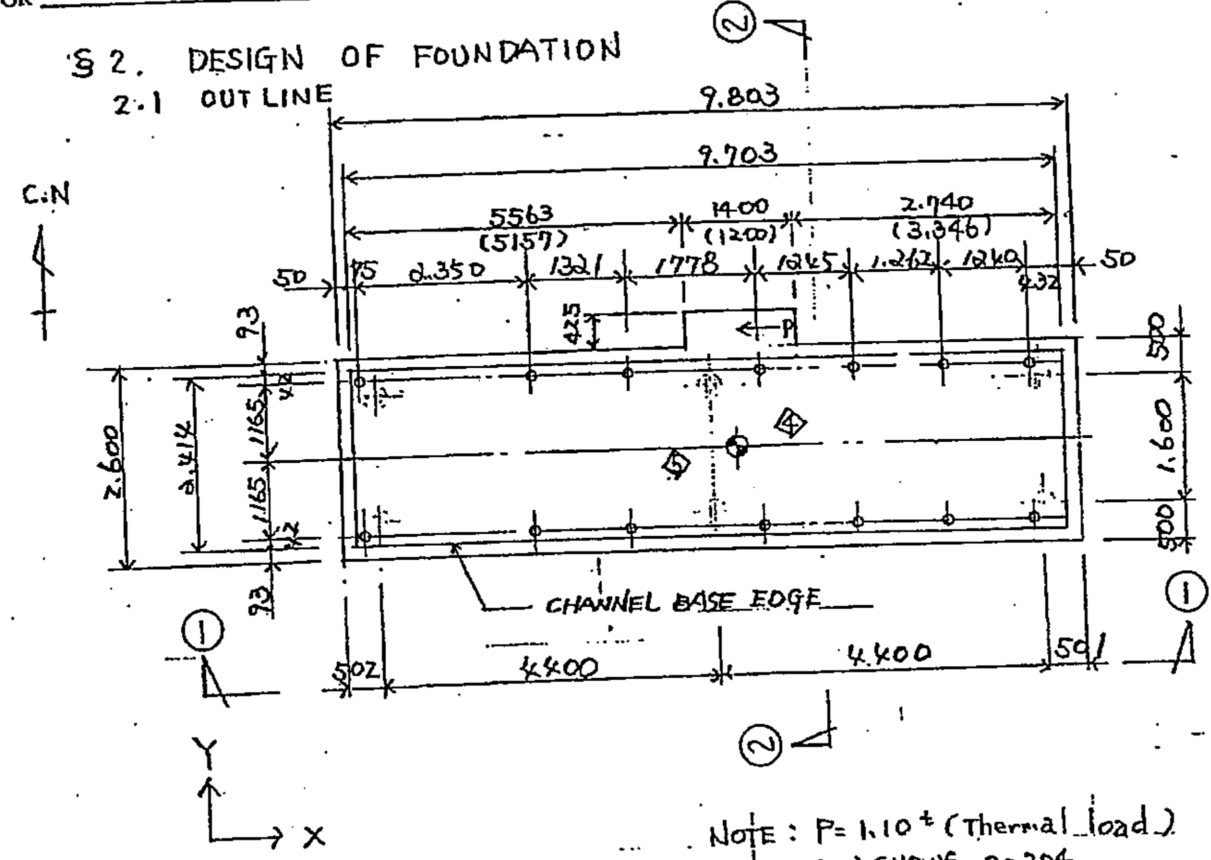
Load Combinations	Formula
A	1.4(a +ee) + 1.7(L +e0+P +t +V+F)
B	0.75[1.4(a +ee) + 1.7(L +e0 +P+t +W+V)]
C	0.75[1.4(a +ee) + 1.7(L +e_t+ P)]
D	0.75[1.4(a +ee) + 1.7(L+ P+j+i)]
E	0.75[1.4(a +e_T) + 1.7 W] or 0.9(a+e_r) +1.3W

1.5 Safety Factores

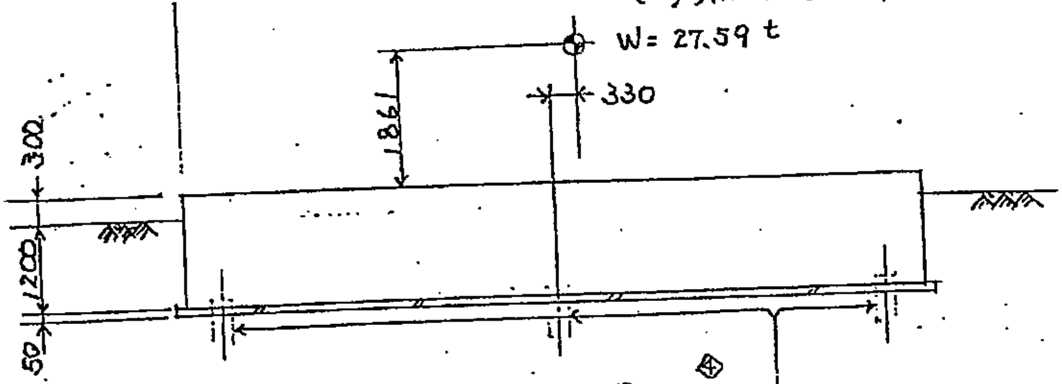
Load Combinations	Safety Factor		
	Overturning	Sliding	UPLIFT
A	1.5	1.5	1.2
B	1.2	1.2	1.1
C			
D			
E			

§ 2. DESIGN OF FOUNDATION

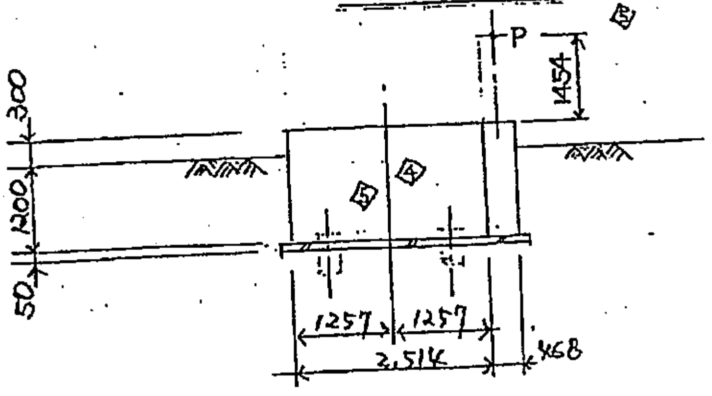
2.1 OUT LINE



NOTE : P= 1.10 t (Thermal load)
( ) SHOWS C-204



VIEW ①-①



VIEW ②-②

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2.2 LOAD

2.2-1 Foundation Weight

$W_F = 2.60 \times 9.803 \times 1.5 \times 2.4 + 0.425 \times 1.4 \times 1.5 \times 2.4 + 0.2$

$= 91.76 + 2.14 + 0.2 = 94.10\ t$

2.2-2 Load Components

a	Foundation Weight	N	94.10 t
L	Live Load	〃	0
e_o	Operating fluid weight	〃	0
e_t	Test fluid weight	〃	0
ee	Empty Weight	〃	27.59
er	Erection Weight	〃	〃
p	Piping Loads	N	0
w	Wind load	Q	4.95
		M	10.68
t	Thermal load	Q	1.10
i	Impact load		0
v	Vibratory load	〃	0

UNIT : ton , ton-metre

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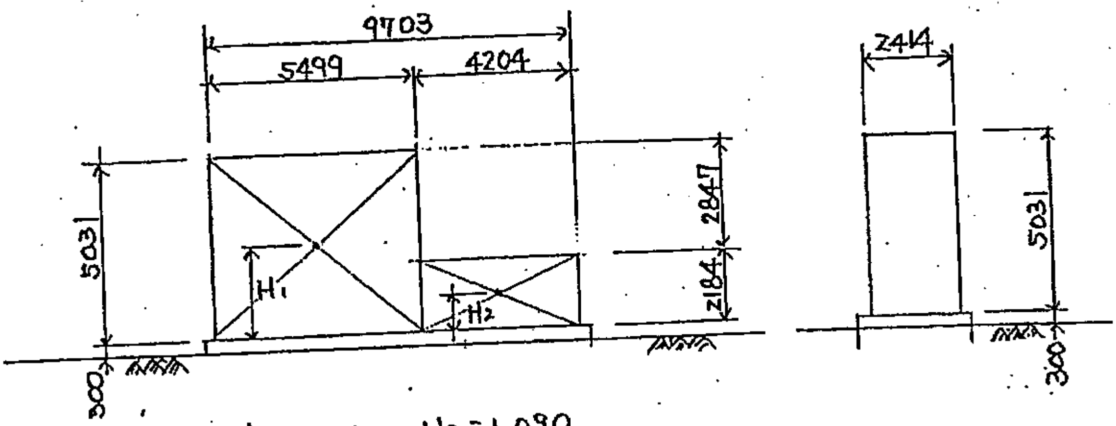
2.2-3. Wind Load (W)



$H_1 = 2520$, $H_2 = 1.090$

$$q_z = 0.0125\ K_z\ (I\ V)^2$$
$$= 0.0125 \times 0.87 \times (1.0 \times 100)^2$$
$$= 108.8\ \mathrm{kg/m^2} \longrightarrow 110\ \mathrm{kg/m^2}$$

$$Q_1 = A_1 \cdot q_z \cdot C_f = 5.1 \times 5.5 \times 0.11 \times 1.2 = 3.70\ t$$
$$Q_2 = A_2\ q_z \cdot C_f = 4.3 \times 2.2 \times 0.11 \times 1.2 = 1.25\ t$$

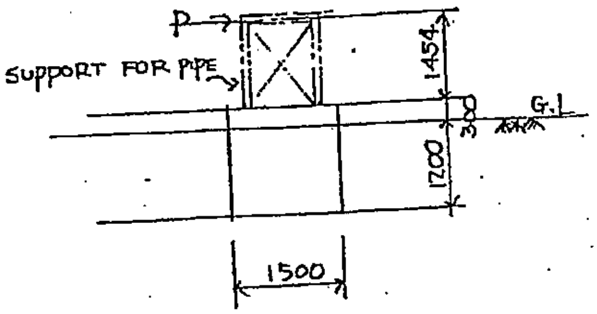
$$\Sigma Q = Q_1 + Q_2 = 3.70 + 1.25 = 4.95\ t$$

$$M_1 = Q_1 \cdot H_1 = 3.70 \times 2.52 = 9.32\ t.m$$
$$M_2 = Q_2 \cdot H_2 = 1.25 \times 1.09 = 1.36\ tm$$

$$\Sigma M = M_1 + M_2 = 9.32 + 1.36 = 10.68\ t.m$$

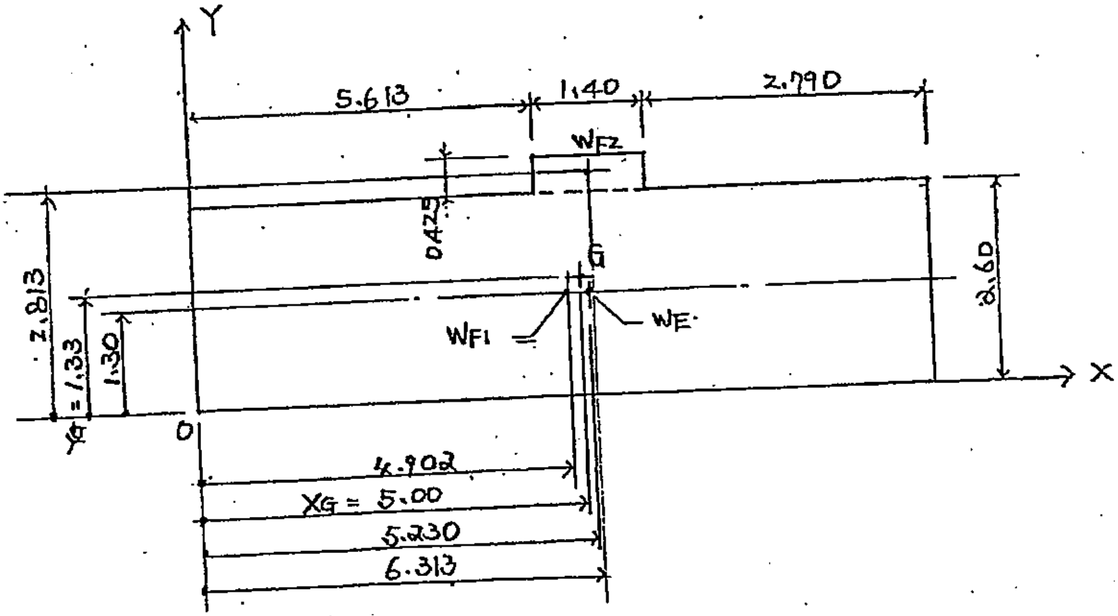
2.2-4. Thermal Load (t)

P = 1.1 t (Thermal load)



2.3. Check of Stability

2.3-1 Calculation for Center of Gravity



$W_{F1} = 91.76$ t , $W_{F2} = 2.14 + 0.2 = 2.34$ t , $W_E = 27.59$ t

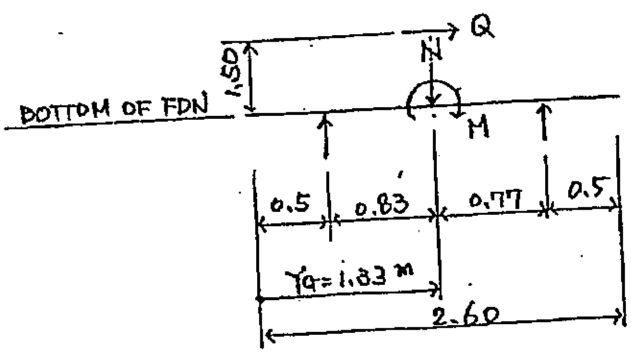
$\Sigma W = 121.69$ t

$$X_G = \frac{91.76 \times 4.902 + 2.34 \times 6.313 + 27.59 \times 5.23}{121.69} = \frac{608.9}{121.69} = 5.00 \text{ m}$$

$$Y_G = \frac{91.76 \times 1.3 + 2.34 \times 2.813 + 27.59 \times 1.3}{121.69} = \frac{161.7}{121.69} = 1.33 \text{ m}$$

2.3-2 Check of Overturning

Load Combination – B / Y-Direction



N = 121.69 t

M = 10.68 tm

Q = 4.95 t

$M_{OT} = 10.68 + 4.95 \times 1.5 = 18.11$ tm

$M_R = 121.69 \times 0.77 = 93.70$ tm

$F = M_R / M_{OT} = 93.70 / 18.11 = 5.2 > 1.2$

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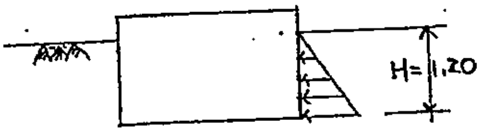
2.3-3 Check of Sliding

Load Combination - B / Y-Direction



$\gamma = 1.7 - 1.0 = 0.7$ t/m^3

N = 12

N = 12

$\phi = \sqrt{20N} + 15 = 30°$

$K_p = \tan^2(45° + \frac{30°}{2}) = 3.0$

$P_p = \frac{1}{2} \gamma H^2 K_p \cdot L$

$= \frac{1}{2} \times 0.7 \times 1.2^2 \times 3.0 \times 9.803$

$= 14.82$ t

$Q = 4.95$ t

$F_s = P_p / Q = 14.82 / 4.95 = 3.0 > 1.2$

O.K

2.3-4 Check of PILE Bearing Capacity

a) Load Combination - A

X, Y - Direction

$W = a + L + e_o + e_e + p + t + V = 121.69$ t

$= 94.10 + 0 + 0 + 27.59 + 0 + 0 + 0 = 121.69$ t

Thermal load

$M_{ex} = 121.69 (5.00 - 4.90) - (1.1 \times 2.954) = 12.17 - 3.25 = 8.92$ tm

$M_{eY} = 121.69 (1.33 - 1.30) = 3.65$ tm

$Z_x = 2 \times 4.4^2 \times 2 / 4.4 = 17.6$

$Z_Y = 3 \times 0.80^2 \times 2 / 0.80 = 4.8$

$R_A = \frac{W}{n} \pm \frac{M_{ex}}{Z_x} \pm \frac{M_{eY}}{Z_Y}$

④ ⑤

$= \frac{121.69}{6} \pm \frac{8.92}{17.6} \pm \frac{3.65}{4.8}$

$= 20.28 \pm 0.51 \pm 0.76 = \begin{cases} 21.55 \text{ t/PILE (MAX)} < 22 \text{ t/PILE} \\ 19.01 \text{ t/PILE (MIN.)} \end{cases}$

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b) Load Combination – B

<u>Y – Direction</u>

$W = a + L + e_o + e_e + P + w + t + V$

$= 121.69 \text{ t}$

$M_Y = 10.68 + 1.1 \times 1.5 = 12.33 \text{ tm}$

$Z_Y = 4.8$

$$R_B = R_A \pm \frac{M_Y}{Z_Y}$$

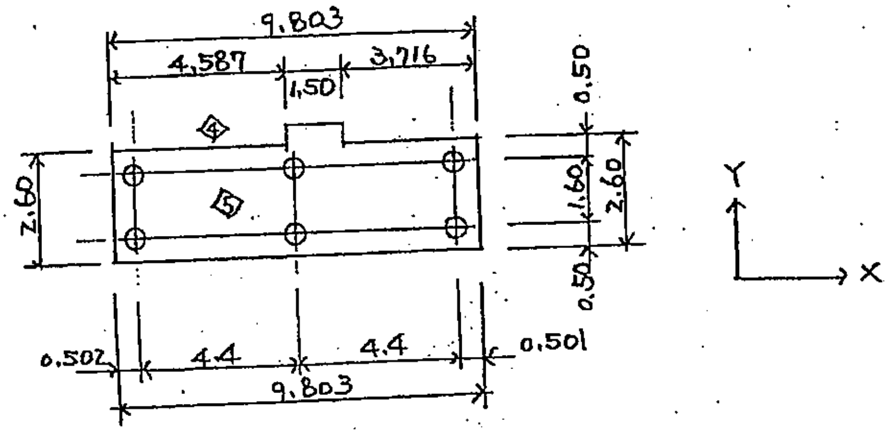
$$= \begin{matrix} 21.55 \\ 19.01 \end{matrix} \pm \frac{12.33}{4.8}$$

④ ⑤

$$= \begin{matrix} 21.55 \\ 19.01 \end{matrix} \pm 2.57$$

$$= \begin{cases} 24.12 \text{ t/PILE} \\ 16.44 \text{ t/PILE} \end{cases} \quad < 22 \times 1.33 = 29.26 \text{ t/PILE}$$

2.4. Design of Footing



- Most critical load Combination will be load Combination – A

R : PILE REACTION

$R = \underbrace{1.4}_{\text{Load factor}} \times 21.55 = 30.17$ t/PILE ⑤ ④

1) X - Direction

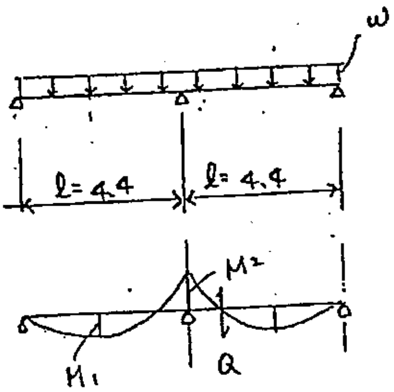
④ ⑤

$w = 30.17 \times 3 / (4.4 \times 2) = 10.29$ t/m

$M_1 = \frac{9}{128} w l^2 = \frac{9}{128} \times 10.29 \times 4.4^2 = 14.01$ tm

$M_2 = \frac{1}{8} w l^2 = \frac{1}{8} \times 10.29 \times 4.4^2 = 24.90$ tm

$Q = \frac{5}{8} w l = \frac{5}{8} \times 10.29 \times 4.4 = 28.30$ t



D= 150 cm , d= 140 cm

b= 260/2 = 130 cm

$b = 130\,cm = 51.2^{in}$, $d = 140\,cm = 55.1^{in}$

$F = bd^2/12000 = 51.2 \times 55.1^2/12000 = 12.95$

i) FOR TOP

④ ⑤

$Mu = 24.90\,tm = 24.90 \times 7.24 = 180.28\ Kf$

$Ku = Mu/F = 180.28/12.95 = 13.92 \xrightarrow{fy=40000} P = 0.0015 \times \frac{13.92}{53} = 0.0004$

$As_1 = 0.0004 \times 51.2 \times 55.1 = 1.13\ in^2 = 7.29\ cm^2$

$As_2 = 1\tfrac{1}{3} \times 1.13 = 1.50\ in^2 = 9.68\ cm^2$

$\}$ Areq = 9.68 cm^2

USE 9-DB16@150 ($As = 2.01 \times 9 = 18.09\ cm^2$)

ii) FOR BOT.

$Mu = 14.01\ tm = 14.01 \times 7.24 = 101.43\ Kf$

$Ku = Mu/F = 101.43/12.95 = 7.83 \xrightarrow{fy=40000} P = 0.0015 \times \frac{7.83}{53} = 0.0002$

$As_1 = 0.0002 \times 51.2 \times 55.1 = 0.56\ in^2 = 3.61\ cm^2$

$As_2 = 1\tfrac{1}{3} \times 0.56 = 0.74\ in^2 = 4.77\ cm^2$

$\}$ Areq = 4.77 cm^2

USE 9-DB16@150 ($As = 2.01 \times 9 = 18.09\ cm^2$)

iii) Check of Shear Force.

$Vu_1 = 28.30t = 62.47^{Kips}$

$\phi Vc = 0.85 \times 2 \times \sqrt{3000} \times 10^{-3} \times 51.2^{in} \times 55.1^{in} = 262.7\ Kips$

$Vu_1 < \phi Vc$ ⓄK

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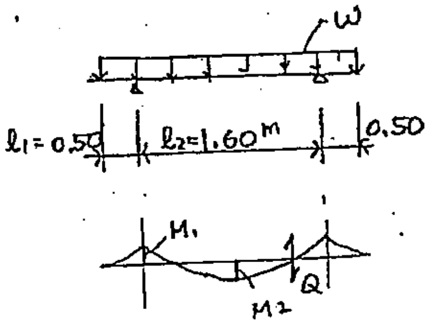
2) Y- Direction



$\omega = 30.17 \times 2/2.6 = 23.21$ t/m

$M_1 = \frac{1}{2}\omega l_1^2 = \frac{1}{2} \times 23.21 \times 0.5^2 = 2.90$ tm

$M_2 = \frac{1}{8}\omega l_2^2 - \frac{1}{2}\omega l_1^2$

$= \frac{1}{8} \times 23.21 \times 1.6^2 - 2.90 = 4.53$ tm

$Q_{max} = \frac{1}{2}\omega l_2 = \frac{1}{2} \times 23.21 \times 1.6 = 18.57$ t

$b = 51 + \frac{30}{2} + 140 = 206$ cm

D = 150 cm , d = 140 cm

4

5

b = 206 cm = 81.1 in , d = 140 cm = 55.1 in

$F = bd^2/12000 = 81.1 \times 55.1^2/12000 = 20.52$

i) FOR TOP

$Mu = 2.90 \text{tm} \times 2.90 \times 7.24 = 21.00$ Kf

$Ku = Mu/F = 21.0/20.52 = 1.02 \xrightarrow{fy=40000} P = 0.0015 \times \frac{1.02}{53} = 0.00003$

$As_1 = 0.00003 \times 81.1 \times 55.1 = 0.13 \text{ in}^2 = 0.84 \text{ cm}^2$
$As_2 = 1\ 1/3 \times 0.13 = 0.17 \text{ in}^2 = 1.10 \text{ cm}^2$
} Areq = 1.10 cm²

USE 14-DB16 @ 150 (As = 2.01 × 14 = 28.14 cm²)

ii) FOR BOT

$Mu = 4.53 \text{ tm} = 4.53 \times 7.24 = 32.80$ Kf

$Ku = Mu/F = 32.80/20.52 = 1.60 \xrightarrow{fy=40000} P = 0.0015 \times \frac{1.60}{53} = 0.00005$

$As_1 = 0.00005 \times 81.1 \times 55.1 = 0.22 \text{ in}^2 = 1.42 \text{ cm}^2$
$As_2 = 1\ 1/3 \times 0.22 = 0.29 \text{ in}^2 = 1.87 \text{ cm}^2$
} Areq = 1.87 cm²

USE 14-DB16 @ 150 (As = 2.01 × 14 = 28.14 cm²)

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iii) Check of Shear Force

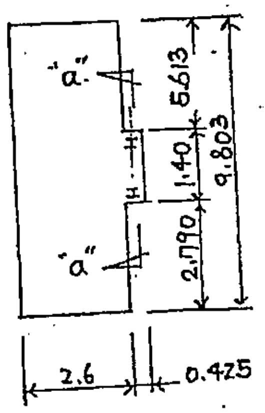
- $V_{u1} = 18.57^t = 41.0$ Kips

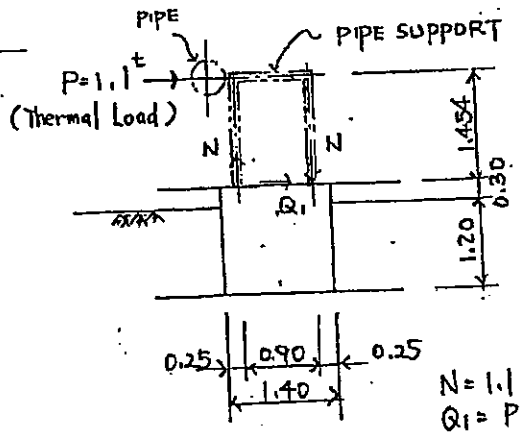
$\phi V_c = 0.85 \times 2 \times \sqrt{3000} \times 10^{-3} \times 81.1 \text{in} \times 55.1 \text{in} = 416.08$ Kips

$V_{u1} < \phi V_c$ (O.K)

2.5 Check of Footing according to PIPE SUPPORT

Load Combination – A





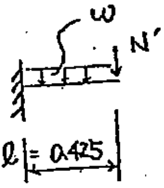
$N = 1.1 \times 1.454 / 0.90 = 1.78^t$
$Q_1 = P = 1.1^t$

i) FOR TOP & BOT.

"a" ~ "a" SECTION

$w = \underbrace{1.4}_{\text{Load factor}} \times 1.5 \times 2.4^{t/m^3} \times \overset{b}{0.75} = 3.78 \text{ t/m}$

$N' = \underbrace{1.7}_{\text{Load factor}} \times 1.78 = 3.03$ t



$b = 150/2 = 75\text{cm} = 29.5^{\text{in}}$, $D = 150\text{cm}$, $d = 140\text{cm} = 55.1^{\text{in}}$

$F = bd^2/12000 = 29.5 \times 55.1^2/12000 = 7.46$

$M = N'\ell + \frac{1}{2} w\ell^2 = 3.03 \times 0.425 + \frac{1}{2} \times 3.78 \times 0.425^2$
$= 1.29 + 0.34$
$= 1.63$ tm

$Q_z = N' + w\ell = 3.03 + 3.78 \times 0.425 = 4.64^t$

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FOR

$Mu = M = 1.63\ tm = 1.63 \times 7.24 = 11.80\ ^{Kf}$

$Ku = Mu/F = 11.80/7.46 = 1.58 \xrightarrow{fy=40000} P = 0.0015 \times \frac{1.58}{53} = 0.0001$

$$\left.\begin{aligned} As_1 &= 0.0001 \times 29.5 \times 55.1 = 0.16\ in^2 = 1.03\ cm^2 \\ As_2 &= 1\,1/3 \times 0.16 \qquad = 0.21\ in^2 = 1.35\ cm^2 \end{aligned}\right\} Areq = 1.35\ cm^2$$

USE 6 - DB16 @ 150 ($As = 2.01 \times 6 = 12.06\ cm^2$)

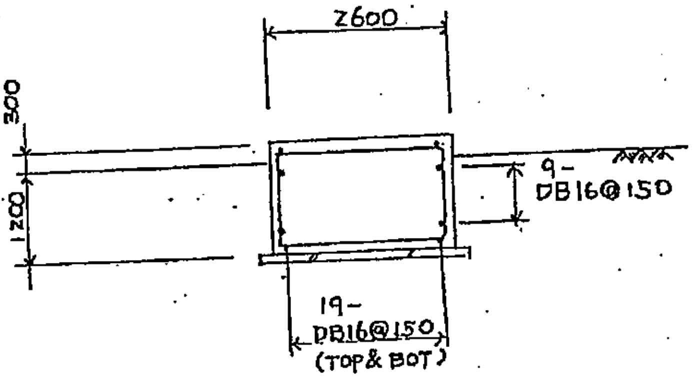
ii) Check of Shear Force —

$Vu_1 = 4.64\ t = 10.24\ kips$

$\phi Vc = 0.85 \times 2 \times \sqrt{3000} \times 10^{-3} \times 29.5^{in} \times 55.1^{in} = 151.4\ ^{kips}$

$Vu_1 < \phi Vc$ $\boxed{O.K}$

2.6 BAR ARRANGEMENT



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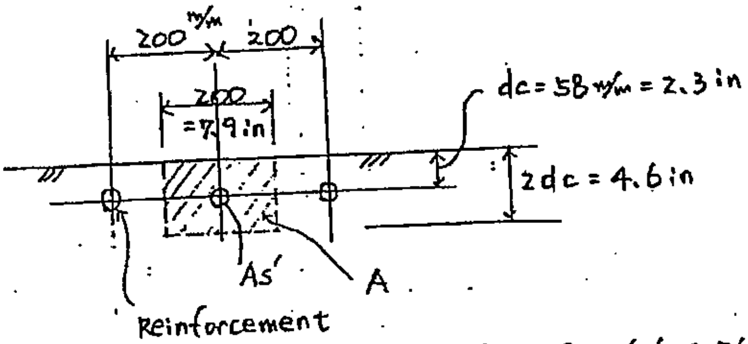
FOR 2.7 CHECK OF MINIMUM REINFORCEMENT

CH.

2.7-1. CASE 1 (based on ACI 207 6.4)



$A = 7.9 \times 4.6 = 36.3 \ in^2$

$As' = \frac{ft'A}{fs}$ or $\frac{A}{100}$ (as a limit for ft'/fs) : SEE ACI 207 EQ (6.11)

$fs = \frac{w \times 10^3}{0.076 \sqrt[3]{dcA}}$

dc = 2.3 in
$A = 36.3 \ in^2$
w = 0.013 in (permissible crack width)

$= \frac{0.013 \times 10^3}{0.076 \sqrt[3]{2.3 \times 36.3}}$

$= \frac{.13}{0.332}$

$= 39.2$ Ksi

$= 39200$ psi

$ft' = 6\sqrt{fc'}$

$As' = \frac{ft'A}{fs} = \frac{6\sqrt{3000}\,A}{39200}$ or $\frac{A}{100}$

$= \frac{A}{119}$ or $\frac{A}{100}$

$\frac{A}{119} < \frac{A}{100}$

$As' = \frac{A}{100} = \frac{36.3}{100} = 0.36 \ in^2 \doteqdot 2.32 \ cm^2 >$ PRESENT RE-BAR DB16@200 $2.01 \ cm^2$

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if RE-BAR SPACING is 150 m/m

$$A = \overset{\text{RE-BAR SPACING}}{5.9} \times \underset{\text{2dc}}{4.6} = 27.1 \text{ in}^2$$

$$As' = \frac{A}{100}$$

$$= \frac{27.1}{100}$$

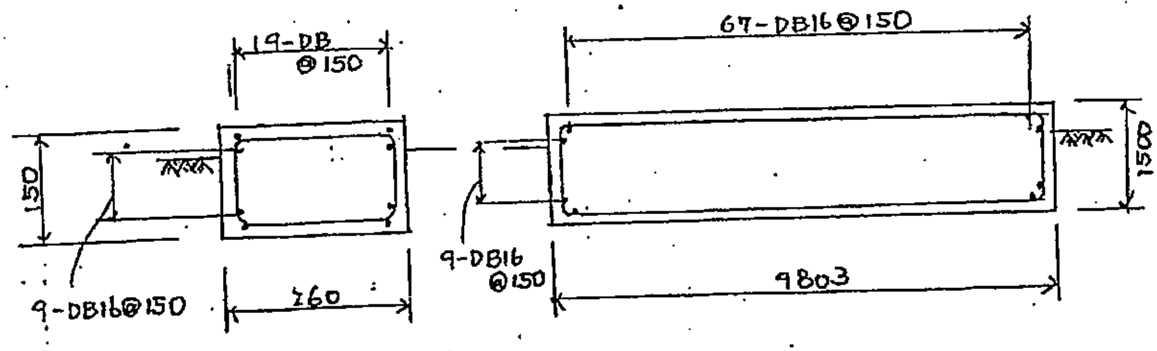
DB16@150

$$= 0.271 \text{ in}^2 = 1.75 \text{ cm}^2 < 2.01 \text{ cm}^2$$

ⓄK

USE DB16@150

2.7-2 CASE 2 (based on ACI 318-83 7.12)



$$P_1 = \frac{\overset{\text{(pcs)}}{(19+9)} \times 2 \times \overset{\text{DB16}}{2.01}^{\text{cm}^2}}{150 \times 260} = 0.00289 > 0.0020$$

Ⓞ.K

$$P_2 = \frac{(67+9) \times 2 \times 2.01^{\text{cm}^2}}{150 \times 980.3} = 0.00208 > 0.0020$$

Ⓞ.K

USE DB16@150

not practical in controlling the crack widths of very large externally restrained masses, and for these structures the principles of mass concrete construction described in Reference 1 must be followed to control cracking. The above formulas for crack spacing, however, can be utilized to establish a somewhat higher allowable temperature drop than normally used for mass concrete by acknowledging an acceptable crack. This can be seen in the design temperatures corresponding to zero steel requirements for the lengths of wall shown in Fig. 6.3 through 6.5.

Design temperatures in unreinforced sections should be kept approximately 10 F less than indicated for zero steel requirements because of the apparent sensitivity of crack widths to temperature in the cracking temperature range. Table 6.3.1 is based on this criteria.

TABLE 6.3.1—DESIGN TEMPERATURE LIMITS FOR UNREINFORCED CONCRETE WALLS (FOR LIMITING CRACKS TO 0.009 IN.)

Contraction joint spacing ft	Coefficient of thermal expansion × 10^{-5}			
	4	5	6	7
100	30 F	24 F	20 F	17 F
80	37 F	30 F	25 F	21 F
40	44 F	35 F	29 F	25 F
20	62 F	50 F	42 F	36 F

6.3.2 *Discontinuous external or end restraint*—Cracking will occur when the stress induced in the concrete by volume change exceeds the tensile strength of concrete as described in Section 2.3.3. When more than one crack is required in order to control crack widths, the total force in the reinforcing steel must equal the total restraint force induced at ends of the member as given in Eq. (2.6) of Section 2.3.1.

More than one crack will be required when the permissible crack width is less than the volume change ($L_R C_T T_E$).

When the volume change is less than the permissible crack width, no steel is required for volume change except as may be required as minimum (see Section 6.4).

6.3.3 *Internal restraint*—For relatively large masses the spacing of surface cracks will be controlled by internal restraint as described in Section 2.4. These cracks, independent of external restraint conditions, are not deep enough to require more than nominal amounts of reinforcing near the surface to control crack widths. In the example given in Section 2.4 the surface tensile stress due to daily temperature fluctuations was more than the surface stress due to the annual change in temperature. The depth of tensile stress block for the daily temperature fluctuations was less than 2.5 ft in the example. If this is assumed as the maximum depth of the critical restraint plane for internal restraint, then a maximum surface crack spacing in large masses of approximately 5 ft can be expected. If $C_T T_E$, using the maximum normal daily temperature fluctuation for T_E, is less than $w/12L'$, for L' in ft, then no surface reinforcement is required (Note L' should not be taken as more than 5 ft). If $C_T T_E > w/12L'$ then the minimum steel requirements of Section 6.4 should probably be utilized.

When internal restraint results from exposure of projecting elements from warm interiors, such as slabs projecting through exterior walls or walls projecting out of the ground, determine the depth of the tensile stress block and restraint factor as outlined in Section 2.4.1. If the required average crack spacing is less than twice the depth of the tensile stress block determine the size of bars to be distributed throughout the tensile stress block by:

$$A_b = \frac{1}{3}\frac{f_t'}{f_s}\frac{Bd_x}{N_B} \qquad (6.10)$$

where:

N_B = the total number of bars distributed throughout d_x

6.4—Recommendation for minimum reinforcement.

The minimum requirements of ACI 318-71 should apply to all superstructure slabs and beams. The minimum total quantity of temperature and shrinkage reinforcement otherwise recommended for walls, slabs, and footings less than 48 in. thick which have been investigated for crack control by the measures outlined herein is 0.0015 times the cross sectional area A_g of the member. Not less than one half nor more than two thirds of the total quantity should be placed in any one face. For crack control the maximum bar spacing should be limited to 12 in. on center. For members more than 48 in. thick the minimum temperature and shrinkage requirements in each face should be limited by depth of cover (d_c) and bar spacing such that:

$$A_s' = \frac{f_t' A}{f_s} \text{ or } \frac{A}{100} \text{ (as a limit for } f_t'/f_s) \qquad (6.11)$$

The minimum bar size and spacing for members of this size should not be less than #6 bars at 12 in. on center.

No minimum temperature and shrinkage reinforcement is required for members 6 ft or more in thickness which are constructed by the principles and practices of Reference 1 to control the

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— APPENDIX —

CALCULATION SHEETS
FOR
PILE BEARING CAPACITY

87

SHEET NO. 2 /

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FOR

CONTENTS

§ 1. DESIGN CRITERIA

1. 1. APPLICABLE DESIGN CODE

UNIFORM BUILDING CODE (UBC)

1. 2. ALLOWABLE STRESS

1-2-1 CONCRETE

DESIGN STRENGTH $f_{cu} = 350^{kg/cm^2}$ △

EXTREME FIBER STRESS IN COMPRESSION (AFTER PRESTRESS) $f_{ca} = 0.45 f_{cu} = 158^{kg/cm^2}$ △

EXTREME FIBER STRESS IN TENSION (AFTER PRESTRESS) $f_{ta} = 1.59\sqrt{f_{cu}} = 29.7^{kg/cm^2}$

COMPRESSIVE STRESS (BY HANDLING AND DRIVING) $f_{ca}' = 0.33 f_{cu} = 116^{kg/cm^2}$

1-2-2 P.C. WIRE

ULTIMATE STRENGTH $f_s = 16500^{kg/cm^2}$

1. 3. YOUNG'S MODULUS OF CONCRETE

$$E_c = (33\gamma^{1.5} \times f_{cu}^{0.5})^{psi} \quad \text{(BY CRITERIA OF UBC)}$$

△

$$= (4300\,\gamma^{1.5} \times f_{cu}^{0.5})^{kg/cm^2} = 2.81 \times 10^{5\,kg/cm^2}$$

γ : $2.3^{t/m^3}$ (CONCRETE WEIGHT)

1. 4 COEFFICIENT OF HORIZONTAL SUBGRADE REACTION

$k = 1.5^{kg/cm^3}$

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§ 2. CAPACITY OF PILE

2.1. SECTIONAL CAPACITY

AREA $Ag = \frac{\pi(D^2-d^2)}{4}$

GEOMETRICAL MOMENT OF INERTIA

$$I = \frac{\pi(D^2-d^2)}{64}$$

SECTION MODULUS $Z = \frac{I}{y_o}$

D: EXTERNAL DIAMETER

d: INTERNAL DIAMETER

y_o: DISTANCE BETWEEN NEUTRAL AXIS AND EDGE

2.2. CALCULATION OF INTERACTION CURVE

2-2-1 CONDITION

$$\frac{N}{Ag} + \frac{Fe}{Ag} + \frac{M}{Z} \leqq f_{ca} = 158^{kg/cm^2}$$

$$\frac{N}{Ag} + \frac{Fe}{Ag} - \frac{M}{Z} \geqq f_{ta} = -29.7\ ^{kg/cm^2}$$

N: AXIAL FORCE

M: BENDING MOMENT

Fe: STRENGTH OF P.C. WIRE

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2-2-2 RELATION FORMULA OF BENDING MOMENT AND HORIZONTAL FORCE

CHANG'S FORMULA

$$M_{max} = 0.3224 \frac{H}{\beta}$$ (THE CASE OF THAT PILE HEAD IS HINGE)

$$H = \frac{\beta \cdot M_{max}}{0.3224}$$

H ; HORIZONTAL FORCE

β ; $\beta = \left(\frac{kB}{4E_cI}\right)^{1/4}$

B ; WIDTH OF PILE

§3. DESIGN OF ϕ300 PILE

3.1. SECTIONAL CAPACITY

$$Ag = \frac{\pi(30^2-17^2)}{4} = 479 \text{ cm}^2$$

$$I = \frac{\pi(30^2-17^2)}{64} = 35661 \text{ cm}^4$$

$$Z = \frac{35661}{15} = 2377 \text{ cm}^3$$

3.2. STRENGTH OF P.C. WIRE

USE 8 × ϕ5 mm P.C. WIRES $As = 0.196 \text{ cm}^2/\text{wire}$

THE WIRES ARE TENSIONED TO 70% OF ULTIMATE STRENGTH

$\therefore$ $0.7 \times fs \times As = 0.7 \times 16500 \times 0.196 = 2264 \text{ Kg}$

ASSUME 18% LOSSES

$Fe = 8 \times 0.82 \times 2264 = 14852 \text{ Kg}$ ③

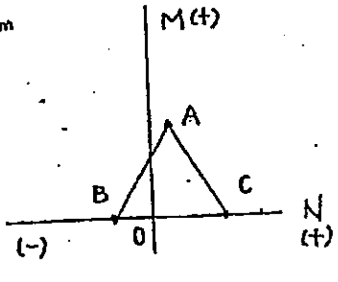
3.3. CALCULATION OF INTERACTION CURVE

$$\frac{Fe}{Ag} = \frac{14852}{479} = 31.0 \text{ Kg/cm}^2$$

$$\left.\begin{array}{l} \dfrac{N}{479} + 31.0 + \dfrac{M}{2377} = 158 \\[2ex] \dfrac{N}{479} + 31.0 - \dfrac{M}{2377} = -29.7 \end{array}\right\} \text{REFER TO "2-2-1"}$$

AS SOLVED UPPER FORMULA

"A" POINT $N = 15.9$ t, $M = 2.23$ tm
"B" POINT $N = -29.1$ t, $M = 0$ tm
"C" POINT $N = 60.8$ t, $M = 0$ tm



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3.4. CALCULATION OF HORIZONTAL FORCE

$B = 30\,cm$

$$\beta = \sqrt[4]{\frac{1.5 \times 30}{4 \times 2.81 \times 10^{5} \times 35661}} = 5.79 \times 10^{-3}\,cm^{-1} = 0.58\ m^{-1}$$

$$H = \frac{0.58 \times M}{0.3224}$$

REFER TO "2-2-2"

$M = 2.23\ tm$

$$H = \frac{0.58 \times 2.23}{0.3224} = 4.01\ t$$

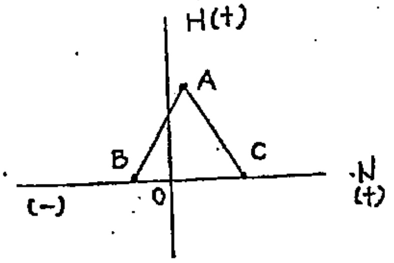
△1

◇3

"A" POINT (M = 2.23 tm), H = 4.01 t , N = 15.9 t

"B" POINT (M = 0 tm) , H = 0 t , N = −29.1 t

"C" POINT (M = 0 tm) , H = 0 t , N = 60.8 t



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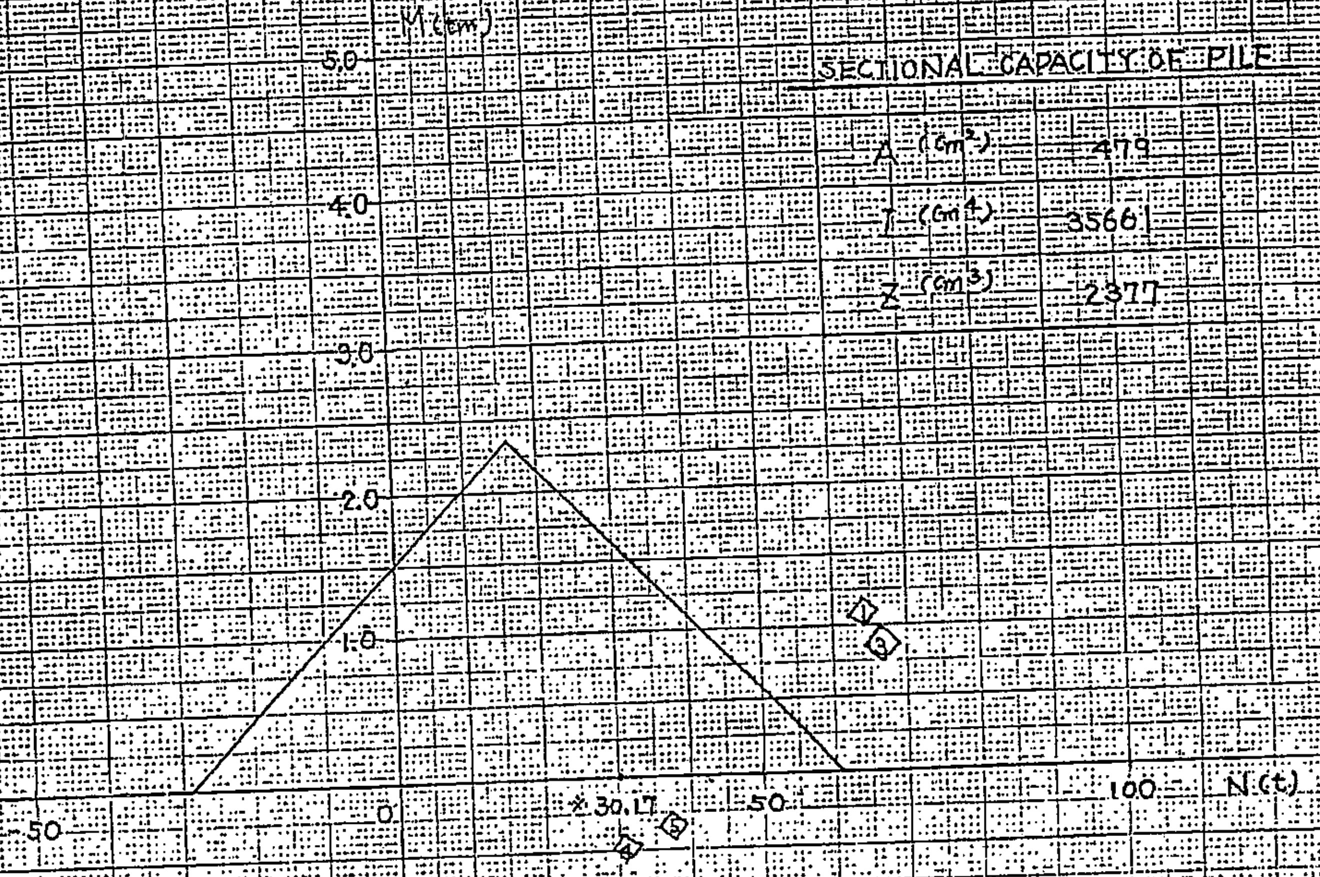
4 INTERACTION CURVE

φ 300



SECTIONAL CAPACITY OF PILE

A (cm²) 479

I (cm⁴) 35661

Z (cm³) 2377

※ REFER TO 「2.4 DESIGN OF FOOTING」 PAGE 12

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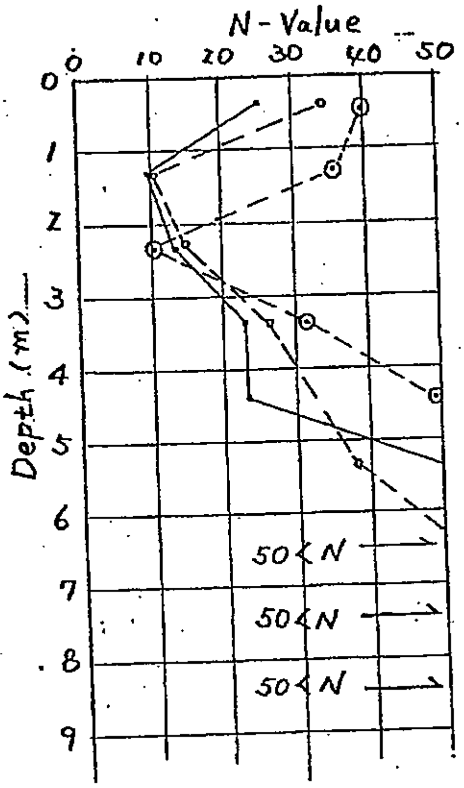
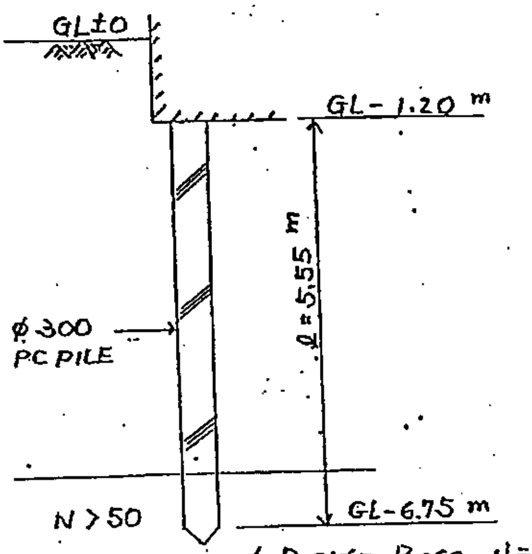
§5. PILE BEARING CAPACITY.

5.1. SOIL CONDITION





< Design Base N≒40 >

5.2. PILE BEARING CAPACITY

$$Qu = 40NAp + \left(\frac{N}{5} l_s + \frac{q_u}{2} l_c\right)\psi$$ (Meyerhoff's equation)

USING only

$$Qa = \frac{1}{Fs} \cdot 40 \cdot N \cdot Ap$$

$Ap = 0.0707\ m^2$

$N = 40$

$Fs = 3$ (Safety Factor)

$$Qa = \frac{1}{3} \times 40 \times 40 \times 0.0707 = 37.7 \text{ ton/PILE}$$

↓

$\boxed{22 \text{ ton/PILE}}$ (depend on result of pile load test)

△4

APPENDIX - 2 PILE CATALOGUE

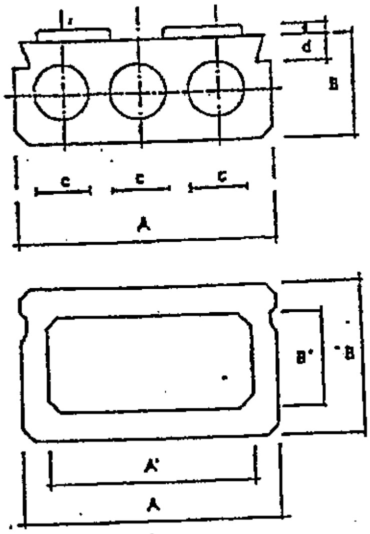
Prestressed Precast, Spun Concrete Piles

MPAC

บริษัท นครหลวงวัสดุก่อสร้างและคอนกรีตอัดแรง จำกัด

Metropolitan Aggregate & Concrete Piles Co., Ltd.

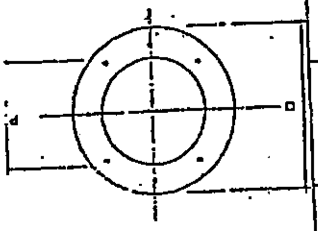
สำนักงาน 134/18-19 ถนนเพชรเกษม ข้างธนาคารกรุงเทพ สาขาท่าพระ เขตภาษีเจริญ กทม.
☎ 4670549, 4670882, 4671678
โรงงาน 92 หมู่ 7 ต. อ้อมน้อย อ. กระทุ่มแบน จ. สมุทรสาคร ☎ 4201744



BOX GIRDER

ความยาว m.	น.น. kgs/pc.	ระยะ cms						
		A	A'	B	B'	c	d	e
6.00	3500	100	-	30	-	15	10	5
8.00	6000	100	-	40	-	22	10	5
10.00	7500	100	-	40	-	22	10	5
12.00	10000	100	-	50	-	22	10	5
14.00	12500	100	80	60	36	-	-	-
16.00	17500	100	76	70	44	-	-	-

SPUN CONCRETE PILE



DIA. OF PILE D. mm.	LENGTH OF PILE L. m.	THICK-NESS T. mm.	CROSS SECTION AREA Ag. cm^2	MOMENT OF INERTIA I. cm^4	SECTION MODULUS Z. cm^3	PRESTRESSED W.			SPIRAL Dia. mm.	Mu. Kg-m.	M. Kg-m.	Nu. TONS.	N. TONS.	SAFE BEARING LOAD. TONS
						Dia mm.	No. wires	Fsc Tons						
250	2x9.5	55	337	17772	1421	7	4	18	3.2	2118	715	111	38	30-35
	2x10.5	55	337	17772	1421	7	4	18	3.2	2118	715	111	38	35-39
300	2x10.5	65	479	35661	2377	7	~~5~~	~~22.5~~	4.0	3177	1117	149	~~52~~	~~40-45~~
	2x11.0	65	479	35661	2377	7	5	22.5	4.0	~~3177~~	~~1117~~	149	52	45-50
	2x11.5	65	479	35661	2377	7	~~5~~	~~22.5~~	4.0	3177	1117	149	~~52~~	~~50-55~~
350	2x10.5	70	615	64115	3664	7	6	27	4.0	4448	1609	193	67	60-65
	2x11.0	70	615	64115	3664	7	6	27	4.0	4448	1609	193	67	62-68
	2x11.5	70	615	64115	3664	7	6	27	4.0	4448	1609	193	67	65-70
400	2x10.5	75	765	106489	5324	7	8	36	4.0	6778	2506	238	83	70-75
	2x11.0	75	765	106489	5324	7	8	36	4.0	6778	2506	238	83	75-90
	2x11.5	75	765	106489	5324	7	8	36	4.0	6778	2506	238	83	80
450	2x10.5	80	929	166570	7403	7	12	54	4.0	11438	4304	283	98	90
	2x11.0	80	929	166570	7403	7	12	54	4.0	11438	4304	283	98	90
	2x11.5	80	929	166570	7403	7	12	54	4.0	11438	4304	283	98	90
500	2x12.0	90	1158	255324	10213	9	10	63	4.22	14759	5531	356	123	100
	2x15.0	90	1158	255324	10213	9	10	63	4.22	14759	5531	356	123	100
600	2x12.0	100	1570	510508	17017	9	17	106	4.22	30109	11558	470	162	120
	2x15.0	100	1570	510508	17017	9	17	106	4.22	30109	11558	470	162	120

③

CIVIL SECTION		PROJECT TEAM	
APPROVED	for H. Sakagami	APPROVED	K. Niwa
			M. Yoritaka
			—
			T. Sumita
DRAWN DATE	JAN. 9, '95		—

PETROLEUM AUTHORITY OF THAILAND
NATURAL GAS PARALLEL PIPELINE PROJECT
(TPP PROJECT)

CERTIFIED (PTT)			SECTION		PROJECT TEAM			DESCRIPTION	REFERENCE NO.
PTT REV.	MHI REV.	DATE							
B	1	May.23 '95		for H.S	T.S	—	for M.Y	Add Wang Noi's Soil Reprt, etc.	
0	2	Jun. 8 '95	T. Nakats	—				For Construction	BIB-T-MHI-545 (F)

TITLE: **PRECONSTRUCTION SURVEYS REPORT (TOPOGRAPHIC SURVEY AND SOIL INVESTIGATION)**

PTT DWG. NO.: **SP C-9304. 07-0010-003 REV.0**

PAGE: **311** SHEETS WITH COVER

CONTRACTOR DRAWING REVIEW

☒ E : Work may proceed
☐ F : Work may proceed. Submit Final Drawings
☐ G : Revise and Resubmit. Work may proceed subject to incorporation of changes indicated
☐ H : Revise and Resebmit. Work may not proceed
☐ I : Review not required. Work may proceed

☐ SUBMIT/RESUBMIT WITHIN ______ DAYS

THIS REVIEW DOES NOT RELIEVE THE CONTRACTOR OF HIS RESPONSIBILITY FOR ERRORS IN DESIGN

By: EMK
Date: 6/16/95

BECHTEL

AS-BUILT DRAWING REVIEW

☑ E: Work may proceed
☐ F: Work may proceed. Submit Final Drawings

THIS REVIEW DOES NOT RELIEVE THE CONTRACTOR OF HIS RESPONSIBILITY FOR ERRORS IN DESIGN

By:
Date: 7/1/97

BECHTEL

配布先	
PTT	7
P M	/
DPM	/
E M	1
経理	/
品証	/
資材	/
工契	/
コスト	/
SCH	/
プロセス	/
建設	/
計装	/
制シ	/
電気	/
機器	/
機械	/
配管	/
土建	3
運輸	/
営業	/
BKK	/
SITE	1
控	/
計	12

MHI DWG. NO.
2552 C300-00-00100 REV.2

CONTRACTOR NAME:	AREA CODE OF SITE LOCATION:	CONTRACTOR JOB NO.
MITSUBISHI HEAVY INDUSTRIES, LTD. (MCEC)	0010	523470
	PTT CONTRACT NO.	PTT PROJECT NO.
	CS/2/75/37	9304.07

⑩

PETROLEUM AUTHORITY OF THAILAND

NATURAL GAS PARALLEL PIPELINE PROJECT
(TPP PROJECT)

PRECONSTRUCTION SURVEYS

TOPOGRAPHIC SURVEY AND SOIL INVESTIGATION

FINAL REPORT

MAY, 1995

MITSUBISHI HEAVY INDUSTRIES, LTD

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APPENDICES

ATTACHED DRAWINGS

Sheet 5	Profile 3, Rayong Gas Receiving Terminal
Sheet 6	Topographic Map, Bang Pakong Compressor Station
Sheet 7	Profile 1, Bang Pakong Compressor Station
Sheet 8	Profile 2, Bang Pakong Compressor Station
Sheet 9	Topographic Map, Wang Noi Metering Station
Sheet 10	Profile 1, Wang Noi Metering Station
Sheet 11	Profile 2, Wang Noi Metering Station
Sheet 12	Topographical Map (1:50,000 Scale), Amphoe Ban Chang, Royal Thai Survey Department

1. INTRODUCTION

1.1 Purpose of Preconstruction Survey

The preconstruction survey was carried out as per "EXECUTION PLAN OF PRECONSTRUCTION SURVEY, PR C-9304.07-0010-001" to obtain basic information for the design of:

1) Rayong Gas Receiving Terminal,
2) Bang Pakong Compressor Station, and
3) Wang Noi Metering Station.

for NATURAL GAS PARALLEL PIPELINE PROJECT(TPP PROJECT), PETROLEUM AUTHORITY OF THAILAND(PTT).

The preconstruction survey is consisting of:

1) Topographic survey at Rayong, Bang Pakong and Wang Noi sites,

2) Soil investigation at Rayong and Bang Pakong sites,

3) Prediction of flood level of 100-year return period at Rayong, Bang Pakong and Wang Noi sites and

4) Prediction of 100-year return periods of wind speed, precipitation, temperature and humidity at Rayong, Bang Pakong and Wang Noi sites.

1.2 Location of Sites

1.2.1 Rayong Gas Receiving Terminal

The site is located near the village of Map Ta Phut, around 80 miles to the south-southeast of Bangkok and around 10 miles to the west of Rayong. Location of the site is shown in Figure 1.1 and its approximate coordinates are given in Table 1.1.

1.2.2 Bang Pakong Compressor Station

The site is located near the villages of Kao and Map Pong, around 38 miles east-southeast of Bangkok and around 6.2 miles to the north-northeast of Chon Buri. The mouth of Bang Pakong River is around 7 miles north-west from the site. Location of the site is shown in Figure 1.1 and its approximate coordinates are given in Table 1.1.

1.2.3 Wang Noi Metering Station

The site is located around 40 miles to the north-northeast of Bangkok and around 12 miles to the south-east of Ayutthaya. Location of the site is shown in Figure 1.1 and its approximate coordinates are given in Table 1.1.

1.3 Scope of Work

1.3.1 Topographic Survey

Items of the topographic survey and number of each item are tabulated in Table 1.2.

1.3.2 Soil Investigation

The soil investigation is consisted of field works and laboratory tests. Items of the investigation and number of each test are summarized in Table 1.3.

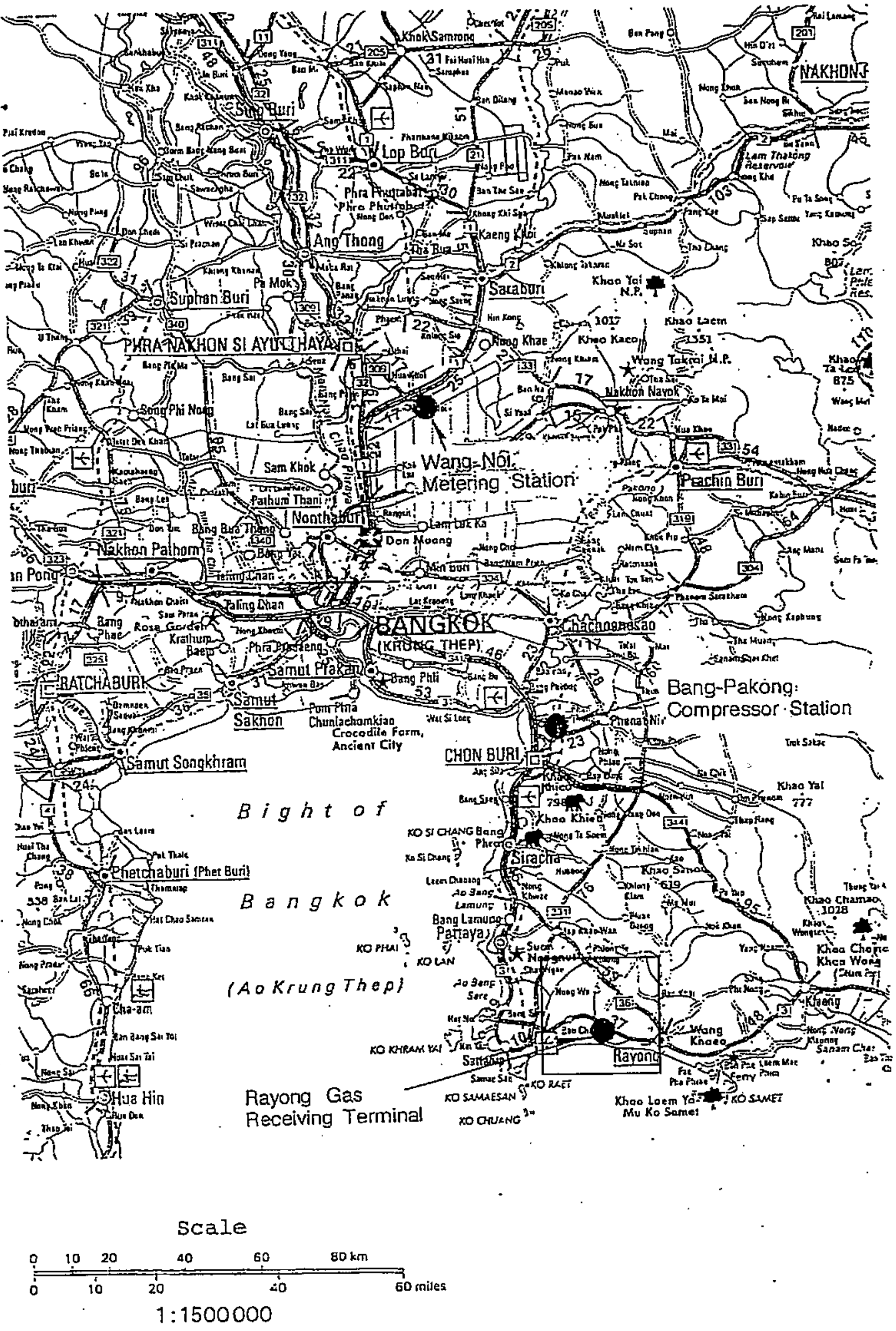

Figure 1.1 Location Map of the Sites

1.3.3 Prediction of Flood Level of 100-Year Return Period

Items of the study for prediction of flood level of 100-year return period are summarized in Table 1.4.

1.3.4 Meteorological Conditions

Items of the study for prediction of meteorological conditions of 100-year return period are summarized in Table 1.5.

1.4 Time Schedule of Work

Time schedule of the investigation is summarized in Figure 1.2.

1.5 Organization of Investigation Team

The organization of the investigation team is presented in Figure 1.3.

1.6 Benchmarks and Elevations

Benchmarks at three sites were given by PTT. Their coordinates and elevations are summarized in Table 1.6. The elevations are based on the mean sea level (MSL).

1.7 Unit

Units of measurement used in the report was the English(Imperial) Unit. In factual data of field investigation and laboratory tests, the metric units were used. Conversion chart from the English unit to the metric unit and vice versa is given in Table 1.7.

Table 1.1 Approximate Coordinates of the Sites

SITE	NORTH LATITUDE	EAST LONGITUDE
RAYONG GAS RECEIVING TERMINAL	12 43'	101 09'
BANG PAKONG COMPRESSOR STATION	13 27'	101 04'
WANG NOI METERING STATION	14 12'	100 48'

Table 1.2 Item and Number of Topographic Survey

DESCRIPTION	UNIT	SITE LOCATION		
		RAYONG GAS RECEIVING TERMINAL	BANG PAKONG COMPRESSOR STATION	WANG NOI METERING STATION
<u>FIELD ACTIVITIES</u>				
(1) Delivery of Base Point/Bench Mark	LS	1	1	1
(2) Topographic Survey consissting of • Distance Measurrement • Level Measurement • Plane Table Survey	m2	53,900	22,500	10,000
<u>OFFICE ACTIVITIES</u>				
(1) Calculation of Survey Results	LS	1	1	1
(2) Drafting	LS	1	1	1

Table 1.3 Items and Numbers of Soil Investigation

DESCRIPTION	UNIT	SITE LOCATION		
		RAYONG GAS RECEIVING TERMINAL	BANG PAKONG COMPRESSOR STATION	WANG NOI METERING STATION
FIELD ACTIVITIES				
(1) Mobilization and Demobilization	LS	1	1	1
(2) Location Survey for Setting out Boring Locations	LS	1	1	1
(3) Boring	m	65 (3 borings)	40 (2 borings)	50 (2 borings)
(4) Standard Penetration Test	nos	64	36	44
(5) Undisturbed Sampling	nos	0	6	6
(6) Groundwater Level Observation	LS	1	1	1
(7) Test Pit Excavation	nos	1	0	0
(8) Soil Resistivity Test	nos	1	1	1
LABORATORY TESTING				
(1) Specific Gravity	nos	7	8	7
(2) Wet & Dry Density	nos	0	3	3
(3) Moisture Content	nos	6	8	7
(4) Particle-size Analysis	nos	7	8	7
(5) Atterberg Limits	nos	1	6	7
(6) Moisture-Density Relation	nos	1	0	0
(7) Consolidation Test	nos	0	3	2
(8) Triaxial Compression Test	nos	0	3	2
(9) Chemical Analysis	nos	3	2	1

Table 1.4 Item and Number of Study for Prediction of Flood Level of 100-Year Return Period

DESCRIPTION	UNIT	SITE LOCATION		
		RAYONG GAS RECEIVING TERMINAL	BANG PAKONG COMPRESSOR STATION	WANG NOI METERING STATION
(1) Data Collection	LS	1	1	1
(2) Analysis	LS	-	1	1

Table 1.5 Item and Number of Study for Prediction of Meteological Conditions of 100-Year Return Period

DESCRIPTION	UNIT	SITE LOCATION		
		RAYONG GAS RECEIVING TERMINAL	BANG PAKONG COMPRESSOR STATION	WANG NOI METERING STATION
(1) Data Collection	LS	1	1	1
(2) Analysis	LS	1	1	1

Table 1.6 Coordinates and Elevation of Benchmarks

Site	Sta. No.	BM Coordinate N (m)	BM Coordinate E (m)	Elevation (MSL m)
Rayong Gas Receiving Terminal	BM-4	2319.981	2052.037	34.887
	BM-5	2404.462	1980.920	34.142
	BM-6	2421.693	2069.184	33.657
Bang Pakong Compressor Station	BM.88	1486796.635	723324.433	2.320
	BM.4	1486831.995	723454.303	2.320
Wang Noi Metering Station	WN-07	1431.471	775.859	3.859
	WN-08	1137.712	778.284	3.913

Table 1. 7 Conversion Chart

	Imperial	Metric	SI
Length	1 mile	1.609 km	1.609 km
	1 ft	0.3048 m	0.3048 m
	1 in	2.54 cm	25.40 mm
Area	1 mile^2	2.590 km^2	2.590 km^2
	1 acre	0.4047 hectare	4046.9 m^2
	1 ft^2	0.0929 m^2	0.0929 m^2
	1 in^2	6.452 cm^2	6.452 cm^2
Volume	1 yd^3	0.7646 m^3	0.7646 m^3
	1 ft^3	0.0283 m^3	0.0283 m^3
	1 ft^3	28.32 litres	0.0283 m^3
	1 UK gal.	4.546 litres	4546 cm^3
	1 US gal.	3.785 litres	3785 cm^3
	1 in^3	16.387 cm^3	16.387 cm^3
Mass	1 ton	1.016 tonne	1.016 Mg
	1 lb	0.4536 kg	0.4536 kg
	1 oz	28.352 g	28.352 g
Density	1 lb/ft^3	16.019 kg/m^3	16.019 kg/m^3
Unit weight	1 lbf/ft^3	16.019 kgf/m^3	0.1571 kN
Force	1 ton f	1.016 tonne f	9.964 kN
	1 lb f	0.4536 kg f	4.448 N
Pressure or stress	1 ton f/in^2	157.47 kg f/cm^2	15.44 MPa
	1 ton f/ft^2	10.936 tonne f/m^2	107.3 kPa
	1 lb f/in^2	0.0703 kg f/cm^2	6.895 kPa
	1 lb f/ft^2	4.882 kg f/m^2	0.04788 kPa
	1 standard atmosphere	1.033 kg f/m^2	101.325 kPa
	14.495 lb f/in^2	1.019 kg f/cm^2	1 bar
	1 ft water	0.0305 kg f/cm^2	2.989 kPa
	1 in mercury	0.0345 kg f/cm^2	3.386 kPa
Permeability	1 ft/year	0.9659 x 10^{-6} cm/s	0.9659 x 10^{-8} m/s
Rate of flow	1 ft^3/s	0.02832 m^3/s	0.02832 m^3/s
Moment	1 lbf ft	0.1383 kgf m	1.3558 Nm
Energy	1 ft lbf	1.3558 J	1,3558 J
Frequency	1 c/s	1 c/s	1 Hz

SI unit prefixes

Prefix	tera	giga	mega	kilo	milli	micro	nano	pico
Symbol	T	G	M	k	m	μ	n	p
Multiplier	10^{12}	10^9	10^6	10^3	10^{-3}	10^{-6}	10^{-9}	10^{-12}

SI symbols and definitions

N = Newton = kg m/s^2
Pa = Pascal = N/m^2
J = Joule = m.N

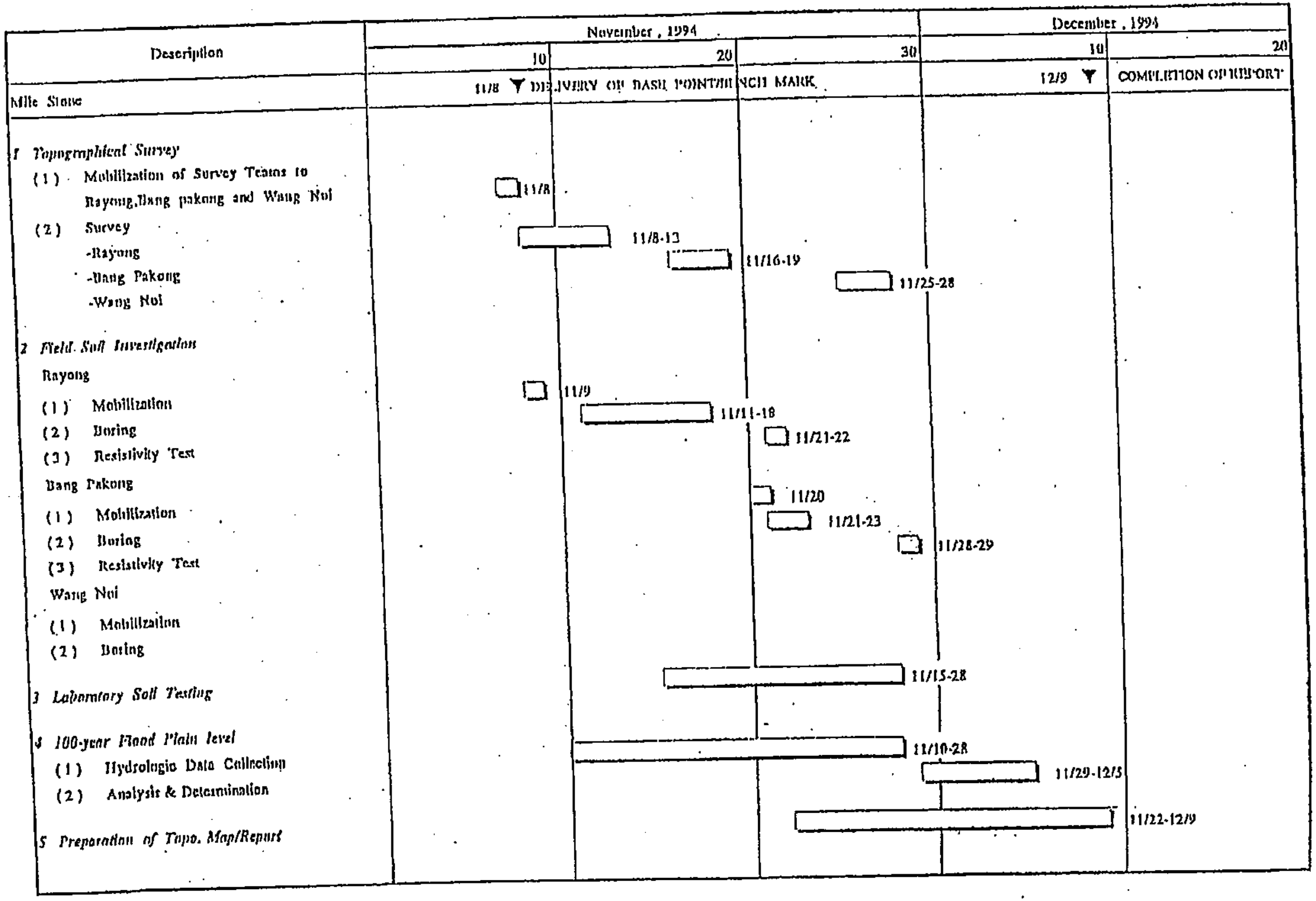

Figure 1.2 Time Schedule of Preconstruction Survey

(continued on page 12)

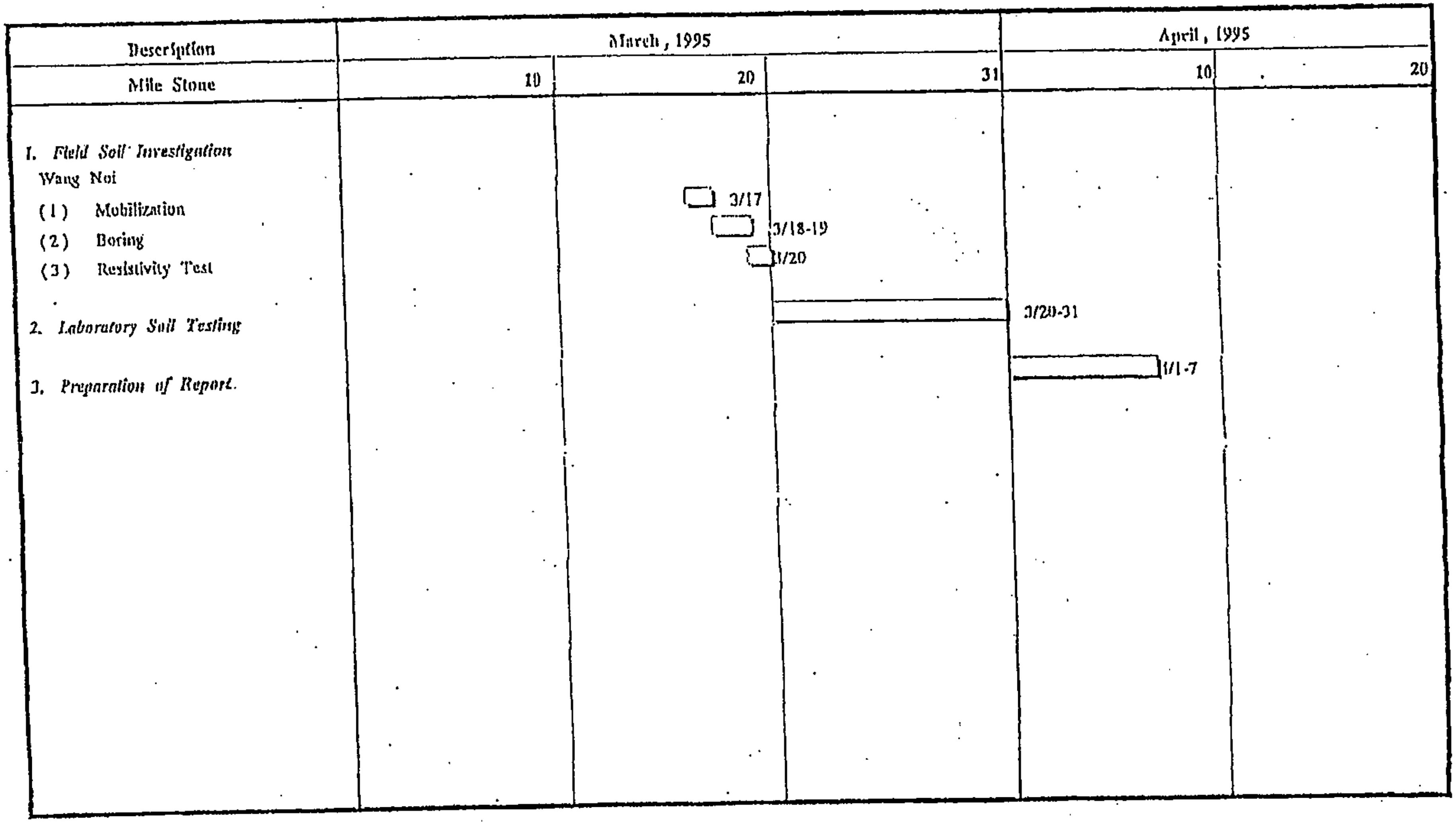

Figure 1.2′ Time Schedule of Preconstruction Survey

Organization Chart

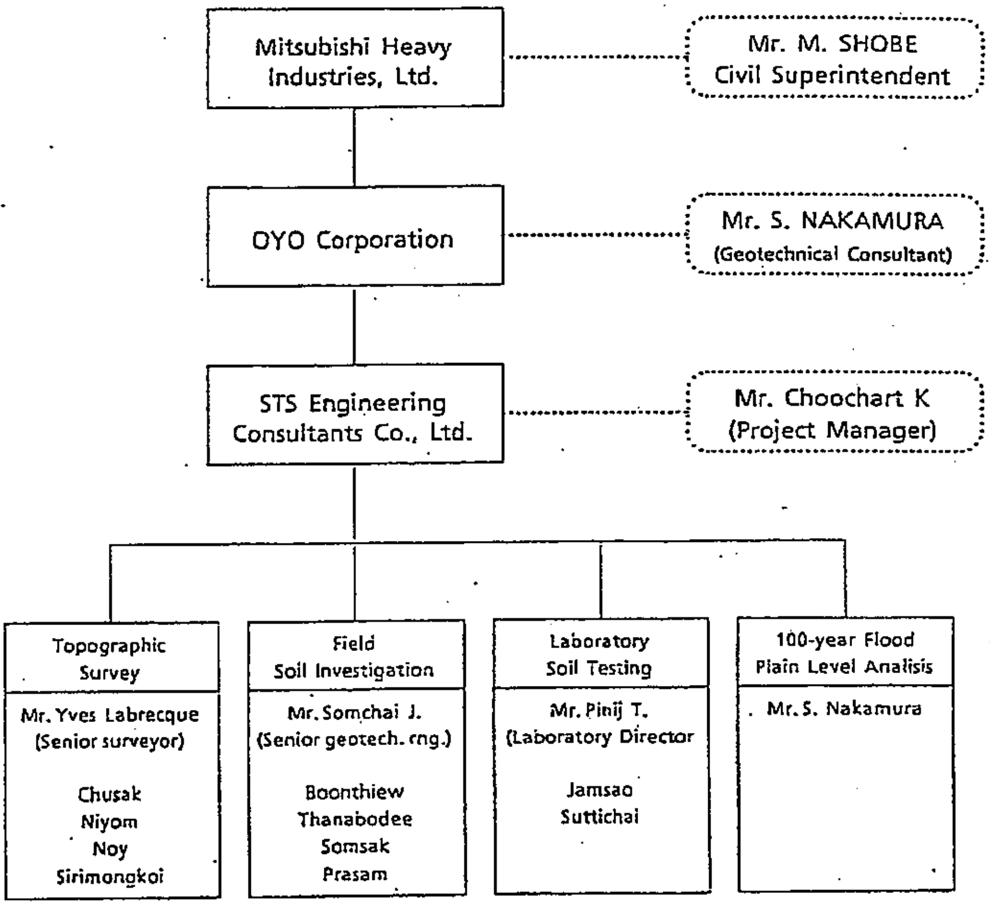

Figure 1.3 Organization Chart of Investigation Team

2. TOPOGRAPHIC SURVEY

Topographic survey was carried out at three sites. Survey report is given in Appendix 1 and the results are presented in attached drawings.

Sheets 1 to 2	Topographic Maps, Rayong Gas Receiving Terminal
Sheets 3 to 5	Profiles, Rayong Gas Receiving Terminal
Sheet 6	Topographic Map, Bang Pakong Compressor Station
Sheets 7 to 8	Profiles, Bang Pakong Compressor Station
Sheet 9	Topographic Map, Wang Noi Metering Station
Sheets 10 to 11	Profiles, Wang Noi Metering Station

3. SOIL INVESTIGATION

3.1 General

The soil investigation was carried out at Rayong Gas Receiving Terminal site, Bang Pakong Compressor Station site and Wang Noi Metering Station site in order to obtain subsurface stratigraphy and conditions, and soil properties for the foundation design at three sites.

3.2 Field Investigation

3.2.1 Boring

Three (3) borings at Rayong Gas Receiving Terminal site, two (2) borings at Bang Pakong Compressor

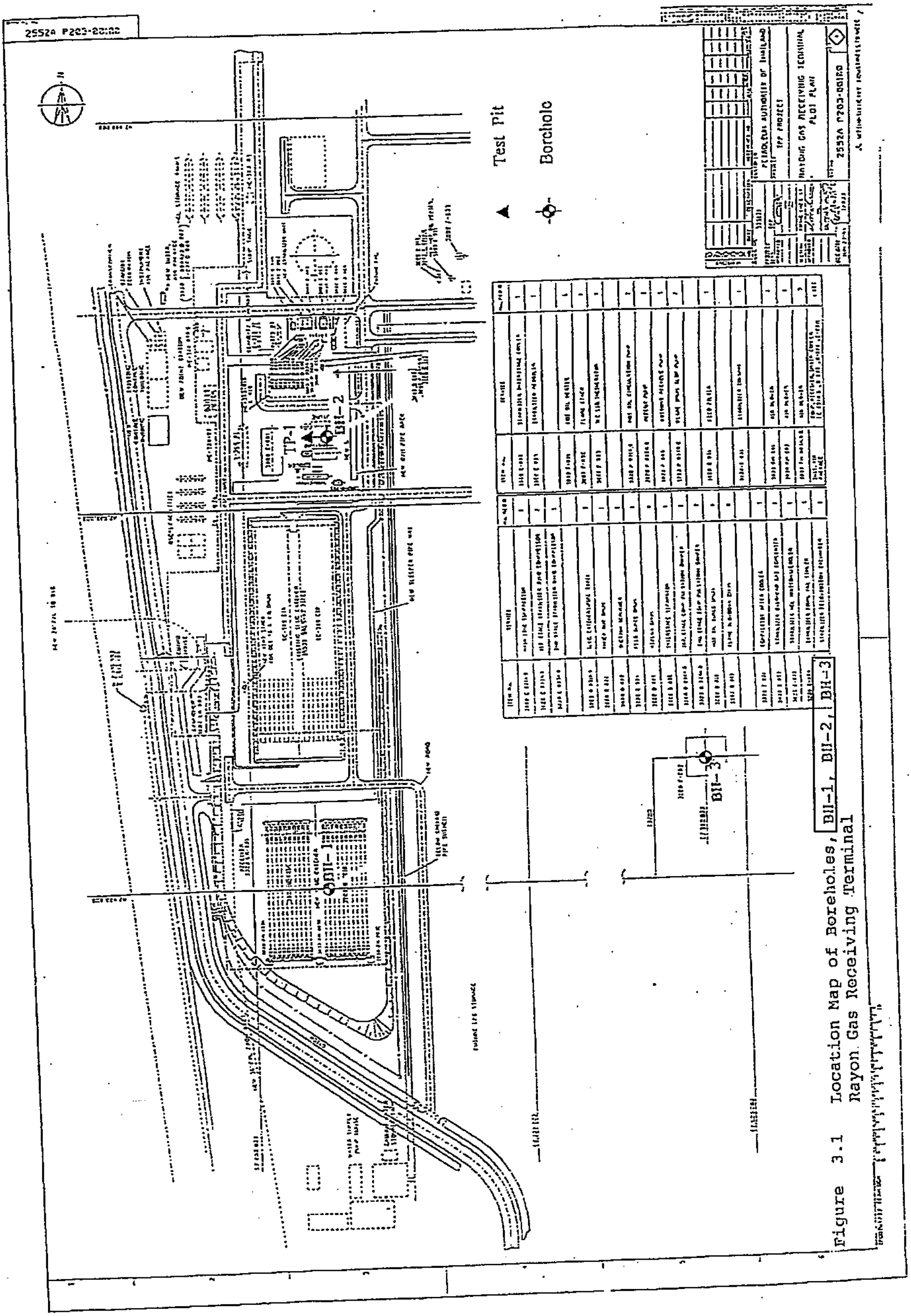

Figure 3.1 Location Map of Boreholes, BH-1, BH-2, BH-3
Rayon Gas Receiving Terminal

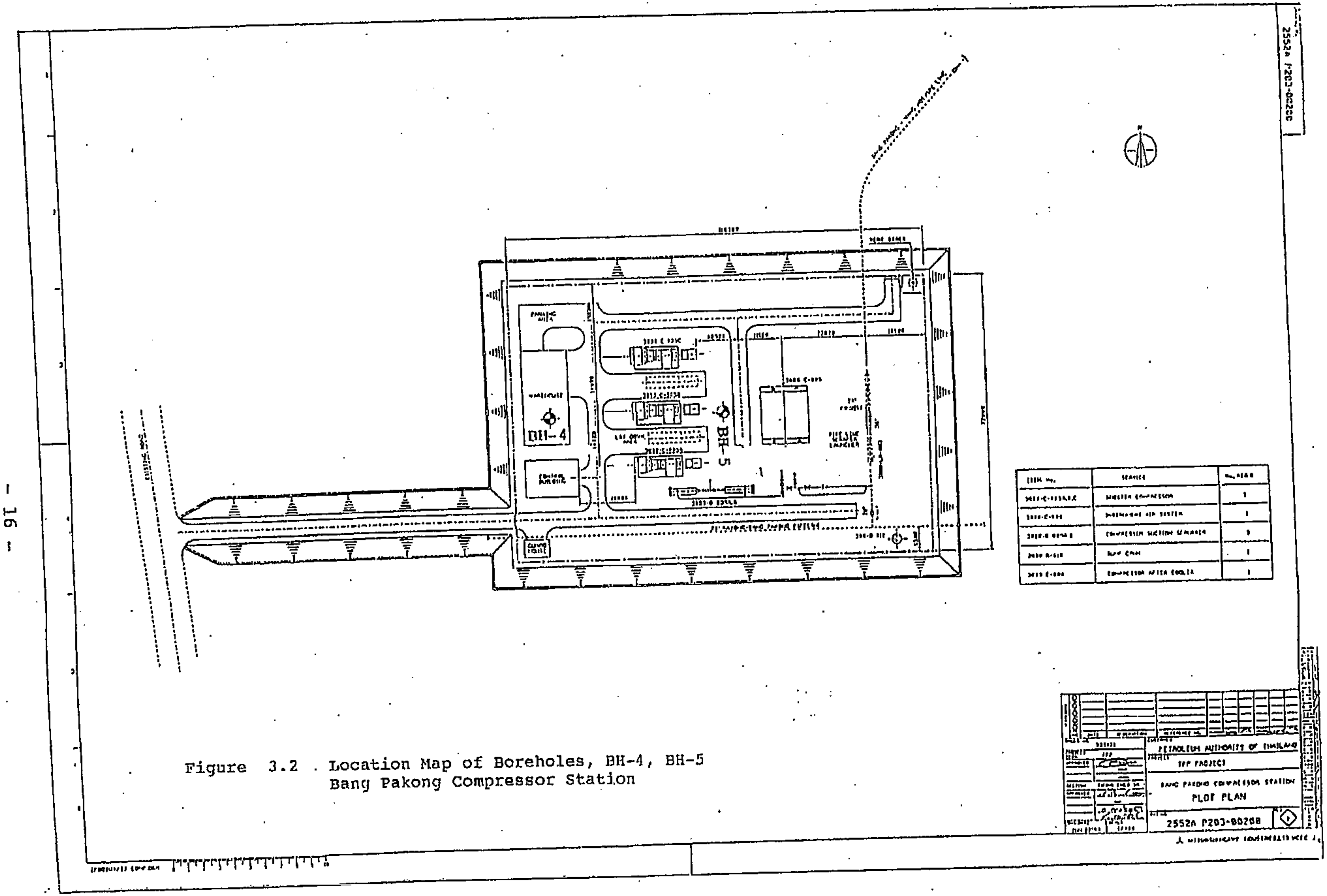

Figure 3.2 . Location Map of Boreholes, BH-4, BH-5
Bang Pakong Compressor Station

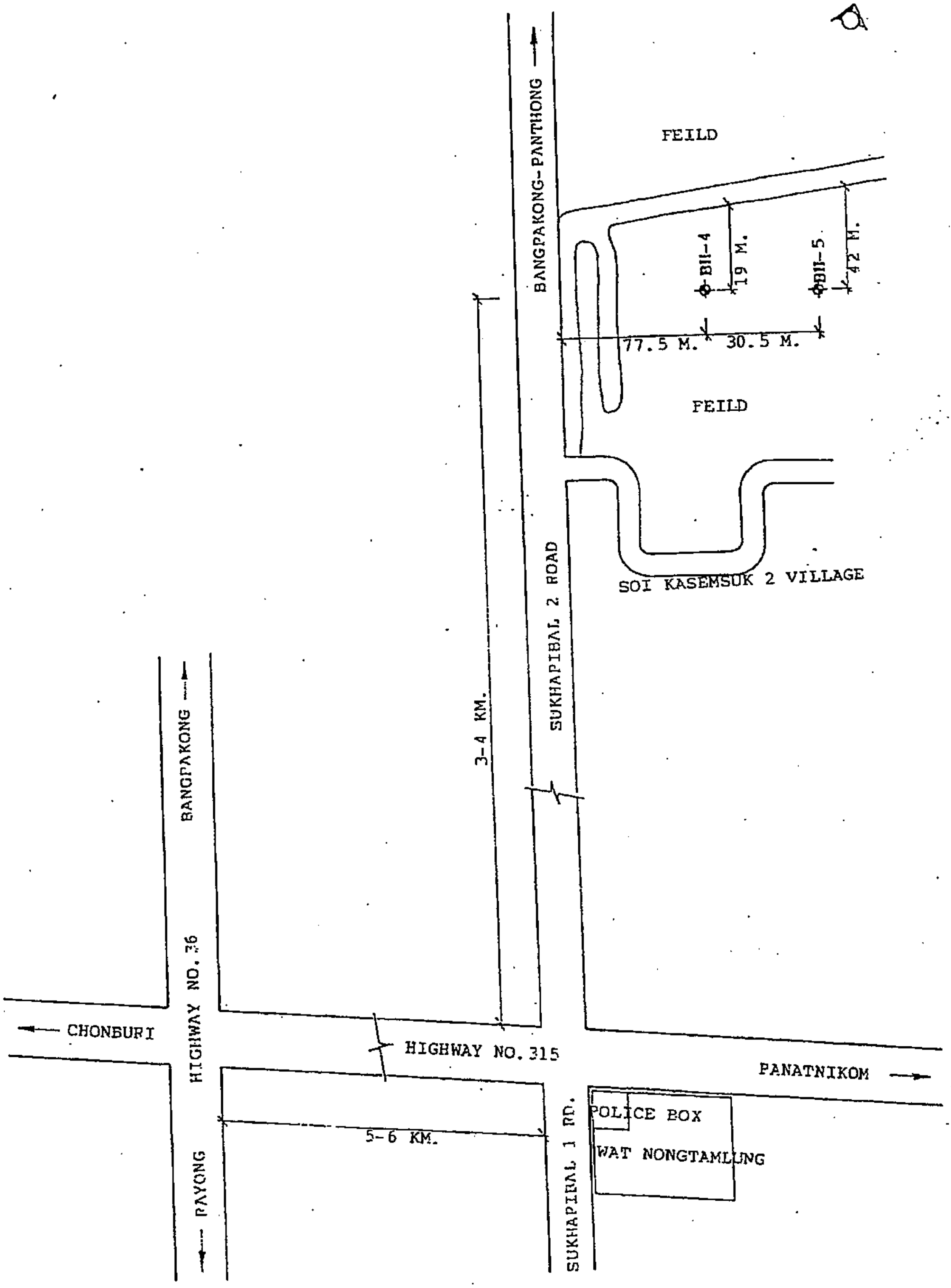

Figure 3.3 Location of Site and Boreholes for THE PARALLEL PIPELINE PROJECT (TPP) at THAILAND BH-4, BH-5 Bang Pakong Compression Station

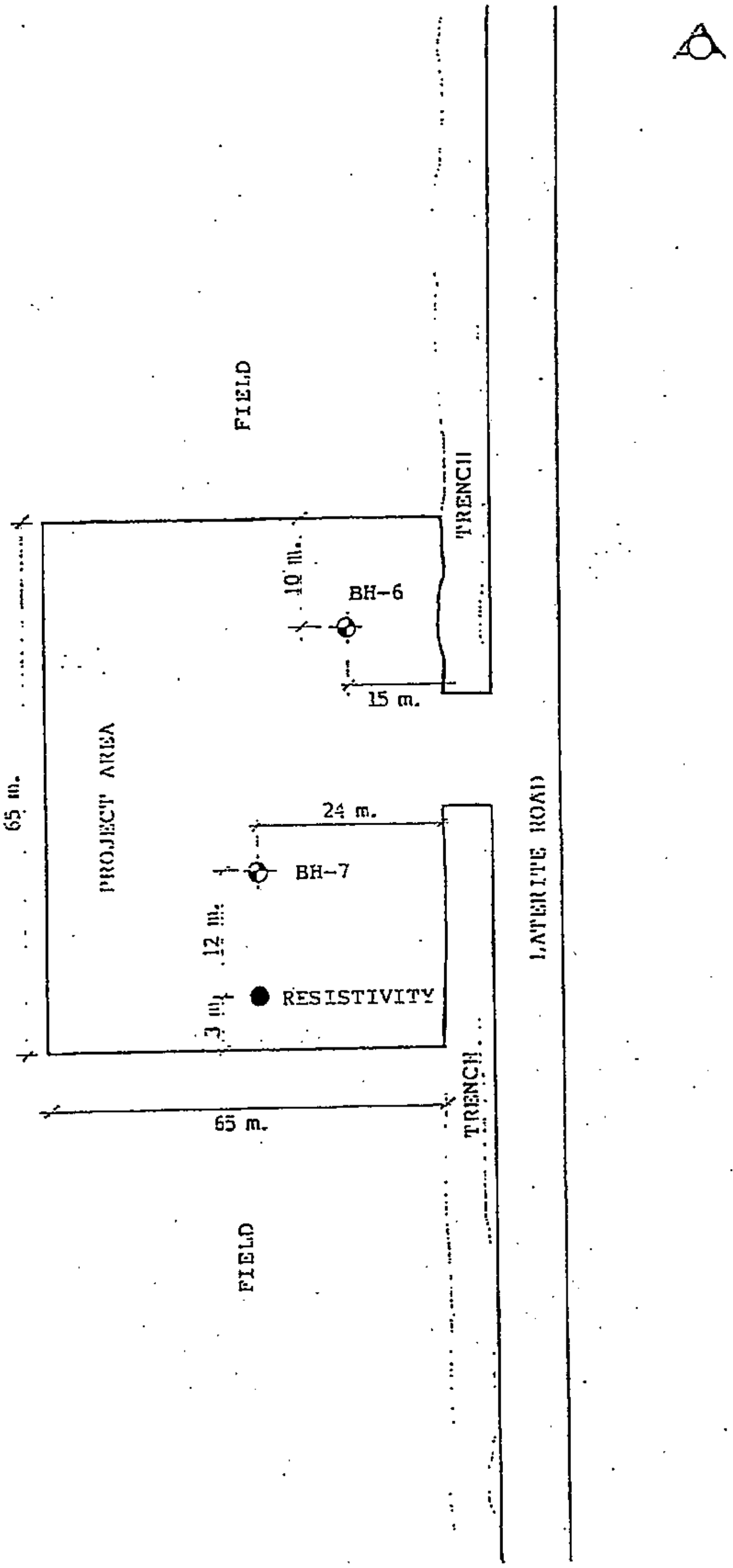

Figure 3.4 Location Map of Boreholes, BH-6, BH-7
Wang Noi Metering Station

Station site and two (2) borings at Wang Noi Metering Station site were conducted. Locations of borings are shown in Figures 3.1 to 3.4. The coordinate and elevation of boring points are summarized in Table 3.1.

Table 3.1 Coordinates and Elevation of Boring Points

Site	Sta. No.	BM Coordinate (m)		Elevation (MSL m)
		N	E	
Rayong Gas Receiving Terminal	BH-1	2400.162	2040.163	34.235
	BH-2	2636.678	2043.602	29.351
	BH-3	2467.954	2588.455	36.675
Bang Pakong Compressor Station	BH-4	1486846.396	723399.638	1.456
	BH-5	1486842.592	723431.386	1.226
Wang Noi Metering Station	BH-6	1454.863	749.120	2.679
	BH-7	1415.331	739.241	2.513

The boreholes were advanced using the mud rotary drilling technique where a prepared solution of bentonite and water was recirculated to remove the cuttings and maintain borehole stability. Diameter of the borehole were 4 inch (102 mm).

Individual logs of borings are presented in Appendix 2.

3.2.2 Standard Penetration Test (SPT)

The standard penetration test (SPT) was performed at an interval of 3.28 ft (1 meter) by using the procedure specified by ASTM D 1586. Disturbed sample were obtained by driving a 1.97-in-OD (50-mm-OD) split barrel sampler.

SPT N values recorded during sampling operations are plotted on the boring logs in Appendix A1.

Disturbed samples obtained by the split barrel sampler were removed from the sampler in the field, visually examined, and classified. The samples were sealed in the plastic bag and transported to a laboratory in Bangkok for further examination and testing.

3.2.3 Undisturbed Sampling

A thin-walled tube of 3 in (76 mm) diameter was used for sampling of soft cohesive soils. The thin-walled tube sampler was pushed to recover samples in accordance with the procedure given by ASTM D 1587-84.

Prior to the sampling, the borehole was flushed with fresh water to remove the remnants of cuttings left at the hole bottom. When the sampler tube was brought to the surface, some soil was removed from each end and the molten wax was applied, in thin layers of seal and to avoid any change in water content. The samples were then transported to the laboratory in Bangkok for testing.

For stiff soils were obtained by a double-tube core barrel.

3.2.4 Soil Resistivity Test

The soil resistivity tests was carried out at one (1) location of Rayong Gas Receiving Terminal, one (1) location of Bang Pakong Compressor Station and one (1) location of Wang Noi Metering Station sites.

The resistivity test with the Wenner Four-Electrode Method specified by ASTM G57-78 was employed to obtain the apparent resistivity, ρa. In this method, by measuring a potential ΔV, and a current I with a spacing between electrodes a, ρa can be calculated as follow:

$$\rho a = 2\pi a \Delta V/I$$

The electrode spacing used at each site were:

Rayong Gas Receiving Terminal - 1.6, 3.3, 6.6, 9.8, 13.1, 16.4, 19.7, 23.0, 26.2, 29.5, 32.8 ft (0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 m),

Bang Pakong Compressor Station - 1.6, 3.3, 5.0, 6.6, 9.8, 13.1, 16.4, 19.7, 23.0 ft (0.5, 1, 1.5, 2, 3, 4, 5, 6, 7 m),

Wang Noi Metering Station - 3.3, 6.6, 9.8, 13.1, 16.4, 19.7, 23.0, 26.2, 29.5, 32.8, 65.6 ft (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20 m),

The results of the resistivity measurement are presented in Appendix 2.

3.3 Laboratory Tests

Laboratory tests were performed both on undisturbed and disturbed samples to obtain the physical and mechanical properties of soils.

The tests were carried out in accordance with the following ASTM Standards or equivalents:
Reference should be made to Appendix 1 for all the factual data of the laboratory tests.

Table 3.2 Standard for Laboratory Tests

Test	Procedure
Physical Properties	
Specific gravity	ASTM D 854
Wet and dry density	by scale
Moisture content	ASTM D 2216
Particle-size analysis	ASTM D 422
Atterberg limits	ASTM D 427
Mechanical Properties	
Consolidation test	ASTM D 2435
Triaxial compression test	ASTM D 2850
Compaction test	ASTM D 698
Chemical Analysis	
pH	BS 1377 Test 11
Soluble sulphate content	BS 1377 Test 9
Chloride content	ASTM
Carbonate content	ASTM

3.4 Summary of Soil Investigation

3.4.1 Topography

(1) Rayong Gas Receiving Terminal

The site is located on the terrace continuing from Nang Yong and Noen Kraprok mountains and leading towards the sea. The terrace is dissected by several rivers. The site is on a high land between two small streams. Elevation of the site is between around 95 ft (29 m) to 120 ft (37 m) above the mean sea level (MSL).

(2) Bang Pakong Compressor Station

The site is in the flood plane of Bang Pakong River. Small rivers, such as Klong Phar, run near the site. Wet land which is reaching to the sea is spreaded east of the site. Elevation of the site is low and ranging between 2.6 ft (0.8 m) and 4.9 ft (1.5 m) MSL.

(3) Wang Noi Metering Station

The site is located in the vast flood plane of Chaophraya River. Major rivers, such as River Pa Sak, and minor rivers run from the mountains found north to east of the site. The site is within the irrigated farm land whose elevation is 5.2 ft (1.6 m) and 10.2 ft (3.1 m) MSL.

3.4.2 Soil Condition

(1) Rayong Gas Receiving Terminal

The exploration boring and observation revealed that the soil formation at the site is mainly consisted of laterite, altered granitic soil, and completely decomposed granitic soil from the ground surface. The soils are classified as silty sand, clayey sand, sandy clay, or silty clay, according to their grain size characteristics (Figure 3.4).

N values of the surface soil to a depth around 6.6 ft (2 m) to 13.0 ft (4 m) is 6 to 12. N value increases to between 15 and 35 to a depth around 50 ft (15 m) and 70 ft (21 m). Within some zones, higher N value, 40 to over 50 is observed. The altered granitic soil, which is found below 50 ft (15 m) to 70 ft (21 m) G.L., shows N value more than 50.

(2) Bang Pakong Compressor Station

The soil formation at the site is top soil, alluvium clay, alternative layer of clayey/sandy soil, and sandy soil (Figure 3.5). The top soil is around 3.3 ft (1 m) thick and classified as sandy clay or clayey sand. The alluvium clay, around 20 ft to 23 ft (6 to 7 m) thick, is very soft and its N value is 1. The alternative layer, around 20 ft to 23 ft (6 to 7 m) thick, has N value of 16 to 39. Sandy soil layer is found from 43 ft (13 m) and has N value more than 50.

Laboratory test data at Bang Pakong Compressor Station site are summarized in Figures 3.6, 3.7, 3.8 and 3.9.

(3) Wang Noi Metering Station

Soil at the site is mainly composed of clayey soils. According to consistency, the soils are divided to, from the surface, soft clay, stiff silty clay, silty fine sand and stiff to hard silty clay (Figure 3.6).

The soft clay is about 13.1 ft (4 m) thick, contains traces of fine sand, its N value is 2. At lower part of the layer (about 6.6 ft or 2 m) N value increases to 4 to 5. The stiff silty/sandy clay is of 13.1ft (4 m) thick, its N value is 9 to 16. Silty fine sand, of 3.3 ft (1 m) to 6.6 ft (2 m) thick, is medium dense and has N value of 24. The underlaying stiff to hard silty clay layer is of over 50.7 ft (15.4 m) to 54 ft (16.4 m) thick and has N value 11 to 34. Although water level in the boreholes is found at the depth of 7.2 - 7.5 ft (2.2 - 2.3 m), groundwater level is expected to be higher, close to the ground surface, from observation of the site.

Laboratory test data at Wang Noi Metering Station site are summarized in Figures 3.10, 3.11, 3.12 and 3.13.

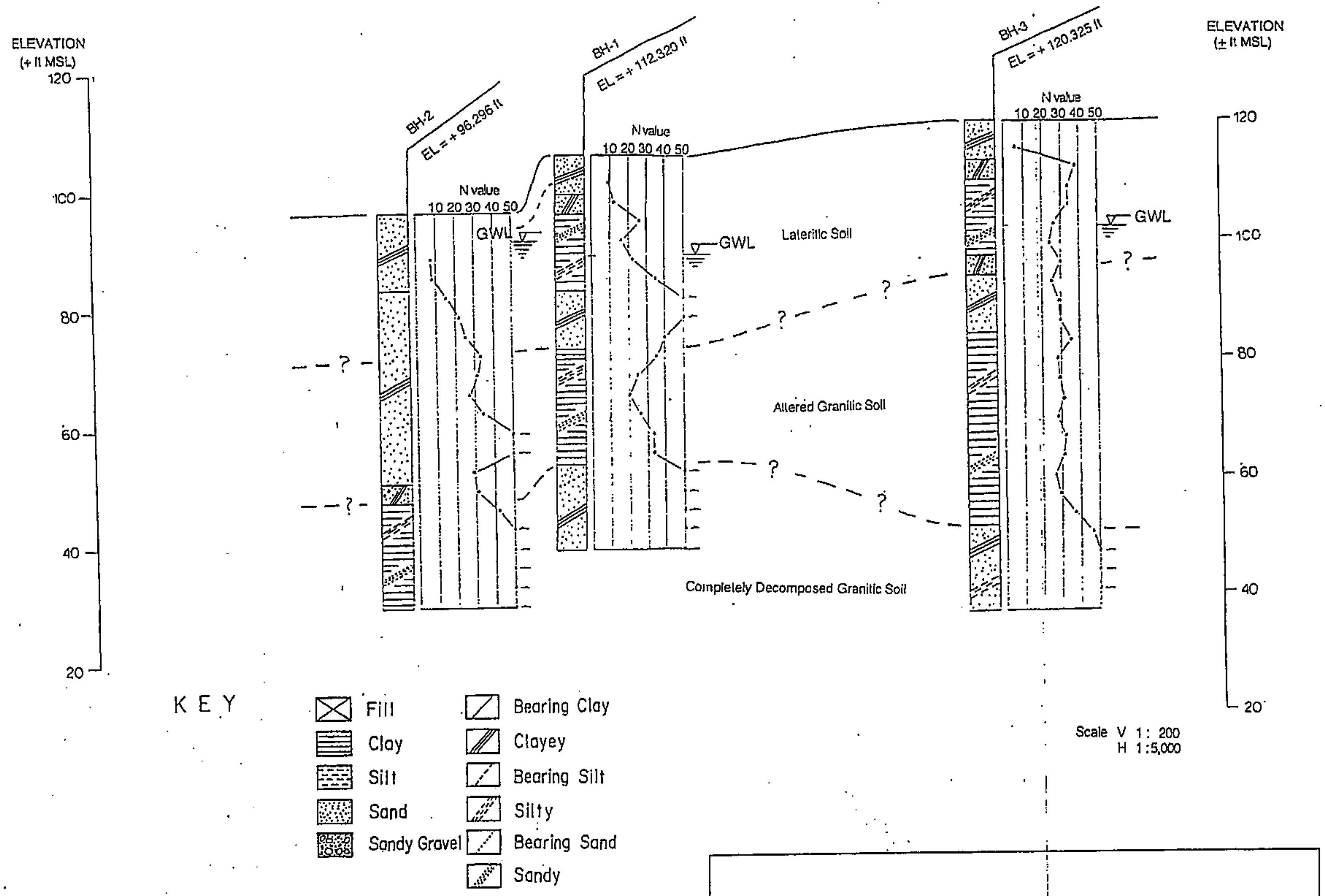

Figure 3.5 Soil Profile at Rayong Gas Receiving Terminal

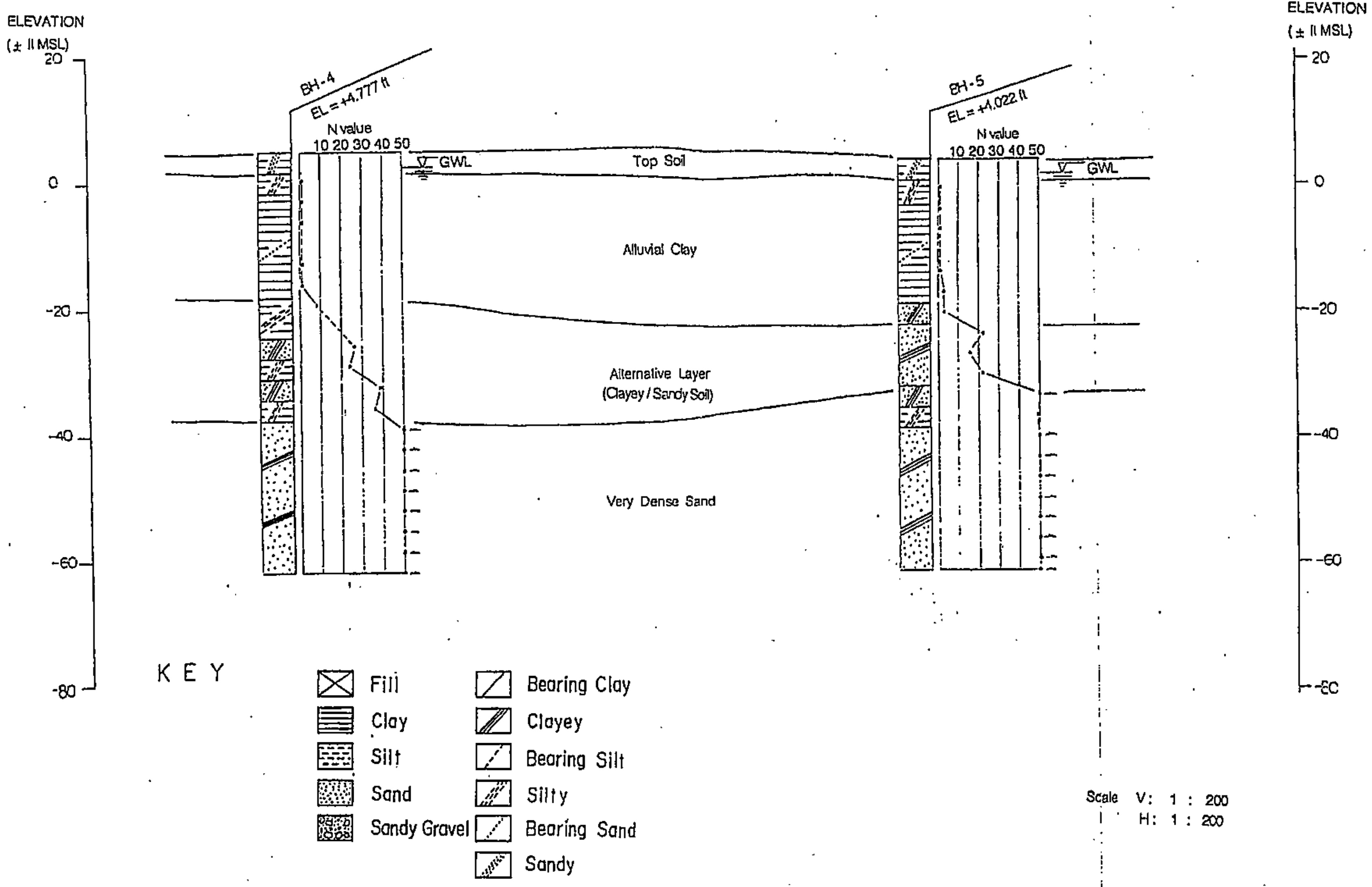

Figure 3.6 Soil Profile at Bang Pakong Compressor Station

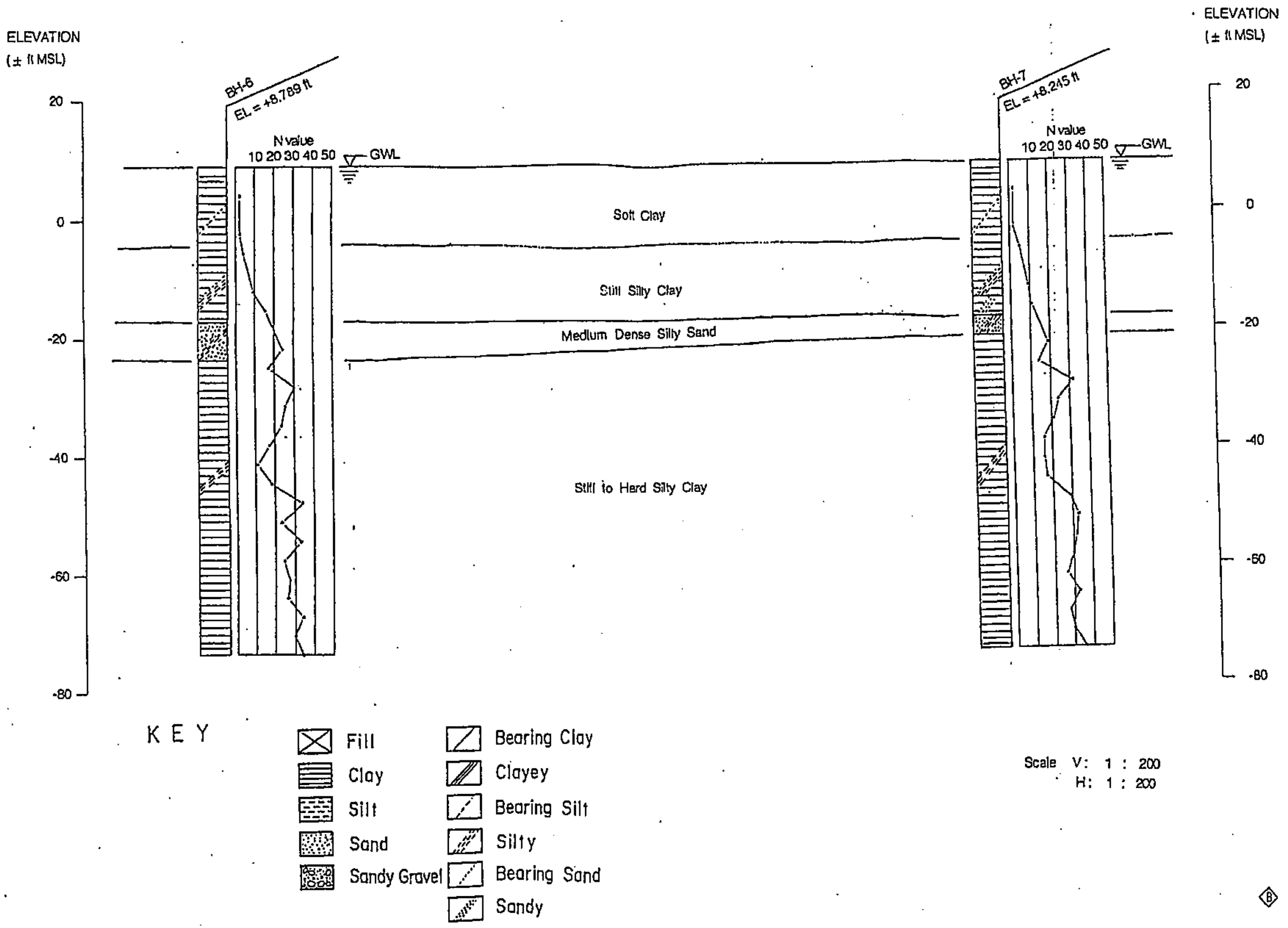

Figure 3.7 Soil Profile at Wang Noi Metering Station

3.5 Engineering Analysis

3.5.1 General

In order to provide general guidance for foundation designs at the project sites, preliminary engineering analyses were performed by using the simple analytical methods.

At the Rayong Gas Receiving Terminal site,

(a) Allowable Bearing Capacity of Shallow Foundation,
(b) Allowable Bearing Capacity of Pile Foundation and
(c) Stability of Cut Slope

were calculated or commented.

At Bang Pakong Compressor Station,

(a) Settlement Analysis of Fill,
(b) Stability Analysis of Fill, and
(c) Allowable Bearing Capacity of Pile Foundation

were calculated.

At Wang Noi Metering Station,

(a) Settlement Analysis of Fill,
(b) Stability Analysis of Fill, and
(c) Allowable Bearing Capacity of Pile Foundation

were calculated.

3.5.2 Geotechnical Design Parameters

Geotechnical design parameters for the analyses were determined from the data obtained from the soil investigation or assumed from empirical relationships. These are summarized in Tables 3.3 to 3.5. B

Table 3.3 Geotechnical Design Parameters at Rayong Receiving Terminal

Layer	Soil	Bulk density (psf)	N value
1	Top layer, loose to medium dense clayey sand	107	use N value at each B.H. and depth
2	Lateritic dense clayey sand and sandy/silty clay	113	ditto
3	Altered granitic clayey sand, medium to very dense and sandy/silty clay	113	ditto
4	Completely decomposed granitic sandy/silty clay to clayey/silty sand	125	ditto

Table 3.4 Geotechnical Design Parameters at Bang Pakong Compressor Station

Layer	Soil	Bulk density, (psf)	N value	Undrained Shear Strength (psi)
1	Fill sand	119	use N value at each B.H. and depth	-
2	Top soil, soft alluvium clay	97	ditto	3
3	Alternate layer clayey/sandy soil	129	ditto	16.5
4	Very dense clayey sand	140	ditto	-

Condolidation Characteristics of layer 2

- coefficient of volume compressibility

  $m_v = 7.0 \times 10^{-2}\ cm^2/kgf$

- coefficient of consolidation

  $C_v = 0.03\ cm^2/min$

Table 3.5 Geotechnical Design Parameters at Wang Noi Metering Station

Layer	Soil	Bulk density, (pcf)	N value	Undrained Shear Strength (psi)
1	Fill	119	use N value at each B.H. and depth	-
2	Soft clay	93	ditto	1.8
3	Stiff silty clay	115	ditto	
4	Medium dense silty sand	125	ditto	-
5	Stiff to hard silty clay	125	ditto	-

Consolidation Characteristics of layer 2

- coefficient of volume compressibility

  $m_v = 0.11\ cm^2/kgf$

- coefficient of consolidation

  $C_v = 0.011\ cm^2/min$

3.5.3 Rayong Gas Receiving Terminal

(1) Allowable Bearing Capacity of shallow Foundation

Conditions

The allowable bearing capacity of shallow footing is calculated using SPT N values at each location of borehole (BH-1 to BH-3). The elevations of the ground level are assumed to be original ones(elevations at the time of survey) at boreholes BH-2 and BH-3, however, at BH-1 excavation is planned and the ground level is taken as 30.000 m MSL instead of original 34.235 m MSL. Conditions of calculations are as follows:

Footing : square footing

Width of footing, B : 3.3 ft (1 m)
6.6 ft (2 m)
9.9 ft (3 m)
13.2 ft (4 m)
16.4 ft (5 m)

Depths of footing base D : 0.0 ft (0 m)
3.3 ft (1 m)
6.6 ft (2 m)

Method of Calculation

The following formulae are used for calculation:

$$q_a=\frac{N}{F_1}K_d \quad B\leq F_4$$

$$q_a=\frac{N}{F_2}(\frac{B+F_3}{B})^2 K_d \quad B>F_4$$

where

q_a : Allowable bearing pressure for $S_0 = 1$ in of settlement, tsf,

N : SPT N value, is statistical average value for the footing influence zone of about 0.5B above footing base to 2B below

$K_d = 1 + 0.33 \ D/B \leq 1.33$ (as suggested by Meyerhof, 1965),

$D(D_f)$: Depth of footing base, ft,

B : Width of footing, ft,

F_{1-4} : Bearing capacity factors,(-) determined as follows:

$F_1 = 0.05$
$F_2 = 0.08$
$F_3 = 0.3$
$F_4 = 1.2$

In these equations the allowable soil pressure is calculated for an assumed 1 in settlement. In general the allowable pressure for any settlementcan be determined as

$$q_a(s_j) = \frac{S_j}{S_o} q_a$$

where

$S_o = 1$ in

S_j : actual settlement which can be tolerated in inches.

Results

Estimated allowable bearing presure of footings are summarized on Figures 3.9 to 3.11. Details of calculation are shown in attached sheets in Appendix 5.

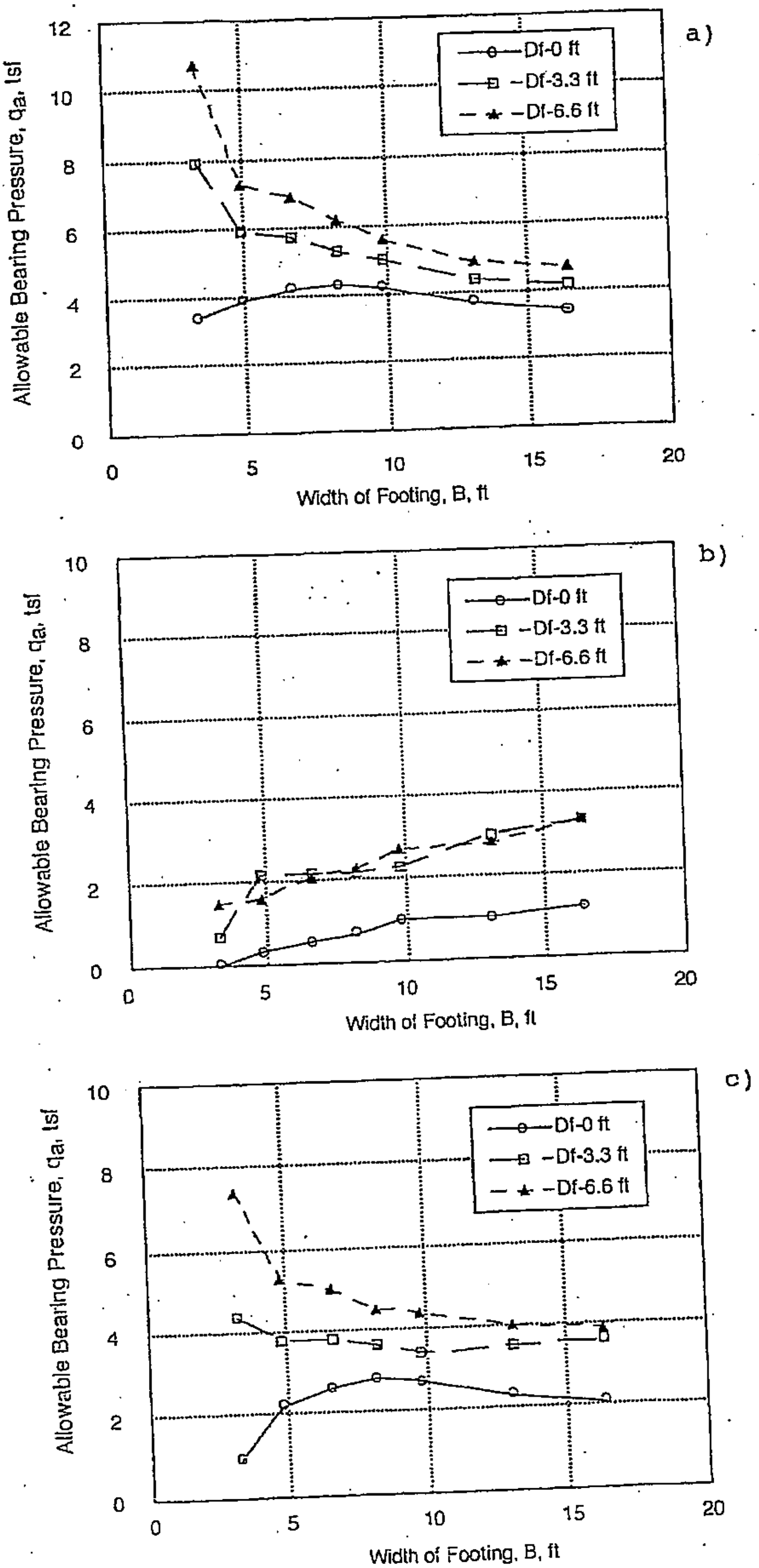

Figure 3.16
Relationship between
Allowable Bearing
Pressure and Width
of Footings at:
a) BH-1
b) BH-2
c) BH-3

As can be seen from Figures, the footing at the surface loading footings have the lowerst bearing pressure. For 3.3 ft and 6.6 ft footing depth the bearing pressure is significantly increased.

(2) Allowable Bearing Capacity of Pile Foundation

Conditions

The load bearing capacity of a single driven pile subjected to axial load is calculated. The square concrete pile of the following dimensions are assumed for the calculation:

(a) Cross Section

7.87 in x 7.87 in	(0.20 m x 0.20 m)
9.84 in x 9.84 in	(0.25 m x 0.25 m)
11.8 in x 11.8 in	(0.30 m x 0.30 m)
13.8 in x 13.8 in	(0.35 m x 0.35 m)
15.7 in x 15.7 in	(0.40 m x 0.40 m)
19.7 in x 19.7 in	(0.50 m x 0.50 m)

(b) Length

from 26 ft (8 m) to 85 ft (26 m), with the steps of 3.3 ft (1 m)

Method of Calculation

The load bearing capacity of pile is calculated by the following formulae:

$$Q_u = Q_e + Q_s - NF - W_p$$

$$Q_a = (Q_e + Q_s)/F_s - NF - W_p$$

where

Q_u : Ultimate load capacity of pile, ton,
Q_a : Allowable load capacity of pile, ton,
Q_e : Ultimate end bearing capacity, ton,
Q_s : Ultimate shaft resistance within supporting layers, ton,
NF : Negative skin friction, ton,
W_p : Weight of pile, ton,
F_s : Factor of safety

Q_e, Q_s, and NF can be determined by the following formulae:

(a) Ultimate Base Bearing Capacity, Q_b

$$Q_e = 0.1 \times A_p (40N) \frac{L_b}{B} \le 0.1 \times A_p (400N) \quad \text{(ton)}$$

where

N : Average of SPT N values in a zone of (for Qe) about 8B above and to 3B below the pile point
B : Width of pile cross-section, ft,
L_b/B : Depth ratio of pile point penetration into bearing stratum,
L_b : Pile point penetration into bearing stratum, ft,

To calculate N corrected N values, $N_{correct}$, were used.

$$N_{correct} = N_{measured} \times C_N$$

where

$N_{correct}$: Corrected SPT N value, ≤ 50,
$N_{measured}$: Measured SPT N value

C_N : Correction factor for overburden pressure (Liao and Whitman, 1986), can be calculated as:

$$C_N=(\frac{p''_o}{p'_o})^{1/2}$$

where

p'_o : Vertical effective overburden pressure at midheight of each soil layer, tsf,

p''_o : Reference overburden pressure, which has been taken as 1 tsf

(b) Ultimate Shaft Resistance, Q_s

i) Driven Pile in Sand Layer

$$Q_s = \rho \, \Sigma(f_s \, l_i)$$

where

ρ : Perimeter of pile section, ft,

f_s : unit ultimate shaft resistance, tsf,

l_i : Length of pile in sand layer, ft

The unit ultimate shaft resistance have been calculated with the use of angle of soil internal friction determined from SPT N-values:

$$f_s = K_o \, p'_o \tan\phi$$

where

K_o : Coefficient of lateral earth pressure at rest,

$$K_o = 1-\sin\phi$$

p'_o : Vertical effective overburden pressure at midheight of each soil layer, tsf,

ϕ : Angle of soil shearing resistance determined from SPT N-values ($N_{correct}$, ≤ 50) as shown in Figure 3.17.

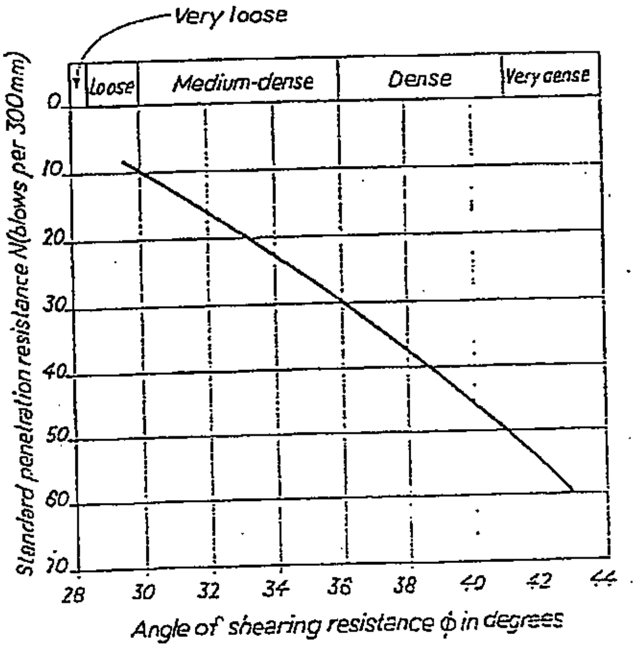

Figure 3.17 Relationship between angle of shearing resistance and standard penetration resistance (N-value) for cohesionless soils (after Peck, Hanson and Thornburn, 1974)

ii) Driven Pile in Clay Layer

Ultimate shaft resistance in clay was estimated by the following formula:

$$Q_s = \alpha \, \rho \, \Sigma(s_u \, l_i)$$

where

α : Adhesion factor, taken from Fig.3.18

after Ng (1983), the curve of Holnberg (1970) for Bangkok clay,

s_u : Undrained shear strength, for the clayey soil at Rayong site s_u was determined from correlation $s_u = q_u/2$, (q_u = Qp obtained using pocket penetrometer data) to SPT N-value, as in Figure 3.19.

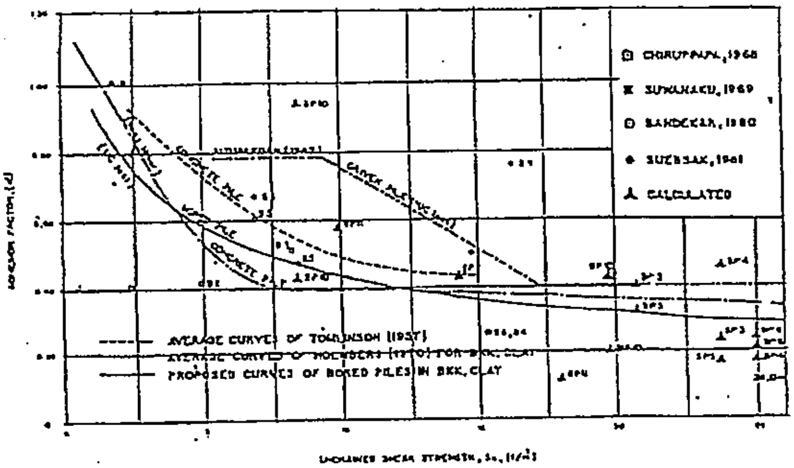

Figure 3.18 Adhesion factor for pile in clay (after Ng, 1983)

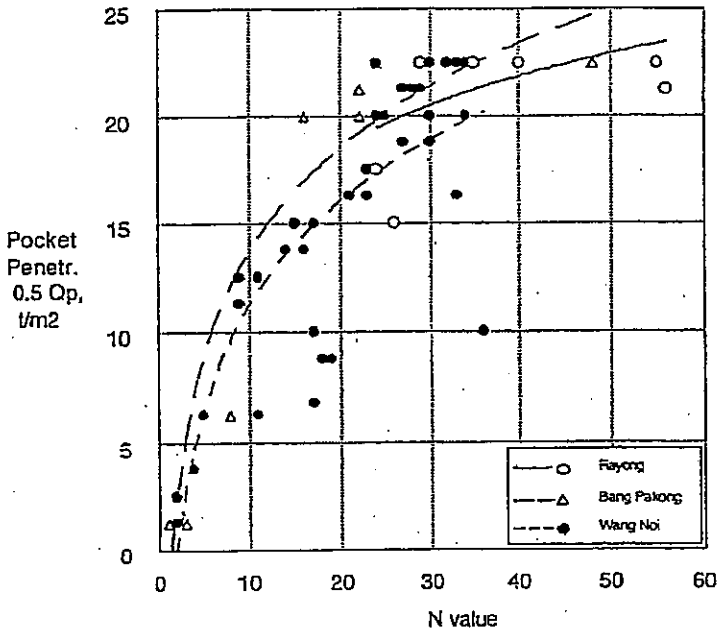

Figure 3.19 Correlation between pocket penetrometer 0.5 Qp values and SPT N-values.

iii) Negative Skin Friction, NF

Negative skin friction was estimated as a sum of negative skin friction in fill sand and soft clay layers:

$$\Sigma Q_{nf} = Q_{nf}^{s} + Q_{nf}^{c}$$

where

ΣQ_{nf} : negative skin friction on pile, ton,
Q_{nf}^{s} : negative skin friction in fill sand layer, ton,
Q_{nf}^{c} : negative skin friction in soft clay layer, ton

$$Q_{nf}^{s} = 0.5 * Ks * \rho * \Sigma(\tan \delta * p'_{oi} * l_i)$$

where

K_s and δ : coefficients (B.Broms, 1966), taking into account the material of pile and relative density of fill, for driven concrete piles and medium relative density:

$$K_s = 1.5,$$

$$\delta = 3/4\ \phi$$

ϕ : angle of internal friction of sand,

ρ, p'_o, l_i: are defined in above formulae

$$Q_{nf}^{c} = \rho * f_n * l_i$$

where

$f_n = 0.2 * p'_o$ for low plastic clays,
$f_n = 0.1 * p'_o$ for highly plastic clays

(L.Bjerrum, 1973).

Results

Estimated allowable bearing capacity of piles are summarized in Figures 3.20 to 3.22, and calculation sheets are attached in Appendix 4.

As can be seen from the Figures 3.20 to 3.22, the bearing capacity of piles is sensitive to variation of N values. Significant increase in bearing capacity is encountered after piles enter the bearing stratum, namely completely decomposed granitic sand at the depth of 50-70 ft (15-21 m) at Rayong site.

(3) Stability of Cut Slope

Typical angles of cut slope is given in Table 3.6 (JHS, 1986). Since cut slopes at Rayong Gas Receiving Terminal will be formed in the upper part of the soils where SPT N values is between 6 to 12 and the soil is classified mainly as sandy soil, it is recommended to use 1 : 1.2 for slopes lower than 16.4 ft (5 m) high , and 1 : 1.5 for slopes of 16.4 ft (5 m) to 32.8 ft (10 m) high.

Table 3.6 Slope Angle of Cut Slope (Japan Highway Association (1990), Guidelines for Slope Protection and Slope Stabilization Works, 1986)

Soil Type		Height of Cut Slope	Slope Angle
sandy soil	dense	lower than 16.4 ft	1:0.8 - 1:1.0
		16.4 ft - 32.8 ft	1:1.0 - 1:1.2
	not dense	lower than 16.4 ft	1:1.0 - 1:1.2
		16.4 ft - 32.8 ft	1:1.2 - 1:1.5
clayey soil		less than 32.8 ft	1:0.8 - 1:1.2

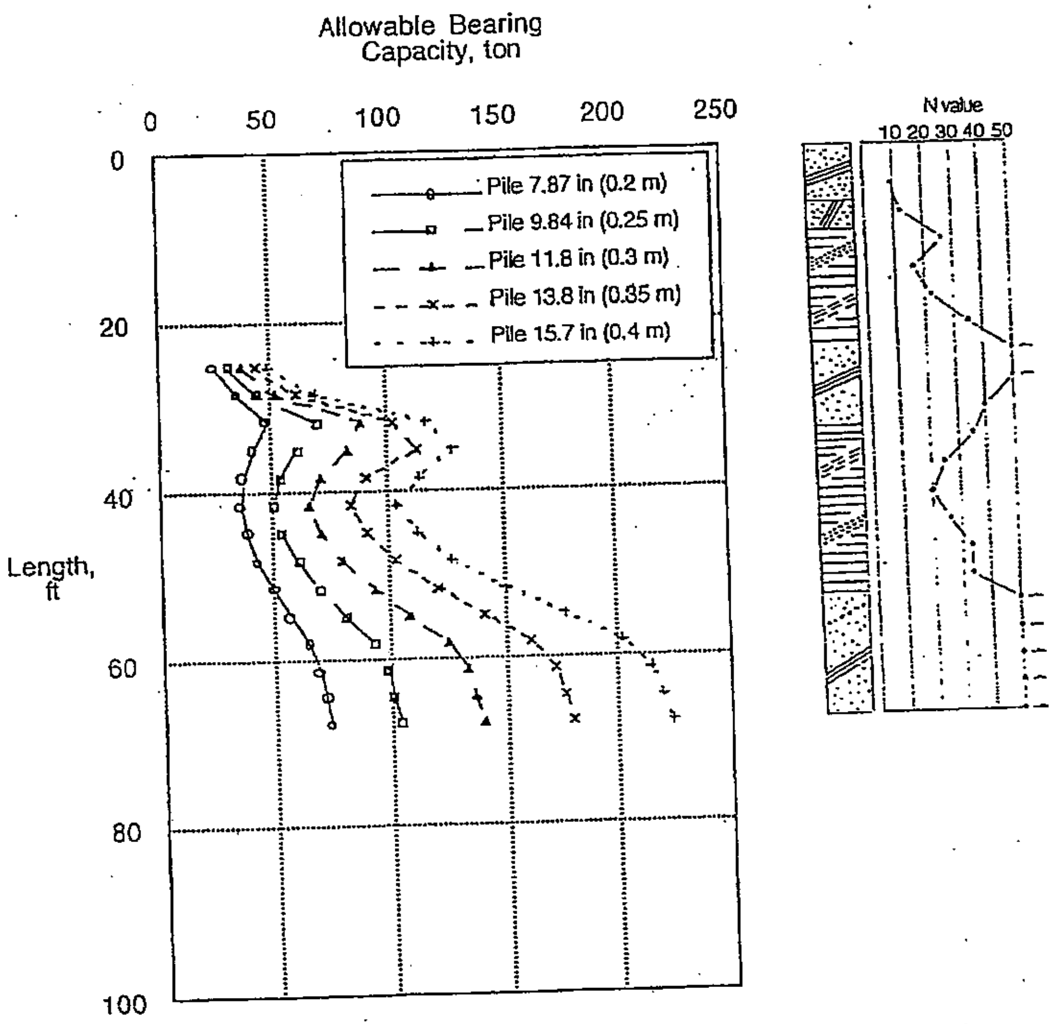

Figure3.20Relationship between Allowable Bearing Capacity and Length of Piles at BH-1

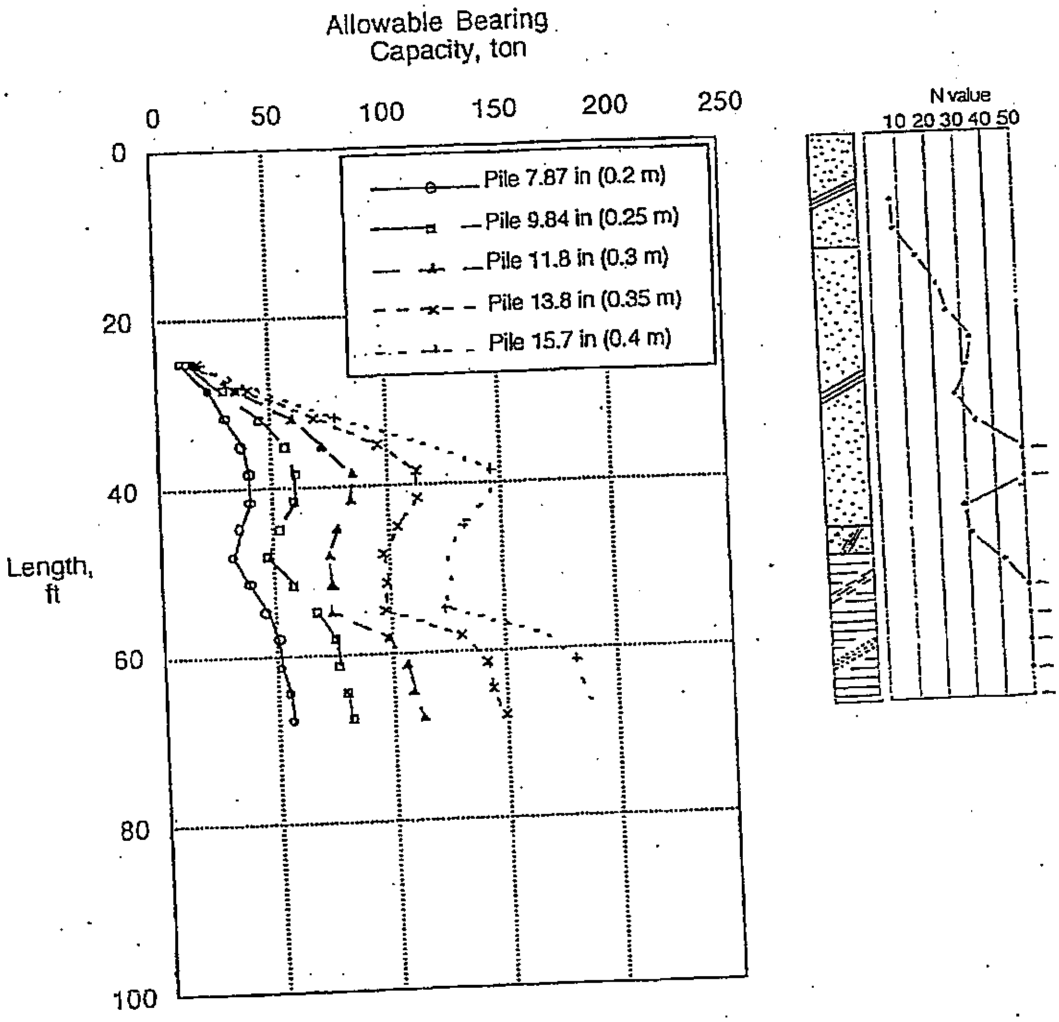

Figure3.21 Relationship between Allowable Bearing Capacity and Length of Piles at BH-2

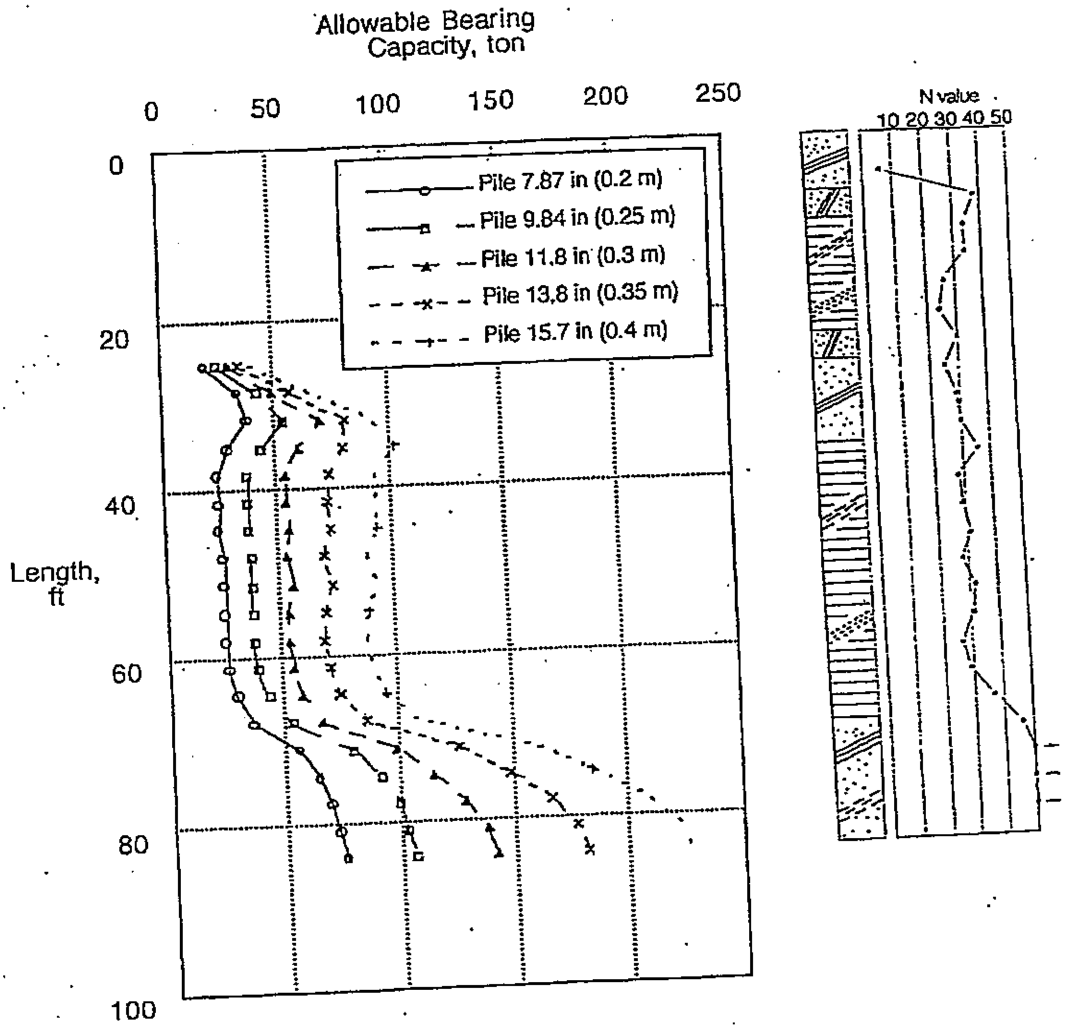

Figure 3.22 Relationship between Allowable Bearing Capacity and Length of Piles at BH-3

The soils exposed at the cut slope surface have vulnerability to erosion by surface water and to weathering. In order to prevent the erosion and the weathering of the slope surface, slope protection works is required. These include slope coverage, drainage system on the slope surface, drainage system at the top of the slope, and drain ditch on the berm if required.

The slope can be covered by vegetation (sadding), suitable to local soil and natural conditions.

4. 100-YEAR FLOOD PLAN LEVEL ANALYSIS

When the protection of flood hazard is one of the objectives in the design and construction of a structure, it is necessary to provide some means of flood control scheme to the structure. Ground elevation is generally the parameter indicating whether the structure will be affected if flooding occurs. Therefore, the ground elevation of the structure should be higher than the design flood water level of a large flood event that could occur in the future.

The study was undertaken to determine the 100 year design flood levels at the metering station of gas pipeline at Wang Noi and the compressor station at Bang Pakong. The 100 year flood water level at the two sites were determined by Gumbel flood frequency analysis of the observed annual maximum flood water levels at the water level gaging stations nearby the two sites. In addition, the computed 100 year design flood levels were checked with the 1942 observed flood levels which the highest ever occurred in the past 50 years.

The final estimated 100 year design flood levels are 4.62 m MSL at the Wang Noi Metering Station and 2.20 m MSL at the Bang Pakong Compressor Station.

Data, detailed analysis, discussions and conclusions are presented in Appendix 3.

Additional information from field surveys shows that the elevation of local road surface at the Bang Pakong site is in the range of 1.1 to 1.48 m MSL. Also the elevation of the tidal dike in Samut Prakarn province in the south of Bangkok near to the coastline of the Gulf of Thailand is about 2.5 m MSL. Compared to the

100 year design flood level at the Bang Pakong site of 2.20 m MSL, the design ground elevation at the Bang Pakong site after landfill should be equal or higher than the local road elevation. This implies a typical design ground elevation of, e.g.3.2 m MSL.

At Wang Noi, the EGAT power plant which is now under construction has its ground elevation of 3.558 m MSL and its ground floor elevation of 4.058 m MSL respectively. The 100 year design flood level at the Wang Noi site is 4.62 m MSL which is based on the 100 year flood level at Klong 10 regulator. Therefore, the designed ground elevation after landfill at the Wang Noi station should be higher than 4.62 m MSL, e.g. 5.00 m MSL.

The 100 year design flood level at the Rayong Receiving Terminal is derived from topographical information (refer topographical map of 1 to 50,000 scale, attached sheet 12). The site is located on a rise whose elevation is over 30.000 m MSL, and this is higher than the stream which dissected around the rise. The level of the streams are normally below 20.000 m MSL. Considering the differences between levels of the ground at the site and the stream, around 10 m, the 100 year design flood level, which is controlled by the height of the stream, is anticipated much lower than the ground level, let say 25.000 m MSL.

5. PREDICTION OF 100 YEAR DESIGN VALUES OF METEOROLOGICAL CONDITIONS

Meteorological data at Sattahip Station, Chon Buri Station and Don Muang Airport Station were collected. These stations are considered to have similar meteorological conditions to the Rayong Gas Receiving Terminal, Bang Pakong Compressor Station, and Wang Noi

Metering Station, respectively. Collected meteorological data, period of records, and sources are summerized in Table 5.1.

Table 5.1 Collected Meteorological Data

Meteorological Data	Period of Record	Sources
Extreme Maximum Wind	1951 - 1994	Meteorological Department
Monthly Mean Wind Speed	1951 - 1994	ditto
Maximum Daily Rainfall	1951 - 1994	ditto
Monthly Rainfall	1951 - 1994	ditto
Monthly Temperature	1951 - 1994	ditto
Monthly Relative Humidity	1951 - 1994	ditto

Maximum or minimum values of meteorological data during 1951 and 1994 (43 years) are summarized in Table 5.2.

The 100 year design level of the meteorological conditions were predicted by the Gumbel frequency analysis of the observed annual maximum values. The predicted values are summarized in Table 5.3, and calculation sheets are attached in appendix .

Table 5.2 Maximum or Minimum Values of Meteorological Data during 1951 and 1994 (43 years)

Item	Sattahip	Chon Buri	Don Muang Airport
Extreme Maximum Wind	73 knots (38 m/sec)	63 knots (32 m/sec)	85 knots (44 m/sec)
Monthly Mean Wind	7.8 knots (4.0 m/sec)	5.3 knots (2.7 m/sec)	6.5 knots (3.3 m/sec)
Maximum Daily Rainfall	12.6 in (319.6 mm)	7.3 in (186.2 mm)	8.2 in (207.7 mm)
Mean Maximum Temperature2)	34.7° C	33.8° C	33.8° C
Mean Minimum Temperature2)	23.5° C	22.1° C	22.6° C
Mean Maximum Humidity2)	89 %	88 %	90 %
Minimum Humidity	16 %	18 %	14 %

Table 5.3 Predicted 100 Year Design Values of Meteorological Data during 1951 and 1994 (43 years)

Item	Sattahip	Chon Buri	Don Muang Airport
Extreme Maximum Wind	81 knots (42 m/sec)	71 knots (37 m/sec)	85 knots (44 m/sec)
Maximum Daily Rainfall	12.6 in (319.6 mm)	7.5 in (190 mm)	8.2 in (209 mm)
Mean Maximum Temperature2)	35.0° C	34.9° C	35.0° C
Mean Minimum Temperature1),2)	23.5° C	22.1° C	22.6° C
Mean Maximum Humidity2)	97 %	94 %	100 %
Minimum Humidity1)	16 %	18 %	14 %

Note 1) Minumum observed values during 1951 and 1994 are used.
2) Anual mean values.

6. RECOMMENDATIONS

Based on the soil investigation and the analysis performed, recommendations for the followings are given:

- selection of foundation type
- pile test
- cut slope
- 100 year design flood level
- 100 year design values of meteorological conditions

(1) Selection of Foundation Type

From the consideration of the allowable bearing pressure, the shallow foundation can be used for the most of foundations at the Rayong Gas Receiving Terminal site. The pile foundation should be used for the foundation experienced heavier load. At Bang Pakong Compressor Station site, the most foundation should be utilized pile foundation.

(2) Pile Test

During construction, pile driving formulae can be used to confirm the bearing capacity values estimated by the analysis. It is recommended to use such as Hiley's formula:

$$R_a = \frac{1}{3} \times \frac{0.5 \times F}{s + \frac{K}{2}}$$

where

Ra : Pile bearing capacity (ton)

F : Pile driving energy (ton-m)
s : Penetration per one blow (m)
K : Pile head elastic rebound (m)

(3) Cut Slope

At the Rayong Gas Receiving Terminal site, it is recommended to use 1 : 1.2 for slopes lower than 16.4 ft (5 m) high , and 1 : 1.5 for slopes of 16.4 ft (5 m) to 32.8 ft (10 m) high.

The slope should be covered by vegetation (sadding), suitable to local soil and natural conditions, in order to prevent the erosion and the weathering of the slope surface.

(4) 100 Year Design Flood Level

100 year design flood levels can be summarized as follows:

Rayong Gas Receiving Terminal	+ 25.00 m MSL
Bang Pakong Compressor Station	+ 2.20 m MSL
Wang Noi Metering Station	+ 4.62 m MSL

(5) 100 Year Design Values of Meteorological Conditions

100 year design values of meteorological conditions are summarized in Table 5.4.

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Appendix 2 Factual Data of Soil Investigation

1) List of Terms Used

2) Unified Soil Classification

3) Characteristics Pertinent to Embankments & Foundations

4) ASTM Specification
D 1587 - 83
D 1586 - 84

5) Summary of Test Results

6) Log of Borings

7) Consolidation Test Results

8) Unconsolidated Undrained Triaxial Compression Test (UU)

9) Hydrometer Test Results

10) Compaction Test Results

11) Soil Resistivity Test Results

12) Chemical Test (pH, Chloride Content, Soluble Sulphate Content, and Carbonate Content)

LIST OF TERMS USED

DRILLING & SAMPLINGA SYMBOLS

SS : Split-Spoon - 1⅜" I.D.,2" O.D., except where noted
ST : Shelby Tube - 2" O.D., except where noted
PA : Power Auger Sample
DB : Diamond Bit - NX:BX:AX:
CB : Carbology Bit - NX:BX:AX:
OS : Osterberg Sampler - 3" Shelby Tube
HS : Housel Sampler
WS : Wash Sample
FT : Fish Tail
RB : Rock Bit
WO : Wash Out

Standard "N" Penetration: Blows per foot of a 140 pound hammer falling 30 inches on 2 inches O.D. split spoon, except where noted.

WATER LEVEL MEASUREMENT SYMBOLS

WL : Water Level
WCI : Wet Cave In
DCI : Dry Cave In
WS : While Sampling
WD : While Drilling
BCR : Before Casing Removal
ACR : After Casing Removal
AB : After Boring

Water levels indicated on the boring logs are the levels measured in the boring at the times indicated. In pervious soils, the indicated elevations are considered reliable ground water levels. In impervious soils, the accurate determination of ground water elevations is not possible in even several days observation, and additional evidence on ground water elevations must be sought.

CLASSIFICATION

COHESIONLESS SOILS

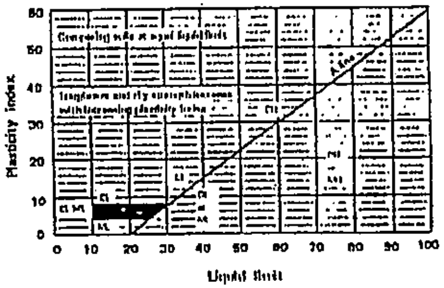
"Trace" : 1 % to 10 %
"Trace to some" : 10 % to 20 %
"Some" : 20 % to 35 %
"And" : 35 % to 50 %
Very Loose : N = 0 - 4 blows
Loose : N = 4 - 10 blows
Medium : N = 10 - 30 blows
Dense : N = 30 - 50 blows
Very Dense : N = over 50 blows

COHESIVE SOILS

If clay content is sufficient to that clay dominates soil properties, then clay becomes the principle noun with the other major soil constituent as modifier; i.e., silty clay. Other minor soil constituents may be added according to classification breakdown for cohesionless soils, i.e., silty clay, trace to some sand, trace gravel.

Very Soft	:	0.00 - 0.25	Tsf. or	0 - 2	blows
Soft	:	0.25 - 0.50	Tsf. or	2 - 4	blows
Medium	:	0.50 - 1.00	Tsf. or	4 - 8	blows
Stiff	:	1.00 - 2.00	Tsf. or	8 - 16	blows
Very Stiff	:	2.00 - 4.00	Tsf. or	16 - 32	blows
Hard	:	over 4.00	Tsf. or	> 32	blows

Unified Soil Classification

Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)						Group Symbols a	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria			
Coarse-grained soils More than half of material is *larger* than No. 200 sieve size^b (The No. 200 sieve size is about the smallest particle visible to naked eye)	Gravels More than half of coarse fraction is larger than No. 4 sieve size (For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size)	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes			*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel; maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbols in parentheses For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics Example: *Silty sand,* gravelly; about 20% hard, angular gravel particles ½ in. maximum size; rounded and subangular sand grains coarse to fine, about 15% non plastic fines with low dry strength; well compacted and moist in place; alluvial sand; *(SM)*	Use grain size curve in identifying the fractions as given under field identification	Determine percentages of gravel and sand from grain size curve Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP* More than 12% *GM, GC, SM, SC* 5% to 12% *Borderline* cases requiring use of dual symbols	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing			*GP*	Poorly graded gravels, gravel sand mixtures, little or no fines				Not meeting all gradation requirements for *GW*	
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)			*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures				Atterberg limits below "A" line, with *PI* less than 4	Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)			*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures				Atterberg limits above "A" line, with *PI* greater than 7	
	Sands More than half of coarse fraction is smaller than No. 4 sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes			*SW*	Well graded sands, gravelly sands, little or no fines				$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing			*SP*	Poorly graded sands, gravelly sands, little or no fines				Not meeting all gradation requirements for *SW*	
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)			*SM*	Silty sands, poorly graded sand-silt mixtures				Atterberg limits below "A" line, with *PI* less than 5	Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)			*SC*	Clayey sands, poorly graded sand-clay mixtures				Atterberg limits above "A" line, with *PI* greater than 7	
	Identification Procedures on Fraction Smaller Than No. 40 Sieve Size		Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)							
Fine-grained soils More than half of material is *smaller* than No. 200 sieve size	Silts and clays liquid limit less than 50		None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses. For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions Example: *Clayey silt,* brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; *(ML)*		 Plasticity chart for laboratory classification of fine grained soils		
			Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays					
			Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity					
	Silts and clays liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts					
			High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays					
			Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity					
Highly Organic Soils			Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils					

From Wagner, 1957.

a *Boundary classifications.* Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW-GC*, well graded gravel-sand mixture with clay binder.

b All sieve sizes on this chart are U.S. standard.

Field Identification Procedure for Fine Grained Soils or Fractions

These procedures are to be performed on the minus No. 40 sieve size particles, approximately $\frac{1}{64}$ in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shaking):

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):

After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):

After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

CHARACTERISTICS PERTINENT TO EMBANKMENTS AND FOUNDATIONS

Major Divisions (1)	(2)	Letter (3)	Symbol Hatching (4)	Symbol Color (5)	Name (6)	Value for Embankments (7)	Permeability Cm Per Sec (8)	Compaction Characteristics (9)	Std AASHTO Max Unit Dry Weight ton per cu. m. (10)	Value for Foundations (11)	Requirements for Seepage Control (12)
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	░	Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Very stable, pervious shells of dikes and dams	$k = 10^{-2}$	Good, tractor, rubber-tired, steel-wheeled roller	2.00 - 2.16	Good bearing value	Positive cutoff
		GP	░		Poorly-graded gravels or gravel-sand mixture, little or no fines	Reasonably stable, pervious shells of dikes and dams	$k = 10^{-2}$	Good, tractor, rubber-tired, steel-wheeled roller	1.84 - 2.00	Good bearing value	Positive cutoff
		GM	▥	Yellow	Silty gravels, gravel-sand silt mixture	Reasonably stable, not particularly suited to shells, but may be used for impervious cores or blankets	$k = 10^{-3}$ to 10^{-6}	Good, with close control, rubber-tired, sheepsfoot roller	1.92 - 2.16	Good bearing value	Toe trench to none
		GC	▨		Clayey gravels, gravel-sand-clay mixtures	Fairly stable, may be used for impervious core	$k = 10^{-6}$ to 10^{-8}	Fair, rubber-tired, sheepsfoot roller	1.84 - 2.08	Good bearing value	None
	SAND AND SANDY SOILS	SW	░	Red	Well-graded sands or gravelly sand, little or no fines	Very stable, pervious sections, slope protection required	$k > 10^{-3}$	Good, tractor	1.76 - 2.08	Good bearing value	Upstream blanket and toe drainage or wells
		SP	░		Poorly-graded sands or gravelly sands, little or no fines	Reasonably stable, may be used in dike section with flat slopes	$k > 10^{-3}$	Good, tractor	1.60 - 1.92	Good to poor bearing value depending on density	Upstream blanket and toe drainage or wells
		SM	▥	Yellow	Silty sands, sand-silt mixtures	Fairly stable, not particularly suited to shells, but may be used for impervious cores or dikes	$k = 10^{-3}$ to 10^{-6}	Good, with close control, rubber-tired, sheepsfoot roller	1.76 - 2.00	Good to poor bearing value depending on density	Upstream blanket and toe drainage or wells
		SC	▨		Clayey sands, sand-silt mixtures	Fairly stable, use for impervious core for flood control structures	$k = 10^{-6}$ to 10^{-8}	Fair, sheepsfoot roller, rubber tired	1.68 - 2.00	Good to poor bearing value	None
FINE GRAINED SOILS	SILTS AND CLAYS LL < 50	ML	▥	Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor stability, may be used for embankments with proper control	$k = 10^{-3}$ to 10^{-6}	Good to poor, close control essential, rubber-tired roller, sheepsfoot roller	1.52 - 1.92	Very poor, susceptible to liquefaction	Toe trench to none
		CL	▨		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Stable, impervious cores and blankets	$k = 10^{-6}$ to 10^{-8}	Fair to poor, close control essential, rubber-tired roller, sheepsfoot roller	1.52 - 1.92	Good to poor bearing	None
		OL	▥		Organic silts and organic silt-clays or low plasticity	Not suitable for embankments	$k = 10^{-4}$ to 10^{-6}	Fair to poor, sheepsfoot roller	1.28 - 1.60	Fair to poor bearing, may have excessive settlements	None
	SILTS AND CLAYS LL > 50	MH	▥	Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor stability, core of hydraulic fill dam, not desirable in rolled fill construction	$k = 10^{-4}$ to 10^{-6}	Poor to very poor, sheepsfoot roller	1.12 - 1.52	Poor bearing	None
		CH	▨		Inorganic clays of high plasticity, fat clays	Fair stability with flat slopes, thin cores, blankets and dike sections	$k = 10^{-6}$ to 10^{-8}	Fair to poor, sheepsfoot roller	1.20 - 1.68	Fair to poor bearing	None
		OH	▨		Organic clays of high plasticity, plasticity, organic silts	Not suitable for embankments	$k = 10^{-6}$ to 10^{-8}	Poor to very poor, sheepsfoot roller	1.04 - 1.60	Very poor bearing	None
HIGHLY ORGANIC SOILS		Pt	▤	Orange	Peat and other highly organic soils	Not used for construction		Compaction not practical		Remove from foundation	

Notes :
1. Values in column 7 and 11 are for guidance only. Design should be based on test results.
2. In column 9, the equipment listed will usually produce the desired densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled.
[illegible]

Designation: D 1587 - 83

Standard Practice for
THIN-WALLED TUBE SAMPLING OF SOILS[1]

This standard is issued under the fixes designation D 1587: the number immediately following the designation indicates the year of original adoption or in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This practice has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This practice covers a procedure for using a thin-walled metal tube to recover relatively undisturbed soil samples suitable for laboratory tests of structural properties. Thin-walled tubes used in piston, plug, or rotary-type samplers, such as the Dension or Pitcher, must comply with the portions of this practice which describe the thin-walled tubes (5.3).

NOTE 1—This practice does not apply to liners used within the above samplers.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 3550 Practice for Ring-Lined Barrel Sampling of Soils[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

3. Summary of Practice

3.1 A relatively undisturbed sample is obtained by pressing a thin-walled metal tube into the in-situ soil, removing the soil-filled tube, and sealing the ends to prevent the soil from being disturbed or losing moisture.

4. Significance and Use

4.1 The practice, or Practice D 3550 is used when it is necessary to obtain a relatively undisturbed specimen suitable for laboratory tests of structural properties or other tests that might be influenced by soil disturbance.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment may be used that provides a reasonably clean hole: that does not disturb the soil to be sampled: and that does not hinder the penetration of the thin-walled sampler. Open borehole diameter and the inside diameter of driven casing or hollow stem auger shall not exceed 3.5 times the outside diameter of the thin-walled tube.

5.2 *Sampler Insertion Equipment*, shall be adequate to provide a relatively rapid continuous penetration force. For hard formations it may be necessary, although not recommended, to drive the thin-walled tube sampler.

5.3 *Thin-Walled Tubes*, should be manufactured as show in Fig. 1. They should have an outside diameter of 2 to 5 in, and be made of metal having adequate strength for use in the soil and formation intended. Tubes shall be clean and free of all surface irregularities including projecting weld seams.

5.3.1 *Length of Tubes*—See Table 1 and 6.4.

5.3.2 *Tolerances*, shall be within the limits shown in Table 2.

5.3.3 *Inside Clearance Ratio*, should be 1% or as specified by the engineer or geologist for the soil and formation to be sampled. Generally, the inside clearance ratio used should increase with the increase in plasticity of the soil being sampled, See Fig. 1 for definition of inside clearance ratio.

5.3.4 *Corrosion Protection*—Corrosion, whether from galvanic or chemical reaction, can damage or destroy both the thin-walled tube and the sample. Severity of damage is a function of

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[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D 18.02 on Sampling and Related Field Testing for Soil Investigations

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[2] *Annual Book of ASTM Standards* Vol 04.08

time as well as interaction between the sampler and the tube. Thin-walled tubes should have some form of protective coating. Tubes which will contain samples for more than 72 h shall be coated. The type of coating to be used may vary depending upon the material to be sampled. Coatings may include a light coat of lubricating oil, lacquer, epoxy, Teflon, and other. Type of coating must be specified by the engineer or geologist if storage will exceed 72 h. Plating of the tubes or alternate base metals may be specified by the engineer or geologist.

5.4 *Sampler Head*, serves to couple the thin-walled tube to the insertion equipment and, together with the thin-walled tube, comprises the thin-walled tube sampler. The sampler head shall contain a suitable check valve and a venting area to the outside equal to or greater than the area through the check valve. Attachment of the head to the tube shall be concentric and coaxial to assure uniform application of force to the tube by the sampler insertion equipment.

6. Procedure

6.1 Clean out the borehole to sampling elevation using whatever method is preferred that will ensure the material to be sampled is not disturbed. If groundwater is encountered, maintain the liquid level in the borehole at or above ground water level during the sampling operation.

6.2 Bottom discharge bits are not permitted. Side discharge bits may be used with caution. Jetting through an open-tube sampler to clean out the borehole to sampling elevation is not permitted. Remove loose material from the center of a casing or hollow stem auger as carefully as possible to avoid disturbance of the material to be sampled.

NOTE 2—Roller bits are available in downward-jetting and diffused-jet configurations. Downward-jetting configuration rock bits are not acceptable. Diffuse-jet configurations are generally acceptable.

6.3 Place the sample tube so that its bottom rests on the bottom of the hole. Advance the sampler without rotation by a continuous relatively rapid motion.

6.4 Determine the length of advance by the resistance and condition of the formation, but the length shall never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clays.

NOTE 3—Weight of sample, laboratory handling capabilities, transportation problems, and commercial availability of tubes will generally limit maximum practical lengths to those shown in Table 1.

6.5 When the formation is too hard for push-type insertion, the tube may be driven of Practice D 3550 may be used. Other methods, as directed by the engineer or geologist, may be used. If driving methods are used, the data regarding weight and fall of the hammer and penetration achieved must be shown in the report. Additionally, that tube must be prominently labeled a "driven sample."

6.6 In no case shall a length of advance be greater than the sample-tube length minus an allowance for the sampler head and a minimum of 3 in. for sludge-end cuttings.

NOTE 4—The tube may be rotated to shear bottom of the sample after pressing is complete.

6.7 Withdraw the sampler from the formation as carefully as possible in order to minimize disturbance of the sample.

7. Preparation for Shipment

7.1 Upon removal of the tube, measure the length of sample in the tube. Remove the disturbed material in the upper end of the tube and measure the length again. Seal the upper end of the tube. Remove at least 1 in. of material from the lower end of the tube. Use this material for soil description in accordance with Practice d 2488. Measure the overall sample length. Seal the lower end of the tube. Alternatively, after measurement, the tube may be sealed without removal of soil from the ends of the tube if so directed by the engineer or geologist.

NOTE 5—Field extrusion and packaging of extruded samples under the specific direction of a geotechnical engineer or geologist is permitted.

NOTE 6—Tubes sealed over the ends as opposed to those sealed with expanding packers should contain end padding in end voids in order to prevent drainage or movement of the sample within the tube.

7.2 Prepare and immediately affix labels or apply markings as necessary to identify the sample. Assure that the markings or labels are adequate to survive transportation and storage.

8. Report

8.1 The appropriate information is required as follows:

8.1.1 Name and location of the project.

8.1.2 Boring number and precise location on project

8.1.3 Surface elevation or reference to a datum.

8.1.4 Date and time of boring—start and finish.

8.1.5 Depth to top of sample and number of sample.

8.1.6 Description of sampler size, type of metal, type of coating.

8.1.7 Method of sample insertion: push or drive.

8.1.8 Method of drilling, size of hole, casing, and drilling fluid use.

8.1.9 Depth to groundwater level: date and time measured.

8.1.10 Any possible current or tidal effect on water level.

8.1.11 Soil description in accordance with Practice D 2488.

8.1.12 Length of sampler advance, and

8.1.13 Recovery: length of sample obtained.

9. Precision and Bias

9.1 This practice does not produce numerical data; therefore, a precision and bias statement is not applicable.

TABLE 1 Suitable Thin-Walled Steel Sample Tubes[A]

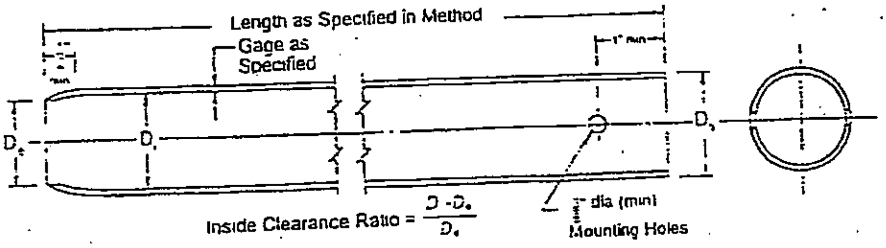
Outside diameter			
in.	2	3	5
mm	50.8	76.2	127
Wall thickness:			
Bwg	18	16	11
in.	0.049	0.065	0.120
mm	1.24	1.65	3.05
Tube length:			
in.	36	36	54
m	0.91	0.91	1.45
Clearance ratio, %	1	1	1

[A] The three diameters recommended in Table 1 are indicated for purposes of standardization, and are not intended to indicate that sampling tubes of intermediate or larger diameters are not acceptable. Lengths of tubes shown are illustrative. Proper lengths to be determined as suited to field conditions.

TABLE 2 Dimensional Tolerances for Thin-Walled Tubes

Nominal Tube Diameters from Table 1[A] Tolerances, in			
Size Outside Diameter	2	3	5
Outside diameter	+0.007 −0.000	+0.010 −0.000	+0.015 −0.000
Inside diameter	+0.000 −0.007	+0.000 −0.010	+0.000 −0.015
Wall thickness	±0.007	±0.010	±0.015
Ovality	0.015	0.020	0.030
Straightness	0.030/ft	0.030/ft	0.030/ft

[A] Intermediate or larger diameters should be proportional. Tolerances shown are essentially standard commercial manufacturing tolerances for seamless steel mechanical tubing. Specify only two of the first three tolerances; that is, O.D. and I.D. or O.D. and Wall, or I.D. and Wall.



NOTE 1—Minimum of two mounting holes on opposite sides for 2 to 3½ in. sampler.

NOTE 2—Minimum of four mounting holes spaced at 90° for sampler 4 in. and larger.

NOTE 3—Tube held with hardened screws.

NOTE 4—Two-inch outside-diameter tubes are specified with an 18-gage wall thickness to comply with area ratio accepted for undisturbed samples. Users are advised that such tubing is difficult to locate and can be extremely expensive in small quantities. Sixteen-gage tubes are generally readily available.

Metric Equivalents

in	mm
3/16	6.77
½	12.7
1	25.4
2	50.8
3½	88.9
4	101.6

FIG. 1 Thin-Walled Tube for Sampling

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103 known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

Designation: D 1586 - 84

Standard Method of PENETRATION TEST AND SPLIT - BARREL SAMPLING OF SOILS[1]

This standard is issued under the fixes designation D 1586:the number immediately following the designation indicates the year of original adoption or in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (e) indicates an editorial change since the last revision or reapproval.

This method has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards.

1. Scope

1.1 This method describes the procedure, generally known as the Standard Penetration Test (SPT), for driving a split-barrel sampler to obtain a representative soil sample, and a measure of the resistance of the soil to penetration of the sampler.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For a specific precautionary statement, see 5.4.1.

1.3 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

D 2487 Test Method for Classification of Soils for Engineering Purposes[2]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[2]

D 4220 Practices for Preserving and Transporting Soil Samples[2]

3. Descriptions of Terms Specific to This Standard

3.1 *anvil*—that portion of the driven-weight assembly which the hammer strikes and through which the hammer energy passes into the drill rods.

3.2 *cathead*—the rotating drum or windlass in the rope-cathead lift system around which the operator wraps a rope to lift and drop the hammer by successively tightening and loosening the rope turns around the drum.

3.3 *drill rods*—rods used to transmit downward force and torque to the drill bit while drilling a borehole.

3.4 *drive-weight assembly*—a device consisting of the hammer, hammer fall guide, the anvil, and any hammer drop system.

3.5 *hammer*—that portion of the drive-weight assembly consisting of the 140 ± 2 lb (63.5 ± 1 kg) impact weight which is successively lifted and dropped to provide the energy that accomplishes the sampling and penetration.

3.6 *hammer drop system*—That portion of the drive-weight assembly by which the operator accomplishes the lifting and dropping of the hammer to produce the blow.

3.7 *hammer fall guide*—that part of the drive-weight assembly used to guide the fall of the hammer.

3.8 *N-value*—that blowcount representation of the penetration resistance of the soil. The *N-value*, reported in blows per foot, equals the sum of the number of blows required to drive the sampler over the depth interval of 6 to 18 in, (150 to 450 mm) (see 7.3).

3.9 ΔN—the number of blows obtained from each of the 6-in, (150-mm) intervals of sampler penetration (see 7.3).

3.10 *number of rope turns*—the total contact angle between the rope and the cathead at the beginning of the

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[1] This method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D 18.02 on Sampling and Related Field Testing for Soil Investigations.

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[2] *Annual Book of ASTM Standards*. Vol. 04.08.

operator's rope slackening to drop the hammer, divided by 360° (See Fig. 1).

3.11 *sampling rods*—rods that connect the drive-weight assembly to the sampler. Drill rods are often used for this purpose.

3.12 *SPT*—abbreviation for Standard Penetration Test, a term by which engineers commonly refer to this method.

4. Significance and Use

4.1 This method provides a soil sample for identification purposes and for laboratory tests appropriate for soil obtained from a sampler that may produce large shear strain disturbance in the sample.

4.2 This method is used extensively in a great variety of geotechnical exploration projects. Many local correlations and widely published correlations which relate SPT blowcount, or *N*-value, and the engineering behavior of earth-works and foundations are available.

5. Apparatus

5.1 *Drilling Equipment*—Any drilling equipment that provides at the time of sampling a suitably clean open hole before insertion of the sampler and ensures that the penetration test is performed on undisturbed soil shall be acceptable. The following pieces of equipment have proven to be suitable for advancing a borehole in some subsurface conditions.

5.1.1 *Drag, Chopping, and Fishtail Bits,* less than 6.5 in. (162 mm) and greater than 2.2 in (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods. To avoid disturbance of the underlying soil, bottom discharge bits are not permitted; only side discharge bits are permitted.

5.1.2 *Roller-Cone Bits,* less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm) in diameter may be used in conjunction with open-hole rotary drilling or casing-advancement drilling methods if the drilling fluid discharge is deflected.

5.1.3 *Hollow-Stem Continuous Flight Augers,* with or without a center bit assembly, may be used to drill the boring. The inside diameter of the hollow-stem augers shall be less than 6.5 in. (162 mm) and greater than 2.2 in. (56 mm).

5.1.4 *Solid, Continuous Flight, Bucket and Hand Augers,* less than 6.5 in. (162 mm) and greater than 2.2 in (56 mm) in diameter may be used if the soil on the side of the boring does not cave onto the sampler or sampling rods during sampling.

5.2 *Sampling Rods*—Flush-joint steel drill rods shall be used to connect the split-barrel sample to the drive-weight assembly. The sampling rod shall have a stiffness (moment of inertia) equal to or greater than that of parallel wall "A" rod (a steel rod which has an outside diameter of 1⅝ in. (41.2 mm) and an inside diameter of 1⅛ in. (28.5 mm).

NOTE 1—Recent research and comparative testing indicates the type rod used, with stiffness ranging from "A" size rod to "N" size rod, will usually have a negligible effect on the N-values to depths of at least 100 ft (30 m).

5.3 *Split-Barrel Sampler*—The sampler shall be constructed with the dimensions indicated in Fig. 2. The driving shoe shall be of hardened steel and shall be replace or repaired when it becomes dented or distorted. The use of liners to produce a constant inside diameter of 1⅜ in. (35 mm) is permitted, but shall be noted on the penetration record if used. The use of a sample retainer basket is permitted, and should also be noted on the penetration record if used.

NOTE 2—Both theory and available test data suggest that *N*-values may increase between 10 to 30% when liners are used.

5.4 *Drive-Weight Assembly:*

5.4.1 *Hammer and Anvil*—The hammer shall weigh 140 ± 2 lb (63.5 ± 1 kg) and shall be a solid rigid metallic mass. The hammer shall strike the anvil and make steel on steel contact when it is dropped. A hammer fall guide permitting a free fall shall be used. Hammers used with the cathead and rope method shall have an un-impeded overlift capacity of at least 4 in. (100 mm). For safety reasons, the use of a hammer assembly with an internal anvil is encouraged.

NOTE 3—It is suggested that the hammer fall guide be permanently marked to enable the operator or inspector to judge the hammer drop height.

5.4.2 *Hammer Drop System*—Rope-cathead, trip, semi-automatic, or automatic hammer drop systems may be used, providing the lifting apparatus will not cause penetration of the sampler while re-engaging and lifting the hammer.

5.5 *Accessory Equipment*—Accessories such as labels, sample containers, data sheets, and groundwater level measuring devices shall be provided in accordance with the requirements of the project and other ASTM standards.

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6. Drilling Procedure

6.1 The boring shall be advanced incrementally to permit intermittent or continuous sampling. Test intervals and locations are normally stipulated by the project engineer or geologist. Typically, the intervals selected are 5 ft (1.5 mm) or less in homogeneous strata with test and sampling locations at every change of strata.

6.2 Any drilling procedure that provides a suitably clean and stable hole before insertion of the sampler and assures that the penetration test is performed on essentially undisturbed soil shall be acceptable. Each of the following procedures have proven to be acceptable for some subsurface conditions. The subsurface conditions anticipated should be considered when selecting the drilling method to be used.

6.2.1 Open-hole rotary drilling method.

6.2.2 Continuous flight hollow-stem auger method.

6.2.3 Wash boring method.

6.2.4 Continuous flight solid auger method.

6.3 Several drilling methods produce unacceptable borings. The process of jetting through an open tube sampler and then sampling when the desired depth is reached shall not be permitted. The continuous flight solid auger method shall not be used for advancing the boring below a water table or below the upper confining bed of a confined non-cohesive stratum that is under artesian pressure. Casing may not be advanced below the sampling elevation prior to sampling. Advancing a boring with bottom discharge bits is not permissible. It is not permissible to advance the boring for subsequent insertion of the sampler solely by means of previous sampling with the SPT sampler.

6.4 The drilling fluid level within the boring or hollow-stem augers shall be maintained at or above the in situ groundwater level at all times during drilling, removal of drill rods, and sampling.

7. Sampling and Testing Procedure

7.1 After the boring has been advanced to the desired sampling elevation and excessive cuttings have been removed, prepare for the test with the following sequence of operations.

7.1.1 Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.

7.1.2 Position the hammer above and attach the anvil to the top of the sampling rods. This may be done before the sampling rods and sampler are lowered into the borehole.

7.1.3 Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings ar encountered at the bottom of the boring, remove the sampler and sampling rods from the boring and remove the cuttings.

7.1.4 Mark the drill rods in three successive 6-in. (0.15-m) increments so that the advance of the sampler under the impact of the hammer can be easily observed for each 6-in. (0.15-m) increment.

7.2 Drive the sampler with blows from the 140-lb (63.5-kg) hammer and count the number of blows applied in each 6-in. (0.15-m) increment until one of the following occurs:

7.2.1 A total of 50 blows have been applied during any one of the three 6-in. (0.15-m) increments described in 7.1.4.

7.2.2 A total of 100 blows have been applied.

7.2.3 There is no observed advance of the sampler during the application of 10 successive blows of the hammer.

7.2.4 The sampler is advanced the complete 18 in. (0.45 m) without the limiting blow counts occurring as described in 7.2.1, 7.2.2, or 7.2.3.

7.3 Record the number of blows required to effect each 6 in. (0.15 m) of penetration or fraction thereof. The first 6 in. is considered to be a seating drive. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance", or the "*N*-value". If the sampler is driven less than 18 in. (0.45 m), as permitted in 7.2.1, 7.2.2, or 7.2.3, the number of blows per each complete 6-in. (0.15-m) increment and per each partial increment shall be recorded on the boring log. For partial increments, the depth of penetration shall be reported to the nearest 1 in. (25 mm), in addition to the number of blows. If the sampler advances below the bottom of the boring under the static weight of the drill rods or the weight of the drill rods plus the static weight of the hammer, this information should be noted on the boring log.

7.4 The raising and dropping of the 140-lb

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(63.5-kg) hammer shall be accomplished using either of the following two methods:

7.4.1 By using a trip, automatic, or semi-automatic hammer drop system which lifts the 140-lb (63.5-kg) hammer and allows it to drop 30± 1.0 in. (0.76 m ± 25 mm) unimpeded.

7.4.2 By using a cathead to pull a rope attached to the hammer. When the cathead and rope method is used the system and operation shall conform to the following:

7.4.2.1 The cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 in. (150 to 250 mm).

7.4.2.2 The cathead should be operated at a minimum speed of rotation of 100 RPM, or the approximate speed of rotation shall be reported on the boring log.

7.4.2.3 No more than 2¼ rope turns on the cathead may be used during the performance of the penetration test, as shown in Fig. 1.

NOTE 4—The operator should generally use either 1¾ or 2¼ rope turns, depending upon whether or not the rope comes off the top (1¾ turns) or the bottom (2¼ turns) of the cathead. It is generally known and accepted that 2¾ or more rope turns considerably impedes the fall of the hammer and should not be used to perform the test. The cathead rope should be maintained in a relatively dry, clean, and unfrayed condition.

7.4.2.4 For each hammer blow, a 30-in. (0.76-m) lift and drop shall be employed by the operator. The operation of pulling and throwing the rope shall be performed rhythmically without holding the rope at the top of the stroke.

7.5 Bring the sampler to the surface and open. Record the percent recovery or the length of sample recovered. Describe the soil samples recovered as to composition, color, stratification, and condition, then place one or more representative portions of the sample into sealable moisture-proof containers (jars) without ramming or distorting any apparent stratification. Seal each container to prevent evaporation of soil moisture. Affix labels to the containers bearing job designation, boring number, sample depth, and the blow count per 6-in. (0.15-m) increment. Protect the samples against extreme temperature changes. If there is a soil change within the sampler, make a jar for each stratum and note its location in the sampler barrel.

8. Report

8.1 Drilling information shall be recorded in the field and shall include the following:

8.1.1 Name and location of job.

8.1.2 Names of crew.

8.1.3 Type and make of drilling machine.

8.1.4 Weather conditions.

8.1.5 Date and time of start and finish of boring.

8.1.6 Boring number and location (station and coordinates, if available and applicable).

8.1.7 Surface elevation, if available.

8.1.8 Method of advancing and cleaning the boring.

8.1.9 Method of keeping boring open.

8.1.10 Depth of water surface and drilling depth at the time of a noted loss of drilling fluid, and time and date when reading or notation was made.

8.1.11 Location of strata changes.

8.1.12 Size of casing, depth of cased portion of boring.

8.1.13 Equipment and method of driving sampler.

8.1.14 Type sampler and length and inside diameter of barrel (note use of liners).

8.1.15 Size, type, and section length of the sampling rods, and

8.1.16 Remarks.

8.2 Data obtained for each sample shall be recorded in the field and shall include the following:

8.2.1 Sample depth and, if utilized, the sample number.

8.2.2 Description of soil.

8.2.3 Strata changes within sample.

8.2.4 Sampler penetration and recovery length, and

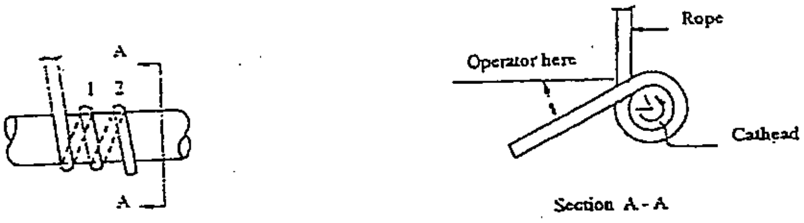
8.2.5 Number of blows per 6-in. (0.15-m) or partial increment.

9. Precision and Bias

9.1 Variations in N-values of 100% or more have been observed when using different standard penetration test apparatus and drillers for adjacent borings in the same soil formation. Current opinion, based on field experience, indicates that when using the same apparatus and driller, N-values in the same soil can be reproduced with a coefficient of variation of about 10%.

9.2 The use of faulty equipment, such as an extremely massive or damaged anvil, a rusty cathead, a low speed cathead, an old, oily rope, or massive or poorly lubricated rope sheaves can significantly contribute to differences in *N*-values obtained between operator-drill rig systems.

9.3 The variability in *N*-values produced by different drill rigs and operators may be reduced by measuring that part of the hammer energy delivered into the drill rods from the sampler and adjusting *N* on the basis of comparative energies. A method for energy measurement and *N*-value adjustment is currently under development.



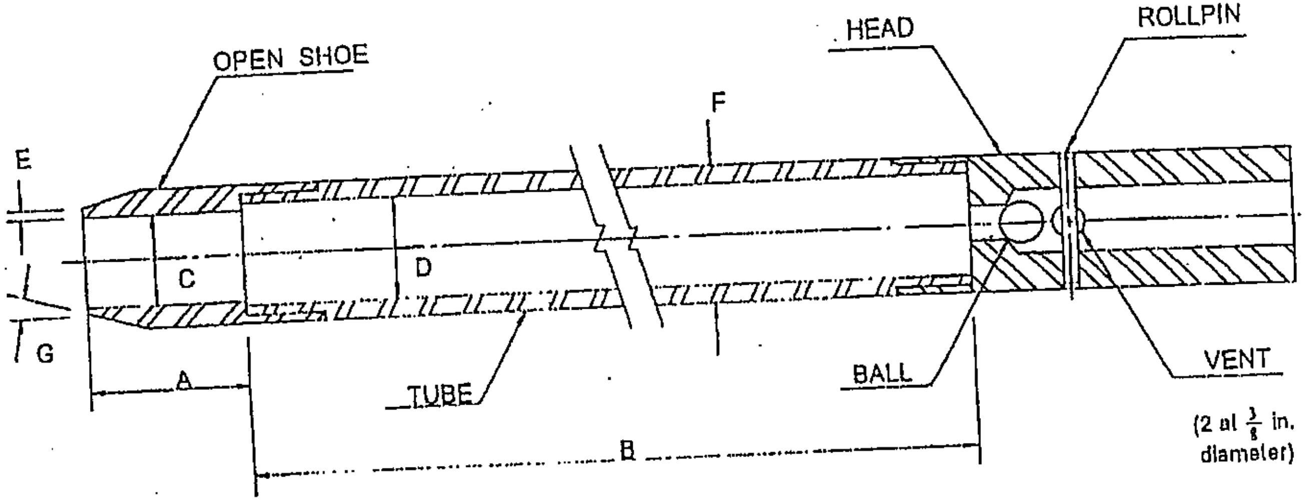
(a) counterclockwise rotation

approximately $1\frac{3}{4}$ turns

(b) clockwise rotation

approximately $2\frac{1}{4}$ turns

FIG. 1 Definitions of the Number of Rope Turns and the Angle for *(a)* Counterclockwise Rotation and *(b)* Clockwise Rotations of the Cathead



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 - 0.00 in. (38.1 ± 1.3 - 0.00 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 - 0.00 in. (50.8 ± 1.3 - 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the driven shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

FIG. 2 Split-Barrel Sampler

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA. 19103.

STS ENGINEERING CONSULTANTS CO.,LTD.
SUMMARY OF TEST RESULTS

LOCATION Rayong Gas Receiving Terminal

PROJECT TPP

DATE 22/11/94 | BORING No. BH-1 | JOB No. 4956 | BY CK | OBSERVED W.L. -5.20 M.

SAMPLE No.	DEPTH M.		WATER CONTENT %	ATTERBERG LIMIT %			WET UNIT WEIGHT t/m³	SIEVE ANALYSIS % FINER					CLASSIFICATION	UNDRAINED SHEAR STRENGTH t/m²						STANDARD PENETRATION(N) (blow/ft)	SPECIFIC GRAVITY,GS
														UNCONFINED SHEAR		FIELD VANE SHEAR		UU TEST	POCKET PENETRATION		
	FROM	TO		LL.	PL.	PI.		No. 3/8"	No. 4	No. 10	No. 40	No. 200		Qu/2	Qu'/2	Qv	Qv'	Su	1/2Qp		
SS-01	1.00	1.45	13.00						100	95	65	45	SC							9	2.64
SS-02	2.00	2.45																		12	
SS-03	3.00	3.45																		26	
SS-04	4.00	4.45																		16	
SS-05	5.00	5.45																		22	
SS-06	6.00	6.45																	22.5+	35	
SS-07	7.00	7.45																	21.25	56	
SS-08	8.00	8.45																	22.5+	55	
SS-09	9.00	9.45																	22.5+	40	
SS-10	10.00	10.45																	22.5+	35	
SS-11	11.00	11.45																		25	
SS-12	12.00	12.45																		20	
SS-13	13.00	13.45																		26	
SS-14	14.00	14.45																		34	
SS-15	15.00	15.45																		34	
SS-16	16.00	16.45																		50	
SS-17	17.00	17.45																		62	
SS-18	18.00	18.45																		50	
SS-19	19.00	19.45																		65	
SS-20	20.00	20.45																		66	

STS ENGINEERING CONSULTANTS CO.,LTD.
SUMMARY OF TEST RESULTS

LOCATION Rayong Gas Receiving Terminal

PROJECT TPP

DATE '22/11/94 | BORING No. BH-2 | JOB No. 4956 | BY CK | OBSERVED W.L. -1.50 M.

SAMPLE No.	DEPTH M.		WATER CONTENT %	ATTERBERG LIMIT %			WET UNIT WEIGHT t/m³	SIEVE ANALYSIS % FINER					CLASSIFICATION	UNDRAINED SHEAR STRENGTH t/m²						STANDARD PENETRATION(N) (blow/ft)	SPECIFIC GRAVITY,GS
														UNCONFINED SHEAR		FIELD VANE SHEAR		UU TEST	POCKET PENETRATION		
	FROM	TO		LL.	PL.	PI.		No. 3/8"	No. 4	No. 10	No. 40	No. 200		Qu/2	Qu'/2	Qv	Qv'	Su	1/2Qp		
SS-01	2.00	2.45	13.30							100	58	32	SC							7	2.64
SS-02	3.00	3.45																		8	
SS-03	4.00	4.45																		15	
SS-04	5.00	5.45																		22	
SS-05	6.00	6.45																		25	
SS-06	7.00	7.45																		33	
SS-07	8.00	8.45																		31	
SS-08	9.00	9.45	12.00						100	99	49	30	SC							27	2.64
SS-09	10.00	10.45																		44	
SS-10	11.00	11.45																		50	
SS-11	12.00	12.45																		88/11"	
SS-12	13.00	13.45																	22.5+	29	
SS-13	14.00	14.45	22.30					100	98	82	64	44	SC							31	2.63
SS-14	15.00	15.45																		42	
SS-15	16.00	16.45																		65	
SS-16	17.00	17.45	16.80					100	95	75	49	33	SC							58	2.65
SS-17	18.00	18.45																		72	
SS-18	19.00	19.45																		68	
SS-19	20.00	20.45																		76	

STS ENGINEERING CONSULTANTS CO.,LTD.

SUMMARY OF TEST RESULTS

LOCATION Rayong Gas Receiving Terminal

PROJECT TPP

BY CK

OBSERVED W.L. -5.4 M.

DATE 22/11/94

BORING No. BH-3

JOB No. 4956

SAMPLE No.	DEPTH M.		WATER CONTENT %	ATTERBERG LIMIT %			WET UNIT WEIGHT t/m³	SIEVE ANALYSIS % FINER					CLASSIFICATION	UNDRAINED SHEAR STRENGTH t/m²						STANDARD PENETRATION(N) (blow/ft)	SPECIFIC GRAVITY,GS
														UNCONFINED SHEAR		FIELD VANE SHEAR		UU TEST	POCKET PENETRATION		
	FROM	TO		LL.	PL.	PI.		No. 3/8"	No. 4	No. 10	No. 40	No. 200		Qu/2	Qu'/2	Qv	Qv'	Su	1/2Qp		
SS-01	1.00	1.45	8.80						100	92	48	35	SC							6	2.64
SS-02	2.00	2.45																		38	
SS-03	3.00	3.45																	22.5+	34	
SS-04	4.00	4.45																	22.5+	34	
SS-05	5.00	5.45																	15.00	26	
SS-06	6.00	6.45																	17.5	24	
SS-07	7.00	7.45																	22.5+	30	
SS-08	8.00	8.45																		25	
SS-09	9.00	9.45																		29	
SS-10	10.00	10.45																		30	
SS-11	11.00	11.45																		35	
SS-12	12.00	12.45																		28	
SS-13	13.00	13.45																		29	
SS-14	14.00	14.45																		31	
SS-15	15.00	15.45																		28	
SS-16	16.00	16.45																		32	
SS-17	17.00	17.45																		31	
SS-18	18.00	18.45																		26	
SS-19	19.00	19.45																		29	
SS-20	20.00	20.45																		37	
SS-21	21.00	21.45																		46	

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STS ENGINEERING CONSULTANTS CO.,LTD.
SUMMARY OF TEST RESULTS

LOCATION 'Rayong Gas Receiving Terminal

PROJECT TPP

BY CK

OBSERVED W.L. -5.4 M.

DATE 22/11/94

BORING No. BH-3

JOB No. 4956

SAMPLE No.	DEPTH M.		WATER CONTENT %	ATTERBERG LIMIT %			WET UNIT WEIGHT t/m³	SIEVE ANALYSIS % FINER					CLASSIFICATION	UNDRAINED SHEAR STRENGTH t/m²						STANDARD PENETRATION(N) (blow/ft)	
														UNCONFINED SHEAR		FIELD VANE SHEAR		UU TEST	POCKET PENETRATION		
	FROM	TO		LL.	PL.	PI.		No. 3/8"	No. 4	No. 10	No. 40	No. 200		Qu/2	Qu'/2	Qv	Qv'	Su	1/2Qp		
SS-22	22.00	22.45																		65	
SS-23	23.00	23.45																		79	
SS-24	24.00	24.45																		50/6"	
SS-25	25.00	25.45																		50/5"	

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STS ENGINEERING CONSULTANTS CO.,LTD.
SUMMARY OF TEST RESULTS OF TEST PITS

PROJECT TPP

LOCATION Rayong Gas Receiving Terminal

DATE 02/12/1994

PIT No.	LOCATION (STA.)	SAMPLE No.	DEPTH M.		DESCRIPTION	CLASSIFICATION		SIEVE ANALYSIS % FINER					ATTERBERG LIMITS		MOISTURE CONTENT %	IN-SITU DENSITY t/m³	COMPACTION AASHTO T99		CBR @ 95% AASHTO T99 %	SWELL %	Gs
			FROM	TO		AASHTO	UNIF.	No. 3/8"	No. 4	No. 10	No. 40	No. 200	LL %	PI %			$\gamma_{d_{max}}$ t/m³	W_{opt} %			
TP-1	GBH-2	BS-1	0.30	1.00	Clayey Sand	A-7-6	SC		100	95	66	49	41.50	25.20			1.83	14.9			2.63

LOG OF BORING No. BH-1

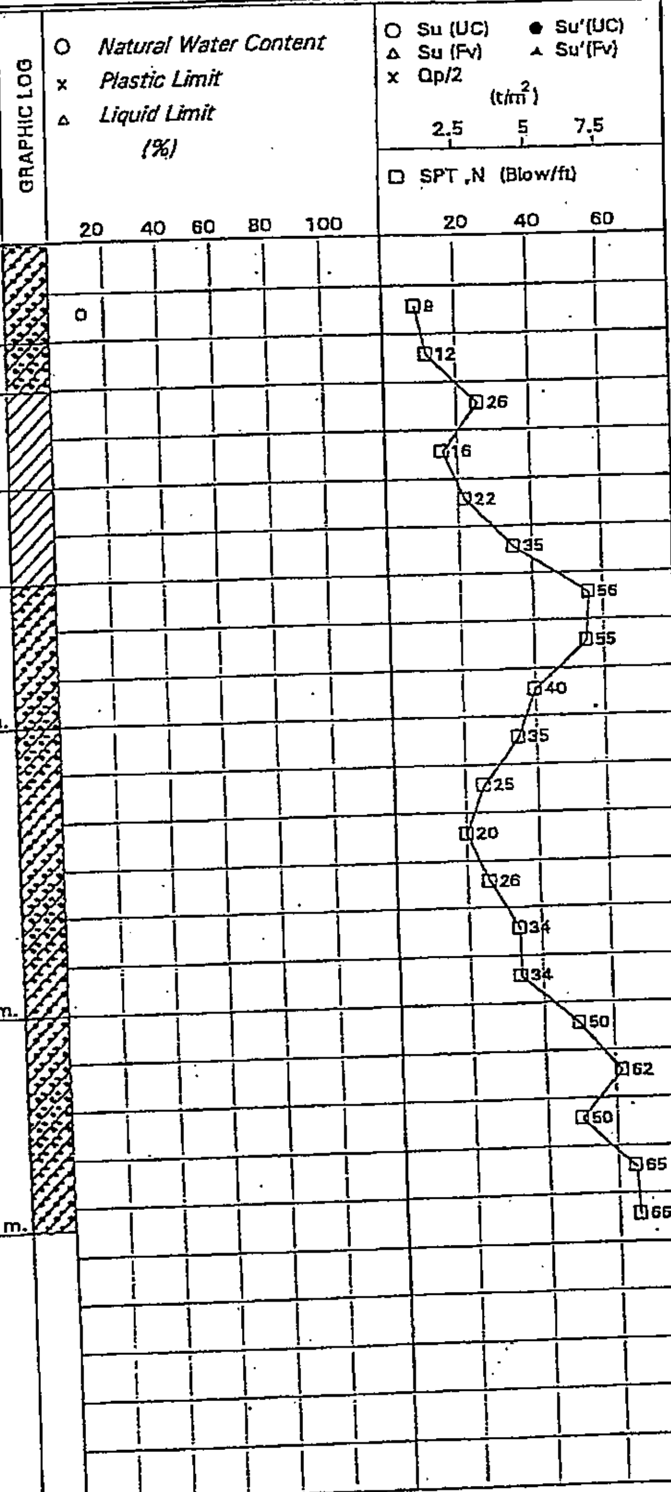
PROJECT : TPP

LOCATION : Rayong Gas Receiving Terminal

CLIENT :

DEPTH,m	SAMPLE No.	TYPE OF SAMPLE	DESCRIPTION OF MATERIAL
0	01	SS	Clayey fine to medium SAND, greyish li-brown, loose. (SC) — 2.00 m.
	02	SS	(A) — 3.00 m.
	03	SS	Fine sandy CLAY with pisolitic granule, reddish brown, stiff to very stiff. (Lateritic soil) (CL)
	04	SS	5.00 m.
5	05	SS	Silty CLAY trace fine sand with pisolitic granule, greyish brown, very stiff to hard. (CL)
	06	SS	7.00 m.
	07	SS	Clayey medium to coarse SAND with pisolitic granule, li-grey & reddish brown, dense to very dense. (SC)
	08	SS	
	09	SS	10.00 m.
10	10	SS	Silty medium to coarse sandy CLAY to clayey silty medium to coarse SAND, white & yellowish brown, very stiff to hard. (Altered Granitic Soil) (SC-CL)
	11	SS	
	12	SS	
	13	SS	
	14	SS	
15	15	SS	16.00 m.
	16	SS	Clayey fine to coarse SAND trace gravel, white & greenish li-grey & brown, very dense. (Completely Decomposed Granitic Soil) (SC)
	17	SS	
	18	SS	
	19	SS	20.45 m.
20	20	SS	END OF BORING
25			

(A)
Clayey fine to medium SAND trace coarse sand, reddish brown, medium dense. (SC)



STS ENGINEERING CONSULTANTS CO.,LTD.	BORING STARTED. 11/11/94	RIG. ACKER	WL. -5.20 M. 24 HRS. AFTER BORING.
	BORING FINISHED. 15/11/94	FOREMAN NW	JOB No. 4956

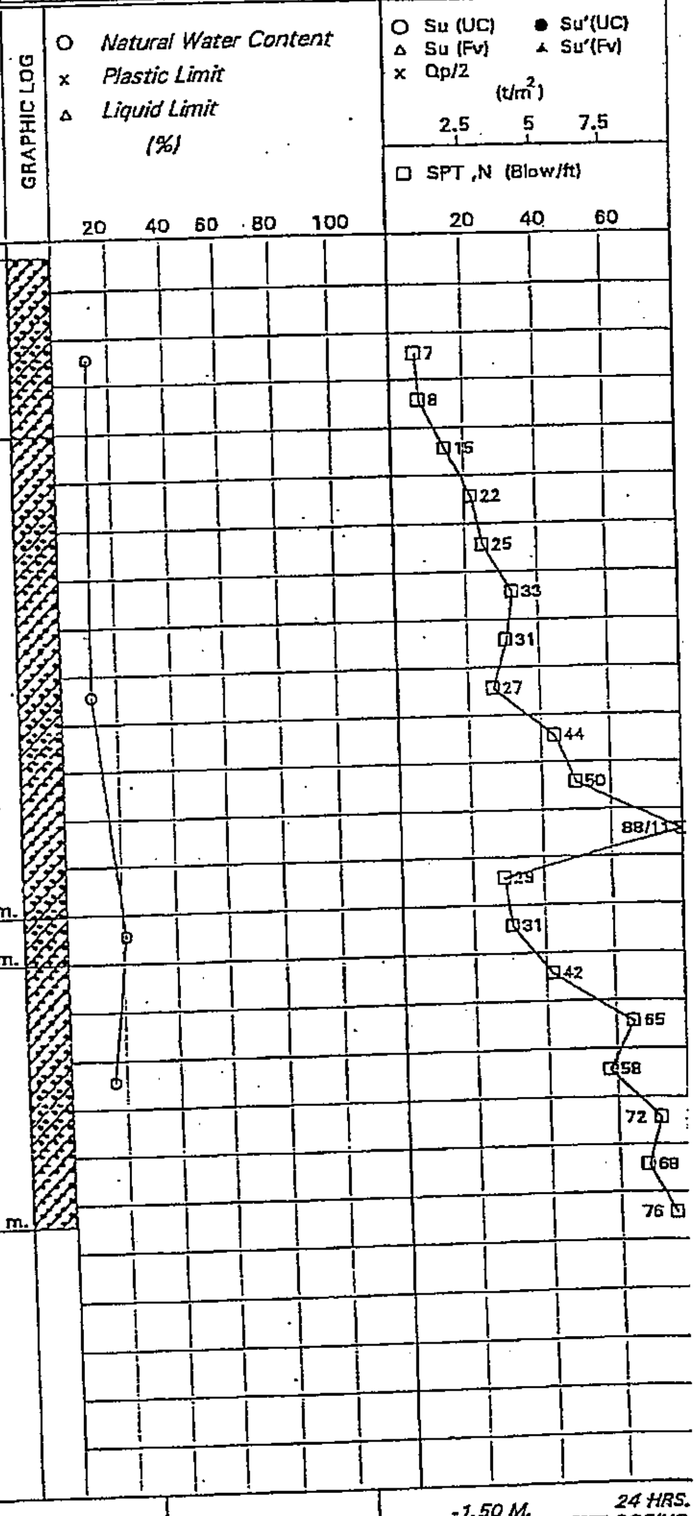
LOG OF BORING No. BH-2

PROJECT : TPP

LOCATION : Rayong Gas Receiving Terminal

CLIENT :

DEPTH,m	SAMPLE No.	TYPE OF SAMPLE	DESCRIPTION OF MATERIAL
0			(A) 0.30 m.
	01	SS	Clayey fine to medium SAND, li-brownish li-grey, loose. (SC)
	02	SS	4.00 m.
	03	SS	
5	04	SS	
	05	SS	
	06	SS	
	07	SS	Clayey fine to coarse SAND, li-grey, medium to very dense. (SC)
	08	SS	
10	09	SS	
	10	SS	
	11	SS	
	12	SS	14.00 m.
	13	SS	(B) 15.00 m.
15	14	SS	
	15	SS	Silty fine to medium sandy CLAY to clayey silty fine to medium SAND, li-grey & yellowish brown & green, very stiff to hard. (Completely Decomposed Granitic Soil) (CL-SC)
	16	SS	
	17	SS	
	18	SS	
20	19	SS	20.45 m.
			END OF BORING
25			(A) Lateritic soil. (B) Clayey medium to coarse SAND trace gravel, white & li-grey, dense. (Altered Granitic Soil) (SC)



STS ENGINEERING CONSULTANTS CO.,LTD.	BORING STARTED. 16/11/94	RIG. ACKER	WL -1.50 M. 24 HRS. AFTER BORING.
	BORING FINISHED. 17/11/94	FOREMAN NW	JOB No. 4956

LOG OF BORING No. BH-3

PROJECT : TPP

LOCATION : Rayong Gas Receiving Terminal

CLIENT :

DEPTH,m	SAMPLE No.	TYPE OF SAMPLE	SPT ,N (Blow/ft)
0			
	01	SS	6
	02	SS	38
	03	SS	34
	04	SS	34
5	05	SS	26
	06	SS	24
	07	SS	30
	08	SS	25
	09	SS	29
10	10	SS	30
	11	SS	35
	12	SS	28
	13	SS	29
	14	SS	31
15	15	SS	28
	16	SS	32
	17	SS	31
	18	SS	26
	19	SS	29
20	20	SS	37
	21	SS	46
	22	SS	65
	23	SS	79
25	24	SS	50/6"

DESCRIPTION OF MATERIAL

Clayey fine to medium SAND, greyish li-brown, loose. (SC) — 2.00 m.

(A) — 3.00 m.

Silty CLAY with pisolitic granule, reddish brown, hard. (CL) — 5.00 m.

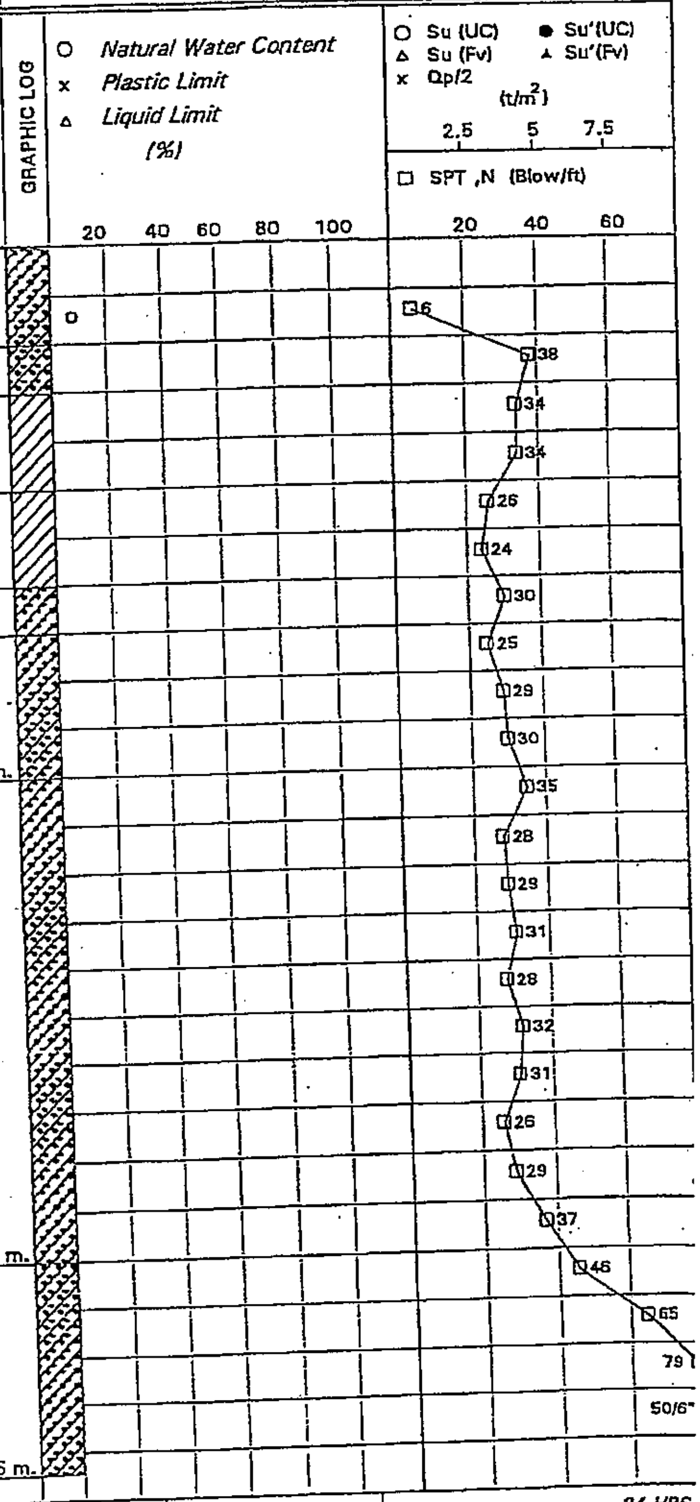
Medium to coarse sandy CLAY with pisolitic granule, li-grey & reddish brown, very stiff. (CL) — 7.00 m.

(B) — 8.00 m.

Clayey fine to coarse SAND trace gravel, white & yellowish brown, medium dense. (Altered Granitic Soil) (SC) — 11.00 m.

Silty fine to medium sandy CLAY to clayey silty fine to medium SAND, white & yellowish brown, very stiff to hard. (Altered Granitic Soil) (CL-SC) — 21.00 m.

Silty fine to medium sandy CLAY to clayey silty fine to medium SAND, green & li-greyish brown, hard. (Completely Decomposed Granitic Soil) (CL-SC) — 25.45 m.



STS ENGINEERING CONSULTANTS CO.,LTD.

BORING STARTED. 11/11/94	RIG. ACKER	WL. -5.4 M. 24 HRS. AFTER BORING.
BORING FINISHED. 15/11/94	FOREMAN NW	JOB No. 4956

LOG OF BORING No. BH-3

PROJECT : TPP

LOCATION : Rayong Gas Receiving Terminal

CLIENT :

DEPTH,m	SAMPLE No.	TYPE OF SAMPLE	SAMPLE DIST / RECOVERY	DESCRIPTION OF MATERIAL	GRAPHIC LOG	○ Natural Water Content × Plastic Limit △ Liquid Limit (%) 20 40 60 80 100	○ Su (UC) ● Su'(UC) △ Su (Fv) ▲ Su'(Fv) × Qp/2 (t/m²) 2.5 5 7.5 ☐ SPT ,N (Blow/ft) 20 40 60
25	25	SS	▨	25.45 m.	▨		50/5" ☐
				END OF BORING			
30							
35							
40							
45							
50							

(A)
Clayey fine to medium SAND with pisolitic granule, reddish brown, dense. (Lateritic soil) (SC)

(B)
Clayey medium to coarse SAND, li-grey & reddish brown, dense. (SC)

STS ENGINEERING CONSULTANTS CO.,LTD.	BORING STARTED. 11/11/94	RIG. ACKER	WL. -5.4 M. 24 HRS. AFTER BORING.
	BORING FINISHED. 15/11/94	FOREMAN NW	JOB No. 4956

STS ENGINEERING CONSULTANTS CO., LTD.

HYDROMETER ANALYSIS

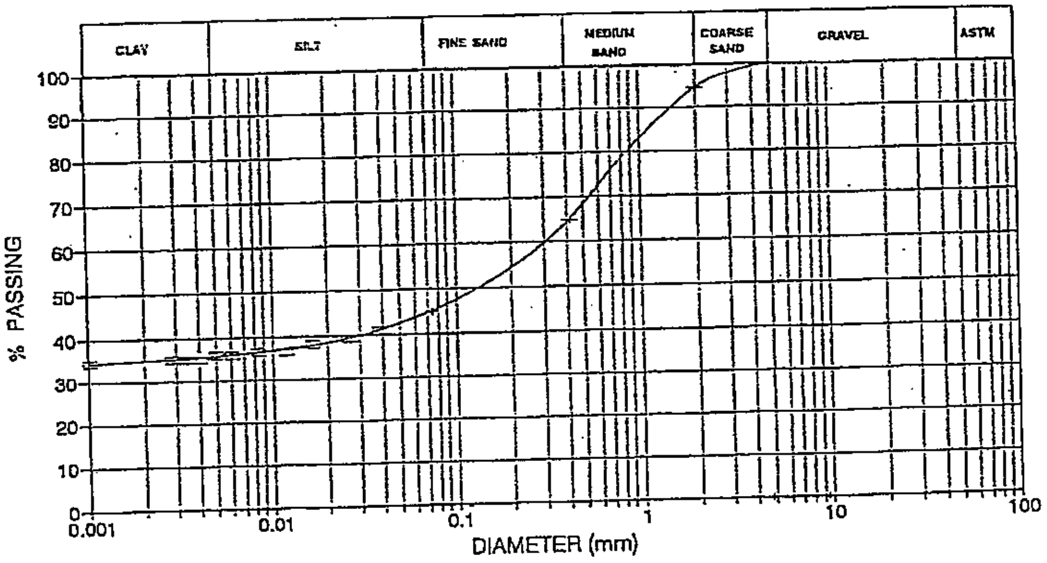
Project: TPP
Borehole: BH - 1 Depth (m) 1.00-1.45
Soil Description: Clayey Sand
% Passing No. 200: 44.8 %
Hydrometer No.: 13
Location: Rayong Gas Receiving Terminal
Sample No.: SS - 1 Job No.: 4956
Tested By: SB Date: 28/11/94
Solid Wt.(g): 50 Gs: 2.64

Date	Time	Elapsed Time (min)	R= 1000(r-1)	Rw= 1000(rw-1)	Temp (C)	Gw (g/cc)	M (gs/cm2)	Zr (cm)	N (%)	Diameter D (mm)	N' (%)
29/11/94		0.15	32.0	2.5	27.0	0.9965	0.000009	9.07	94.6	0.0981	42.4
		0.30	31.5	2.5	27.0	0.9965	0.000009	9.21	93.0	0.0699	41.6
	9.21	1	31.0	2.5	27.0	0.9965	0.000009	9.34	91.4	0.0385	40.9
	9.22	2	30.0	2.5	27.0	0.9965	0.000009	9.60	88.2	0.0276	39.5
	9.25	2	30.0	2.5	27.0	0.9965	0.000009	8.55	88.2	0.0261	39.5
	9.30	5	29.0	2.5	27.0	0.9965	0.000009	8.81	85.0	0.0167	38.1
	9.35	10	28.0	2.5	27.0	0.9965	0.000009	9.08	81.8	0.0120	36.6
	9.45	20	28.0	2.5	27.0	0.9965	0.000009	9.08	81.8	0.0085	36.6
	10.05	40	27.5	2.5	27.0	0.9965	0.000009	9.21	80.2	0.0061	35.9
	10.25	60	27.5	2.5	27.0	0.9965	0.000009	9.21	80.2	0.0049	35.9
	10.55	90	27.0	2.5	27.0	0.9965	0.000009	9.34	78.6	0.0041	35.2
	11.25	120	27.0	2.5	27.0	0.9965	0.000009	9.34	78.6	0.0035	35.2
	11.55	150	27.0	2.5	27.0	0.9965	0.000009	9.34	78.6	0.0031	35.2
	12.25	180	27.0	2.5	27.0	0.9965	0.000009	9.34	78.6	0.0029	35.2
30/11/94	9.00	1420	26.5	2.5	27.0	0.9965	0.000009	9.47	77.0	0.0010	34.5

SIEVE

Weight of Container	14.61	g
Weight of Container÷Dry Soil	191.64	g
Weight of Dry Soil	177.03	g

Sieve No.	Sieve Opening (mm)	Weight of Sieve (g)	Weight of Sieve + Mat. (g)	Weight of Soil Retained (g)	Cumulative Retained (g)	Cumulative Retained (%)	Percent Finer
3/6	9.525			0.00	0.00	0.0	0.0
4	4.760			0.00	0.00	0.0	0.0
10	2.000	525	534.2	9.20	9.20	5.2	94.8
40	0.420	342.4	395.4	53.00	62.20	35.1	64.9
200	0.074	284.0	319.6	35.60	97.80	55.2	44.8
				0.00	0.00	0.0	0.0
				0.00	0.00	0.0	0.0



STS ENGINEERING CONSULTANTS CO., LTD.

HYDROMETER ANALYSIS

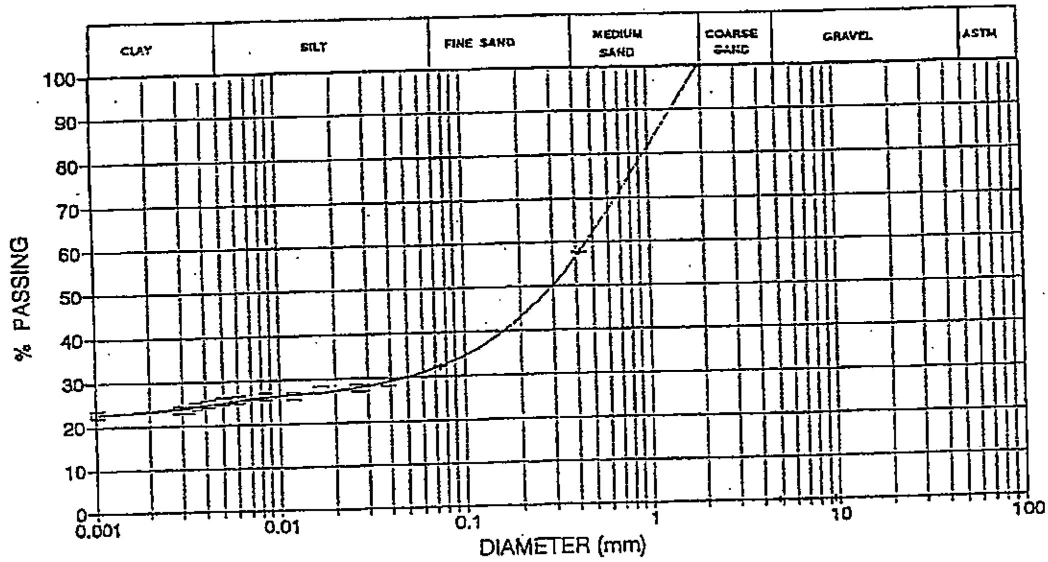
Project:	TPP		Location:	Rayong Gas Receiving Terminal	
Borehole	BH - 2	Depth (m) 2.00-2.45	Sample No.: SS - 1	Job No.:	4956
Soil Description:	Clayey Fine to Medium Sand		Tested By: SB	Date:	28/11/94
% Passing No. 200:	32.1 %	Hydrometer No.: 14	Solid Wt.(g): 50	Gs:	2.64

Date	Time	Elapsed Time (min)	R= 1000(r-1)	Rw= 1000(rw-1)	Temp (C)	Gw (g/cc)	M (gs/cm2)	Zr (cm)	N (%)	Diameter D (mm)	N' (%)
28/11/94		0.15	32.0	2.5	27.0	0.9965	0.000009	9.07	94.6	0.0981	30.4
		0.30	31.0	2.5	27.0	0.9965	0.000009	9.34	91.4	0.0704	29.4
	8.01	1	30.5	2.5	27.0	0.9965	0.000009	9.47	89.8	0.0388	28.8
	8.02	2	29.5	2.5	27.0	0.9965	0.000009	9.73	86.6	0.0278	27.8
	8.05	2	29.5	2.5	27.0	0.9965	0.000009	8.73	86.6	0.0264	27.8
	8.10	5	29.0	2.5	27.0	0.9965	0.000009	8.86	85.0	0.0168	27.3
	8.15	10	28.0	2.5	27.0	0.9965	0.000009	9.13	81.8	0.0120	26.3
	8.25	20	28.0	2.5	27.0	0.9965	0.000009	9.13	81.8	0.0085	26.3
	8.45	40	27.5	2.5	27.0	0.9965	0.000009	9.26	80.2	0.0061	25.8
	9.05	60	27.0	2.5	27.0	0.9965	0.000009	9.39	78.6	0.0050	25.2
	9.35	90	26.5	2.5	27.0	0.9965	0.000009	9.52	77.0	0.0041	24.7
	10.05	120	26.0	2.5	27.0	0.9965	0.000009	9.65	75.4	0.0036	24.2
	10.35	150	25.5	2.5	27.0	0.9965	0.000009	9.78	73.8	0.0032	23.7
	11.05	180	25.5	2.5	27.0	0.9965	0.000009	9.78	73.8	0.0029	23.7
29/11/94	9.00	1500	24.5	2.5	27.0	0.9965	0.000009	10.05	70.6	0.0010	22.7

SIEVE

Weight of Container	15.89	g
Weight of Container+Dry Soil	227.99	g
Weight of Dry Soil	212.10	g

Sieve No.	Sieve Opening (mm)	Weight of Sieve (g)	Weight of Sieve + Mat. (g)	Weight of Soil Retained (g)	Cumulative Retained (g)	Cumulative Retained (%)	Percent Finer
3/8	9.525			0.00	0.00	0.0	0.0
4	4.760			0.00	0.00	0.0	0.0
10	2.000	525	525.6	0.60	0.60	0.3	99.7
40	0.420	342.4	431.4	89.00	89.60	42.2	57.8
200	0.074	284.0	338.4	54.40	144.00	67.9	32.1
				0.00	0.00	0.0	0.0
				0.00	0.00	0.0	0.0



STS ENGINEERING CONSULTANTS CO., LTD.

HYDROMETER ANALYSIS

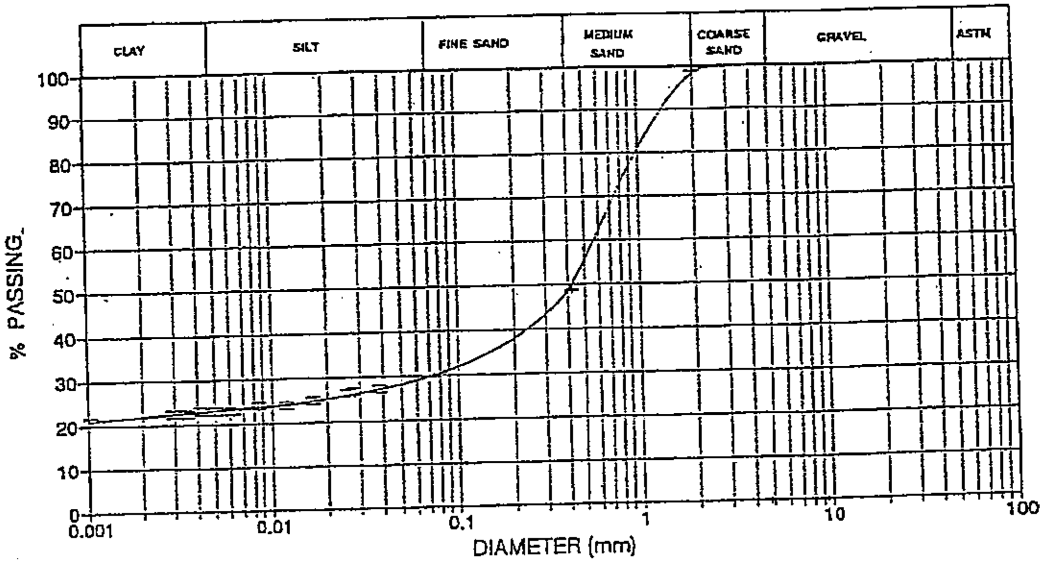
Project:	TPP		Location:	Rayong Gas Receiving Terminal	
Borehole	BH - 2	Depth (m) 9.00 - 9.45	Sample No.: SS - 8	Job No.:	4956
Soil Description:	Clayey Fine to Medium Sand		Tested By: SB	Date:	28/11/94
% Passing No. 200:	29.7 %	Hydrometer No.: 15	Solid Wt.(g): 50	Gs:	2.64

Date	Time	Elapsed Time (min)	R= 1000(r-1)	Rw= 1000(rw-1)	Temp (C)	Gw (g/cc)	M (gs/cm2)	Zr (cm)	N (%)	Diameter D (mm)	N' (%)
28/11/94		0.15	32.0	2.5	27.0	0.9965	0.000009	9.07	94.6	0.0981	28.1
		0.30	31.5	2.5	27.0	0.9965	0.000009	9.21	93.0	0.0699	27.6
	8.11	1	31.0	2.5	27.0	0.9965	0.000009	9.34	91.4	0.0385	27.1
	8.12	2	30.5	2.5	27.0	0.9965	0.000009	9.47	89.8	0.0274	26.7
	8.15	2	30.0	2.5	27.0	0.9965	0.000009	8.61	88.2	0.0262	26.2
	8.20	5	28.5	2.5	27.0	0.9965	0.000009	9.00	83.4	0.0169	24.7
	8.25	10	27.5	2.5	27.0	0.9965	0.000009	9.27	80.2	0.0121	23.8
	8.35	20	27.5	2.5	27.0	0.9965	0.000009	9.27	80.2	0.0086	23.8
	8.55	40	26.5	2.5	27.0	0.9965	0.000009	9.53	77.0	0.0062	22.8
	9.15	60	26.5	2.5	27.0	0.9965	0.000009	9.53	77.0	0.0050	22.8
	9.45	90	26.5	2.5	27.0	0.9965	0.000009	9.53	77.0	0.0041	22.8
	10.15	120	26.0	2.5	27.0	0.9965	0.000009	9.66	75.4	0.0036	22.4
	10.45	150	26.0	2.5	27.0	0.9965	0.000009	9.66	75.4	0.0032	22.4
	11.15	180	26.0	2.5	27.0	0.9965	0.000009	9.66	75.4	0.0029	22.4
29/11/94	9.01	1491	24.5	2.5	27.0	0.9965	0.000009	10.06	70.6	0.0010	20.9

SIEVE

Weight of Container	14.86	g
Weight of Container+Dry Soil	236.24	g
Weight of Dry Soil	221.38	g

Sieve No.	Sieve Opening (mm)	Weight of Sieve (g)	Weight of Sieve + Mat. (g)	Weight of Soil Retained (g)	Cumulative Retained (g)	Cumulative Retained (%)	Percent Finer
3/8	9.525			0.00	0.00	0.0	0.0
4	4.760			0.00	0.00	0.0	0.0
10	2.000	525	527.7	2.70	2.70	1.2	98.8
40	0.420	342.4	452.8	110.40	113.10	51.1	48.9
200	0.074	284.0	326.6	42.60	155.70	70.3	29.7
				0.00	0.00	0.0	0.0
				0.00	0.00	0.0	0.0



STS ENGINEERING CONSULTANTS CO., LTD.

HYDROMETER ANALYSIS

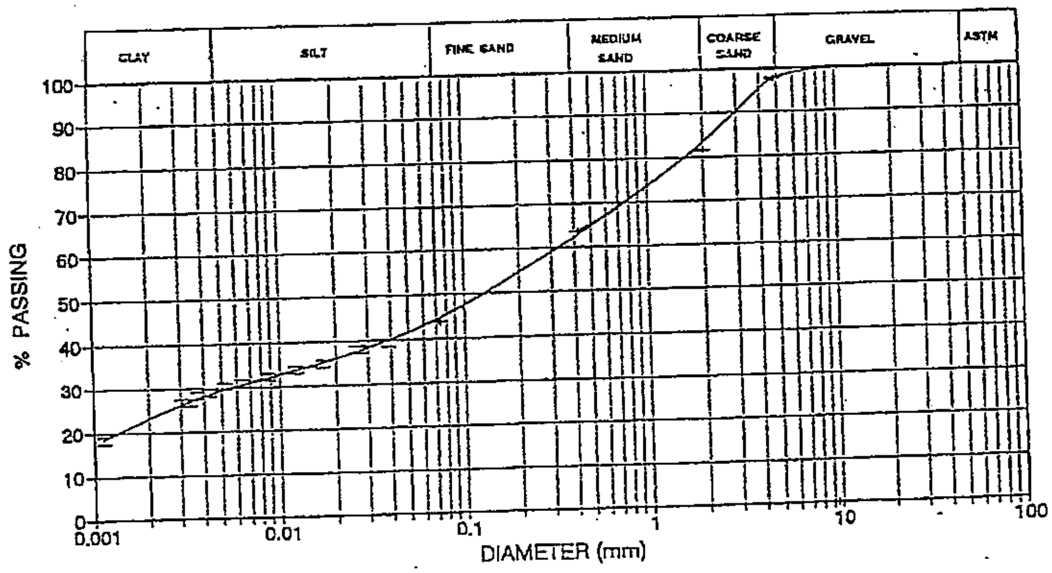
Project: TPP
Borehole: BH - 2 Depth (m) 14.00 - 14.45
Soil Description: Clayey Sand
% Passing No. 200: 43.6 % Hydrometer No.: 9
Location: Rayong Gas Receiving Terminal
Sample No.: SS -13 Job No.: 4956
Tested By: SB Date: 28/11/94
Solid Wt.(g): 50 Gs: 2.63

Date	Time	Elapsed Time (min)	R= 1000(r-1)	Rw= 1000(rw-1)	Temp (C)	Gw (g/cc)	M (gs/cm2)	Zr (cm)	N (%)	Diameter D (mm)	N' (%)
28/11/94		0.15	31.5	2.5	27.0	0.9965	0.000009	9.21	93.3	0.0991	40.7
		0.30	31.5	2.5	27.0	0.9965	0.000009	9.21	93.3	0.0701	40.7
	8.21	1	30.5	2.5	27.0	0.9965	0.000009	9.47	90.0	0.0389	39.3
	8.22	2	29.5	2.5	27.0	0.9965	0.000009	9.73	86.8	0.0279	37.9
	8.25	2	29.5	2.5	27.0	0.9965	0.000009	8.64	86.8	0.0263	37.9
	8.30	5	27.5	2.5	27.0	0.9965	0.000009	9.17	80.4	0.0171	35.1
	8.35	10	26.5	2.5	27.0	0.9965	0.000009	9.43	77.2	0.0123	33.7
	8.45	20	25.5	2.5	27.0	0.9965	0.000009	9.69	74.0	0.0088	32.3
	9.05	40	24.5	2.5	27.0	0.9965	0.000009	9.96	70.7	0.0063	30.9
	9.25	60	24.0	2.5	27.0	0.9965	0.000009	10.09	69.1	0.0052	30.2
	9.55	90	23.0	2.5	27.0	0.9965	0.000009	10.35	65.9	0.0043	28.8
	10.25	120	22.5	2.5	27.0	0.9965	0.000009	10.48	64.3	0.0037	28.1
	10.55	150	21.5	2.5	27.0	0.9965	0.000009	10.75	61.1	0.0034	26.6
	11.25	180	21.5	2.5	27.0	0.9965	0.000009	10.75	61.1	0.0031	26.6
29/11/94	9.02	1482	15.5	2.5	27.0	0.9965	0.000009	12.32	41.8	0.0012	18.2

SIEVE

Weight of Container	17.40	g
Weight of Container÷Dry Soil	205.57	g
Weight of Dry Soil	188.17	g

Sieve No.	Sieve Opening (mm)	Weight of Sieve (g)	Weight of Sieve + Mat. (g)	Weight of Soil Retained (g)	Cumulative Retained (g)	Cumulative Retained (%)	Percent Finer
3/8	9.525			0.00	0.00	0.0	0.0
4	4.760	580.7	584.8	4.10	4.10	2.2	97.8
10	2.000	525	555.2	30.20	34.30	18.2	81.8
40	0.420	342.4	376.3	33.90	68.20	36.2	63.8
200	0.074	284.0	321.9	37.90	106.10	56.4	43.6
				0.00	0.00	0.0	0.0
				0.00	0.00	0.0	0.0



STS ENGINEERING CONSULTANTS CO., LTD.

HYDROMETER ANALYSIS

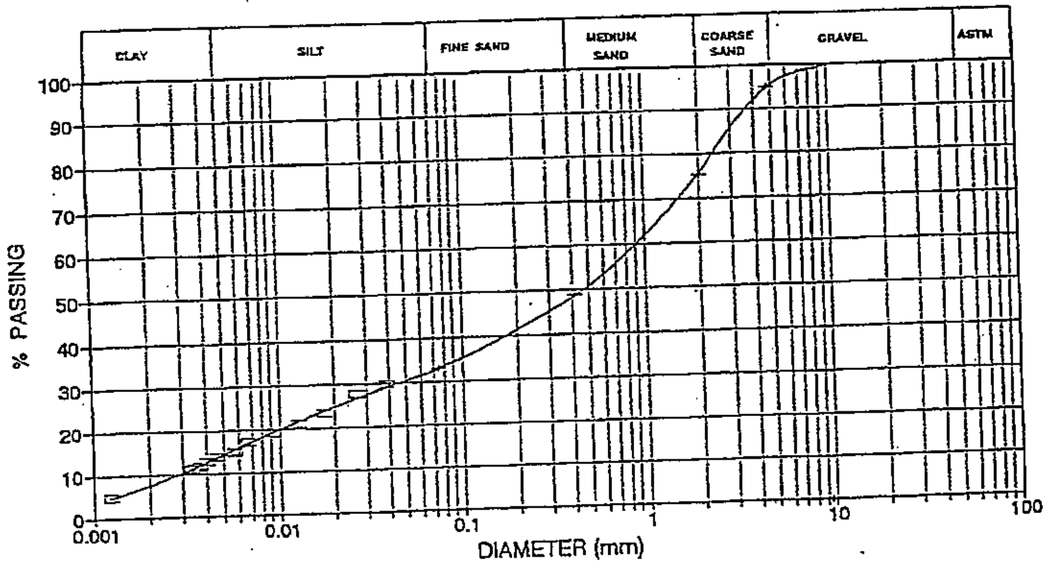
Project: TPP
Borehole: BH - 2 Depth (m) 17.00 - 17.45
Soil Description: Clayey Sand
% Passing No. 200: 33.0 % Hydrometer No.: 3
Location: Rayong Gas Receiving Terminal
Sample No.: SS - 16 Job No.: 4956
Tested By: SB Date: 28/11/94
Solid Wt.(g): 50 Gs: 2.65

Date	Time	Elapsed Time (min)	R= 1000(r-1)	Rw= 1000(rw-1)	Temp (C)	Gw (g/cc)	M (gs/cm2)	Zr (cm)	N (%)	Diameter D (mm)	N' (%)
28/11/94		0.15	32.0	2.5	27.0	0.9965	0.000009	9.07	94.4	0.0978	31.2
		0.30	31.5	2.5	27.0	0.9965	0.000009	9.21	92.8	0.0697	30.6
	8.31	1	30.5	2.5	27.0	0.9965	0.000009	9.47	89.6	0.0387	29.6
	8.32	2	28.5	2.5	27.0	0.9965	0.000009	9.99	83.2	0.0281	27.5
	8.35	2	28.5	2.5	27.0	0.9965	0.000009	8.88	83.2	0.0265	27.5
	8.40	5	24.5	2.5	27.0	0.9965	0.000009	9.94	70.4	0.0177	23.2
	8.45	10	22.5	2.5	27.0	0.9965	0.000009	10.46	64.0	0.0129	21.1
	8.55	20	20.5	2.5	27.0	0.9965	0.000009	10.99	57.6	0.0093	19.0
	9.15	40	18.5	2.5	27.0	0.9965	0.000009	11.51	51.2	0.0067	16.9
	9.35	60	16.5	2.5	27.0	0.9965	0.000009	12.04	44.8	0.0056	14.8
	10.05	90	15.5	2.5	27.0	0.9965	0.000009	12.30	41.6	0.0046	13.7
	10.35	120	14.5	2.5	27.0	0.9965	0.000009	12.57	38.4	0.0041	12.7
	11.05	150	13.5	2.5	27.0	0.9965	0.000009	12.83	35.2	0.0037	11.6
	11.35	180	13.0	2.5	27.0	0.9965	0.000009	12.96	33.6	0.0034	11.1
29/11/94	9.03	1473	7.0	2.5	27.0	0.9965	0.000009	14.54	14.4	0.0012	4.8

SIEVE

Weight of Container	21.27	g
Weight of Container+Dry Soil	223.35	g
Weight of Dry Soil	202.08	g

Sieve No.	Sieve Opening (mm)	Weight of Sieve (g)	Weight of Sieve + Mat. (g)	Weight of Soil Retained (g)	Cumulative Retained (g)	Cumulative Retained (%)	Percent Finer
3/8	9.525			0.00	0.00	0.0	0.0
4	4.760	580.7	590.7	10.00	10.00	4.9	95.1
10	2.000	525	564.8	39.80	49.80	24.6	75.4
40	0.420	342.4	396.0	53.50	103.40	51.2	48.8
200	0.074	284.0	316.0	32.00	135.40	67.0	33.0
				0.00	0.00	0.0	0.0
				0.00	0.00	0.0	0.0



STS ENGINEERING CONSULTANTS CO., LTD.

HYDROMETER ANALYSIS

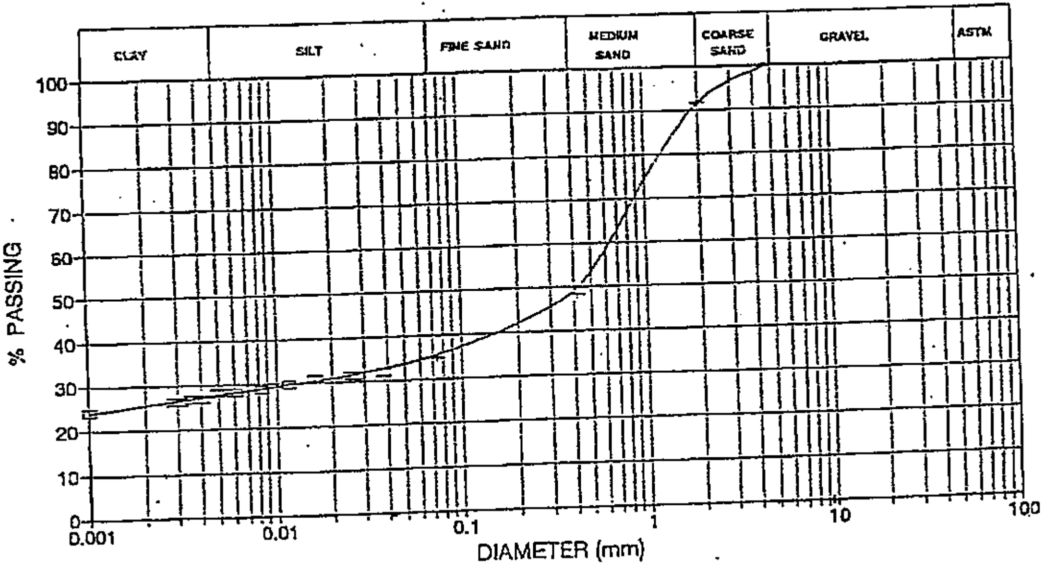
Project: TPP
Borehole: BH - 3 Depth (m) 1.00-1.45
Soil Description: Clayey Sand
% Passing No. 200: 34.8 % Hydrometer No.: 12
Location: Rayong Gas Receiving Terminal
Sample No.: SS - 1 Job No.: 4956
Tested By: SB Date: 29/11/94
Solid Wt.(g): 50 Gs: 2.64

Date	Time	Elapsed Time (min)	R= 1000(r-1)	Rw= 1000(rw-1)	Temp (C)	Gw (g/cc)	M (gs/cm2)	Zr (cm)	N (%)	Diameter D (mm)	N' (%)
29/11/94		0.15	31.5	2.5	27.0	0.9965	0.000009	9.21	93.0	0.0988	32.4
		0.30	31.5	2.5	27.0	0.9965	0.000009	9.21	93.0	0.0699	32.4
	8.01	1	31.0	2.5	27.0	0.9965	0.000009	9.34	91.4	0.0385	31.8
	8.02	2	30.5	2.5	27.0	0.9965	0.000009	9.47	89.8	0.0274	31.3
	8.05	2	30.5	2.5	27.0	0.9965	0.000009	8.24	89.8	0.0256	31.3
	8.10	5	30.0	2.5	27.0	0.9965	0.000009	8.37	88.2	0.0163	30.7
	8.15	10	29.0	2.5	27.0	0.9965	0.000009	8.63	85.0	0.0117	29.6
	8.25	20	28.0	2.5	27.0	0.9965	0.000009	8.90	81.8	0.0084	28.5
	8.45	40	27.5	2.5	27.0	0.9965	0.000009	9.03	80.2	0.0060	27.9
	9.05	60	27.5	2.5	27.0	0.9965	0.000009	9.03	80.2	0.0049	27.9
	9.35	90	26.5	2.5	27.0	0.9965	0.000009	9.29	77.0	0.0041	26.8
	10.05	120	26.5	2.5	27.0	0.9965	0.000009	9.29	77.0	0.0035	26.8
	10.35	150	26.0	2.5	27.0	0.9965	0.000009	9.42	75.4	0.0032	26.2
	11.05	180	26.0	2.5	27.0	0.9965	0.000009	9.42	75.4	0.0029	26.2
30/11/94	9.00	1500	24.0	2.5	27.0	0.9965	0.000009	9.95	69.0	0.0010	24.0

SIEVE

Weight of Container	15.47	g
Weight of Container+Dry Soil	169.92	g
Weight of Dry Soil	154.45	g

Sieve No.	Sieve Opening (mm)	Weight of Sieve (g)	Weight of Sieve + Mat. (g)	Weight of Soil Retained (g)	Cumulative Retained (g)	Cumulative Retained (%)	Percent Finer
3/8	9.525			0.00	0.00	0.0	0.0
4	4.760			0.00	0.00	0.0	0.0
10	2.000	525	537.7	12.70	12.70	8.2	91.8
40	0.420	342.4	409.5	67.10	79.80	51.7	46.3
200	0.074	284.0	304.9	20.90	100.70	65.2	34.8
				0.00	0.00	0.0	0.0
				0.00	0.00	0.0	0.0



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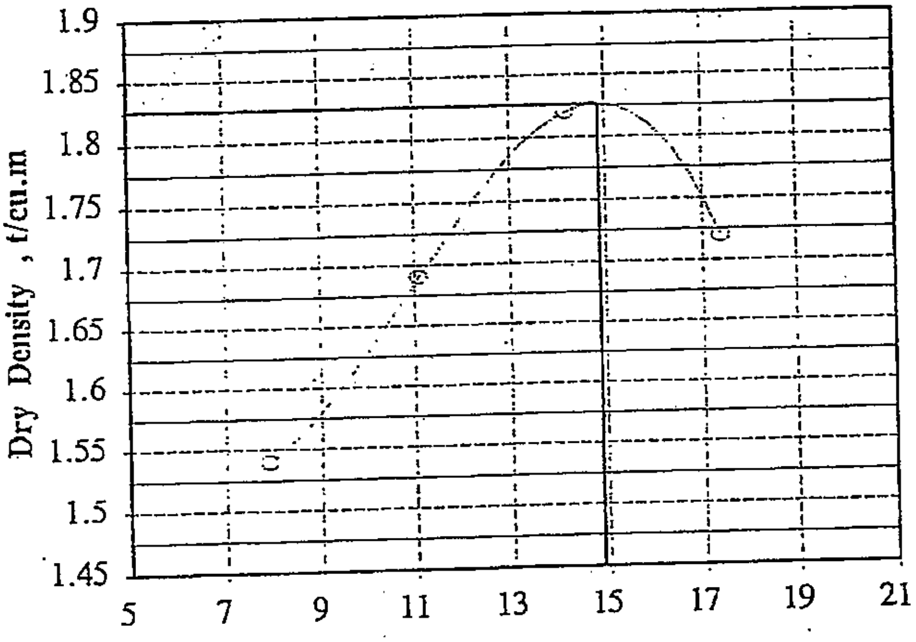
MOISTURE DENSITY RELATIONS OF SOILS

Project :	TPP	STS Job No. :	4956
Location :	Rayong Gas Receiving Terminal	Source :	TP-1 (BH-2)
Date :	28/11/94	Owner :	
Client :		Tested by :	CS



WATER CONTENT-PERCENT OF DRY WEIGHT

Test Procedure Used : ASTM - 1557

Test Result :

Maximum Dry Density 1.83 t/cu.m

Optimum Water Content 14.9 %

Soil Type	Clayey Sand
Liquid Limit	41.5 %
Plastic Limit	16.3 %
Plasticity Index	25.2 %
Specific Gravity	2.63

Remark : Certified The Sample Received Only

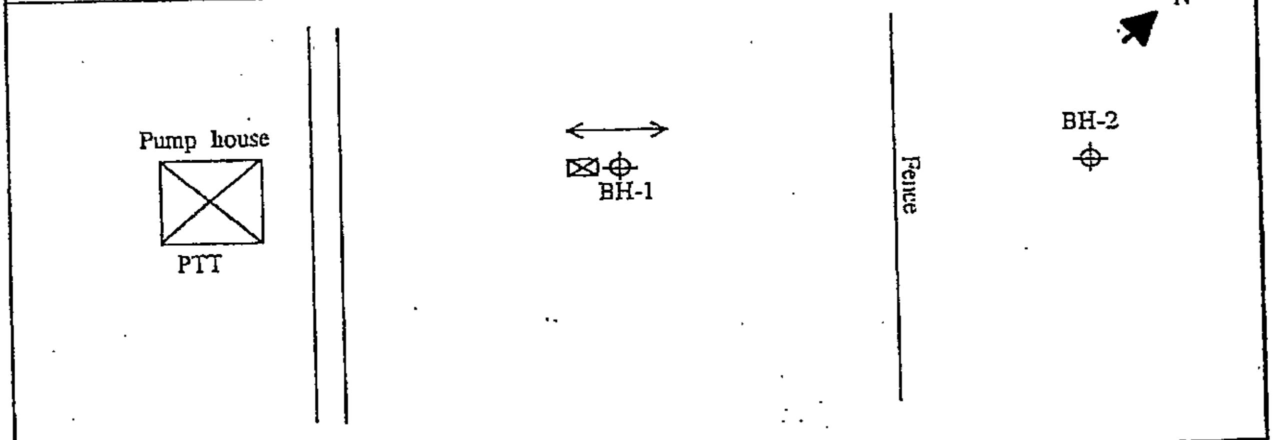
STS ENGINEERING CONSULTANTS CO., LTD.

SOIL RESISTIVITY TEST

Measurement of soil resistivity Four-electrode method (wenner method)	@ BH-1	Station N 2400.162 , E 2040.163	Test No. : 1 Job no. : 4956

Project : TPP

Location : Rayong Gas Receiving Terminal



Measuring Section :	$\rho = 2 \pi a R$			Measuring instrument :
a in m	$2 \pi a$ in m	R in Ohms	ρ in Ohm m	Place of measurement/remarks
0.5	3.14	282 x 0.1	88.54	
1	6.28	113 x 0.1	70.96	
2	12.56	057 x 0.1	71.59	
3	18.84	045 x 0.1	84.78	
4	25.13	039 x 0.1	98.00	
5	31.41	031 x 0.1	97.37	
6	37.69	032 x 0.1	120.60	
7	43.98	016 x 0.1	70.36	
8	50.26	006 x 0.1	30.15	
9	56.54	033 x 0.01	18.65	
10	62.53	005 x 0.01	3.14	
20				

Soil Type Depth 0.00-0.30 Lateritic soil (Fill)

Depth 0.30 -10.00 Clayey sand

Weather : Temperature : Time :

Supervisor : Sign : Date : 22/11/94

Customer/ Consultant : Sign : Date :

STS ENGINEERING CONSULTANTS CO., LTD.

SOIL RESISTIVITY TEST

Measurement of soil resistivity Four-electrode method (wenner method)	Station @BH-5;N 1486842.592.E 723431.386	Test No. : 2 Job no. : 4956

Project : TPP

Location : Bang-Pakong Compressor Station

Measuring Section :	$\rho = 2\pi a R$			Measuring instrument :
a in m	$2\pi a$ in m	R in Ohms	ρ in Ohm m	Place of measurement/remarks
0.5	3.14	269x0.01	8.45	
1	6.28	127x0.01	7.98	
1.5	9.42	060x0.01	5.65	
2	12.57	036x0.01	4.52	
3	18.85	016x0.01	3.02	
4	25.13	008x0.01	2.01	
5	31.42	Very low		
6	37.70	Very low		
7	43.98	Very low		

Soil Type Soft clay

Weather :	Temperature :	Time :
Supervisor :	Sign :	Date : 07/12/94
Customer/ Consultant :	Sign :	Date :

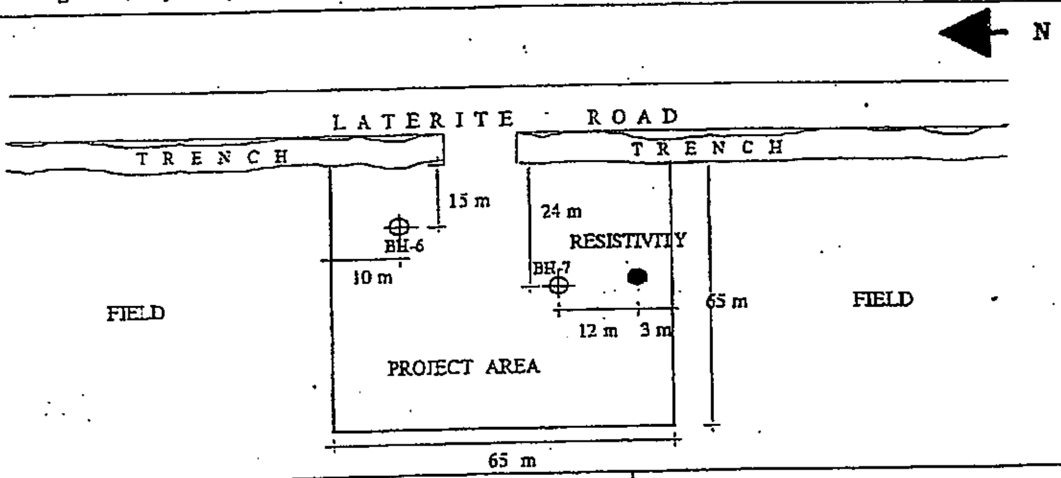
STS ENGINEERING CONSULTANTS CO., LTD.

SOIL RESISTIVITY TEST

Measurement of soil resistivity Four-electrode method (wenner method)	Station @ BH-7 ; N 1415.331 , E 739.241	Test No. : 1 Job no. : 5170

Project : TPP

Location : Wang Noi, Ayutthaya Province



Measuring Section :	$p = 2\pi a R$			Measuring instrument :
a in m	$2\pi a$ in m	R in Ohms	p in Ohm m	Place of measurement/remarks
1	6.28	148 x 0.01	9.30	
2	12.57	054 x 0.01	6.79	
3	18.85	029 x 0.01	5.47	
4	25.13	019 x 0.01	4.78	
5	31.42	002 x 0.1	6.28	
6	37.70	002 x 0.1	7.54	
7	43.98	001 x 0.1	4.40	
8	50.27	001 x 0.1	5.03	
9	56.55	009 x 1	508.94	
10	62.83	009 x 1	565.49	
20	125.66	004 x 1	502.65	

Soil Type :

Weather :	Temperature :	Time :
Supervisor :	Sign :	Date : 08/04/95
Customer/ Consultant :	Sign :	Date :

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SUMMARY OF CHEMICAL TEST RESULT

Borehole No.	Sample No.	Depth, m	pH	Cl ppm	Suluble-$So^{=}_4$ ppm	Cabornate Content $CO^{=}_3$ meq/100gm
BH-1	SS-1	1.00 - 1.45	7.7	673	89	0.390
BH-2	SS-1	2.00 - 2.45	4.8	7	6	Very low
BH-3	SS-1	1.00 - 1.45	8.1	867	81	0.200
BH-4	SS-1	1.00 - 1.45	7.8	650	447	2.250
BH-5	SS-1	1.00 - 1.45	7.5	545	406	1.000

SUMMARY OF CHEMICAL TEST RESULTS

BOREHOLE NO.	*SAMPLE NO.*	*DEPTH (M)*	*pH*	*Cl^- (ppm)*	*SULPHATE (SOIL : WATER, 1:2)*	
					%	*g / litter*
BH-6	SS-1	1.00-1.45	7.2	88.4	0.0089	0.0524

B

Table Calculation of Footing Bearing Pressure

BH-1

Depth of Footing (ft)		Df:		0 ft			3.3 ft (1 m)			6.6 ft (2 m)		
Depth D (ft)	N val (-)	B ft	B m	N for qa (-)	Kd (-)	qa tsf	N for qa (-)	Kd (-)	qa tsf	N for qa (-)	Kd (-)	qa tsf
4.3	9	3.3	1.0	18.5	1.0	3.4	31.9	1.3	7.9	43.3	1.33	10.7
7.5	12	4.9	1.5	23.4	1.0	3.9	35.6	1.2	5.9	42.5	1.33	7.3
10.8	26	6.6	2.0	27.5	1.0	4.2	36.5	1.2	5.7	40.4	1.3	6.9
14.1	16	8.2	2.5	29.3	1.0	4.3	35.2	1.1	5.3	37.9	1.3	6.2
17.4	22	9.8	3.0	29.5	1.0	4.2	33.4	1.1	5.0	35.0	1.2	5.6
20.7	35	13.1	4.0	27.4	1.0	3.7	29.6	1.1	4.4	31.4	1.2	4.9
24.0	56	16.4	5.0	26.1	1.0	3.4	28.8	1.1	4.2	31.1	1.1	4.7
27.2	55											
30.5	40											
33.8	35											
37.1	25											
40.4	20											
43.6	26											
46.9	34											
50.2	34											
53.5	50											
56.8	62											
60.0	50											
63.3	65											
66.6	66											

Note:

D : Depth of SPT test
N : SPT N value
B : Width of footing
N for qa: Average of N value in a zone of 0.5 B above to 2 B below the footing base, used for qa calculation
qa : Allowable bearing pressure on footing
Kd : Coefficient of footing depth, Kd = 1 - 1.33

Table Calculation of Footing Bearing Pressure

BB-2

Depth of Footing (ft)		Df:		0 ft			3.3 ft (1 m)			6.6 ft (2 m)		
Depth D (ft)	N val (-)	B ft	B m	N for qa (-)	Kd (-)	qa tsf	N for qa (-)	Kd (-)	qa tsf	N for qa (-)	Kd (-)	qa tsf
4.3	0	3.3	1.0	0.0	1.0	0.0	2.8	1.3	0.7	6.0	1.33	1.5
7.5	7	4.9	1.5	1.9	1.0	0.3	4.0	1.2	2.2	8.0	1.33	1.6
10.8	8	6.6	2.0	3.0	1.0	0.5	6.0	1.2	2.2	10.4	1.3	2.1
14.1	15	8.2	2.5	4.8	1.0	0.7	8.3	1.1	2.2	12.3	1.3	2.3
17.4	22	9.8	3.0	6.9	1.0	1.0	10.3	1.1	2.3	14.7	1.2	2.7
20.7	25	13.1	4.0	7.7	1.0	1.0	14.1	1.1	3.0	16.8	1.2	2.8
24.0	33	16.4	5.0	8.8	1.0	1.2	17.0	1.1	3.3	21.0	1.1	3.3
27.2	31											
30.5	27											
33.8	44											
37.1	50											
40.4	88											
43.6	29											
46.9	31											
50.2	42											
53.5	65											
56.8	58											
60.0	72											
63.3	68											
66.6	76											

Note:

D : Depth of SPT test

N : SPT N value

B : Width of footing

N for qa: Average of N value in a zone of 0.5 B above to 2 B below the footing base, used for qa calculation

qa : Allowable bearing pressure on footing

Kd : Coefficient of footing depth, Kd = 1 - 1.33

Table Calculation of Footing Bearing Pressure

BH-3

Depth of Footing (ft)		Df:		0 ft			3.3 ft (1 m)			6.6 ft (2 m)		
Depth D (ft)	N val (-)	B ft	B m	N for qa (-)	Kd (-)	qa tsf	N for qa (-)	Kd (-)	qa tsf	N for qa (-)	Kd (-)	qa tsf
4.3	6.0	3.3	1.0	4.8	1.0	0.9	17.6	1.3	4.4	30.0	1.33	7.4
7.5	38.0	4.9	1.5	13.3	1.0	2.2	20.8	1.2	3.8	29.5	1.33	5.3
10.8	34.0	6.6	2.0	16.8	1.0	2.6	22.4	1.2	3.8	27.6	1.3	5.0
14.1	34.0	8.2	2.5	18.9	1.0	2.8	22.1	1.1	3.6	26.2	1.3	4.5
17.4	26.0	9.8	3.0	19.2	1.0	2.7	21.6	1.1	3.4	26.0	1.2	4.4
20.7	24.0	13.1	4.0	16.8	1.0	2.3	21.7	1.1	3.5	25.2	1.2	4.0
24.0	30.0	16.4	5.0	15.8	1.0	2.1	22.1	1.1	3.6	25.4	1.1	3.9
27.2	25.0											
30.5	29.0											
33.8	30.0											
37.1	35.0											
40.4	28.0											
43.6	29.0											
46.9	31.0											
50.2	28.0											
53.5	32.0											
56.8	31.0											
60.0	26.0											
63.3	29.0											
66.6	37.0											

Note:

D	:	Depth of SPT test
N	:	SPT N value
B	:	Width of footing
N for qa	:	Average of N value in a zone of 0.5 B above to 2 B below the footing base, used for qa calculation
qa	:	Allowable bearing pressure on footing
Kd	:	Coefficient of footing depth, Kd = 1 - 1.33

Calculation
No.1

Borehole
BH-1

Bearing Capacity on Vertical Compression Load

Soil Parameters	1	2	3	4	5
γ , psf	107	113	113	113	125
φ , deg	33	25	41	40.5	40.6

Pile Cross-Section (in) : 7.87 x 7.87 (0.2 m x 0.2 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
							Layer 1 (loose to medium dense clayey sand)										
0.66	-	4.3	9	2.3	20.7		33	0.5	107	0.2	6.6	0.02	0.4				
0.66	-	7.5	12	1.82	21.8		33.5	0.4	107	0.36	3.3	0.04	0.3				
										Subtotal			0.7				
							Layer 2 (lateritic sandy/silty clay)										
0.66	-	10.8	26	1.58	41.1		39	0.4	113	0.52	3.3	0.65	5.6				
0.66	-	14.1	16	1.43	22.9		34	0.4	113	0.64	3.3	0.58	5.0				
0.66	-	17.4	22	1.31	28.8		35.5	0.4	113	0.71	3.3	0.63	5.4				
0.66	-	20.7	35	1.23	43.1		39.5	0.4	113	0.79	3.3	0.71	6.1				
										Subtotal			22.1				
					Layer 3 (altered granitic medium to very dense clayey sand)												
0.66	25.3	24	56	1.15	50.0	47.7	41	0.3	113	0.86	3.3	0.26	2.2	27	0.7	51	25
0.66	28.5	27.2	55	1.1	50.0	33.3	41	0.3	113	0.93	3.3	0.28	2.4	45	0.8	71	35
0.66	31.8	30.5	40	1.05	42.0	42.3	41	0.3	113	1.01	3.3	0.3	2.6	68	0.9	97	48
										Subtotal			7.2				
						Layer 4 (altered granitic silty/sandy clay to clayey/silty sand)											
0.66	35.1	33.8	35	1	35.0	33.6	37	0.4	113	1.08	3.3	0.32	2.8	54	1.0	86	42
0.66	38.4	37.1	25	0.95	23.8	25.7	34.5	0.4	113	1.16	3.3	0.34	3.0	41	1.1	76	37
0.66	41.7	40.4	20	0.92	18.4	21.8	32.5	0.5	113	1.23	3.3	0.36	3.1	35	1.2	73	36
0.66	44.9	43.6	26	0.89	23.1	23.7	34	0.4	113	1.3	3.3	0.39	3.3	38	1.3	79	39
0.66	48.2	46.9	34	0.87	29.6	27.2	36	0.4	113	1.38	3.3	0.41	3.6	44	1.4	88	43
0.66	51.5	50.2	34	0.85	28.9	33.3	35.5	0.4	113	1.45	3.3	0.43	3.7	54	1.5	101	50
											Subtotal		19.5				
					Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand												
0.66	54.8	53.7	50	0.83	41.5	40.1	39	0.4	125	1.53	3.3	0.46	4.0	64	1.6	116	57
0.66	58.1	56.8	62	0.81	50.0	47.2	41	0.3	125	1.63	3.3	0.49	4.2	76	1.7	132	65
0.66	61.4	60	50	0.79	50.0	50.0	41	0.3	125	1.72	3.3	0.51	4.4	80	1.8	141	69
0.66	64.6	63.3	65	0.77	50.0	50.0	41	0.3	125	1.81	3.3	0.54	4.7	80	1.9	145	72
0.66	67.9	66.6	66	0.74	50.0	50.0	41	0.3	125	1.9	3.3	0.57	4.9	80	2.0	150	74

Note:
d : Size of pile cross-section
N : SPT N value
CN : Correction coefficient to N value for overburden pressure
N corr: Corrected N value
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile

Calculation
No.2

Bearing Capacity on Vertical Compression Load

Borehole
BH-1

Soil Parameters	1	2	3	4	5
γ , psf	107	113	113	113	125
ϕ , deg	33	25	41	40.5	40.6

Pile Cross-Section (in) : 9.84 x 9.84 (0.25 m x 0.25 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	ϕ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
0.82	-	4.3	9	2.3	20.7		33	0.5	107	0.2	6.6	0.02	0.5				
0.82	-	7.5	12	1.82	21.8		33.5	0.4	107	0.36	3.3	0.04	0.4				
										Subtotal			0.9				
Layer 2 (lateritic sandy/silty clay)																	
0.82	-	10.8	26	1.58	41.1		39	0.4	113	0.52	3.3	0.65	7.0				
0.82	-	14.1	16	1.43	22.9		34	0.4	113	0.64	3.3	0.58	6.2				
0.82	-	17.4	22	1.31	28.8		35.5	0.4	113	0.71	3.3	0.63	6.7				
0.82	-	20.7	35	1.23	43.1		39.5	0.4	113	0.79	3.3	0.71	7.6				
										Subtotal			27.6				
Layer 3 (altered granitic medium to very dense clayey sand)																	
0.82	25.3	24	56	1.15	50.0	47.7	41	0.3	113	0.86	3.3	0.26	2.8	34	1.2	64	31
0.82	28.5	27.2	55	1.1	50.0	33.3	41	0.3	113	0.93	3.3	0.28	3.0	56	1.3	89	44
0.82	31.8	30.5	40	1.05	42.0	42.3	41	0.3	113	1.01	3.3	0.3	3.2	106	1.5	142	70
										Subtotal			9.0				
Layer 4 (altered granitic silty/sandy clay to clayey/silty sand)																	
0.82	35.1	33.8	35	1	35.0	33.6	37	0.4	113	1.08	3.3	0.32	3.5	84	1.6	124	61
0.82	38.4	37.1	25	0.95	23.8	25.7	34.5	0.4	113	1.16	3.3	0.34	3.7	65	1.8	107	53
0.82	41.7	40.4	20	0.92	18.4	21.8	32.5	0.5	113	1.23	3.3	0.36	3.9	55	1.9	101	50
0.82	44.9	43.6	26	0.89	23.1	23.7	34	0.4	113	1.3	3.3	0.39	4.2	59	2.1	110	54
0.82	48.2	46.9	34	0.87	29.6	27.2	36	0.4	113	1.38	3.3	0.41	4.4	68	2.2	123	61
0.82	51.5	50.2	34	0.85	28.9	33.3	35.5	0.4	113	1.45	3.3	0.43	4.7	84	2.4	143	70
												Subtotal	24.4				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
0.82	54.8	53.7	50	0.83	41.5	40.1	39	0.4	125	1.53	3.3	0.46	5.0	101	2.5	165	81
0.82	58.1	56.8	62	0.81	50.0	47.2	41	0.3	125	1.63	3.3	0.49	5.2	118	2.7	188	93
0.82	61.4	60	50	0.79	50.0	50.0	41	0.3	125	1.72	3.3	0.51	5.5	125	2.8	200	99
0.82	64.6	63.3	65	0.77	50.0	50.0	41	0.3	125	1.81	3.3	0.54	5.8	125	3.0	206	101
0.82	67.9	66.6	66	0.74	50.0	50.0	41	0.3	125	1.9	3.3	0.57	6.1	125	3.1	212	104

Note:
d : Size of pile cross-section
N : SPT N value
CN : Correction coefficient to N value for overburden pressure
N corr: Corrected N value
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile

Calculation
No.3

Borehole
BH-1

Bearing Capacity on Vertical Compression Load

Soil Parameters	1	2	3	4	5
γ , psf	107	113	113	113	125
φ , deg	33	25	41	40.5	40.6

Pile Cross-Section (in) : 11.8 x 11.8 (0.3 m x 0.3 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
0.98	-	4.3	9	2.3	20.7		33	0.5	107	0.2	6.6	0.02	0.6				
0.98	-	7.5	12	1.82	21.8		33.5	0.4	107	0.36	3.3	0.04	0.5				
Subtotal													1.0				
Layer 2 (lateritic sandy/silty clay)																	
0.98	-	10.8	26	1.58	41.1		39	0.4	113	0.52	3.3	0.65	8.4				
0.98	-	14.1	16	1.43	22.9		34	0.4	113	0.64	3.3	0.58	7.5				
0.98	-	17.4	22	1.31	28.8		35.5	0.4	113	0.71	3.3	0.63	8.1				
0.98	-	20.7	35	1.23	43.1		39.5	0.4	113	0.79	3.3	0.71	9.1				
Subtotal													33.1				
Layer 3 (altered granitic medium to very dense clayey sand)																	
0.98	25.3	24	56	1.15	50.0	47.7	41	0.3	113	0.86	3.3	0.26	3.3	40	1.7	76	37
0.98	28.5	27.2	55	1.1	50.0	33.3	41	0.3	113	0.93	3.3	0.28	3.6	67	1.9	106	52
0.98	31.8	30.5	40	1.05	42.0	42.3	41	0.3	113	1.01	3.3	0.3	3.9	137	2.1	180	89
Subtotal													10.8				
Layer 4 (altered granitic silty/sandy clay to clayey/silty sand)																	
0.98	35.1	33.8	35	1	35.0	33.6	37	0.4	113	1.08	3.3	0.32	4.2	121	2.3	168	83
0.98	38.4	37.1	25	0.95	23.8	25.7	34.5	0.4	113	1.16	3.3	0.34	4.4	93	2.5	144	71
0.98	41.7	40.4	20	0.92	18.4	21.8	32.5	0.5	113	1.23	3.3	0.36	4.7	79	2.7	134	66
0.98	44.9	43.6	26	0.89	23.1	23.7	34	0.4	113	1.3	3.3	0.39	5.0	86	3.0	146	71
0.98	48.2	46.9	34	0.87	29.6	27.2	36	0.4	113	1.38	3.3	0.41	5.3	98	3.2	164	80
0.98	51.5	50.2	34	0.85	28.9	33.3	35.5	0.4	113	1.45	3.3	0.43	5.6	120	3.4	191	94
Subtotal													29.2				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
0.98	54.8	53.7	50	0.83	41.5	40.1	39	0.4	125	1.53	3.3	0.46	5.9	145	3.6	222	109
0.98	58.1	56.8	62	0.81	50.0	47.2	41	0.3	125	1.63	3.3	0.49	6.3	170	3.8	253	125
0.98	61.4	60	50	0.79	50.0	50.0	41	0.3	125	1.72	3.3	0.51	6.6	181	4.0	270	133
0.98	64.6	63.3	65	0.77	50.0	50.0	41	0.3	125	1.81	3.3	0.54	7.0	181	4.3	276	136
0.98	67.9	66.6	66	0.74	50.0	50.0	41	0.3	125	1.9	3.3	0.57	7.3	181	4.5	284	140

Note:
d : Size of pile cross-section
N : SPT N value
CN : Correction coefficient to N value for overburden pressure
N corr: Corrected N value
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile

Calculation
No.4

Bearing Capacity on Vertical Compression Load

Borehole
BH-1

Soil Parameters	1	2	3	4	5
γ , psf	107	113	113	113	125
φ , deg	33	25	41	40.5	40.6

Pile Cross-Section (in) : 13.8 x 13.8 (0.35 m x 0.35 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
1.15	-	4.3	9	2.3	20.7		33	0.5	107	0.2	6.6	0.02	0.6				
1.15	-	7.5	12	1.82	21.8		33.5	0.4	107	0.36	3.3	0.04	0.6				
										Subtotal			1.2				
Layer 2 (lateritic sandy/silty clay)																	
1.15	-	10.8	26	1.58	41.1		39	0.4	113	0.52	3.3	0.65	9.8				
1.15	-	14.1	16	1.43	22.9		34	0.4	113	0.64	3.3	0.58	8.7				
1.15	-	17.4	22	1.31	28.8		35.5	0.4	113	0.71	3.3	0.63	9.4				
1.15	-	20.7	35	1.23	43.1		39.5	0.4	113	0.79	3.3	0.71	10.6				
										Subtotal			38.6				
Layer 3 (altered granitic medium to very dense clayey sand)																	
1.15	25.3	24	56	1.15	50.0	47.7	41	0.3	113	0.86	3.3	0.26	3.9	47	2.3	88	43
1.15	28.5	27.2	55	1.1	50.0	33.3	41	0.3	113	0.93	3.3	0.28	4.2	79	2.6	124	61
1.15	31.8	30.5	40	1.05	42.0	42.3	41	0.3	113	1.01	3.3	0.3	4.5	160	2.8	209	103
										Subtotal			12.6				
Layer 4 (altered granitic silty/sandy clay to clayey/silty sand)																	
1.15	35.1	33.8	35	1	35.0	33.6	37	0.4	113	1.08	3.3	0.32	4.9	174	3.1	228	113
1.15	38.4	37.1	25	0.95	23.8	25.7	34.5	0.4	113	1.16	3.3	0.34	5.2	126	3.4	186	91
1.15	41.7	40.4	20	0.92	18.4	21.8	32.5	0.5	113	1.23	3.3	0.36	5.5	107	3.7	171	84
1.15	44.9	43.6	26	0.89	23.1	23.7	34	0.4	113	1.3	3.3	0.39	5.8	117	4.0	186	91
1.15	48.2	46.9	34	0.87	29.6	27.2	36	0.4	113	1.38	3.3	0.41	6.2	134	4.3	209	103
1.15	51.5	50.2	34	0.85	28.9	33.3	35.5	0.4	113	1.45	3.3	0.43	6.5	164	4.6	246	121
										Subtotal			34.1				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
1.15	54.8	53.7	50	0.83	41.5	40.1	39	0.4	125	1.53	3.3	0.46	6.9	197	4.9	286	141
1.15	58.1	56.8	62	0.81	50.0	47.2	41	0.3	125	1.63	3.3	0.49	7.3	232	5.2	328	161
1.15	61.4	60	50	0.79	50.0	50.0	41	0.3	125	1.72	3.3	0.51	7.7	246	5.5	349	172
1.15	64.6	63.3	65	0.77	50.0	50.0	41	0.3	125	1.81	3.3	0.54	8.1	246	5.8	357	176
1.15	67.9	66.6	66	0.74	50.0	50.0	41	0.3	125	1.9	3.3	0.57	8.6	246	6.1	365	179

Note:
d : Size of pile cross-section
N : SPT N value
CN : Correction coefficient to N value for overburden pressure
N corr: Corrected N value
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile

Calculation
No.5

Borehole
BH-1

Bearing Capacity on Vertical Compression Load

Soil Parameters	1	2	3	4	5
γ , psf	107	113	113	113	125
φ , deg	33	25	41	40.5	40.6

Pile Cross-Section (in) : 15.7 x 15.7 (0.4 m x 0.4 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
1.31	-	4.3	9	2.3	20.7		33	0.5	107	0.2	6.6	0.02	0.7				
1.31	-	7.5	12	1.82	21.8		33.5	0.4	107	0.36	3.3	0.04	0.6				
Subtotal													1.4				
Layer 2 (lateritic sandy/silty clay)																	
1.31	-	10.8	26	1.58	41.1		39	0.4	113	0.52	3.3	0.65	11.3				
1.31	-	14.1	16	1.43	22.9		34	0.4	113	0.64	3.3	0.58	9.9				
1.31	-	17.4	22	1.31	28.8		35.5	0.4	113	0.71	3.3	0.63	10.8				
1.31	-	20.7	35	1.23	43.1		39.5	0.4	113	0.79	3.3	0.71	12.1				
Subtotal													44.1				
Layer 3 (altered granitic medium to very dense clayey sand)																	
1.31	25.3	24	56	1.15	50.0	47.7	41	0.3	113	0.86	3.3	0.26	4.4	54	3.0	101	49
1.31	28.5	27.2	55	1.1	50.0	33.3	41	0.3	113	0.93	3.3	0.28	4.8	90	3.3	141	69
1.31	31.8	30.5	40	1.05	42.0	42.3	41	0.3	113	1.01	3.3	0.3	5.2	182	3.7	239	117
Subtotal													14.4				
Layer 4 (altered granitic silty/sandy clay to clayey/silty sand)																	
1.31	35.1	33.8	35	1	35.0	33.6	37	0.4	113	1.08	3.3	0.32	5.6	199	4.1	260	128
1.31	38.4	37.1	25	0.95	23.8	25.7	34.5	0.4	113	1.16	3.3	0.34	5.9	165	4.5	232	114
1.31	41.7	40.4	20	0.92	18.4	21.8	32.5	0.5	113	1.23	3.3	0.36	6.2	140	4.9	213	104
1.31	44.9	43.6	26	0.89	23.1	23.7	34	0.4	113	1.3	3.3	0.39	6.7	152	5.3	231	113
1.31	48.2	46.9	34	0.87	29.6	27.2	36	0.4	113	1.38	3.3	0.41	7.1	175	5.6	251	127
1.31	51.5	50.2	34	0.85	28.9	33.3	35.5	0.4	113	1.45	3.3	0.43	7.5	214	6.0	307	150
Subtotal													39.0				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
1.31	54.8	53.7	50	0.83	41.5	40.1	39	0.4	125	1.53	3.3	0.46	7.9	258	6.4	358	176
1.31	58.1	56.8	62	0.81	50.0	47.2	41.	0.3	125	1.63	3.3	0.49	8.4	303	6.8	411	202
1.31	61.4	60	50	0.79	50.0	50.0	41	0.3	125	1.72	3.3	0.51	8.8	321	7.2	438	215
1.31	64.6	63.3	65	0.77	50.0	50.0	41	0.3	125	1.81	3.3	0.54	9.3	321	7.6	447	220
1.31	67.9	66.6	66	0.74	50.0	50.0	41	0.3	125	1.9	3.3	0.57	9.8	321	7.9	456	224

Note:
d : Size of pile cross-section
N : SPT N value
CN : Correction coefficient to N value for overburden pressure
N corr: Corrected N value
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile

Calculation
No.6

Bearing Capacity on Vertical Compression Load

Borehole
BH-2

Soil Parameters	1	2	4	5
γ , psf	107	113	113	125
φ , deg	31	36.5	35	40.2

Pile Cross-Section (in) : 7.87 x 7.87 (0.2 m x 0.2 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
0.66	-	3.3	3	2.3	6.9		29	0.5	107	0.16	6.6	0.02	0.3				
0.66	-	7.5	7	1.82	12.7		31	0.5	107	0.28	3.3	0.03	0.3				
0.66	-	10.8	8	1.82	14.6		31.5	0.5	107	0.35	3.3	0.04	0.3				
									Subtotal				0.8				
Layer 2 (lateritic dense clayey sand)																	
0.66	-	14.1	15	1.43	21.5		33.5	0.4	113	0.42	3.3	0.12	1.1				
0.66	-	17.4	22	1.31	28.8		35.5	0.4	113	0.49	3.3	0.15	1.3				
0.66	-	20.7	25	1.23	30.8		36	0.4	113	0.57	3.3	0.17	1.5				
0.66	25.3	24	33	1.15	38.0	30.6	35.5	0.4	113	0.64	3.3	0.19	1.6	17	0.7	23	11
0.66	28.5	27.2	21	1.1	23.1	29.8	34	0.4	113	0.71	3.3	0.21	1.8	40	0.8	47	23
0.66	31.8	30.5	27	1.05	28.4	31.8	35.5	0.4	113	0.79	3.3	0.24	2.0	51	0.9	60	30
0.66	35.1	33.8	44	1	44.0	40.0	39.5	0.4	113	0.86	3.3	0.26	2.2	64	1.0	76	37
0.66	38.4	37.1	50	0.95	47.5	42.1	40.5	0.4	113	0.57	3.3	0.17	1.5	68	1.1	80	40
0.56	41.7	40.4	96	0.92	50.0	41.1	41	0.3	113	0.64	3.3	0.19	1.6	66	1.2	80	40
0.66	44.9	43.6	29	0.89	25.8	34.3	35	0.4	113	0.71	3.3	0.21	1.8	55	1.3	71	35
									Subtotal				16.5				
Layer 4 (altered granitic dense clayey sand)																	
0.66	48.2	46.9	31	0.87	27.0	29.5	35	0.4	113	0.79	3.3	0.24	2.0	47	1.4	65	32
										Subtotal			2.0				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
0.66	51.5	50.2	42	0.85	35.7	37.6	37.5	0.4	125	0.87	3.3	0.26	2.3	60	1.5	80	39
0.66	54.8	53.7	65	0.83	50.0	44.2	41	0.3	125	0.96	3.3	0.29	2.5	71	1.6	93	46
0.66	58.1	56.8	58	0.81	47.0	49.0	40	0.4	125	1.05	3.3	0.32	2.7	79	1.7	104	51
0.66	61.4	60	72	0.79	50.0	49.0	41	0.3	125	1.15	3.3	0.34	3.0	79	1.8	107	52
0.66	64.6	63.3	68	0.77	50.0	50.0	41	0.3	125	1.24	3.3	0.37	3.2	80	1.9	111	55
0.66	67.9	66.6	76	0.74	50.0	50.0	41	0.3	125	1.33	3.3	0.4	3.4	80	2.0	115	56

Note:
d : Size of pile cross-section
N : SPT N value
CN : Correction coefficient to N value for overburden pressure
N corr: Corrected N value
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile

Calculation
No.7

Bearing Capacity on Vertical Compression Load

Soil Parameters	1	2	4	5
γ , psf	107	113	113	125
φ , deg	31	36.5	35	40.2

Borehole
BH-2

Pile Cross-Section (in) : 9.84 x 9.84 (0.25 m x 0.25 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
0.82	-	3.3	2	2.3	4.6		29	0.5	107	0.16	6:6	0.02	0.3				
0.82	-	7.5	7	1.82	12.7		31	0.5	107	0.28	3.3	0.03	0.3				
0.82	-	10.8	8	1.82	14.6		31.5	0.5	107	0.35	3.3	0.04	0.4				
									Subtotal				1.1				
Layer 2 (lateritic dense clayey sand)																	
0.82	-	14.1	15	1.43	21.5		33.5	0.4	113	0.42	3.3	0.12	1.3				
0.82	-	17.4	22	1.31	28.8		35.5	0.4	113	0.49	3.3	0.15	1.6				
0.82	-	20.7	25	1.23	30.8		36	0.4	113	0.57	3.3	0.17	1.8				
0.82	25.3	24	33	1.15	38:0	30.6	35.5	0.4	113	0.64	3.3	0.19	2.1	22	1.2	28	14
0.82	28.5	27.2	21	1.1	23.1	29.8	34	0.4	113	0.71	3.3	0.21	2.3	50	1.3	59	29
0.82	31.8	30.5	27	1.05	28.4	31.8	35.5	0.4	113	0.79	3.3	0.24	2.5	80	1.5	91	45
0.82	35.1	33.8	44	1	44.0	40.0	39.5	0.4	113	0.86	3.3	0.26	2.8	100	1.6	114	56
0.82	38.4	37.1	50	0.95	47.5	42.1	40.5	0.4	113	0.57	3.3	0.17	1.8	106	1.8	121	60
0.82	41.7	40.4	96	0.92	50.0	41.1	41	0.3	113	0.64	3.3	0.19	2.1	103	1.9	121	59
0.82	44.9	43.6	29	0.89	25.8	34.3	35	0.4	113	0.71	3.3	0.21	2.3	86	2.1	106	52
									Subtotal				20.6				
Layer 4 (altered granitic dense clayey sand)																	
0.82	48.2	46.9	31	0.87	27.0	29.5	35	0.4	113	0.79	3.3	0.24	2.5	74	2.2	96	47
									Subtotal				2.5				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
0.82	51.5	50.2	42	0.85	35.7	37.6	37.5	0.4	125	0.87	3.3	0.26	2.8	94	2.4	119	58
0.82	54.8	53.7	65	0.83	50.0	44.2	41	0.3	125	0.96	3.3	0.29	3.1	111	2.5	139	68
0.82	58.1	56.8	58	0.81	47.0	49.0	40	0.4	125	1.05	3.3	0.32	3.4	123	2.7	154	76
0.82	61.4	60	72	0.79	50.0	49.0	41	0.3	125	1.15	3.3	0.34	3.7	123	2.8	157	77
0.82	64.6	63.3	68	0.77	50.0	50.0	41	0.3	125	1.24	3.3	0.37	4.0	125	3.0	164	80
0.82	67.9	66.6	76	0.74	50.0	50.0	41	0.3	125	1.33	3.3	0.4	4.3	125	3.1	168	82

Note:
d : Size of pile cross-section
N : SPT N value
CN : Correction coefficient to N value for overburden pressure
N corr: Corrected N value
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile

Calculation
No.8

Bearing Capacity on Vertical Compression Load

Borehole
BH-2

Soil Parameters	1	2	4	5
γ , psf	107	113	113	125
φ , deg	31	36.5	35	40.2

Pile Cross-Section (in) : 11.8 x 11.8 (0.3 m x 0.3 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
0.98		3.3	2	2.3	4.6		29	0.5	107	0.16	6.6	0.02	0.4				
0.98		7.5	7	1.82	12.7		31	0.5	107	0.28	3.3	0.03	0.4				
0.98		10.8	8	1.82	14.6		31.5	0.5	107	0.35	3.3	0.04	0.5				
									Subtotal				1.3				
Layer 2 (lateritic dense clayey sand)																	
0.98		14.1	15	1.43	21.5		33.5	0.4	113	0.42	3.3	0.12	1.6				
0.98		17.4	22	1.31	28.8		35.5	0.4	113	0.49	3.3	0.15	1.9				
0.98		20.7	25	1.23	30.8		36	0.4	113	0.57	3.3	0.17	2.2				
0.98	25.3	24	33	1.15	38.0	30.2	35.5	0.4	113	0.64	3.3	0.19	2.5	25	1.7	33	16
0.98	28.5	27.2	21	1.1	23.1	30.0	34	0.4	113	0.71	3.3	0.21	2.7	61	1.9	71	35
0.98	31.8	30.5	27	1.05	28.4	33.4	35.5	0.4	113	0.79	3.3	0.24	3.0	108	2.1	121	59
0.98	35.1	33.8	44	1	44.0	35.7	39.5	0.4	113	0.86	3.3	0.26	3.3	129	2.3	145	72
0.98	38.4	37.1	50	0.95	47.5	42.5	40.5	0.4	113	0.57	3.3	0.17	2.2	153	2.5	172	85.
0.98	41.7	40.4	96	0.92	50.0	41.8	41	0.3	113	0.64	3.3	0.19	2.5	151	2.7	172	84
0.98	44.9	43.6	29	0.89	25.8	37.6	35	0.4	113	0.71	3.3	0.21	2.8	136	3.0	159	78
									Subtotal				24.7				
Layer 4 (altered granitic dense clayey sand)																	
0.98	48.2	46.9	31	0.87	27.0	34.6	35	0.4	113	0.79	3.3	0.24	3.0	125	3.2	151	74
									Subtotal				3.0				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
0.98	51.5	50.2	42	0.85	35.7	34.6	37.5	0.4	125	0.87	3.3	0.26	3.4	125	3.4	154	75
0.98	54.8	53.7	65	0.83	50.0	33.2	41	0.3	125	0.96	3.3	0.29	3.7	120	3.6	152	74
0.98	58.1	56.8	58	0.81	47.0	45.7	40	0.4	125	1.05	3.3	0.32	4.1	165	3.8	201	99
0.98	61.4	60	72	0.79	50.0	49.2	41	0.3	125	1.15	3.3	0.34	4.4	178	4.0	219	107
0.98	64.6	63.3	68	0.77	50.0	49.2	41	0.3	125	1.24	3.3	0.37	4.8	178	4.3	223	109
0.98	67.9	66.6	76	0.74	50.0	50.0	41	0.3	125	1.33	3.3	0.4	5.1	181	4.5	231	113

Note:
d : Size of pile cross-section
N : SPT N value
CN : Correction coefficient to N value for overburden pressure
N corr: Corrected N value
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile

Calculation
No. 9

Bearing Capacity on Vertical Compression Load

Borehole
BH-2

Soil Parameters	1	2	4	5
γ , psf	107	113	113	125
ϕ , deg	31	36.5	35	40.2

Pile Cross-Section (in) : 13.8 x 13.8 (0.35 m x 0.35 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	ϕ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
1.15		3.3	2	2.3	4.6		29	0.5	107	0.16	6.6	0.02	0.5				
1.15		7.5	7	1.82	12.7		31	0.5	107	0.28	3.3	0.03	0.4				
1.15		10.8	8	1.82	14.6		31.5	0.5	107	0.35	3.3	0.04	0.5				
										Subtotal			1.5				
Layer 2 (lateritic dense clayey sand)																	
1.15		14.1	15	1.43	21.5		33.5	0.4	113	0.42	3.3	0.12	1.9				
1.15		17.4	22	1.31	28.8		35.5	0.4	113	0.49	3.3	0.15	2.2				
1.15		20.7	25	1.23	30.8		36	0.4	113	0.57	3.3	0.17	2.6				
1.15	25.3	24	33	1.15	38.0	30.2	35.5	0.4	113	0.64	3.3	0.19	2.9	30	2.3	38	18
1.15	28.5	27.2	21	1.1	23.1	30.0	34	0.4	113	0.71	3.3	0.21	3.2	71	2.6	82	40
1.15	31.8	30.5	27	1.05	28.4	33.4	35.5	0.4	113	0.79	3.3	0.24	3.6	126	2.8	141	69
1.15	35.1	33.8	44	1	44.0	35.7	39.5	0.4	113	0.86	3.3	0.26	3.9	176	3.1	194	96
1.15	38.4	37.1	50	0.95	47.5	42.5	40.5	0.4	113	0.57	3.3	0.17	2.6	209	3.4	230	113
1.15	41.7	40.4	96	0.92	50.0	41.8	41	0.3	113	0.64	3.3	0.19	2.9	206	3.7	229	113
1.15	44.9	43.6	29	0.89	25.8	37.6	35	0.4	113	0.71	3.3	0.21	3.2	185	4.0	211	104
										Subtotal			28.8				
Layer 4 (altered granitic dense clayey sand)																	
1.15	48.2	46.9	31	0.87	27.0	34.6	35	0.4	113	0.79	3.3	0.24	3.5	170	4.3	200	98
											Subtotal		3.5				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
1.15	51.5	50.2	42	0.85	35.7	34.6	37.5	0.4	125	0.87	3.3	0.26	3.9	170	4.6	203	99
1.15	54.8	53.7	65	0.83	50.0	33.2	41	0.3	125	0.96	3.3	0.29	4.3	163	4.9	200	98
1.15	58.1	56.8	58	0.81	47.0	45.7	40	0.4	125	1.05	3.3	0.32	4.8	225	5.2	266	131
1.15	61.4	60	72	0.79	50.0	49.2	41	0.3	125	1.15	3.3	0.34	5.2	242	5.5	289	142
1.15	64.6	63.3	68	0.77	50.0	49.2	41	0.3	125	1.24	3.3	0.37	5.6	242	5.8	294	144
1.15	67.9	66.6	76	0.74	50.0	50.0	41	0.3	125	1.33	3.3	0.4	6.0	246	6.1	303	149

Note:		
	d :	Size of pile cross-section
	N :	SPT N value
	CN :	Correction coefficient to N value for overburden pressure
	N corr:	Corrected N value
	N for Qb :	Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
	Qb :	Base resistance of pile
	Qnf :	Negative skin friction
	Qs :	Skin resistance of pile
	Qu :	Ultimate bearing capacity of pile
	Qa :	Allowable bearing capacity of pile

Calculation
No.10

Bearing Capacity on Vertical Compression Load

Borehole
BH-2

Soil Parameters	1	2	4	5
γ , psf	107	113	113	125
φ' , deg	31	36.5	35	40.2

Pile Cross-Section (in) : 15.7 x 15.7 (0.4 m x 0.4 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
1.31	-	3.3	2	2.3	4.6		29	0.5	107	0.16	6.6	0.02	0.6				
1.31	-	7.5	7	1.62	12.7		31	0.5	107	0.28	3.3	0.03	0.5				
1.31	-	10.8	8	1.62	14.6		31.5	0.5	107	0.35	3.3	0.04	0.6				
Subtotal													1.7				
Layer 2 (lateritic dense clayey sand)																	
1.31	-	14.1	15	1.43	21.5		33.5	0.4	113	0.42	3.3	0.12	2.1				
1.31	-	17.4	22	1.31	28.8		35.5	0.4	113	0.49	3.3	0.15	2.5				
1.31	-	20.7	25	1.23	30.8		36	0.4	113	0.57	3.3	0.17	2.9				
1.31	25.3	24	33	1.15	38.0	30.2	35.5	0.4	113	0.64	3.3	0.19	3.3	34	3.0	44	20
1.31	28.5	27.2	21	1.1	23.1	30.0	34	0.4	113	0.71	3.3	0.21	3.7	81	3.3	94	45
1.31	31.8	30.5	27	1.05	28.4	33.4	35.5	0.4	113	0.79	3.3	0.24	4.1	144	3.7	160	78
1.31	35.1	33.8	44	1	44.0	35.7	39.5	0.4	113	0.86	3.3	0.26	4.5	212	4.1	232	114
1.31	38.4	37.1	50	0.95	47.5	42.5	40.5	0.4	113	0.57	3.3	0.17	2.9	273	4.5	296	146
1.31	41.7	40.4	96	0.92	50.0	41.8	41	0.3	113	0.64	3.3	0.19	3.3	269	4.9	295	145
1.31	44.9	43.6	29	0.89	25.8	37.6	35	0.4	113	0.71	3.3	0.21	3.7	241	5.3	271	133
Subtotal													33.0				
Layer 4 (altered granitic dense clayey sand)																	
1.31	48.2	46.9	31	0.87	27.0	34.6	35	0.4	113	0.79	3.3	0.24	4.1	222	5.6	255	125
Subtotal													4.1				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
1.31	51.5	50.2	42	0.85	35.7	34.6	37.5	0.4	125	0.87	3.3	0.26	4.5	222	6.0	260	127
1.31	54.8	53.7	65	0.83	50.0	33.2	41	0.3	125	0.96	3.3	0.29	5.0	213	6.4	255	124
1.31	58.1	56.8	58	0.81	47.0	45.7	40	0.4	125	1.05	3.3	0.32	5.4	293	6.8	340	167
1.31	61.4	60	72	0.79	50.0	49.2	41	0.3	125	1.15	3.3	0.34	5.9	316	7.2	369	181
1.31	64.6	63.3	68	0.77	50.0	49.2	41	0.3	125	1.24	3.3	0.37	6.4	316	7.6	375	184
1.31	67.9	66.6	76	0.74	50.0	50.0	41	0.3	125	1.33	3.3	0.4	6.8	321	7.9	386	189

Note:		
	d :	Size of pile cross-section
	N :	SPT N value
	CN :	Correction coefficient to N value for overburden pressure
	N corr:	Corrected N value
	N for Qb :	Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
	Qb :	Base resistance of pile
	Qnf :	Negative skin friction
	Qs :	Skin resistance of pile
	Qu :	Ultimate bearing capacity of pile
	Qa :	Allowable bearing capacity of pile

Calculation
No.11

Bearing Capacity on Vertical Compression Load

Borehole
BH-3

Soil Parameters	1	2	3	4	5
γ , psf	107	113	113	113	125
φ , deg	22	29.5	30.6	25.7	47.6

Pile Cross-Section (in) : 7.87 x 7.87 (0.2 m x 0.2 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
0.66	-	4.3	6	2.3	13.8		33	0.5	107	0.2	6.6	0.02	0.4				
0.66	-	7.5	38	1.82	50.0		33.5	0.4	107	0.36	3.3	0.04	0.3				
										Subtotal			0.7				
Layer 2 (lateritic sandy/silty clay)																	
0.66	-	10.8	34	1.58	50.0		39	0.4	113	0.52	3.3	0.7	6.0				
0.66	-	14.1	34	1.43	48.6		34	0.4	113	0.64	3.3	0.7	6.0				
0.66	-	17.4	26	1.31	34.1		35.5	0.4	113	0.71	3.3	0.65	5.6				
0.66	-	20.7	24	1.23	29.5		39.5	0.4	113	0.79	3.3	0.64	5.5				
										Subtotal			23.1				
Layer 3 (altered granitic medium to very dense clayey sand)																	
0.66	25.3	24	30	1.15	34.5	30.5	41	0.3	113	0.86	3.3	0.26	2.2	17	0.7	53	21
0.66	28.5	27.2	25	1.1	27.5	30.8	41	0.3	113	0.93	3.3	0.28	2.4	41	0.8	74	34
0.66	31.8	30.5	29	1.05	30.5	29.3	41	0.3	113	1.01	3.3	0.3	2.6	47	0.9	59	38
0.66	35.1	33.8	30	1	30.0	31.2	37	0.4	113	1.08	3.3	0.32	2.8	50	1.0	83	30
										Subtotal			7.2				
Layer 4 (altered granitic silty/sandy clay to clayey/silty sand)																	
0.66	38.4	37.1	35	0.95	33.3	29.7	34.5	0.4	113	1.16	3.3	0.34	3.0	48	1.1	49	24
0.66	41.7	40.4	28	0.92	25.8	28.3	32.5	0.5	113	1.23	3.3	0.36	3.1	45	1.2	50	25
0.66	44.9	43.6	29	0.89	25.8	26.2	34	0.4	113	1.3	3.3	0.39	3.3	42	1.3	50	24
0.66	48.2	46.9	31	0.87	27.0	25.5	36	0.4	113	1.38	3.3	0.41	3.6	41	1.4	53	26
0.66	51.5	50.2	28	0.85	23.8	23.8	35.5	0.4	113	1.45	3.3	0.43	3.7	38	1.5	53	26
0.66	54.8	53.7	32	0.83	26.6	25.8	39	0.4	125	1.39	3.3	0.42	3.6	41	1.6	53	26
0.66	58.1	56.8	31	0.81	25.1	24.1	41	0.3	125	1.48	3.3	0.44	3.8	39	1.7	54	26
0.66	61.4	60	26	0.79	20.5	22.7	41	0.3	125	1.57	3.3	0.47	4.0	36	1.8	55	27
0.66	64.6	63.3	29	0.77	22.3	23.4	41	0.3	125	1.66	3.3	0.5	4.3	38	1.9	61	29
0.66	67.9	66.6	37	0.74	27.4	29.3	41	0.3	125	1.75	3.3	0.52	4.5	47	2.0	75	36
										Subtotal			20.2				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
0.66	71.2	69.9	46	0.83	38.2	38.5	39	0.4	125	1.84	3.3	0.55	4.8	62	2.1	116	57
0.66	74.5	73.2	65	0.81	50.0	46.1	41	0.3	125	1.94	3.3	0.58	5.0	74	2.2	133	65
0.66	77.7	76.4	79	0.79	50.0	50.0	41	0.3	125	2.03	3.3	0.61	5.2	80	2.3	144	71
0.66	81	79.7	100	0.77	50.0	50.0	41	0.3	125	2.12	3.3	0.63	5.5	80	2.4	150	74
0.66	84.3	83	120	0.74	50.0	50.0	41	0.3	125	2.21	3.3	0.66	5.7	80	2.5	155	76

Note:
d : Size of pile cross-section
N : SPT N value
CN : Correction coefficient to N value for overburden pressure
N corr: Corrected N value
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile

Calculation
No.12

Borehole
BH-3

Bearing Capacity on Vertical Compression Load

Soil Parameters	1	2	3	4	5
γ , psf	107	113	113	113	125
φ , deg	22	29.5	30.6	25.7	47.6

Pile Cross-Section (in) : 9.84 x 9.84 (0.25 m x 0.25 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
0.82	-	4.3	6	2.3	13.8		33	0.5	107	0.2	6.6	0.02	0.5				
0.82	-	7.5	38	1.82	50.0		33.5	0.4	107	0.36	3.3	0.04	0.4				
										Subtotal			0.9				
Layer 2 (lateritic sandy/silty clay)																	
0.82	-	10.8	34	1.58	50.0		39	0.4	113	0.52	3.3	0.7	7.5				
0.82	-	14.1	34	1.43	48.6		34	0.4	113	0.64	3.3	0.7	7.5				
0.82	-	17.4	26	1.31	34.1		35.5	0.4	113	0.71	3.3	0.65	7.1				
0.82	-	20.7	24	1.23	29.5		39.5	0.4	113	0.79	3.3	0.64	6.9				
										Subtotal			29.1				
Layer 3 (altered granitic medium to very dense clayey sand)																	
0.82	25.3	24	30	1.15	34.5	30.5	41	0.3	113	0.86	3.3	0.26	2.8	21	1.2	66	26
0.82	28.5	27.2	25	1.1	27.5	30.8	41	0.3	113	0.93	3.3	0.28	3.0	52	1.3	93	42
0.82	31.8	30.5	29	1.05	30.5	29.3	41	0.3	113	1.01	3.3	0.3	3.3	74	1.5	88	55
0.82	35.1	33.8	30	1	30.0	31.2	37	0.4	113	1.08	3.3	0.32	3.5	78	1.6	119	45
										Subtotal			9.0				
Layer 4 (altered granitic silty/sandy clay to clayey/silty sand)																	
0.82	38.4	37.1	35	0.95	33.3	29.7	34.5	0.4	113	1.16	3.3	0.34	3.7	74	1.8	76	37
0.82	41.7	40.4	28	0.92	25.8	28.3	32.5	0.5	113	1.23	3.3	0.36	3.9	71	1.9	77	37
0.82	44.9	43.6	29	0.89	25.8	26.2	34	0.4	113	1.3	3.3	0.39	4.2	66	2.1	75	37
0.82	48.2	46.9	31	0.87	27.0	25.5	36	0.4	113	1.38	3.3	0.41	4.5	64	2.2	78	38
0.82	51.5	50.2	28	0.85	23.8	23.6	35.5	0.4	113	1.45	3.3	0.43	4.7	60	2.4	78	38
0.82	54.8	53.7	32	0.83	26.6	25.6	39	0.4	125	1.39	3.3	0.42	4.5	65	2.5	79	38
0.82	58.1	56.8	31	0.81	25.1	24.1	41	0.3	125	1.48	3.3	0.44	4.8	60	2.7	79	38
0.82	61.4	60	26	0.79	20.5	22.7	41	0.3	125	1.57	3.3	0.47	5.1	57	2.8	80	39
0.82	64.6	63.3	29	0.77	22.3	23.4	41	0.3	125	1.66	3.3	0.5	5.4	59	3.0	87	42
0.82	67.9	66.6	37	0.74	27.4	29.3	41	0.3	125	1.75	3.3	0.52	5.7	74	3.1	108	52
										Subtotal			25.4				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
0.82	71.2	69.9	46	0.83	38.2	38.5	39	0.4	125	1.84	3.3	0.55	6.0	97	3.3	164	80
0.82	74.5	73.2	65	0.81	50.0	46.1	41	0.3	125	1.94	3.3	0.58	6.3	116	3.4	189	93
0.82	77.7	76.4	79	0.79	50.0	50.0	41	0.3	125	2.03	3.3	0.61	6.6	125	3.6	205	101
0.82	81	79.7	100	0.77	50.0	50.0	41	0.3	125	2.12	3.3	0.63	6.9	125	3.7	212	104
0.82	84.3	83	120	0.74	50.0	50.0	41	0.3	125	2.21	3.3	0.66	7.1	125	3.9	219	107

Note:

d	:	Size of pile cross-section
N	:	SPT N value
CN	:	Correction coefficient to N value for overburden pressure
N corr:		Corrected N value
N for Qb	:	Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb	:	Base resistance of pile
Qnf	:	Negative skin friction
Qs	:	Skin resistance of pile
Qu	:	Ultimate bearing capacity of pile
Qa	:	Allowable bearing capacity of pile

Calculation
No.13

Borehole
BH-3

Bearing Capacity on Vertical Compression Load

Soil Parameters	1	2	3	4	5
γ , psf	107	113	113	113	125
φ , deg	22	29.5	30.6	25.7	47.6

Pile Cross-Section (in) : 11.8 x 11.8 (0.3 m x 0.3 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
0.98	-	4.3	6	2.3	13.8		33	0.5	107	0.2	6.6	0.02	0.6				
0.98	-	7.5	38	1.82	50.0		33.5	0.4	107	0.36	3.3	0.04	0.5				
									Subtotal				1.0				
Layer 2 (lateritic sandy/silty clay)																	
0.98	-	10.8	34	1.58	50.0		39	0.4	113	0.52	3.3	0.7	9.0				
0.98	-	14.1	34	1.43	48.6		34	0.4	113	0.64	3.3	0.7	9.0				
0.98	-	17.4	26	1.31	34.1		35.5	0.4	113	0.71	3.3	0.65	8.4				
0.98	-	20.7	24	1.23	29.5		39.5	0.4	113	0.79	3.3	0.64	8.3				
									Subtotal				34.7				
Layer 3 (altered granitic medium to very dense clayey sand)																	
0.98	25.3	24	30	1.15	34.5	31.4	41	0.3	113	0.86	3.3	0.26	3.3	27	1.7	80	31
0.98	28.5	27.2	25	1.1	27.5	30.5	41	0.3	113	0.93	3.3	0.28	3.6	62	1.9	110	50
0.98	31.8	30.5	29	1.05	30.5	30.6	41	0.3	113	1.01	3.3	0.3	3.9	99	2.1	116	71
0.98	35.1	33.8	30	1	30.0	30.3	37	0.4	113	1.08	3.3	0.32	4.2	109	2.3	158	61
									Subtotal				10.8				
Layer 4 (altered granitic silty/sandy clay to clayey/silty sand)																	
0.98	38.4	37.1	35	0.95	33.3	29.9	34.5	0.4	113	1.16	3.3	0.34	4.4	108	2.5	110	54
0.98	41.7	40.4	28	0.92	25.8	28.7	32.5	0.5	113	1.23	3.3	0.36	4.7	104	2.7	110	54
0.98	44.9	43.6	29	0.89	25.8	27.9	34	0.4	113	1.3	3.3	0.39	5.0	101	3.0	112	55
0.98	48.2	46.9	31	0.87	27.0	25.6	36	0.4	113	1.38	3.3	0.41	5.3	92	3.2	109	53
0.98	51.5	50.2	28	0.85	23.8	25.8	35.5	0.4	113	1.45	3.3	0.43	5.6	93	3.4	115	56
0.98	54.8	53.7	32	0.83	26.6	25.6	39	0.4	125	1.39	3.3	0.42	5.4	93	3.6	108	52
0.98	58.1	56.8	31	0.81	25.1	24.0	41	0.3	125	1.48	3.3	0.44	5.7	87	3.8	108	52
0.98	61.4	60	26	0.79	20.5	23.6	41	0.3	125	1.57	3.3	0.47	6.1	85	4.0	113	54
0.98	64.6	63.3	29	0.77	22.3	23.8	41	0.3	125	1.66	3.3	0.5	6.4	86	4.3	120	58
0.98	67.9	66.6	37	0.74	27.4	27.1	41	0.3	125	1.75	3.3	0.52	6.8	98	4.5	138	67
									Subtotal				30.3				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
0.98	71.2	69.9	46	0.83	38.2	34.5	39	0.4	125	1.84	3.3	0.55	7.1	125	4.7	204	100
0.98	74.5	73.2	65	0.81	50.0	41.4	41	0.3	125	1.94	3.3	0.58	7.5	150	4.9	236	116
0.98	77.7	76.4	79	0.79	50.0	47.0	41	0.3	125	2.03	3.3	0.61	7.8	170	5.1	264	130
0.98	81	79.7	100	0.77	50.0	50.0	41	0.3	125	2.12	3.3	0.63	8.2	181	5.3	283	139
0.98	84.3	83	120	0.74	50.0	50.0	41	0.3	125	2.21	3.3	0.66	8.5	181	5.6	291	143

Note:		
	d :	Size of pile cross-section
	N :	SPT N value
	CN :	Correction coefficient to N value for overburden pressure
	N corr:	Corrected N value
	N for Qb :	Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
	Qb :	Base resistance of pile
	Qnf :	Negative skin friction
	Qs :	Skin resistance of pile
	Qu :	Ultimate bearing capacity of pile
	Qa :	Allowable bearing capacity of pile

Calculation
No.14

Borehole
BH-3

Bearing Capacity on Vertical Compression Load

Soil Parameters	1	2	3	4	5
γ , psf	107	113	113	113	125
φ , deg	22	29.5	30.6	25.7	47.6

Pile Cross-Section (in) : 13.8 x 13.8 (0.35 m x 0.35 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
1.15	-	4.3	6	2.3	13.8		33	0.5	107	0.2	6.6	0.02	0.6				
1.15	-	7.5	38	1.82	50.0		33.5	0.4	107	0.36	3.3	0.04	0.6				
												Subtotal	1.2				
Layer 2 (lateritic sandy/silty clay)																	
1.15	-	10.8	34	1.58	50.0		39	0.4	113	0.52	3.3	0.7	10.5				
1.15	-	14.1	34	1.43	48.6		34	0.4	113	0.64	3.3	0.7	10.5				
1.15	-	17.4	26	1.31	34.1		35.5	0.4	113	0.71	3.3	0.65	9.8				
1.15	-	20.7	24	1.23	29.5		39.5	0.4	113	0.79	3.3	0.64	9.7				
												Subtotal	40.5				
Layer 3 (altered granitic medium to very dense clayey sand)																	
1.15	25.3	24	30	1.15	34.5	31.4	41	0.3	113	0.86	3.3	0.26	3.9	31	2.3	93	36
1.15	28.5	27.2	25	1.1	27.5	30.5	41	0.3	113	0.93	3.3	0.28	4.2	72	2.6	128	58
1.15	31.8	30.5	29	1.05	30.5	30.6	41	0.3	113	1.01	3.3	0.3	4.5	115	2.8	135	82
1.15	35.1	33.8	30	1	30.0	30.3	37	0.4	113	1.08	3.3	0.32	4.9	149	3.1	205	81
												Subtotal	12.6				
Layer 4 (altered granitic silty/sandy clay to clayey/silty sand)																	
1.15	38.4	37.1	35	0.95	33.3	29.9	34.5	0.4	113	1.16	3.3	0.34	5.2	147	3.4	149	73
1.15	41.7	40.4	28	0.92	25.8	28.7	32.5	0.5	113	1.23	3.3	0.36	5.5	141	3.7	148	72
1.15	44.9	43.6	29	0.89	25.8	27.9	34	0.4	113	1.3	3.3	0.39	5.8	137	4.0	150	73
1.15	48.2	46.9	31	0.87	27.0	25.6	36	0.4	113	1.38	3.3	0.41	6.2	126	4.3	144	70
1.15	51.5	50.2	28	0.85	23.8	25.8	35.5	0.4	113	1.45	3.3	0.43	6.5	127	4.6	151	73
1.15	54.8	53.7	32	0.83	26.6	25.6	39	0.4	125	1.39	3.3	0.42	6.3	126	4.9	144	69
1.15	58.1	56.8	31	0.81	25.1	24.0	41	0.3	125	1.48	3.3	0.44	6.7	118	5.2	142	68
1.15	61.4	60	26	0.79	20.5	23.6	41	0.3	125	1.57	3.3	0.47	7.1	116	5.5	147	71
1.15	64.6	63.3	29	0.77	22.3	23.8	41	0.3	125	1.66	3.3	0.5	7.5	117	5.8	155	75
1.15	67.9	66.6	37	0.74	27.4	27.1	41	0.3	125	1.75	3.3	0.52	7.9	133	6.1	179	86
												Subtotal	35.4				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand																	
1.15	71.2	69.9	46	0.83	38.2	34.5	39	0.4	125	1.84	3.3	0.55	8.3	170	6.4	261	127
1.15	74.5	73.2	65	0.81	50.0	41.4	41	0.3	125	1.94	3.3	0.58	8.7	204	6.7	304	148
1.15	77.7	76.4	79	0.79	50.0	47.0	41	0.3	125	2.03	3.3	0.61	9.1	231	7.0	340	167
1.15	81	79.7	100	0.77	50.0	50.0	41	0.3	125	2.12	3.3	0.63	9.5	246	7.3	364	178
1.15	84.3	83	120	0.74	50.0	50.0	41	0.3	125	2.21	3.3	0.66	10.0	246	7.6	374	183

Note:
d : Size of pile cross-section
N : SPT N value
CN : Correction coefficient to N value for overburden pressure
N corr: Corrected N value
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile

Calculation
No.15

Borehole
BH-3

Bearing Capacity on Vertical Compression Load

Soil Parameters	1	2	3	4	5
γ , psf	107	113	113	113	125
φ , deg	22	29.5	30.6	25.7	47.6

Pile Cross-Section (in) : 15.7 x 15.7 (0.4 m x 0.4 m)

d (ft)	L (ft)	z (ft)	N val (-)	CN (-)	N corr (-)	N for Qb (-)	φ (o)	Ks	γ (pcf)	p'oi (tsf)	li (ft)	fs (tsf)	Qs (ton)	Qb (ton)	Wp (ton)	Qu (ton)	Qa (ton)
Layer 1 (loose to medium dense clayey sand)																	
1.31	–	4.3	6	2.3	13.8		33	0.5	107	0.2	6.6	0.02	0.7				
1.31	–	7.5	38	1.82	50.0		33.5	0.4	107	0.36	3.3	0.04	0.6				
										Subtotal			1.4				
Layer 2 (lateritic sandy/silty clay)																	
1.31	–	10.8	34	1.58	50.0		39	0.4	113	0.52	3.3	0.7	12.0				
1.31	–	14.1	34	1.43	48.6		34	0.4	113	0.64	3.3	0.7	12.0				
1.31	–	17.4	26	1.31	34.1		35.5	0.4	113	0.71	3.3	0.65	11.3				
1.31	–	20.7	24	1.23	29.5		39.5	0.4	113	0.79	3.3	0.64	11.0				
										Subtotal			46.3				
Layer 3 (altered granitic medium to very dense clayey sand)																	
1.31	25.3	24	30	1.15	34.5	31.4	41	0.3	113	0.86	3.3	0.26	4.4	35	3.0	106	41
1.31	28.5	27.2	25	1.1	27.5	30.5	41	0.3	113	0.93	3.3	0.28	4.8	82	3.3	146	66
1.31	31.8	30.5	29	1.05	30.5	30.6	41	0.3	113	1.01	3.3	0.3	5.2	132	3.7	154	93
1.31	35.1	33.8	30	1	30.0	30.3	37	0.4	113	1.08	3.3	0.32	5.6	195	4.1	258	104
										Subtotal			14.4				
Layer 4 (altered granitic silty/sandy clay to clayey/silty sand)																	
1.31	38.4	37.1	35	0.95	33.3	29.9	34.5	0.4	113	1.16	3.3	0.34	5.9	192	4.5	193	94
1.31	41.7	40.4	28	0.92	25.8	28.7	32.5	0.5	113	1.23	3.3	0.36	6.2	184	4.9	192	93
1.31	44.9	43.6	29	0.89	25.8	27.9	34	0.4	113	1.3	3.3	0.39	6.7	180	5.3	193	94
1.31	48.2	46.9	31	0.87	27.0	25.6	36	0.4	113	1.38	3.3	0.41	7.1	164	5.6	185	89
1.31	51.5	50.2	28	0.85	23.8	25.8	35.5	0.4	113	1.45	3.3	0.43	7.5	166	6.0	193	93
1.31	54.8	53.7	32	0.83	26.6	25.6	39	0.4	125	1.39	3.3	0.42	7.2	164	6.4	184	89
1.31	58.1	56.8	31	0.81	25.1	24.0	41	0.3	125	1.48	3.3	0.44	7.6	154	6.8	181	87
1.31	61.4	60	26	0.79	20.5	23.6	41	0.3	125	1.57	3.3	0.47	8.1	152	7.2	186	90
1.31	64.6	63.3	29	0.77	22.3	23.8	41	0.3	125	1.66	3.3	0.5	8.6	153	7.6	196	94
1.31	67.9	66.6	37	0.74	27.4	27.1	41	0.3	125	1.75	3.3	0.52	9.0	174	7.9	225	109
										Subtotal			40.4				
Layer 5 (completely decomposed granitic silty/sandy clay to clayey/silty sand)																	
1.31	71.2	69.9	46	0.83	38.2	34.5	39	0.4	125	1.84	3.3	0.55	9.5	221	8.3	325	158
1.31	74.5	73.2	65	0.81	50.0	41.4	41	0.3	125	1.94	3.3	0.58	10.0	266	8.7	379	185
1.31	77.7	76.4	79	0.79	50.0	47.0	41	0.3	125	2.03	3.3	0.61	10.4	302	9.1	425	208
1.31	81	79.7	100	0.77	50.0	50.0	41	0.3	125	2.12	3.3	0.63	10.9	321	9.5	455	223
1.31	84.3	83	120	0.74	50.0	50.0	41	0.3	125	2.21	3.3	0.66	11.4	321	9.9	466	228

Note:
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N : SPT N value
CN : Correction coefficient to N value for overburden pressure.
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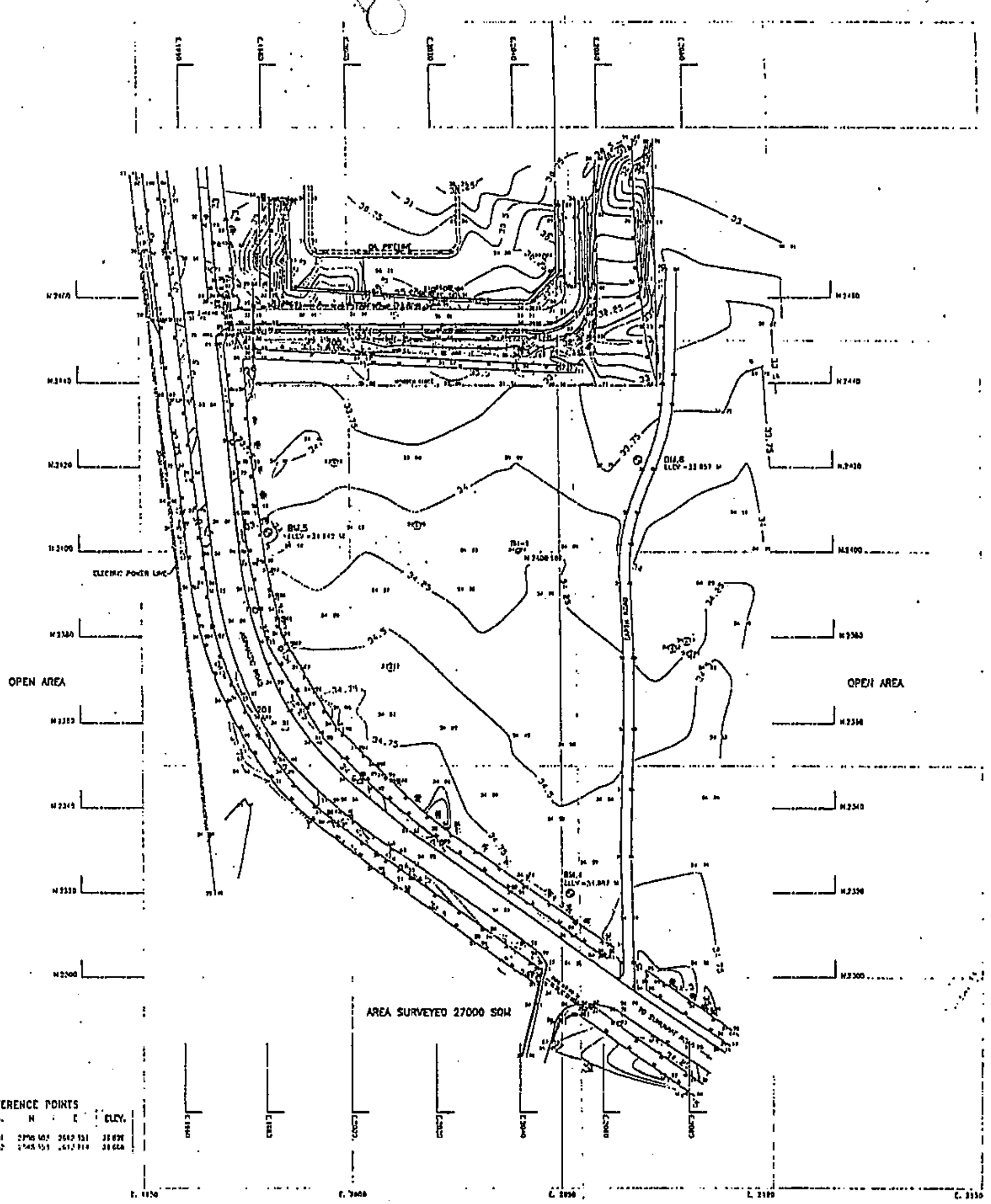
N for Qb : Average of N value in a zone of 8 d above to 3d below the pile point, used for Qb calculation
Qb : Base resistance of pile
Qnf : Negative skin friction
Qs : Skin resistance of pile
Qu : Ultimate bearing capacity of pile
Qa : Allowable bearing capacity of pile.

88



N

SCALE 1 : 500

NOTES :

1. NORTH IS NORTH USED FOR EXISTING SITE DEVELOPMENT OF GAS SEPARATION PLANT (GSP)
2. CO-ORDINATE AND ELEVATIONS ARE BASED ON POINTS GS.101 AND GS.102 LOCATED INSIDE THE SITE OF GSP
3. DISTANCES AND ELEVATION ARE IN METER.

LEGEND :

△	TRAVERSE POINT
⊕	BENCH MARK
×34.0	SPOT ELEVATION
○	ELECTRIC POLE
■	[illegible]
●	GUARD RAIL
○	[illegible]
⊢⊣	GATE
X	[illegible]
⊕	[illegible]

REVISION

NO.	DATE	DESCRIPTION

STS ENGINEERING CONSULTANTS CO.,LTD.

PROJECT NAME

RAYONG GAS RECEIVING TERMINAL
MAB TA PHUT

DRAWING TITLE

TOPOGRAPHIC MAP

SURVEYED

DRAWN

CHECKED Yves Labrecque

DATE 23/12/94.

TRAVERSE POINTS :

STA.	N	E	ELEV.
200	2447.731	1998.734	33.974
201	2361.144	1979.241	34.397
BM-4	2318.891	2052.037	34.807
BM-5	2401.467	1998.970	34.142
BM-6	2421.893	2089.180	33.857

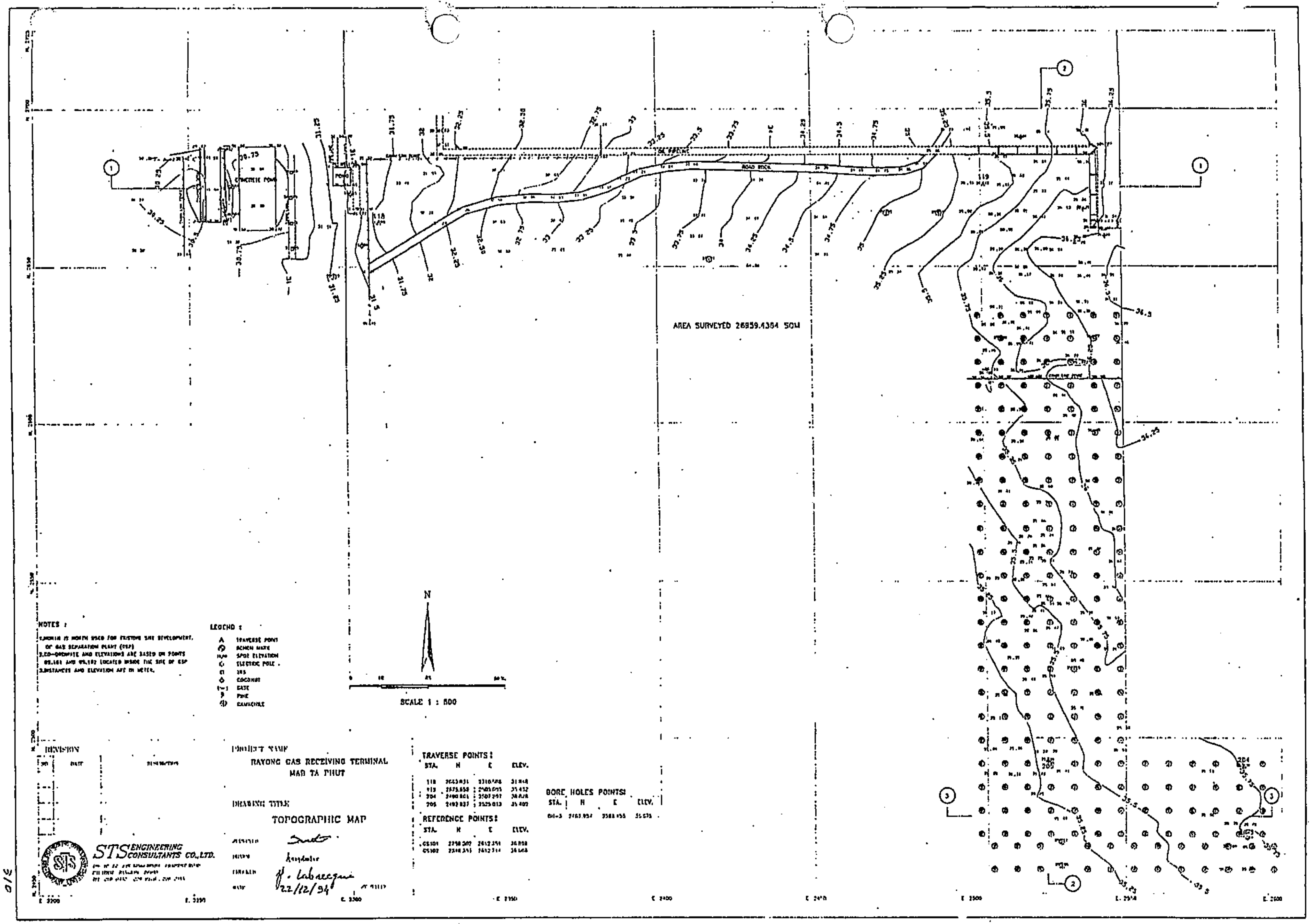
BORE HOLES POINTS :

STA.	N	E	ELEV.
BH-1	2410.142	2018.153	34.035
BH-2	2435.876	2043.402	[illegible]
BH-3	2467.981	2079.625	[illegible]

REFERENCE POINTS

STA.	N	E	ELEV.
GS101	[illegible]	[illegible]	[illegible]
GS102	[illegible]	[illegible]	[illegible]

309



NOTES :

1.NORTH IS NORTH USED FOR EXISTING SITE DEVELOPMENT, OF GAS SEPARATION PLANT (GSP)
2.CO-ORDINATE AND ELEVATIONS ARE BASED ON POINTS GS.101 AND GS.102 LOCATED INSIDE THE SITE OF GSP
3.DISTANCES AND ELEVATION ARE IN METER.

LEGEND :

A	TRAVERSE POINT
⊕	BENCH MARK
35.40	SPOT ELEVATION
○	ELECTRIC POLE .
◻	[illegible]
◇	COCONUT
[illegible]	CASE
[illegible]	PINE
⊕	CAMACHILE

TRAVERSE POINTS :

STA.	N	E	ELEV.
118	[illegible]	[illegible]	[illegible]
119	[illegible]	[illegible]	[illegible]
204	[illegible]	[illegible]	[illegible]
205	[illegible]	[illegible]	[illegible]

REFERENCE POINTS :

STA.	N	E	ELEV.
GS101	[illegible]	[illegible]	[illegible]
GS102	[illegible]	[illegible]	[illegible]

BORE HOLES POINTS :

STA.	N	E	ELEV.
BH-3	[illegible]	[illegible]	[illegible]

REVISION

NO.	DATE	DESCRIPTION

PROJECT NAME
RAYONG GAS RECEIVING TERMINAL
MAB TA PHUT

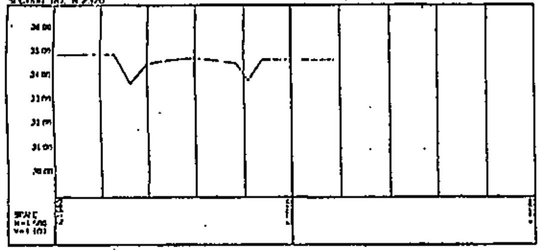
DRAWING TITLE
TOPOGRAPHIC MAP

SURVEYED
DRAWN Kangdualar
CHECKED
DATE 22/12/94

STS ENGINEERING CONSULTANTS CO.,LTD.

310

SECTION NO. N.2320



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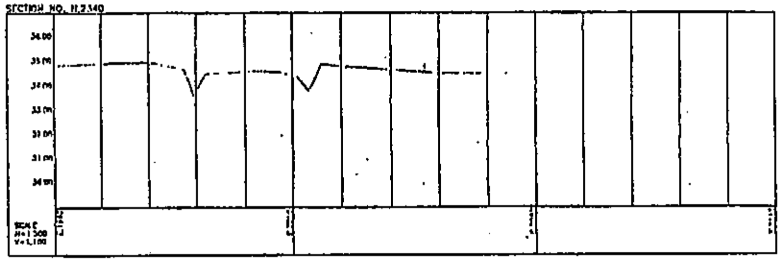

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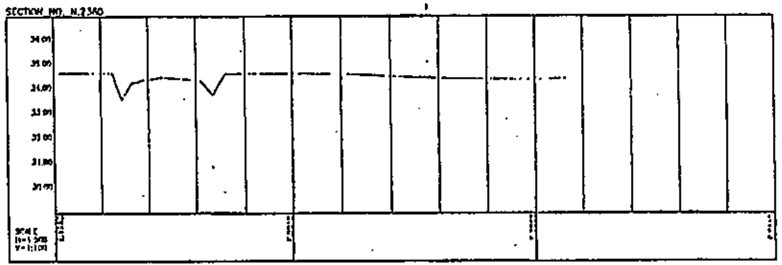

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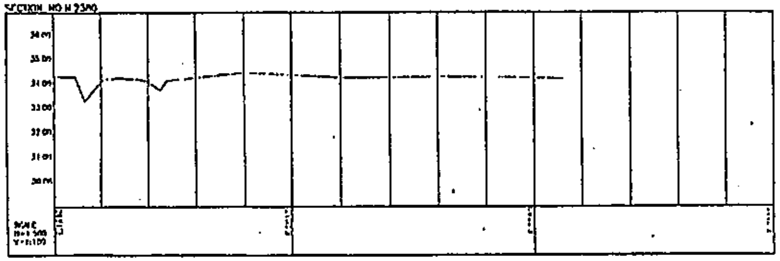

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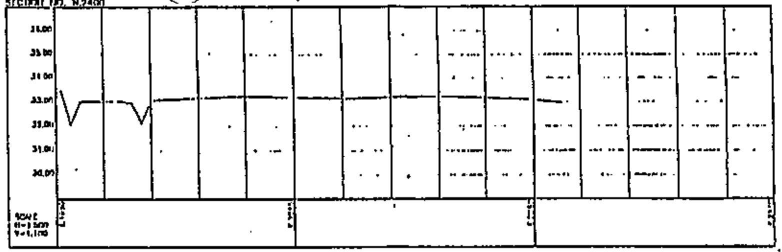

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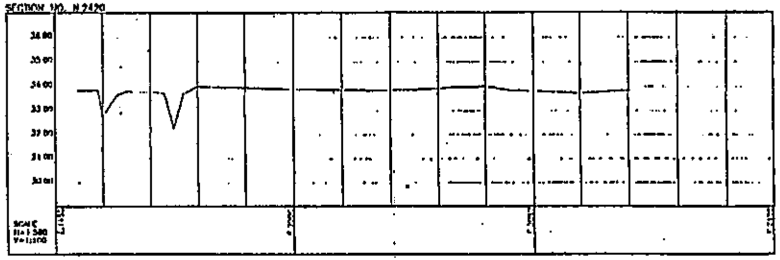

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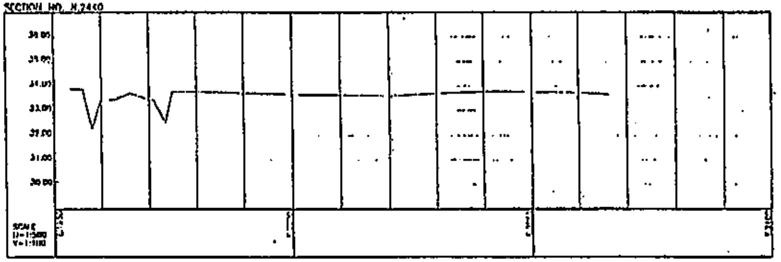

SECTION NO. N.2460

PROJECT NAME :

RAYONG GAS RECEIVING TERMINAL
MAB TA PHUT

STS ENGINEERING CONSULTANTS CO.,LTD.

REVISION :

NO.	DATE	DESCRIPTION

DRAWING TITLE :

CROSS-SECTION

HORIZONTAL SCALE = 1 : 500
VERTICAL SCALE = 1 : 100

STA. N.2320-N.2460

SURVEYED :
DRAWN :
CHECKED :
DATE :

SHEET NO.
1

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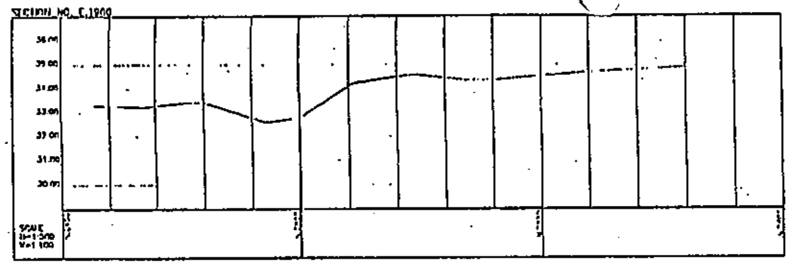

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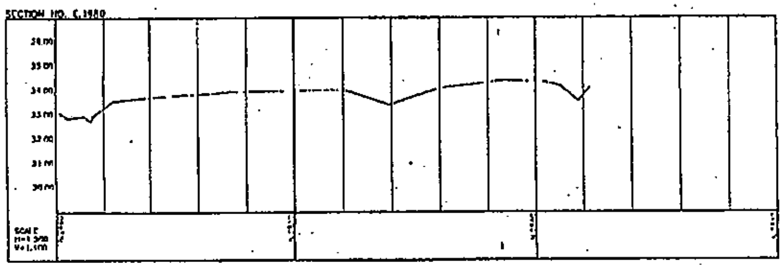

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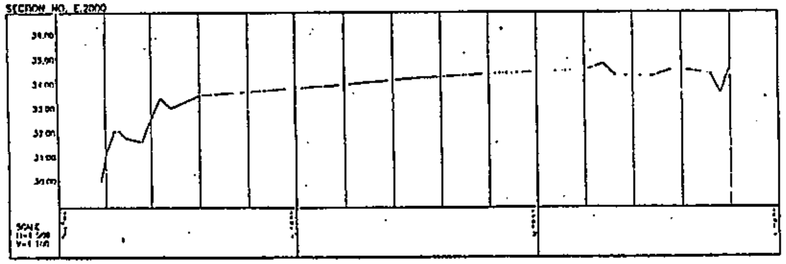

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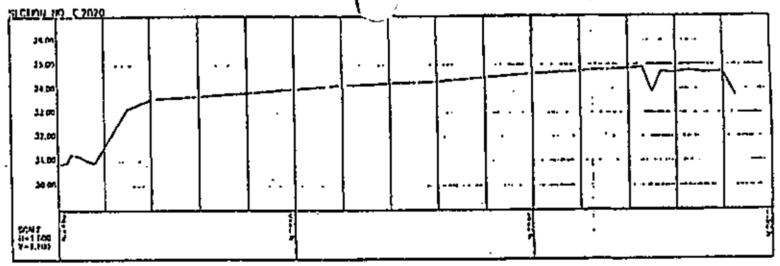

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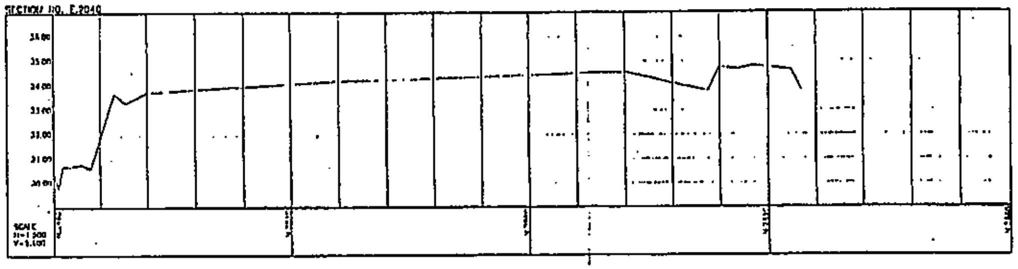

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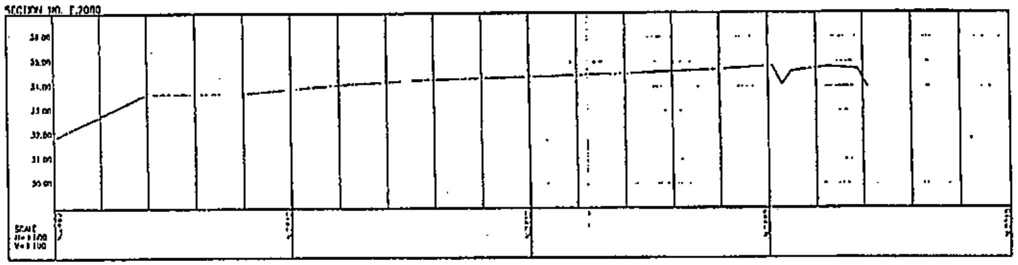

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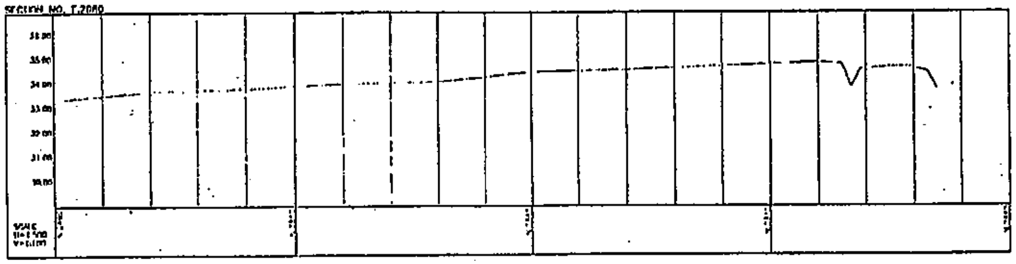


PROJECT NAME :

RAYONG GAS RECEIVING TERMINAL
MAB TA PHUT

STS ENGINEERING CONSULTANTS CO.,LTD.

REVISION :

NO.	DATE	DESCRIPTION

DRAWING TITLE :

CROSS-SECTION

HORIZONTAL SCALE = 1:500
VERTICAL SCALE = 1:100

SURVEYED : Suwit
DRAWN : [illegible]
CHECKED : Labuegun
DATE : 22/12/34

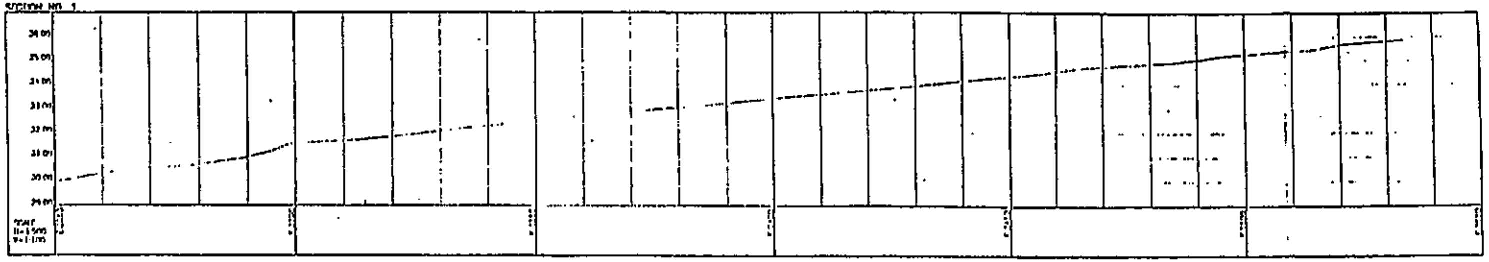
STA. E.1960-E.2080

SHEET NO.

2

3/2

SECTION NO. 1



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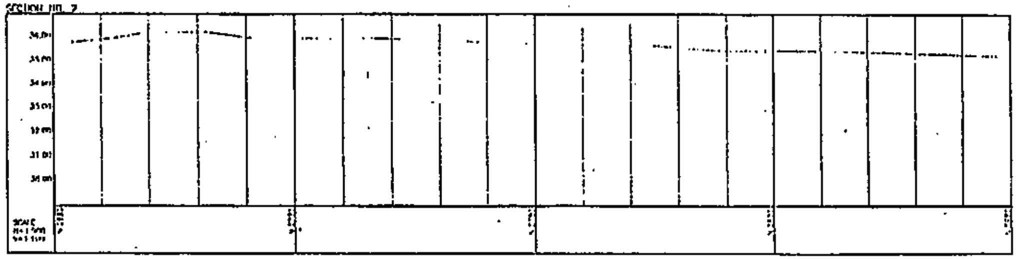

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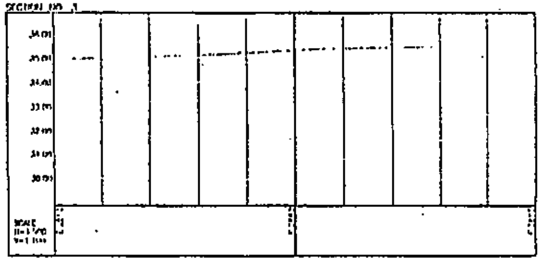

PROJECT NAME :

RAYONG GAS RECEIVING TERMINAL
MAB TA PHUT

STS ENGINEERING CONSULTANTS CO.,LTD.

REVISION :

NO.	DATE	DESCRIPTION

DRAWING TITLE :

CROSS-SECTION

HORIZONTAL SCALE = 1:500
VERTICAL SCALE = 1:100

SURVEYED :
DRAWN :
CHECKED :
DATE : /11/94

STA.1-3

SHEET NO.

3

3/3