INDIAN RIVER INLET BRIDGE

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SUMMARY OF DESIGN SOIL PARAMETERS

REPLACEMENT OF 3-156, SR 1 OVER THE INDIAN RIVER INLET

DelDOT PROJECT NO. 1204

MACTEC PROJECT NO. 3530-03-1245

September 30, 2004

Prepared By

MACTEC

For

Figg Engineering Group

In Cooperation With

DelDOT

MACTEC Engineering and Consulting, Inc. 1606 Ownby Lane Richmond, VA 23229	Project: Indian River Inlet Bridge		
	By: AJA	Date: 9/30/2004	Project No.: 3530-03-1245.02
	Checked: JRW	Date: 9/30/04	

SUMMARY OF DESIGN PARAMETERS

South Approach

Soil Layer	Stratum	Elevation (ft) Top	Elevation (ft) Base	γ (pcf)	φ (deg)	Su (psf)	Lateral Design Parameters: kh (pci)	ε50	G (ksi)	ν	Settlement Parameters: E (ksf)	OCR	Cεc	Cεr	Cα	Cv (in2/d)	Ch (in2/d)
Med. Dense Sand (unsat.)	1	5	0	120	32	0	90	N/A	8.3	0.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Med. Dense Sand (sat.)	1	0	-15	120	32	0	60	N/A	8.3	0.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dense Sand	1	-15	-30	125	34	0	125	N/A	14.2	0.30	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Soft Clay	2	-30	-85	100	0	400	20	0.02	5.2	0.45	N/A	1.00	0.208	0.022	0.004	7.2	14.4
Dense Sand	3	-85	-131	125	38	0	125	N/A	25.3	0.30	1,000	N/A	N/A	N/A	N/A	N/A	N/A
Sandy Clay	4	-131	-135	115	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.25	N/A	N/A	0.001	N/A	N/A
Medium Dense Sand	3	-135	-145	125	N/A	N/A	N/A	N/A	N/A	N/A	500	N/A	N/A	N/A	N/A	N/A	N/A
Sandy Clay	4	-145	-155	115	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.50	N/A	N/A	0.001	N/A	N/A
Medium Dense Sand	3	-155	-170	125	N/A	N/A	N/A	N/A	N/A	N/A	500	N/A	N/A	N/A	N/A	N/A	N/A

North Approach

Soil Layer		Elevation (ft) Top	Elevation (ft) Base	γ (pcf)	φ (deg)	Su (psf)	Lateral Design Parameters: kh (pci)	ε50	G (ksi)	ν	Settlement Parameters: E (ksf)	OCR	Cεc	Cεr	Cα	Cv (in2/d)	Ch (in2/d)
Med. Dense Sand (unsat.)	1	5	0	120	32	0	90	N/A	8.9	0.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Med. Dense Sand (sat.)	1	0	-15	120	32	0	60	N/A	8.9	0.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dense Sand	1	-15	-25	125	34	0	125	N/A	15.6	0.30	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Soft Clay	2	-25	-50	100	0	400	20	0.02	4.2	0.45	N/A	1.00	0.208	0.022	0.004	7.2	14.4
Medium Dense Sand	3	-50	-63	120	32	0	60	N/A	23.3	0.32	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Dense Sand	3	-63	-133	125	38	0	125	N/A	25.3	0.30	1,000	N/A	N/A	N/A	N/A	N/A	N/A
Sandy Clay	4	-133	-138	115	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.25	0.150	0.015	0.001	N/A	N/A
Medium Dense Sand	3	-138	-155	125	N/A	N/A	N/A	N/A	N/A	N/A	500	N/A	N/A	N/A	N/A	N/A	N/A
Sandy Clay	4	-155	-170	115	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.50	0.150	0.015	0.001	N/A	N/A

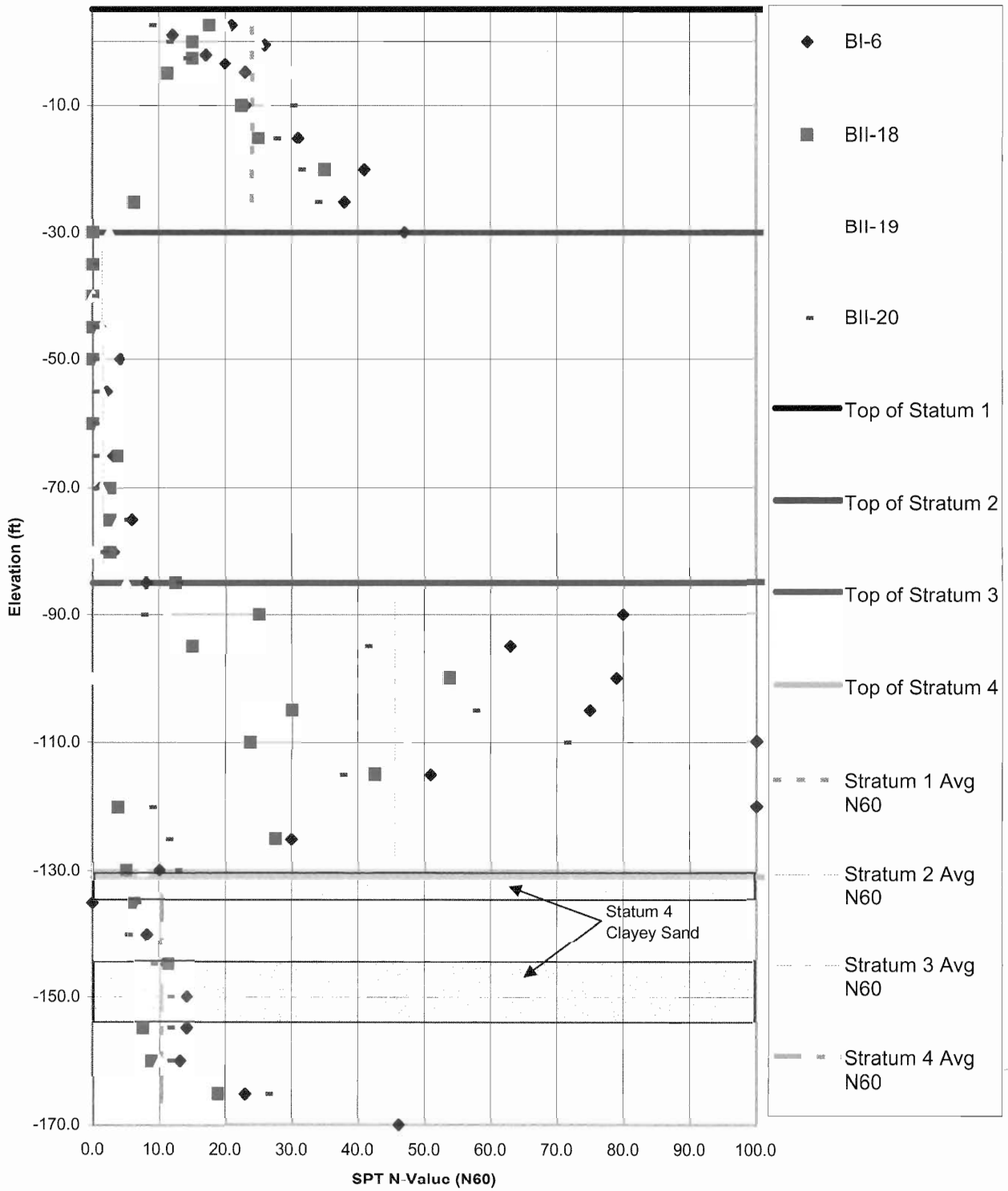
N/A = Parameter not necessary for this material

γ = total unit weight
φ = internal friction angle of cohesionless soil
Su = undrained shear strength
kh = Horizontal soil modulus, static loading
ε50 = axial strain at 1/2 unconfined compressive strength (qu)
G = shear modulus
ν = Poisson's ratio

E = Soil Modulus
OCR = Overconsolidation Ratio
Cεc = Compression Ratio
Cεr = Recompression Ratio
Cα = Coefficient of Secondary Compression
Cv = Coefficient of vertical consolidation
Ch = Coefficient of horizontal consolidation

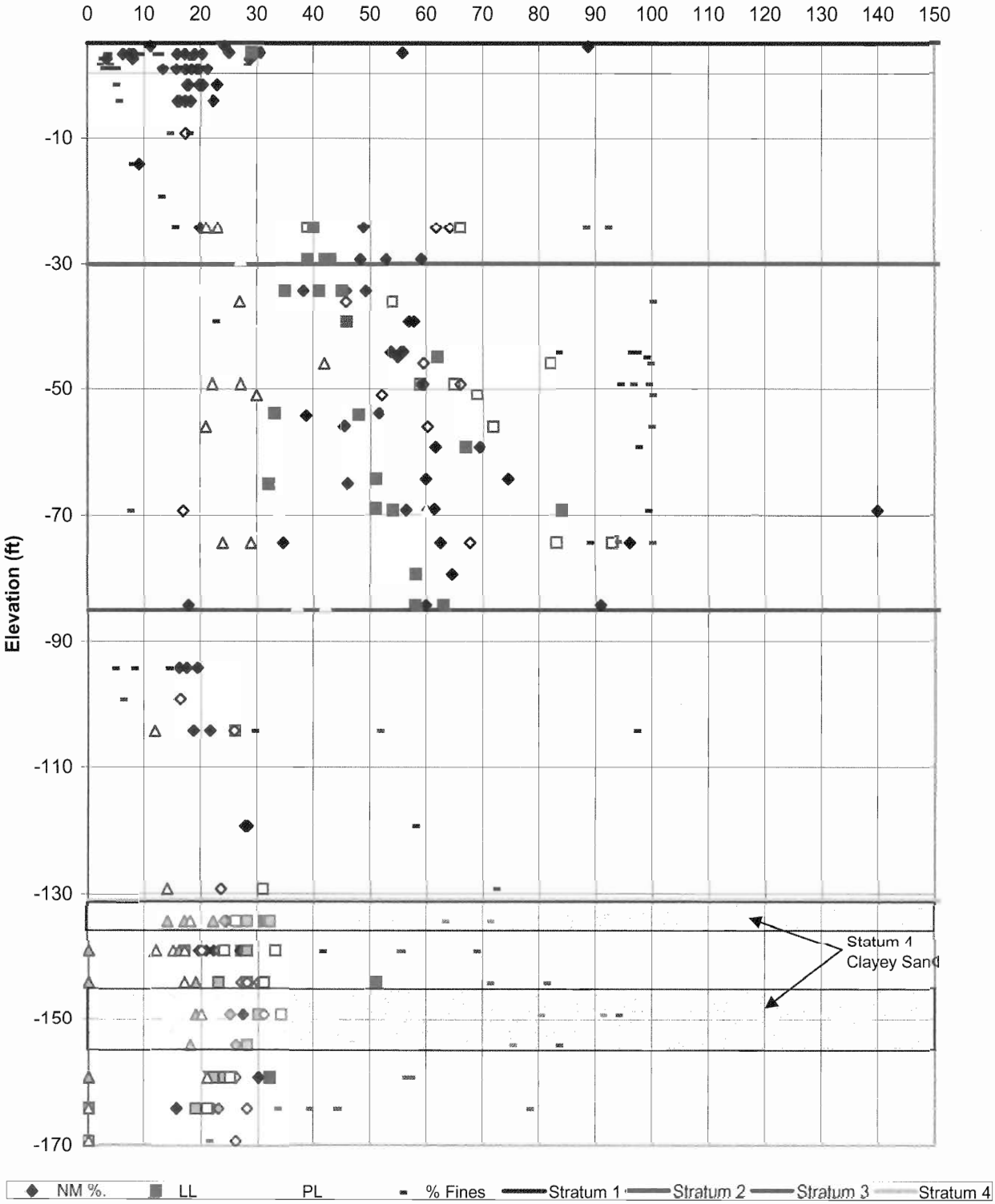
SPT AND LAB DATA
SUMMARY SHEETS

SPT vs. Depth Near South Pier

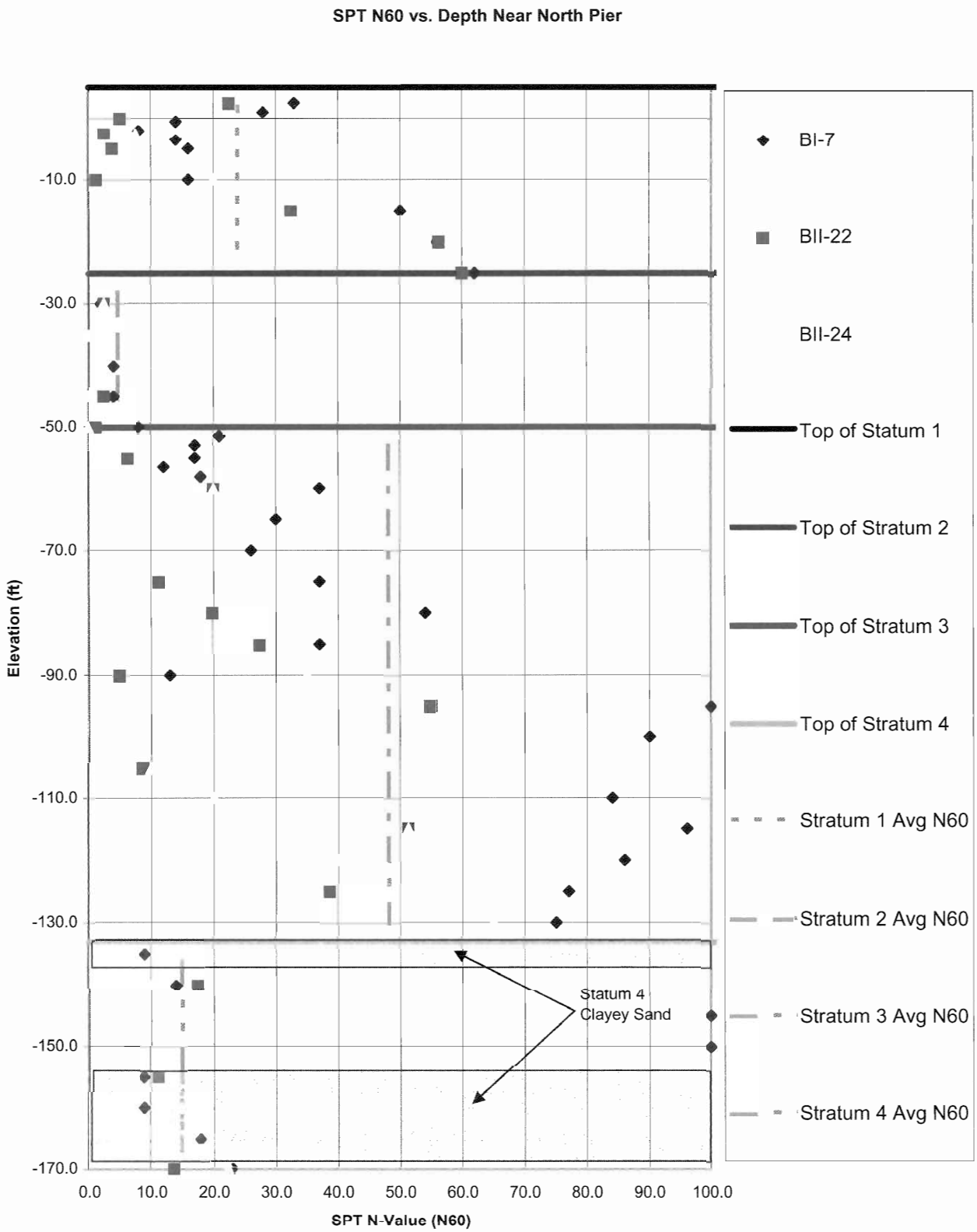


JRW
9/30/04

Lab Data vs. Depth (South Approach)

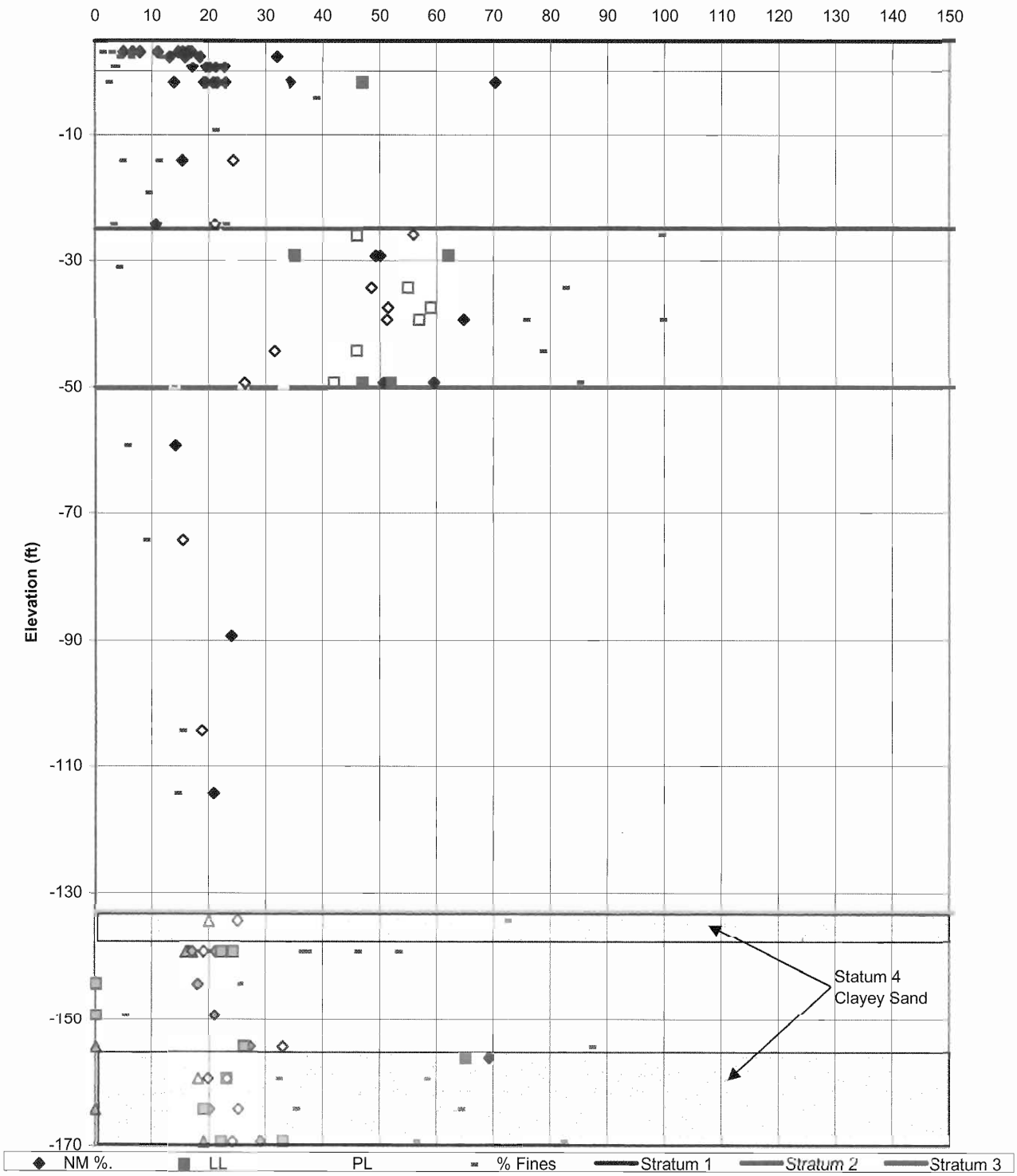


JKW 9/30/04


SPT N60 vs. Depth Near North Pier
Elevation (ft)
-10.0
-30.0
-50.0
-70.0
-90.0
-110.0
-130.0
-150.0
-170.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
SPT N-Value (N60)
Statum 4
Clayey Sand
BI-7
BII-22
BII-24
Top of Statum 1
Top of Stratum 2
Top of Stratum 3
Top of Stratum 4
Stratum 1 Avg N60
Stratum 2 Avg N60
Stratum 3 Avg N60
Stratum 4 Avg N60

JEW 9/30/09

Lab Data vs. Depth (North Approach)



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γ_m

UNIT WEIGHT

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JOB NO. 3530-03-1245.02 SHEET 1 OF 4
PHASE
TASK 02
JOB NAME IRIB - Soil Parameters
BY ATA DATE 12/02/03
CHECKED BY JRW DATE 12/19/03

Purpose: Estimate the unit weight of the soils at the Indian River Inlet bridge site.

Method: Use published tables of values correlated with density + blow counts (SPT)

Solution: Stratum 1 - Medium Dense to Dense Sands.

- From Bowles (1996) - Med Dense Sand $\gamma_m = 110-130$ pcf
  - Dense Sand $\gamma_m = 110-140$ pcf.

North Side: El. +5 → -15', Medium Dense Sand, Avg $N_{60} \sim 15$ bpf
→ use $\gamma_m = 120$ pcf ✓

El. -15 → -25', Dense Sand, Avg $N_{60} \sim 45$ bpf
→ use $\gamma_m = 125$ pcf ✓

South Side El. +5 → -15, Med. dense Sand, Avg $N_{60} \sim 20$ bpf
→ use $\gamma_m = 120$ pcf

El -15 → -30', Dense Sand, Avg $N_{60} \sim 33$ bpf
→ use $\gamma_m = 125$ pcf.

Stratum 2 - Soft Clays

- From Bowles (1996) - Soft clay → $\gamma_m = 100-120$ pcf

North + South Side: Avg $N_{60} \sim 1-5$ bpf → use $\gamma_m = 100$ pcf ✓

Stratum 3 - Medium Dense to very dense Sands

- From Bowles (1996) - Med. Dense Sand → $\gamma_m = 110-130$ pcf
  Very Dense Sand → $\gamma_m = 110-140$ pcf

North Side: El. -50 → -63', Avg $N_{60} \sim 20$ bpf, El. -138 → -155 Avg $N_{60} = 15$
→ use $\gamma_m = 120$ pcf ✓ → use $\gamma_m = 125$ pcf
El -63 → -133', Avg $N_{60} \sim 48$ bpf
→ use $\gamma_m = 125$ pcf ✓

South Side: El. -85 → -131' Avg $N_{60} \sim 46$ bpf
→ use $\gamma_m = 125$ pcf. ✓

El -135 → -145 + -155 → -170' → Avg $N_{60} \sim 15$ → use $\gamma_m = 125$ pcf

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JOB NO. 3530-03-1245 02 SHEET 2 OF 4
PHASE TASK 02
JOB NAME IRIB - Soil Parameters
BY AJA DATE 12/02/03
CHECKED BY JRW DATE 12/19/03

Stratum 4 - Medium Stiff Sandy Clays

- From Bowles (1996) Med. Stiff Clay → γ_m = 110-130 pcf

North + South Sides: N_{60} Range from ~5-25 bpf

→ Use γ_m = 115 pcf. ✓

Foundation Analysis and Design – 2nd Edition
Chap. 3 & 4

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Table 3-2. Standard designation and sizes for drill rods and casing

Drill rod	OD, in	Casing and core barrel	Core-barrel-bit OD, in	Approx. diam of borehole,* in	Diam of core sample, in
E	$1\frac{5}{16}$	EX	$1\frac{7}{16}$	$1\frac{1}{2}$	$\frac{7}{8}$
A	$1\frac{5}{8}$	AX	$1\frac{7}{8}$	2	$1\frac{1}{8}$
B	$1\frac{7}{8}$	BX†	$2\frac{3}{8}$	$2\frac{1}{2}$	$1\frac{5}{8}$
N	$2\frac{3}{8}$	NX	$1\frac{15}{16}$	3	$2\frac{1}{8}$

* Diameter of borehole is very nearly the ID of the casing.
† In soft or fractured rock, BX or larger cores are preferred.

The SPT was originally developed for cohesionless soils so that samples would not have to be taken. The test has evolved to the current practice of routinely determining N for all soils. In the zones of particular interest from about 2.5 ft or 1 m below ground surface to considerable depth below the estimated base of the foundation the test is performed every 2.5 ft or 1 m depth increment. At considerable depths where the boring becomes more informational the depth increment for testing is often increased to 5 ft or 2 m.

Empirical correlations between N and various soil properties have been attempted for cohesionless soils (Table 3-3). Table 3-3 should be used cautiously; for example, a "loose" soil with a range of D_r between 15 and 35 percent places rather arbitrary numbers on a rather tenuous description of a soil.

Table 3-3. Empirical values for ϕ, D_r, and unit weight of granular soils based on the standard penetration number with corrections for depth and for fine saturated sands

Description	Very loose	Loose	Medium	Dense	Very dense
Relative density D_r*	0 – 0.15	0.15 – 0.35	0.35 – 0.65	0.65 – 0.85	0.85 – 1.00
Standard penetration no. N	4	4 – 10	10 – 30	30 – 50	50
Approx. angle of internal friction ϕ°†	25°–30°	27–32°	30–35°	35–40°	38–43°
Approx. range of moist unit weight, (γ) pcf (kN/m^3)	70–100‡ (11–16)	90–115 (14–18)	110–130 (17–20)	110–140 (17–22)	130–150 (20–23)

* USBR [Gibbs and Holtz (1957)].
† After Meyerhof (1956). $\phi = 25 + 25D_r$ with more than 5 percent fines and $\phi = 30 + 25D_r$ with less than 5 percent fines. Use larger values for granular material with 5 percent or less fine sand and silt.
‡ It should be noted that excavated material or material dumped from a truck will weigh 70 to 90 pcf. Material must be quite dense and hard to weigh much over 130 pcf. Values of 105 to 115 pcf for nonsaturated soils are common.

Table 3-4. Empirical values for q_u* and consistency of cohesive soils based on the standard penetration number

Consistency	Very soft	Soft	Medium	Stiff	Very stiff	Hard
q_u, ksf	0	0.5	1.0	2.0	4.0	8.0
N, standard penetration resistance	0	2	4	8	16	32
$\gamma_{(sat)}$, pcf (kN/m^3)		100–120 (16–19)	110–130 (17–20)		120–140 (19–22)	

* These values should be used as a guide only. Local cohesive samples should be tested, and the relationship between N and the unconfined compressive strength q_u established as $q_u = KN$.

Correlation between unconfined compressive strength and penetration number of cohesive coils has also been published, as in Table 3-4. The indicated values of unconfined compressive strength correlated to penetration number in Table 3-4 should be used cautiously, however. Experiences in different areas indicate that it is not unusual to get penetration numbers of 6 to 10 on soils where the unconfined compressive strength may be from 6 to 12 ksf, which is considerably different from data shown in the table, where q_u is approximately one-fourth of the penetration number. A valid correlation between the penetration number and the shear strength of cohesive (ϕ-c) soils can be made only on a local basis, and then the validity may be suspect, unless large enough quantities of tests are made to allow a statistical analysis.

In general, to correlate penetration number to the shear strength of a cohesive (ϕ-c) soil involves evaluating the following expression for the constant of proportionality:

$$q_u = KN \tag{3-4}$$

where K = proportionality constant
N = penetration number

The penetration test applied to gravel or gravelly soils and silty sands yields results which require careful interpretation. In loose gravel the voids formed when the gravel is displaced by the driving shoe of the split spoon may yield low penetration numbers. On the other hand, if the spoon pushes a large piece of rock, the number may be too high.

In very fine, or silty, saturated sand Terzaghi and Peck (1st ed., p. 426) recommended that the penetration number be adjusted if N is greater than 15 as

$$N = 15 + \tfrac{1}{2}(N' - 15) \tag{3-5}$$

where N' is to be used in further computations or is for use in Table 3-3. Bazaraa (1967) also studied Eq. (3-5) for numerous sites. From a plot of N' vs. N a better fit is obtained using

$$N = 0.6N' \tag{3-5a}$$

φ
FRICTION ANGLE

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JOB NO. 3530-03-1245 SHEET 1 OF 5
PHASE TASK 02
JOB NAME IRIB - Soil Parameters
BY AJA DATE 12/2/03
CHECKED BY JRW DATE 12/19/03

Purpose: Estimate the friction angle of granular soils at Indian River Inlet Bridge Site.

Method: Use published tables of values correlated with density and SPT Blowcounts.

Solution: Published Values + Tables:

Medium Dense Sand: EPRI (1990) → $\phi = 30°-36°$
CGPR (1997) → $\phi = 26°-44°$
Bowles (1996) → $\phi = 30°-35°$
Peck (1974) → $\phi = 30°-36°$
(FNDN Eng. Handbook)

Dense Sand: EPRI (1990) → $\phi = 36-41°$
CGPR (1997) → $\phi = 34-50°$
Bowles (1996) → $\phi = 35°-40°$
Peck (1974) → $\phi = 36°-41°$
(FNDN Eng Handbook)

Stratum I - Medium Dense to Dense Sands

North Side: El. +5 → -15, Med. Dense Sand, Avg $N_{60} \sim 15$ bpf
→ use $\phi = 32°$ ✓

El -15 → -25 Dense Sand, Avg $N_{60} \sim 45$ bpf
→ use $\phi = 34°$ ✓

South Side: El +5 → -15, Med Dense Sand, Avg $N_{60} \sim 20$ bpf
→ use $\phi = 32°$ ✓

El -15 → -30', Dense Sand Avg $N_{60} \sim 33$ bpf
→ use $\phi = 34°$ ✓

Stratum III - Medium dense to Very Dense Sands

North Side: El. -50 → -63', Medium dense Sand, Avg $N_{60} \sim 20$ bpf
→ use $\phi = 32°$ ✓

El -63' → -133' Dense Sand, Avg $N_{60} \sim 48$ bpf
→ use $\phi = 38°$ ✓

South Side: El. -85 → -131' Dense Sand, Avg $N_{60} \sim 46$ bpf
→ use $\phi = 38°$ ✓

Table 4-3

N VERSUS $\bar{\phi}_{tc}$ RELATIONSHIPS

N Value (blows/ft or 305 mm)	Relative Density	Approximate $\bar{\phi}_{tc}$ (degrees) (a)	(b)
0 to 4	Very loose	< 28	< 30
4 to 10	Loose	28 to 30	30 to 35
10 to 30	Medium	30 to 36	35 to 40
30 to 50	Dense	36 to 41	40 to 45
> 50	Very dense	> 41	> 45

a - Source: Peck, Hanson, and Thornburn (12), p. 310.
b - Source: Meyerhof (13), p. 17.

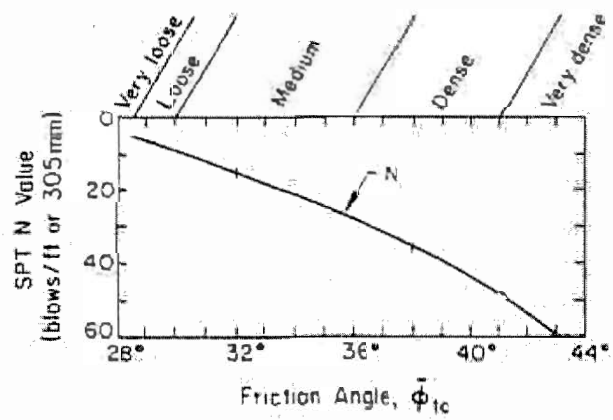

Figure 4-12. N versus $\bar{\phi}_{tc}$

Source: Peck, Hanson, and Thornburn (12), p. 310.

$$\bar{\phi}_{tc} = \tan^{-1}[N/(12.2 + 20.3\ \sigma_{vo}/p_a)]^{0.34} \qquad (4\text{-}11)$$

These results tend to be somewhat conservative and should not be used at very shallow depths, less than 1 to 2 m (3.3 to 6.6 ft). Improved correlations with the other variables described in Section 2 have not been developed to date.

Correlations with CPT q_c Value

Similarly, correlations of $\bar{\phi}_{tc}$ with cone tip resistance, q_c, have been

McGregor, J.A. Duncan, J.M., CGPR, Blacksburg, VA, 1998.

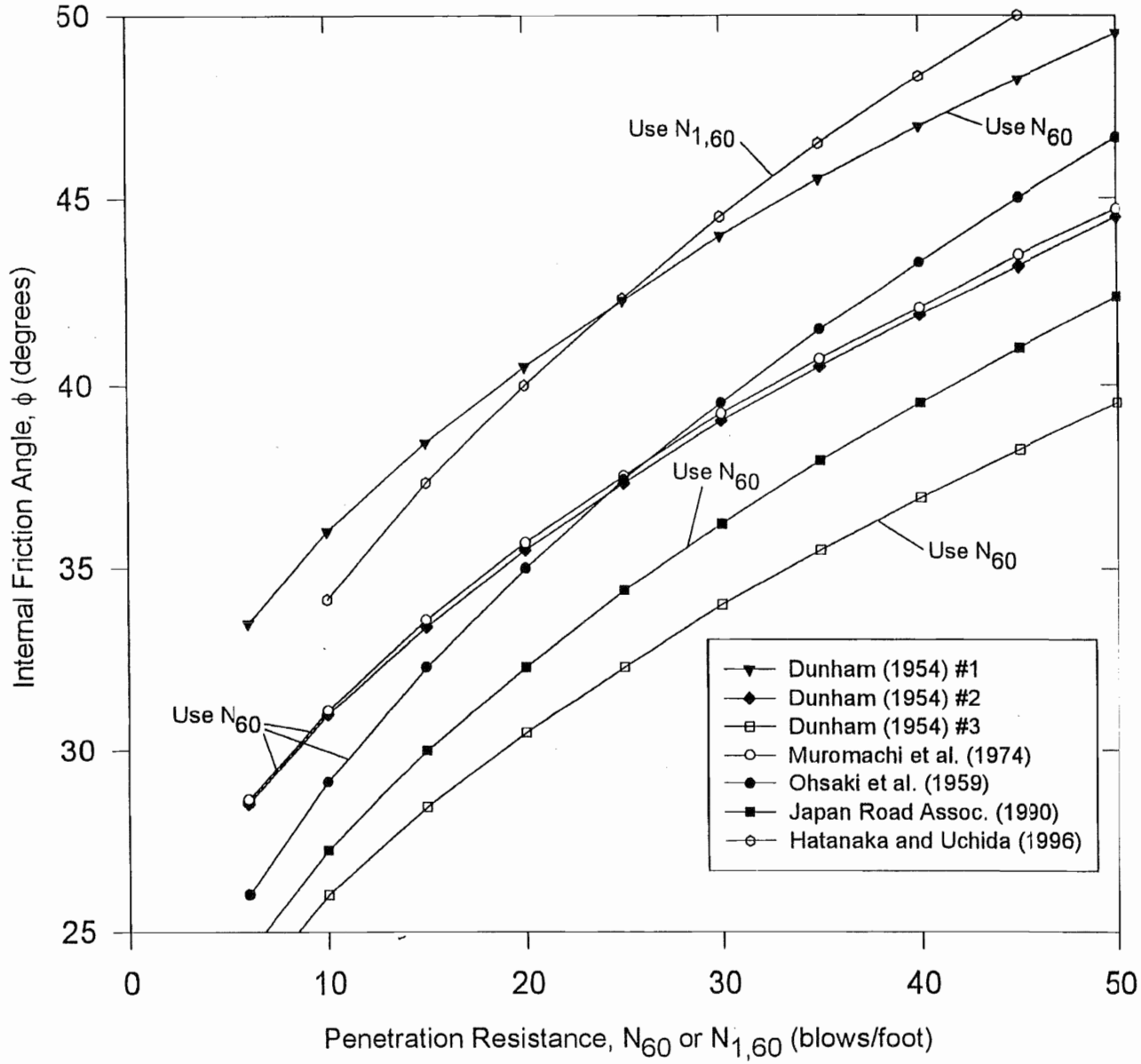

Figure 33. Correlations between internal friction angle and penetration resistance

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By J. E. Bowles

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Table 3-2. Standard designation and sizes for drill rods and casing

Drill rod	OD, in	Casing and core barrel	Core-barrel-bit OD, in	Approx. diam of borehole,* in	Diam of core sample, in
E	$1\frac{5}{16}$	EX	$1\frac{7}{16}$	$1\frac{1}{2}$	$\frac{7}{8}$
A	$1\frac{5}{8}$	AX	$1\frac{7}{8}$	2	$1\frac{1}{8}$
B	$1\frac{7}{8}$	BX†	$2\frac{3}{8}$	$2\frac{1}{2}$	$1\frac{5}{8}$
N	$2\frac{3}{8}$	NX	$1\frac{15}{16}$	3	$2\frac{1}{8}$

* Diameter of borehole is very nearly the ID of the casing.
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Empirical correlations between N and various soil properties have been attempted for cohesionless soils (Table 3-3). Table 3-3 should be used cautiously; for example, a "loose" soil with a range of D_r between 15 and 35 percent places rather arbitrary numbers on a rather tenuous description of a soil.

Table 3-3. Empirical values for ϕ, D_r, and unit weight of granular soils based on the standard penetration number with corrections for depth and for fine saturated sands

Description	Very loose	Loose	Medium	Dense	Very dense
Relative density D_r*	0 – 0.15	0.15 – 0.35	0.35 – 0.65	0.65 – 0.85	0.85 – 1.00
Standard penetration no. N	4	10	30	50	
Approx. angle of internal friction ϕ°†	25°–30°	27–32°	30–35°	35–40°	38–43°
Approx. range of moist unit weight, (γ) pcf (kN/m^3)	70–100‡ (11–16)	90–115 (14–18)	110–130 (17–20)	110–140 (17–22)	130–150 (20–23)

* USBR [Gibbs and Holtz (1957)].
† After Meyerhof (1956). $\phi = 25 + 25D_r$ with more than 5 percent fines and $\phi = 30 + 25D_r$ with less than 5 percent fines. Use larger values for granular material with 5 percent or less fine sand and silt.
‡ It should be noted that excavated material or material dumped from a truck will weigh 70 to 90 pcf. Material must be quite dense and hard to weigh much over 130 pcf. Values of 105 to 115 pcf for nonsaturated soils are common.

Foundation Engineering Handbook

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D = diameter of the vane
M = total resisting moment at failure (resisting moment from the circumference of cylinder plus resisting moment from the end of cylinder)

The assumptions made in the vane test are that the maximum value of torque is used, which means the shear strength is computed from one reading only. The test is assumed to be an undrained test which means that no drainage is allowed to take place during the test. No disturbance of the soil caused by the drilling operations or the installation of the vane is considered. It is assumed that the undrained shear strength is the same in both horizontal and vertical directions, and also that the height of the vane is equal to twice its diameter. The factors affecting the vane test, including the method of installation, vane dimensions, time effect, mode of failure, and inhomogeneities of soil layers are given by Flaate (1966). Other information such as test procedures and interpretation of test results are given in ASTM publications and by Cox (1967).

Pressuremeter

The Menard Type of pressuremeter (1956, 1969) consists of two main portions; a probe and a pressure-volumeter, connected by plastic tubes through which water and gas are applied. The required pressures and volume changes are measured, giving a type of stress-strain test in place.

The probe is a cylindrical metal assembly with rubber membranes attached to three independent cells. The central cell contains water under gas pressure (CO_2), so that the increase in volume of this cell is measured by the lowering of the water level in the volumeter at the surface. The lower and upper cells are called guard cells and expand under equal gas pressure from the surface to minimize the effects of end restraint on the measuring cell. The volumeter is so equipped that a monitored gas pressure can be used to force water into the measuring cell. The pressuremeter probe applies a radial pressure to the soil around the probe in the borehole. The pressure gauge and volumeter permit simultaneous measurement of pressure and volume change of the probe. A correlation study of pressuremeter data and conventional shear test results for various types of soil is given by Higgins (1969). Other types of pressuremeters incorporating similar principles were developed independently at the AASHO Road Test in 1956 (Fang, 1969), where the probe has been used to measure the internal deformation characteristics of embankment soil and of base and subbase material.

With regard to cohesionless soils, Table 2.43 shows general relationships between relative density, standard penetration resistance, and angle of internal friction (Peck, 1974; Meyerhof, 1956). These data can be used for preliminary design. For a fundamental theoretical treatment see Winterkorn (1971).

TABLE 2.43 RELATIONSHIP BETWEEN RELATIVE DENSITY, PENETRATION RESISTANCE, AND ANGLE OF INTERNAL FRICTION OF COHESIONLESS SOILS.

Type of Soil	*Penetration Resistance N*	*Relative Density D_r*	*Angle of Internal Friction ϕ*	
			Peck (1974)	*Meyerhof (1956)*
loose sand	<4	<0.2	<29	<30
Loose sand	4–10	0.2–0.4	29–30	30–35
Medium sand	10–30	0.4–0.6	30–36	35–40
Dense sand	30–50	0.6–0.8	36–41	40–45
Very dense sand	>50	>0.8	>41	>45

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S_u
UNDRAINED SHEAR STRENGTH

MACTEC

MACTEC Engineering and Consulting, Inc.
1606 Ownby Lane
Richmond, VA 23220

JOB NO. 3530-03-1245 SHEET 1 OF 17
PHASE TASK 02
JOB NAME IRIB - Soil parameters
BY AJA DATE 12/22/04
CHECKED BY JRW DATE 12/23/04

Purpose: To Estimate the Shear strength of the fine grained soils at the Indian River Inlet Bridge Site.

Method: Use Laboratory Strength Tests, In-Situ vane shear tests + tables of published values based on Consistency + SPT blowcount.

Solution:

Stratum 2 - Soft Clays.

North + South Sides: Lab Strength tests (Attached)
→ Min S_u = 245 psf Max S_u = 1270 psf
- Avg ~ 815 psf

VST Tests (Attached)
→ Min S_u = 387 psf Max S_u = 559 psf
- Avg ~ 437 psf

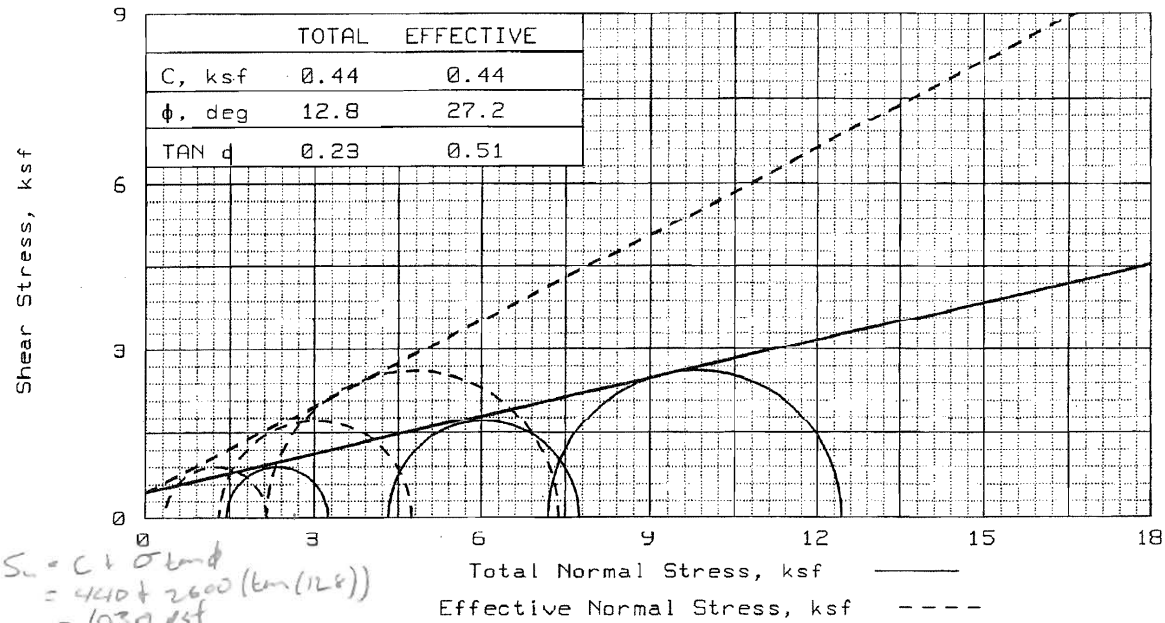
SPT Correlations: CGPR SPT Manual (1997)
→ Soft Clays (N_{60} = 2-4 bpf) → S_u ~ 250-500 psf
→ use 400 psf in design. ✓

Stratum 4 - Stiff Sandy Clays

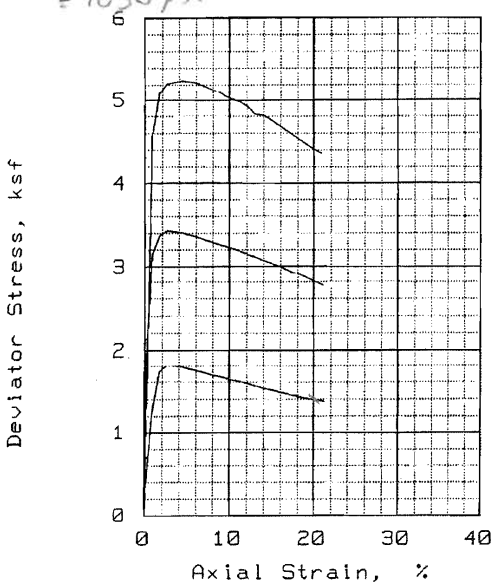
North + South Sides: Lab Strength Test (Attached)
S_u = 3740 psf

SPT Correlations: CGPR SPT Manual (1997)
→ Stiff Clays (N_{60} ~ 8-15 bpf)
- S_u = 1000-2000 psf
- S_u = 1200-2400 psf
→ use S_u = 2000 psf in design. ✓

2/17



$S_u = C + \bar{\sigma} \tan\phi$
$= 440 + 2600(\tan(12.8))$
$= 1030$ psf



SAMPLE NO.:		1	2	3
INITIAL	WATER CONTENT, %	49.2	51.7	53.7
	DRY DENSITY, pcf	71.3	69.9	68.9
	SATURATION, %	96.8	98.9	100.0
	VOID RATIO	1.383	1.411	1.448
	DIAMETER, in	2.85	2.84	2.85
	HEIGHT, in	5.50	5.50	5.58
AT TEST	WATER CONTENT, %	46.8	42.7	38.1
	DRY DENSITY, pcf	73.8	78.2	81.9
	SATURATION, %	97.8	99.7	97.1
	VOID RATIO	1.302	1.156	1.059
	DIAMETER, in	2.80	2.68	2.61
	HEIGHT, in	5.50	5.50	5.58
Strain rate, in/min		0.0016	0.0016	0.0016
BACK PRESSURE, ksf		5.62	5.62	5.62
CELL PRESSURE, ksf		7.06	9.94	12.82
FAILURE STRESS, ksf		1.81	3.43	5.25
TOTAL PORE PR., ksf		6.71	8.63	10.67
ULTIMATE STRESS, ksf		1.37	2.76	4.35
TOTAL PORE PR., ksf		6.81	9.03	11.13
$\bar{\sigma}_1$ FAILURE, ksf		2.16	4.74	7.39
$\bar{\sigma}_3$ FAILURE, ksf		0.35	1.31	2.15

TYPE OF TEST:
CU with Pore Pressures
SAMPLE TYPE: Undisturbed
DESCRIPTION: Dark gray fat CLAY (CH)
LL= 54 PL= 27 PI= 27
SPECIFIC GRAVITY= 2.72
REMARKS:

9/20/03

Fig. No.: 1

CLIENT:

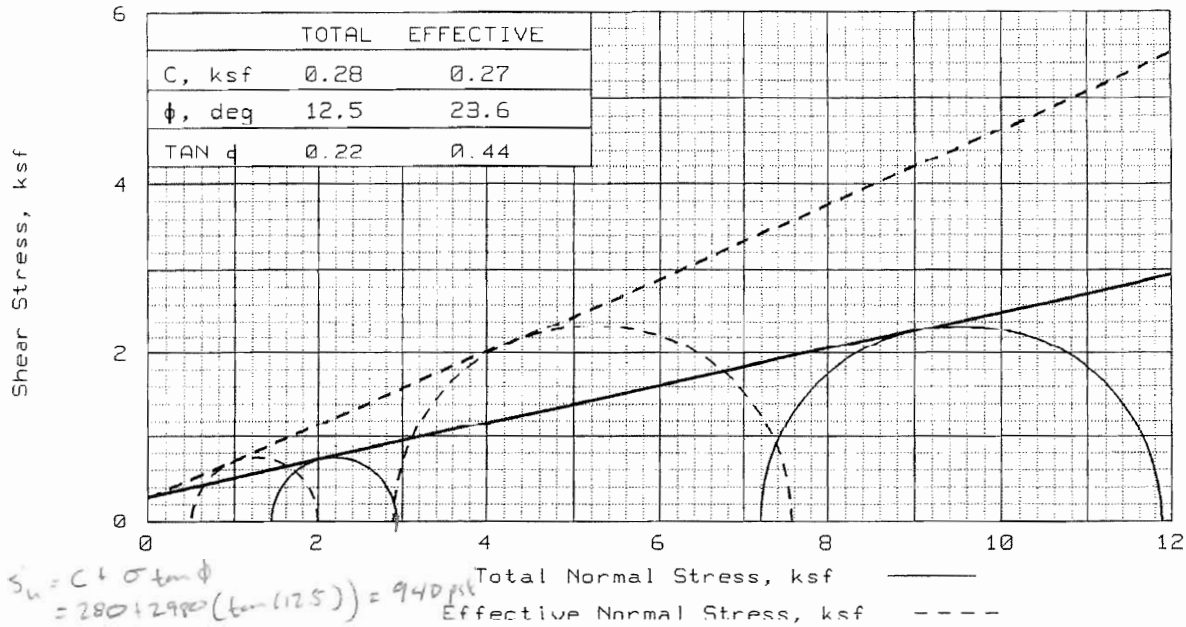
PROJECT: Indian River Inlet Bridges

SAMPLE LOCATION: BI-3 UD-8 @ 40' - 42'
$\sigma'_{v_0} \sim 30(125) + 11(100) - 36(62.4) \sim 2600$ psf

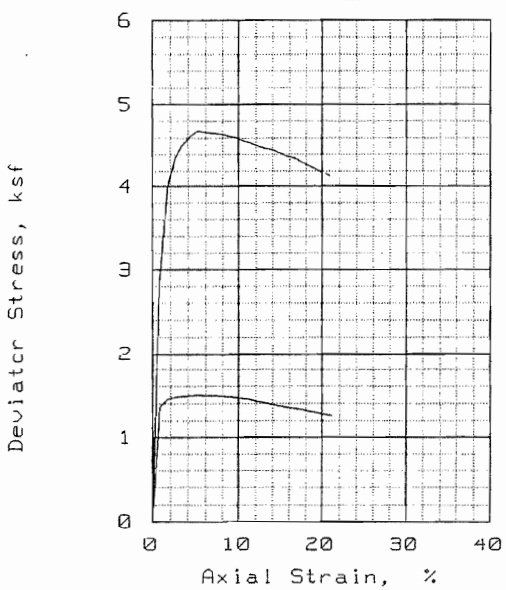
PROJ. NO. 3530-03-1245 Phase 01 DATE: 9/3/03

TRIAXIAL SHEAR TEST REPORT

LAW ENGINEERING AND ENVIRONMENTAL SERVICES



$S_u = C + \sigma \tan\phi$
$= 280 + 2980(\tan(12.5)) = 940$ psf



SAMPLE NO.:		1	2
INITIAL	WATER CONTENT, %	59.5	58.9
	DRY DENSITY, pcf	62.1	62.9
	SATURATION, %	93.7	94.6
	VOID RATIO	1.714	1.680
	DIAMETER, in	2.84	2.85
	HEIGHT, in	5.50	5.55
AT TEST	WATER CONTENT, %	59.8	42.8
	DRY DENSITY, pcf	62.7	76.5
	SATURATION, %	95.8	96.0
	VOID RATIO	1.686	1.202
	DIAMETER, in	2.83	2.58
	HEIGHT, in	5.50	5.55
Strain rate, in/min		0.0016	0.0016
BACK PRESSURE, ksf		5.62	4.18
CELL PRESSURE, ksf		7.06	11.38
FAILURE STRESS, ksf		1.49	4.68
TOTAL PORE PR., ksf		6.55	8.48
ULTIMATE STRESS, ksf		1.26	4.12
TOTAL PORE PR., ksf		6.47	8.77
$\bar{\sigma}_1$ FAILURE, ksf		2.00	7.58
$\bar{\sigma}_3$ FAILURE, ksf		0.50	2.89

TYPE OF TEST:
CU with Pore Pressures
SAMPLE TYPE: Undisturbed
DESCRIPTION: Dark greenish gray elastic SILT (MH)
LL= 82 PL= 42 PI= 40
SPECIFIC GRAVITY= 2.7
REMARKS: 9/24/03

CLIENT:

PROJECT: Indian River Inlet Bridges

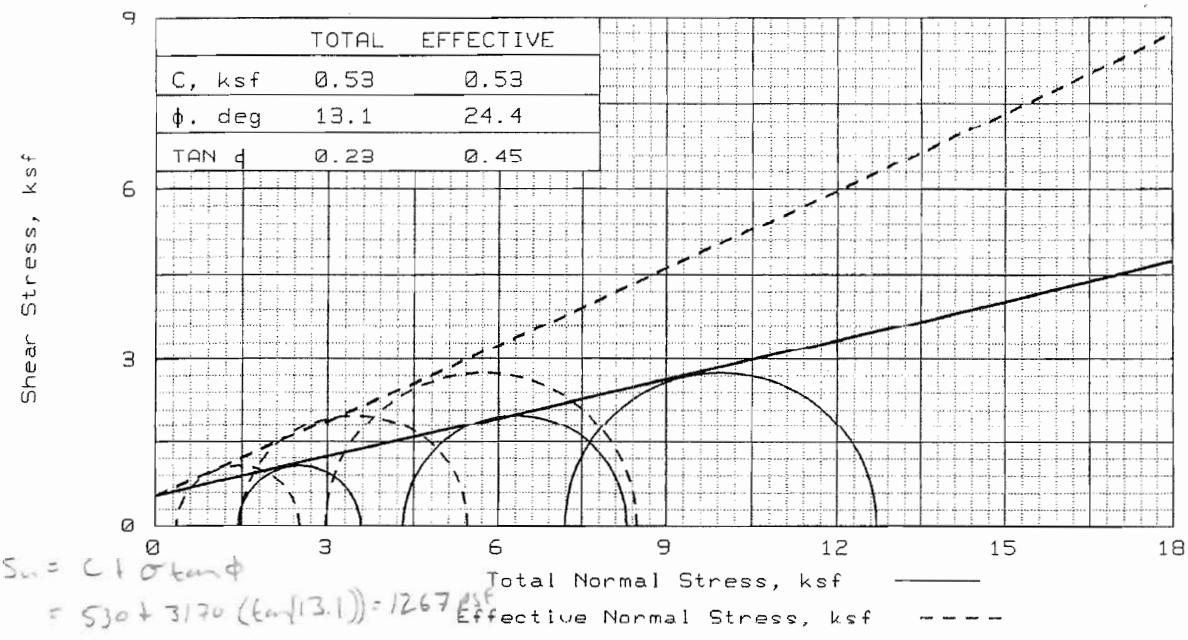
SAMPLE LOCATION: Boring BI-3 @ 50' - 52'
$\sigma_{vo}' \sim 30(125) + 21(100) - 46(62.4) \sim 2980$ psf

PROJ. NO.: 3530-03-1243 Task 01 DATE: 9/18/03

TRIAXIAL SHEAR TEST REPORT

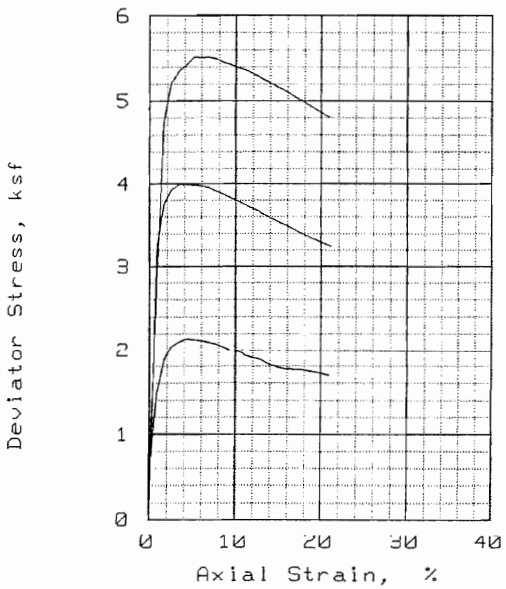
LAW ENGINEERING AND ENVIRONMENTAL SERVICES

Fig. No.: 1



	TOTAL	EFFECTIVE
C, ksf	0.53	0.53
ϕ, deg	13.1	24.4
TAN ϕ	0.23	0.45

$S_u = C + \sigma \tan\phi$
$= 530 + 3170(\tan(13.1)) = 1267$ psf



SAMPLE NO.:		1	2	3
INITIAL	WATER CONTENT, %	52.2	48.1	52.0
	DRY DENSITY, pcf	68.6	73.2	68.9
	SATURATION, %	96.7	99.6	97.1
	VOID RATIO	1.457	1.304	1.447
	DIAMETER, in	2.86	2.84	2.83
	HEIGHT, in	5.56	5.53	5.57
AT TEST	WATER CONTENT, %	48.5	39.1	40.2
	DRY DENSITY, pcf	72.6	81.9	80.7
	SATURATION, %	99.1	99.8	99.6
	VOID RATIO	1.321	1.059	1.090
	DIAMETER, in	2.78	2.69	2.61
	HEIGHT, in	5.56	5.53	5.57
Strain rate, in/min		0.0016	0.0016	0.0016
BACK PRESSURE, ksf		4.18	5.62	5.62
CELL PRESSURE, ksf		5.62	9.94	12.82
FAILURE STRESS, ksf		2.14	3.99	5.52
TOTAL PORE PR., ksf		5.24	8.47	9.85
ULTIMATE STRESS, ksf		1.70	3.24	4.81
TOTAL PORE PR., ksf		5.37	8.83	10.32
$\bar{\sigma}_1$ FAILURE, ksf		2.51	5.46	8.49
$\bar{\sigma}_3$ FAILURE, ksf		0.37	1.47	2.97

TYPE OF TEST:
CU with Pore Pressures
SAMPLE TYPE: Undisturbed
DESCRIPTION: Dark gray fat CLAY (CH)

SPECIFIC GRAVITY= 2.7
REMARKS:

9/23/03

CLIENT:

PROJECT: Indian River Inlet Bridges

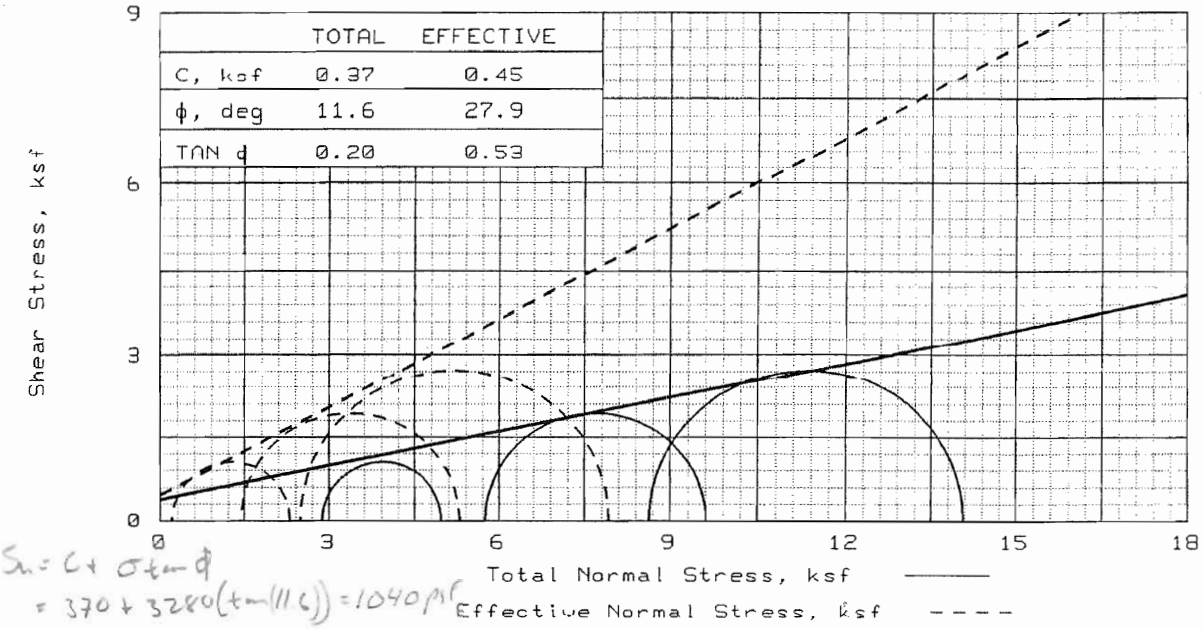
SAMPLE LOCATION: Boring BI 6 @ 55' - 57'
$\sigma_{vo} \sim 30(125) + 26(100) - 51(62.4) = 3170$ psf

PROJ. NO.: 3530-03-1245 Phase 01 DATE: 9/22/03

TRIAXIAL SHEAR TEST REPORT

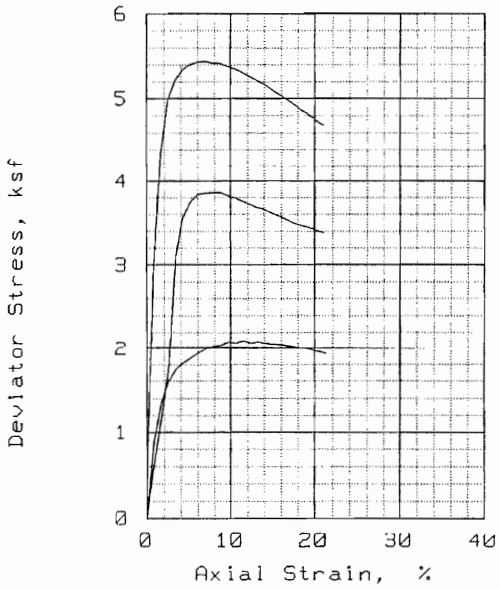
LAW ENGINEERING AND ENVIRONMENTAL SERVICES

Fig. No.: 1



	TOTAL	EFFECTIVE
C, ksf	0.37	0.45
ϕ, deg	11.6	27.9
TAN ϕ	0.20	0.53

$S_u = C + \sigma \tan\phi$
$= 370 + 3280(\tan(11.6)) = 1040$ psf



SAMPLE NO.:		1	2	3
INITIAL	WATER CONTENT, %	53.9	57.4	51.5
	DRY DENSITY, pcf	68.3	65.1	70.0
	SATURATION, %	99.1	97.0	98.8
	VOID RATIO	1.467	1.608	1.408
	DIAMETER, in	2.85	2.86	2.86
	HEIGHT, in	5.50	5.53	5.54
AT TEST	WATER CONTENT, %	47.1	43.2	36.9
	DRY DENSITY, pcf	73.7	77.0	84.0
	SATURATION, %	98.8	97.7	99.0
	VOID RATIO	1.288	1.205	1.006
	DIAMETER, in	2.74	2.63	2.61
	HEIGHT, in	5.50	5.53	5.54
Strain rate, in/min		0.0001	0.0016	0.0016
BACK PRESSURE, ksf		2.88	4.18	4.18
CELL PRESSURE, ksf		5.76	9.94	12.82
FAILURE STRESS, ksf		2.10	3.86	5.44
TOTAL PORE PR., ksf		5.54	8.50	10.32
ULTIMATE STRESS, ksf				
TOTAL PORE PR., ksf				
$\bar{\sigma}_1$ FAILURE, ksf		2.32	5.30	7.93
$\bar{\sigma}_3$ FAILURE, ksf		0.22	1.44	2.49

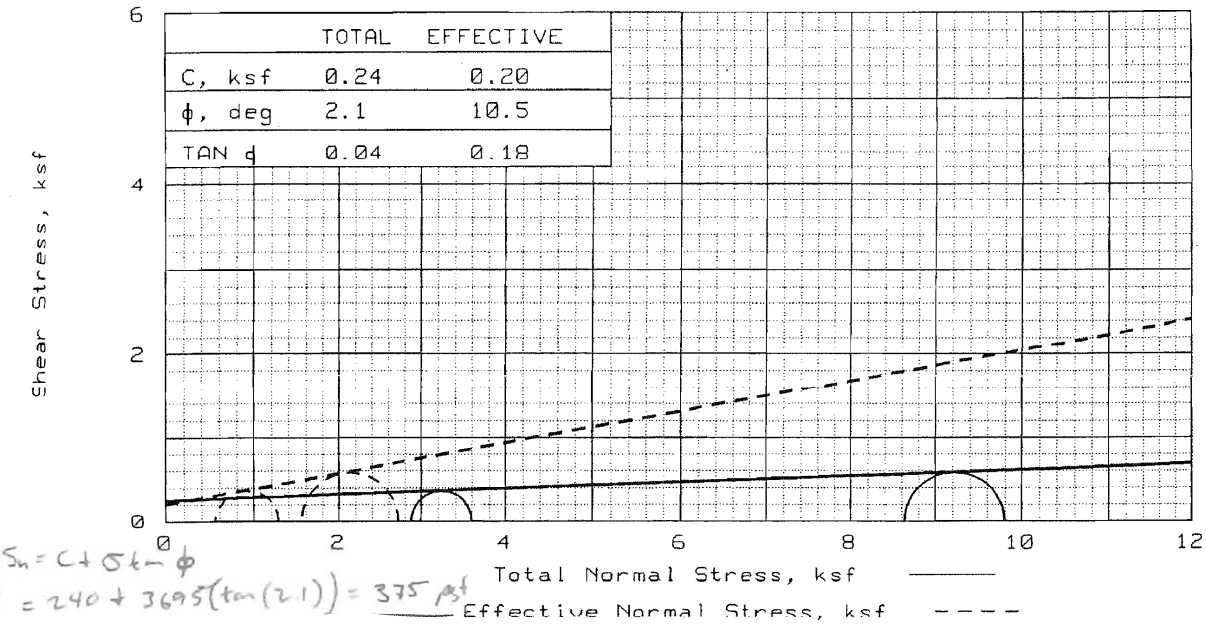
TYPE OF TEST:
CU with Pore Pressures
SAMPLE TYPE: Undisturbed
DESCRIPTION: Dark gray lean CLAY (CL)
LL= 38 PL= 22 PI= 16
SPECIFIC GRAVITY= 2.7
REMARKS:

CLIENT:
4/22/03
PROJECT. Indian River Inlet Bridges
SAMPLE LOCATION: Boring BII-14 @ 59' - 60'
$\sigma_{vo} = 30(115) + 29(100) - 54(62.4) = 3280$ psf
PROJ. NO.: 3530-03-1245 Task 02 DATE: 12/22/03

TRIAXIAL SHEAR TEST REPORT

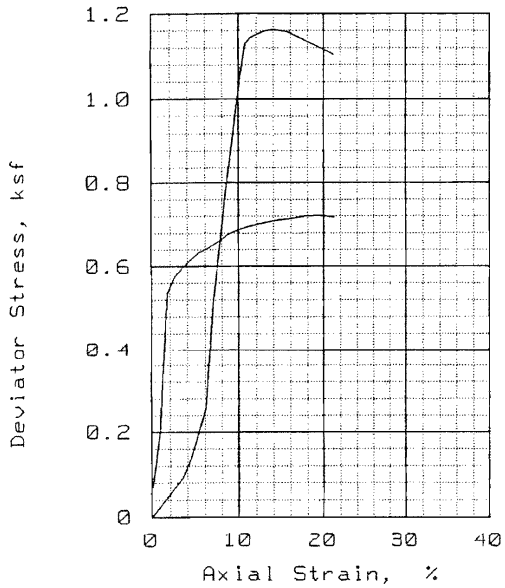
LAW ENGINEERING AND ENVIRONMENTAL SERVICES

Fig. No.: 1



	TOTAL	EFFECTIVE
C, ksf	0.24	0.20
ϕ, deg	2.1	10.5
TAN ϕ	0.04	0.18

$S_u = C + \sigma \tan \phi$
$= 240 + 3695(\tan(2.1)) = 375$ psf



SAMPLE NO.:		1	2
INITIAL	WATER CONTENT, %	54.9	43.0
	DRY DENSITY, pcf	66.2	76.0
	SATURATION, %	95.9	95.5
	VOID RATIO	1.545	1.217
	DIAMETER, in	2.87	2.87
	HEIGHT, in	5.50	5.50
AT TEST	WATER CONTENT, %	31.0	29.2
	DRY DENSITY, pcf	91.2	93.4
	SATURATION, %	98.9	98.1
	VOID RATIO	0.847	0.805
	DIAMETER, in	2.45	2.59
	HEIGHT, in	5.50	5.50
Strain rate, in/min		0.0016	0.0016
BACK PRESSURE, ksf		4.18	4.18
CELL PRESSURE, ksf		7.06	12.82
FAILURE STRESS, ksf		0.72	1.16
TOTAL PORE PR., ksf		6.49	11.26
ULTIMATE STRESS, ksf			
TOTAL PORE PR., ksf			
$\bar{\sigma}_1$ FAILURE, ksf		1.28	2.72
$\bar{\sigma}_3$ FAILURE, ksf		0.56	1.56

TYPE OF TEST:
CU with Pore Pressures
SAMPLE TYPE: Undisturbed
DESCRIPTION: Dark brown lean CLAY (CL)
LL= 32 PL= 21 PI= 11
SPECIFIC GRAVITY- 2.7
REMARKS:

CLIENT:

12/4/03

PROJECT: Indian River Inlet Bridges

SAMPLE LOCATION: Boring BII-17 @ 69' - 71'
$\sigma_{v_0}' = 30(125) + 40(100) - 65(62.4) \sim 3695$ psf

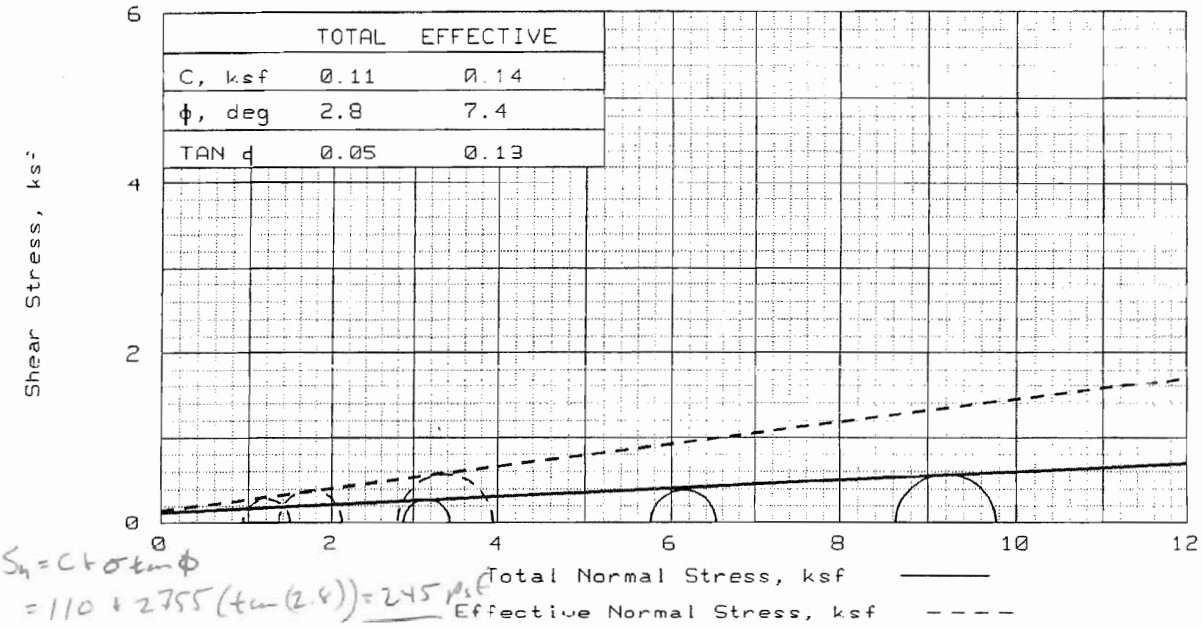
PROJ. NO.: 3530-03-1245 Task 02 DATE: 11/20/03

TRIAXIAL SHEAR TEST REPORT

LAW ENGINEERING AND ENVIRONMENTAL SERVICES

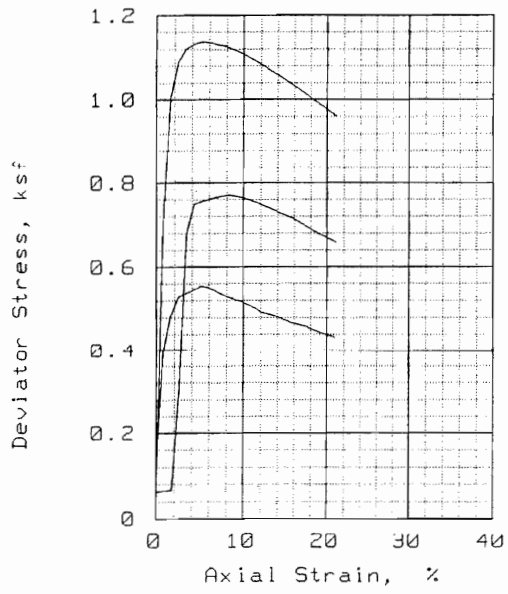
Fig. No.: 1

7/17



	TOTAL	EFFECTIVE
C, ksf	0.11	0.14
ϕ, deg	2.8	7.4
TAN ϕ	0.05	0.13

$S_u = C + \sigma \tan\phi$
$= 110 + 2755(\tan(2.8)) = 245$ psf



SAMPLE NO.:		1	2	3
INITIAL	WATER CONTENT, %	53.2	50.0	50.1
	DRY DENSITY, pcf	68.8	69.2	71.4
	SATURATION, %	99.0	93.9	99.5
	VOID RATIO	1.451	1.437	1.360
	DIAMETER, in	2.85	2.87	2.84
	HEIGHT, in	5.56	5.50	5.51
AT TEST	WATER CONTENT, %	48.7	40.5	38.2
	DRY DENSITY, pcf	73.2	78.4	82.5
	SATURATION, %	100.9	95.3	98.9
	VOID RATIO	1.303	1.149	1.044
	DIAMETER, in	2.76	2.70	2.64
	HEIGHT, in	5.56	5.50	5.51
Strain rate, in/min		0.0017	0.0016	0.0016
BACK PRESSURE, ksf		5.62	4.18	4.18
CELL PRESSURE, ksf		8.50	9.94	12.82
FAILURE STRESS, ksf		0.56	0.77	1.14
TOTAL PORE PR., ksf		7.56	8.58	10.01
ULTIMATE STRESS, ksf				
TOTAL PORE PR., ksf				
$\bar{\sigma}_1$ FAILURE, ksf		1.49	2.12	3.94
$\bar{\sigma}_3$ FAILURE, ksf		0.94	1.35	2.81

TYPE OF TEST:
CU with Pore Pressures
SAMPLE TYPE: Undisturbed
DESCRIPTION: Dark gray lean CLAY (CL)
LL= 35 PL= 18 PI= 17
SPECIFIC GRAVITY= 2.7
REMARKS:

CLIENT:

PROJECT: Indian River Inlet Bridges

SAMPLE LOCATION: Boring BII-22 @ 44.5-46.5
$\sigma_{vo}' = 30(125) + 15(100) - 46(62.4) = 2755$ psf

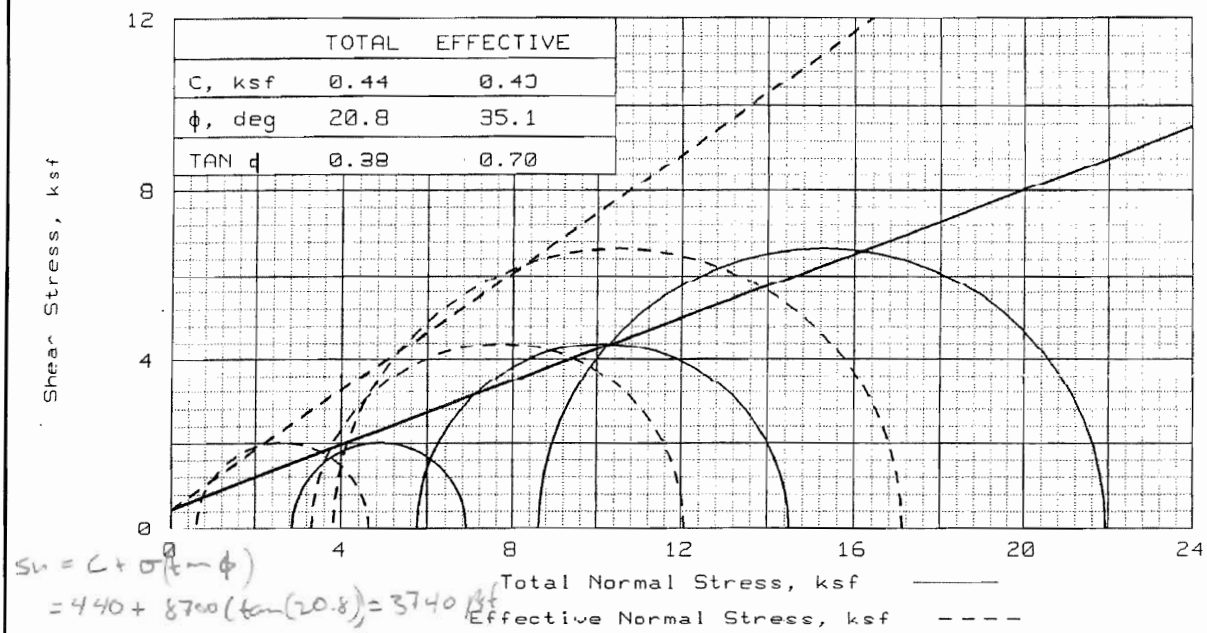
PROJ. NO.: 3530-03-1245 Task 02 DATE: 12/1/03 12/24/03

TRIAXIAL SHEAR TEST REPORT

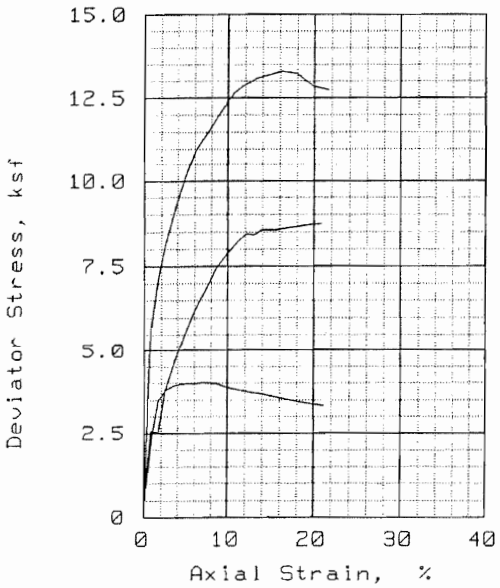
LAW ENGINEERING AND ENVIRONMENTAL SERVICES

Fig. No.: 1

8/17



$S_u = C + \sigma_t \tan\phi$
$= 440 + 8700(\tan(20.8)) = 3740$ psf



SAMPLE NO.:		1	2	3
INITIAL	WATER CONTENT, %	59.1	30.8	29.3
	DRY DENSITY, pcf	64.8	91.3	93.5
	SATURATION, %	99.8	98.2	98.7
	VOID RATIO	1.600	0.846	0.802
	DIAMETER, in	2.83	2.86	2.85
	HEIGHT, in	5.53	5.53	5.38
AT TEST	WATER CONTENT, %	56.2	27.8	23.3
	DRY DENSITY, pcf	66.9	96.1	103.4
	SATURATION, %	99.9	99.4	99.9
	VOID RATIO	1.520	0.755	0.630
	DIAMETER, in	2.79	2.78	2.71
	HEIGHT, in	5.53	5.53	5.38
Strain rate, in/min		0.0016	0.0016	0.0016
BACK PRESSURE, ksf		4.2	5.6	5.6
CELL PRESSURE, ksf		7.1	11.4	14.3
FAILURE STRESS, ksf		4.0	8.7	13.3
TOTAL PORE PR., ksf		6.4	8.0	10.4
ULTIMATE STRESS, ksf				
TOTAL PORE PR., ksf				
$\bar{\sigma}_1$ FAILURE, ksf		4.6	12.1	17.1
$\bar{\sigma}_3$ FAILURE, ksf		0.6	3.3	3.8

TYPE OF TEST:
CU with Pore Pressures
SAMPLE TYPE: Undisturbed
DESCRIPTION: Gray fat CLAY

LL= 65 PL= 28 PI= 37
SPECIFIC GRAVITY= 2.7
REMARKS:

CLIENT:

PROJECT: Indian River Inlet Bridge

12/22/03

SAMPLE LOCATION: Boring BII-22 @ 160 - 162

$\sigma_{vo}' \sim 30(125) + 30(110) + 13(120) + 53(125) + 30(115) - 155(62.4)$
~ 8700 psf

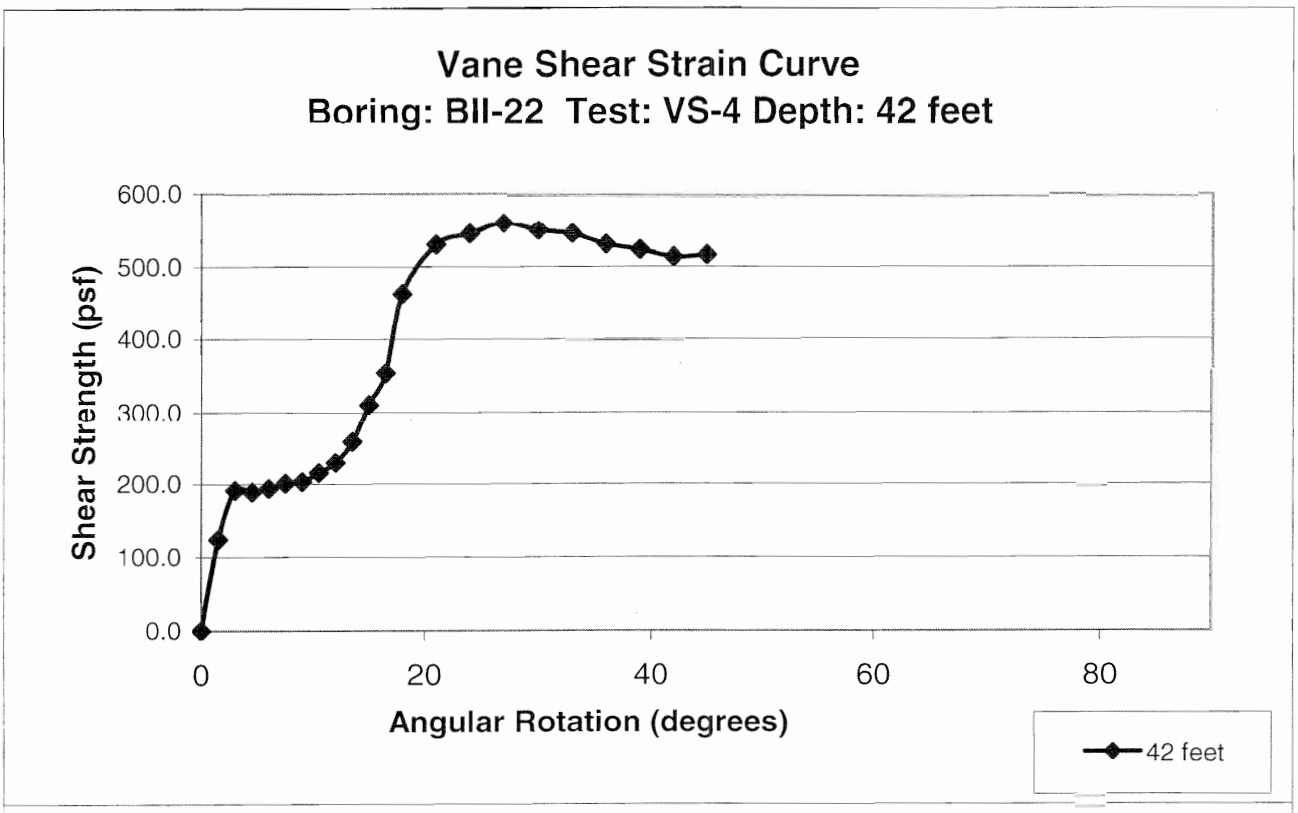
PROJ. NO.: 3530-03-1245.02 DATE: 12/11/03.

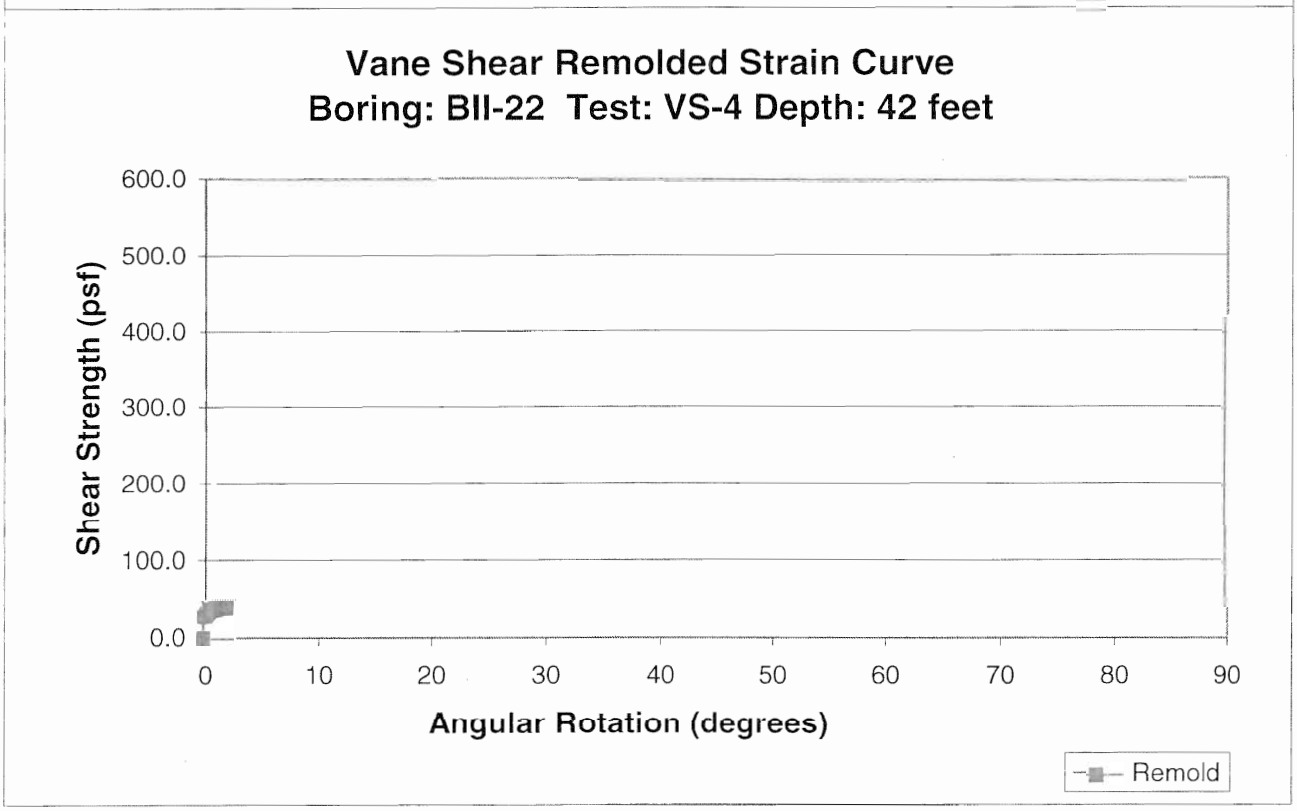
TRIAXIAL SHEAR TEST REPORT

LAW ENGINEERING AND ENVIRONMENTAL SERVICES

Fig. No.: 1

Strength Curves BI-22





FIELD VANE SHEAR TEST

MACTEC

Project: Indian River Inlet

Date:

Engineer: Shane Clark

MACTEC Project No. 3530-03-1245.02DRIL

Drill Crew: MACTEC-Sterling

Boring Location: BH-22

Depth: 42 ft

Vane Dimensions:

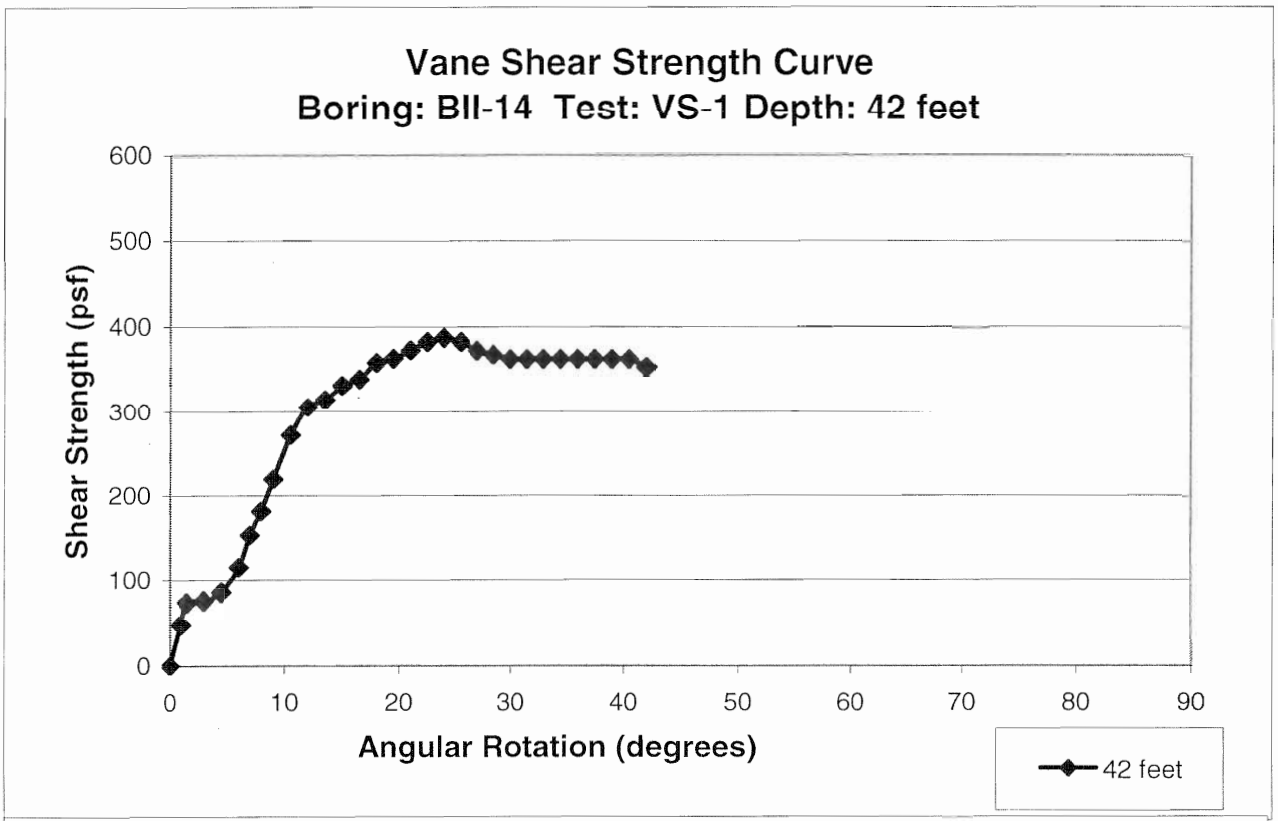
H =	2.31	cm	5.875 in	Rod Friction neglected - vane inserted just after SPT testing
d =	0.30	cm	0.75 in	Peak Undisturbed Strength (psf) 559.11
D =	1.43	cm	3.625 in	Peak Remolded Strength (psf) 41

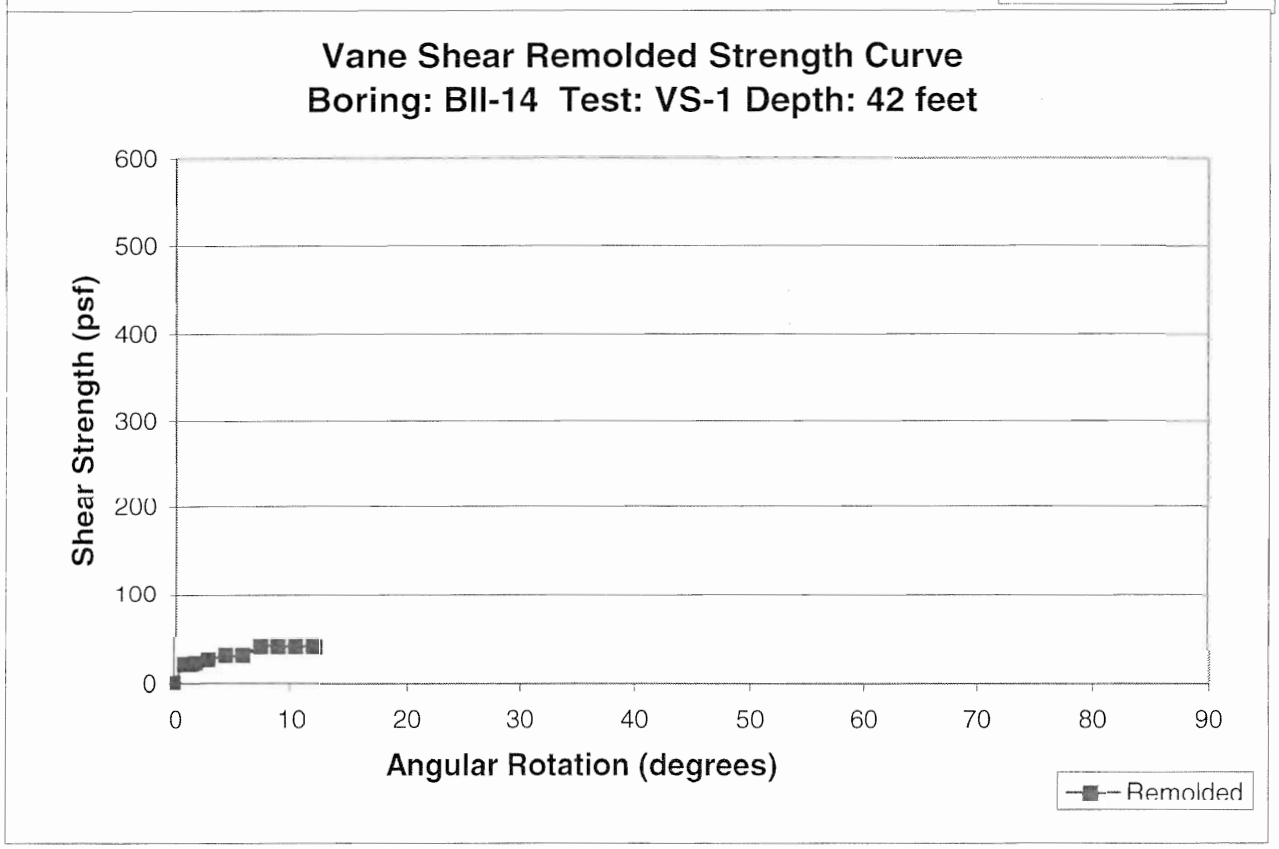
Torque arm (ft.) 1

k = 0.106911263

Time (minutes)	Gauge Reading (pounds)	Guage Correction (pounds)	Torque (ft-lbs)	Shear Strength (lb/ft^2)	Shear Strength (kPa)	Time (minutes)	Gauge Reading (pounds)	Guage Correction (pounds)	Torque (ft-lbs)	Shear Strength (lb/ft^2)	Shear Strength (kPa)
0	0	0	0.0	0.0	0.0	0	0	0	0.0	0.0	0.0
0.25	13	13.2834	13.3	124.2	5.9	0.16	3	3.0654	3.1	28.7	1.4
0.5	20	20.436	20.4	191.1	9.2	0.33	3.25	3.32085	3.3	31.1	1.5
0.75	19.75	20.18055	20.2	188.8	9.0	0.5	3.5	3.5763	3.6	33.5	1.6
1	20.25	20.69145	20.7	193.5	9.3	0.66	4	4.0872	4.1	38.2	1.8
1.25	21	21.4578	21.5	200.7	9.6	0.83	4	4.0872	4.1	38.2	1.8
1.5	21.25	21.71325	21.7	203.1	9.7	1	4	4.0872	4.1	38.2	1.8
1.75	22.5	22.9905	23.0	215.0	10.3	1.16	4.25	4.34265	4.3	40.6	1.9
2	24	24.5232	24.5	229.4	11.0	1.33	4.25	4.34265	4.3	40.6	1.9
2.25	27	27.5886	27.6	258.1	12.4	1.5	4.25	4.34265	4.3	40.6	1.9
2.5	32.5	33.2085	33.2	310.6	14.9	1.66	4.25	4.34265	4.3	40.6	1.9
2.75	37	37.8066	37.8	353.6	16.9	1.83	4.25	4.34265	4.3	40.6	1.9
3	48.5	49.5573	49.6	463.5	22.2	2	4.25	4.34265	4.3	40.6	1.9
3.5	55.5	56.7099	56.7	530.4	25.4						
4	57	58.2426	58.2	544.8	26.1						
4.5	58.5	59.7753	59.8	559.1	26.8						
5	57.5	58.7535	58.8	549.6	26.3						
5.5	57	58.2426	58.2	544.8	26.1						
6	55.5	56.7099	56.7	530.4	25.4						
6.5	54.75	55.94355	55.9	523.3	25.1						
7	53.75	54.92175	54.9	513.7	24.6						
7.5	54	55.1772	55.2	516.1	24.7						

Strength Curves BI-14





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FIELD VANE SHEAR TEST

Project: Indian River Inlet

Date:

Engineer: Shane Clark

MACTEC Project No. 3530-03-1245.02DRIL

Drill Crew: MACTEC-Sterling

Boring Location: BII-14

Depth: 41 ft

Vane Dimensions:

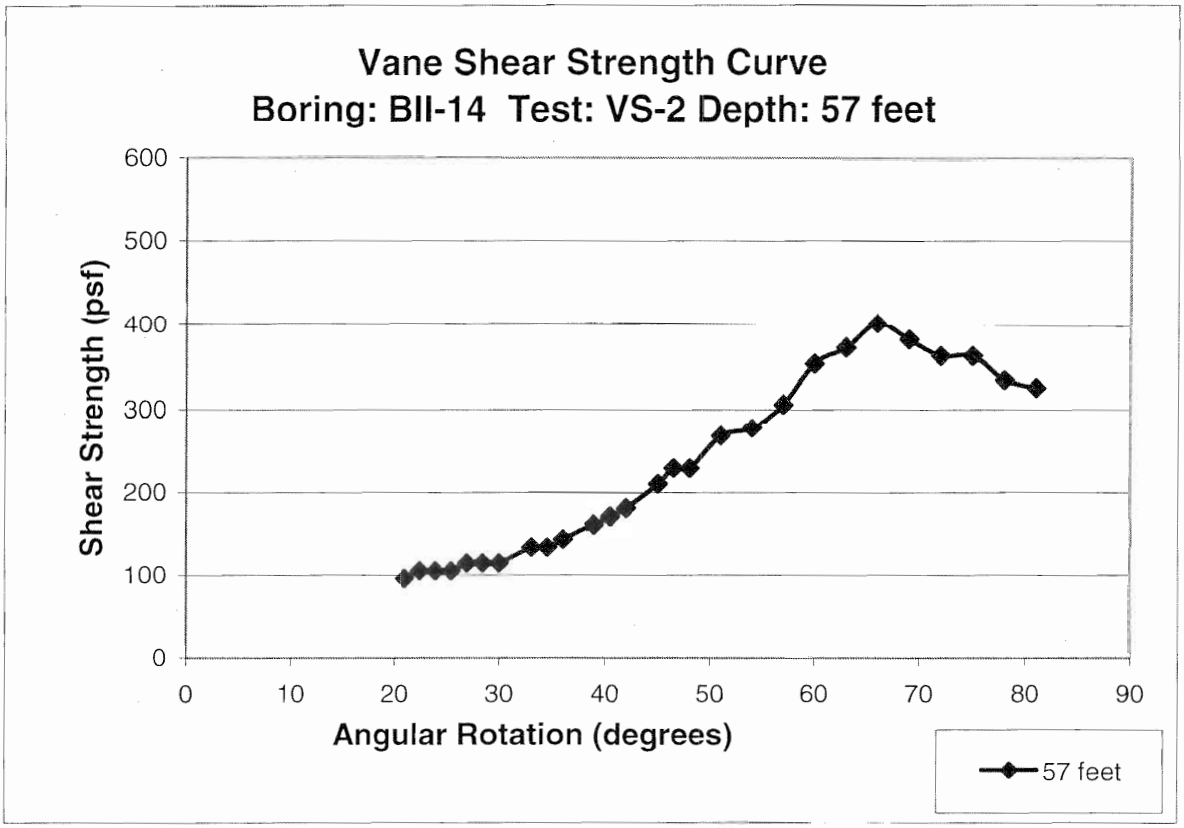
H =	2.31	**cm**	5.875 **in**	Rod Friction neglected - vane inserted just after SPT testing
d =	0.30	**cm**	0.75 **in**	Peak Undisturbed Strength (psf) 387.08
D =	1.43	**cm**	3.625 **in**	Peak Remolded Strength (psf) 40

Torque arm (ft.) 1

k = 0.106911263

Time (minutes)	Gauge Reading (pounds)	Guage Correction (pounds)	Torque (ft-lbs)	Shear Strength (lb/ft^2)	Shear Strength (kPa)	Time (minutes)	Gauge Reading (pounds)	Guage Correction (pounds)	Torque (ft-lbs)	Shear Strength (lb/ft^2)	Shear Strength (kPa)
0	0	0	0.0	0.0	0.0	0	0	0	0.0	0.0	0.0
0.16	5	5.109	5.1	47.8	2.3	0.16	2.2	2.24795	2.2	21.0	1.0
0.25	7.8	7.97004	8.0	74.5	3.6	0.25	2.2	2.24796	2.2	21.0	1.0
0.5	8	8.1744	8.2	76.5	3.7	0.32	2.3	2.35014	2.4	22.0	1.1
0.75	9	9.1962	9.2	86.0	4.1	0.5	2.7	2.75886	2.8	25.8	1.2
1	12	12.2616	12.3	114.7	5.5	0.75	3.2	3.26976	3.3	30.6	1.5
1.16	16	16.3488	16.3	152.9	7.3	1	3.2	3.26976	3.3	30.6	1.5
1.32	19	19.4142	19.4	181.6	8.7	1.25	4.2	4.29156	4.3	40.1	1.9
1.5	23	23.5014	23.5	219.8	10.5	1.5	4.2	4.29156	4.3	40.1	1.9
1.75	28.5	29.1213	29.1	272.4	13.0	1.75	4.2	4.29156	4.3	40.1	1.9
2	32	32.6976	32.7	305.8	14.6	2	4.2	4.29156	4.3	40.1	1.9
2.25	33	33.7194	33.7	315.4	15.1						
2.5	34.75	35.50755	35.5	332.1	15.9						
2.75	35.5	36.2739	36.3	339.3	16.2						
3	37.5	38.3175	38.3	358.4	17.2						
3.25	38	38.8284	38.8	363.2	17.4						
3.5	39	39.8502	39.9	372.7	17.8						
3.75	40	40.872	40.9	382.3	18.3						
4	40.5	41.3829	41.4	387.1	18.5						
4.25	40	40.872	40.9	382.3	18.3						
4.5	39	39.8502	39.9	372.7	17.8						
4.75	38.5	39.3393	39.3	368.0	17.6						
5	38	38.8284	38.8	363.1834	17.38922						
5.25	38	38.8284	38.8	363.1834	17.38922						
5.5	38	38.8284	38.8	363.1834	17.38922						
5.75	38	38.8284	38.8	363.1834	17.38922						
6	38	38.8284	38.8	363.1834	17.38922						
6.25	38	38.8284	38.8	363.1834	17.38922						
6.5	38	38.8284	38.8	363.1834	17.38922						
6.75	38	38.8284	38.8	363.1834	17.38922						
7	37	37.8066	37.8	353.626	16.93161						

Strength Curves BI-14



FIELD VANE SHEAR TEST

Project: Indian River Inlet

Date:

Engineer: Shane Clark

MACTEC Project No. 3530-03-1245.02DRIL

Drill Crew: MACTEC-Sterling

Boring Location: BII-14

Depth: 57 ft

Vane Dimensions:

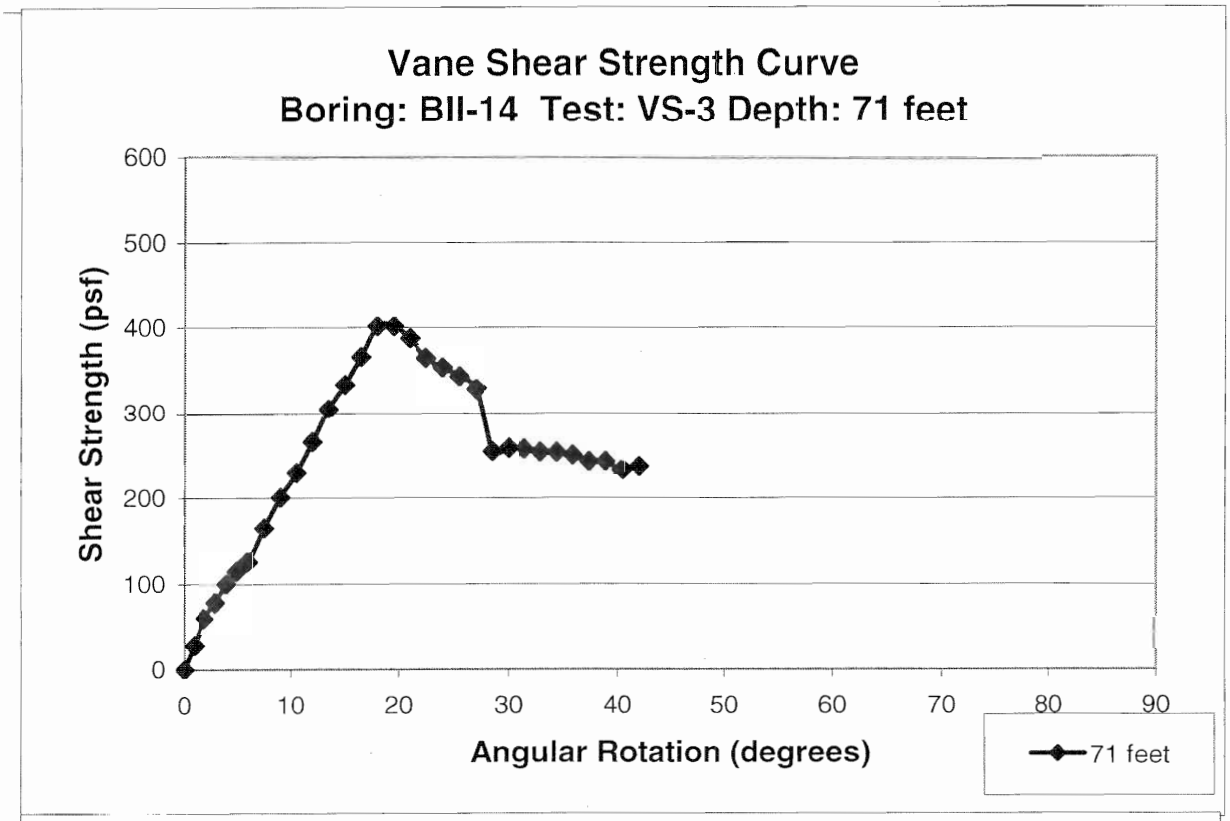
H =	2.31 cm	5.875 in	Rod Friction neglected - vane inserted just after SPT testing
d =	0.30 cm	0.75 in	Peak Undisturbed Strength (psf) 401.41
D =	1.43 cm	3.625 in	

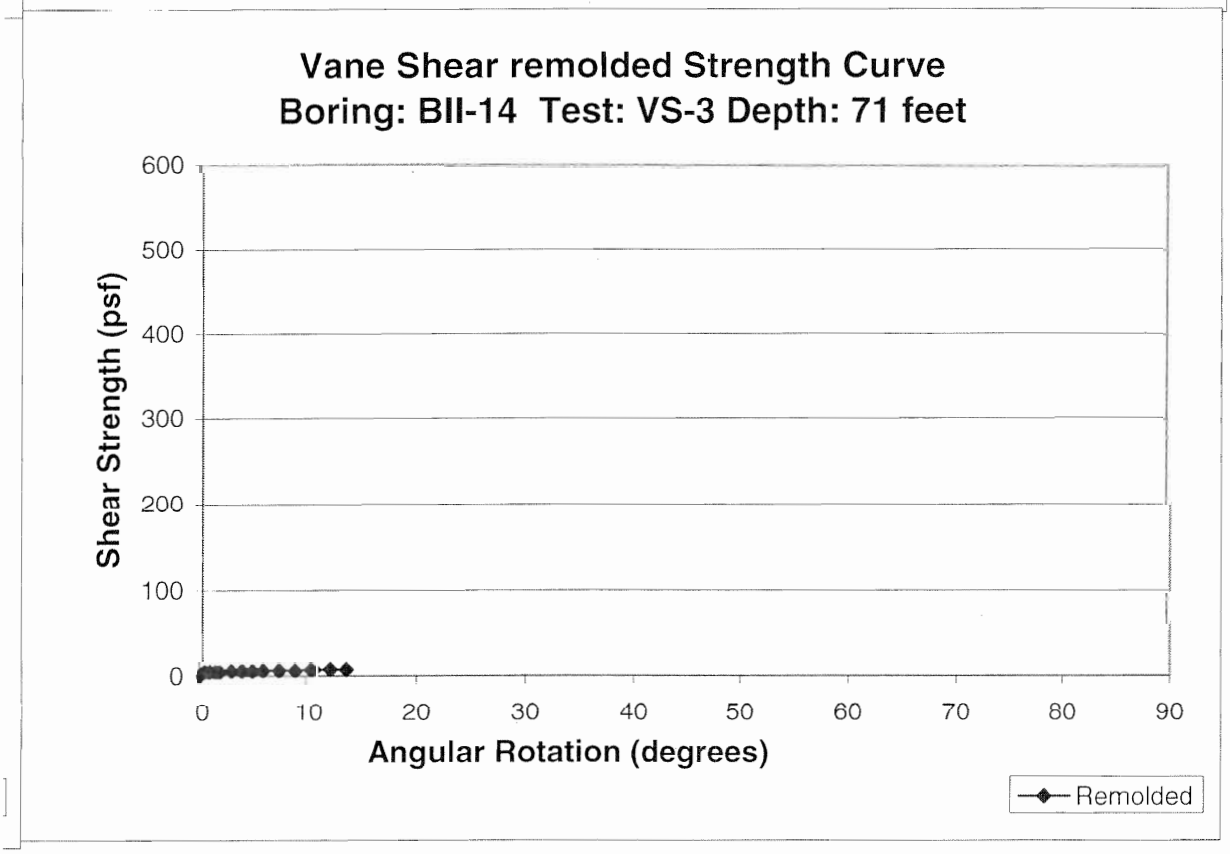
Torque arm (ft.) 1

k = 0.106911263

Time (minutes)	Gauge Reading (pounds)	Guage Correction (pounds)	Torque (ft-lbs)	Shear Strength (lb/ft^2)	Shear Strength (kPa)
3.5	10	10.218	10.2	95.6	4.6
3.75	11	11.2398	11.2	105.1	5.0
4	11	11.2398	11.2	105.1	5.0
4.25	11	11.2398	11.2	105.1	5.0
4.5	12	12.2616	12.3	114.7	5.5
4.75	12	12.2616	12.3	114.7	5.5
5	12	12.2616	12.3	114.7	5.5
5.5	14	14.3052	14.3	133.8	6.4
5.75	14	14.3052	14.3	133.8	6.4
6	15	15.327	15.3	143.4	6.9
6.5	17	17.3706	17.4	162.5	7.8
6.75	18	18.3924	18.4	172.0	8.2
7	19	19.4142	19.4	181.6	8.7
7.5	22	22.4796	22.5	210.3	10.1
7.75	24	24.5232	24.5	229.4	11.0
8	24	24.5232	24.5	229.4	11.0
8.5	28	28.6104	28.6	267.6	12.8
9	29	29.6322	29.6	277.2	13.3
9.5	32	32.6976	32.7	305.8	14.6
10	37	37.8066	37.8	353.6	16.9
10.5	39	39.8502	39.9	372.7	17.8
11	42	42.9156	42.9	401.4	19.2
11.5	40	40.872	40.9	382.3	18.3
12	38	38.8284	38.8	363.2	17.4
12.5	38	38.8284	38.8	363.2	17.4
13	35	35.763	35.8	334.5	16.0
13.5	34	34.7412	34.7	325.0	15.6

Strength Curves BI-14





FIELD VANE SHEAR TEST

Project: Indian River Inlet

Date:

Engineer: Shane Clark

MACTEC Project No. 3530-03-1245.02DRIL

Drill Crew: MACTEC-Sterling

Boring Location: BH-14

Depth: 71 ft

Vane Dimensions:

H =	2.31	cm	5.875 in	Rod Friction neglected - vane inserted just after SPT testing
d =	0.30	cm	0.75 in	Peak Undisturbed Strength (psf) 401.41
D =	1.43	cm	3.625 in	Peak Remolded Strength (psf) 11

Torque arm (ft.) 1.5

k = 0.106911263

Time (minutes)	Gauge Reading (pounds)	Guage Correction (pounds)	Torque (ft-lbs)	Shear Strength (lb/ft^2)	Shear Strength (kPa)	Time (minutes)	Gauge Reading (pounds)	Guage Correction (pounds)	Torque (ft-lbs)	Shear Strength (lb/ft^2)	Shear Strength (kPa)
0	0	0	0.0	0.0	0.0	0	0	0	0.0	0.0	0.0
0.16	2	2.0436	3.1	28.7	1.4	0.083	0.5	0.5109	0.8	7.2	0.3
0.32	4.25	4.34265	6.5	60.9	2.9	0.16	0.5	0.5109	0.8	7.2	0.3
0.5	5.5	5.6199	8.4	78.8	3.8	0.25	0.5	0.5109	0.8	7.2	0.3
0.67	7	7.1526	10.7	100.4	4.8	0.32	0.5	0.5109	0.8	7.2	0.3
0.83	8	8.1744	12.3	114.7	5.5	0.5	0.6	0.61308	0.9	8.6	0.4
1	8.75	8.94075	13.4	125.4	6.0	0.67	0.6	0.61308	0.9	8.6	0.4
1.25	11.5	11.7507	17.6	164.9	7.9	0.83	0.6	0.61308	0.9	8.6	0.4
1.5	14	14.3052	21.5	200.7	9.6	1	0.7	0.71526	1.1	10.0	0.5
1.75	16	16.3488	24.5	229.4	11.0	1.25	0.7	0.71526	1.1	10.0	0.5
2	18.5	18.9033	28.4	265.2	12.7	1.5	0.7	0.71526	1.1	10.0	0.5
2.25	21.25	21.71325	32.6	304.6	14.6	1.75	0.8	0.81744	1.2	11.5	0.5
2.5	23.25	23.75685	35.6	333.3	16.0	2	0.8	0.81744	1.2	11.5	0.5
2.75	25.5	26.0559	39.1	365.6	17.5	2.25	0.8	0.81744	1.22616	11.46895	0.5
3	28	28.6104	42.9	401.4	19.2						
3.25	28	28.6104	42.9	401.4	19.2						
3.5	27	27.5886	41.4	387.1	18.5						
3.75	25.5	26.0559	39.1	365.6	17.5						
4	24.75	25.28955	37.9	354.8	17.0						
4.25	24	24.5232	36.8	344.1	16.5						
4.5	23	23.5014	35.3	329.7	15.8						
4.75	17.75	18.13695	27.2	254.5	12.2						
5	18	18.3924	27.6	258.1	12.4						
5.25	18	18.3924	27.6	258.1	12.4						
5.5	17.75	18.13695	27.2	254.5	12.2						
5.75	17.75	18.13695	27.2	254.5	12.2						
6	17.5	17.8815	26.8	250.9	12.0						
6.25	17	17.3706	26.1	243.7152	11.669084						
6.5	17	17.3706	26.1	243.7152	11.669084						
6.75	16.25	16.60425	24.9	232.9631	11.154271						
7	16.5	16.8597	25.3	236.5471	11.325875						

Table 24. Approximate values of undrained shear strength for cohesive soils based on SPT blow count N-values (from Terzaghi and Peck, 1967)

Soil Consistency	SPT N (See Note)	S_u (psf)
Very Soft	< 2	< 250
Soft	2 - 4	250 - 500
Medium	4 - 8	500 - 1000
Stiff	8 - 15	1000 - 2000
Very Stiff	15 - 30	2000 - 4000
Hard	> 30	> 4000

Table 25. Approximate undrained shear strength for cohesive soils based on SPT blow counts (from Tschebotarioff, 1973 and Parcher and Means, 1968)

SPT N (See Note)	S_u (kgf/cm^2)		S_u (psf)	
	Ref. a	Ref b.	Ref a.	Ref b.
< 2	0.15	< 0.12	300	-
2 - 4	0.15 - 0.3	0.12 - 0.25	300 - 600	250 - 500
4 - 8	0.3 - 0.6	0.25 - 0.5	600 - 1200	500 - 1000
8 - 15	0.6 - 1.2	0.5 - 1.0	1200 - 2400	1000 - 2000
15 - 30	1.2	1.0 - 2.0	2400	2000 - 4000
> 30	> 2.25	> 2.0	> 4500	> 4000

Ref. (a) Tschebotarioff (1973)
(b) Parcher and Means (1968)

Note. As originally proposed, this correlation used the uncorrected SPT blowcount, N. However, hammers delivering 60% of the theoretical energy have been the most commonly used hammers for SPT tests, and it seems likely that the data on which the correlation was based was obtained primarily from tests with such hammers. It therefore seems logical to use N_{60} with this correlation, and it is the recommendation of this report that this be done.

K_H
HORIZONTAL SOIL MODULUS

MACTEC

MACTEC Engineering and Consulting
1725 Louisville Drive
Knoxville, TN 37921-5904

Horiz. Soil-Modulus K

- Soft clay:
  $K_h = 30$ pci (L-PILE Users Manual)

- Medium Sand:
  - Above water table $k = 90$ pci
  - Submerged Sand $k = 60$ pci
  (L-PILE Users Manual)

- Dense Sand:
  - Submerged Sand $k = 125$ pci – (L-PILE Users Manual)

- Stiff Clay $K = 500$ pci – (L-PILE Users Manual)

- V. Dense Sand:
  Submerged Sand $K = 125$ pci – (L-Pile Users Manual)

→ From In-situ Pressuremeter tests (Data Attached)

- Stratum 1 → K_h = Min = 102 pci, Max = 115 pci, Avg = 107 pci ✓
- Stratum 2 → K_h = min = 11 pci, max = 17 pci, Avg = 15 pci ✓
- Stratum 3 → K_h = min = 59 pci, Max = 171 pci, Avg = 106 pci ✓

→ Values from pressuremeter testing correlate well with values from L-PILE Users Manual → Use values from L-Pile Users manual in design for sand, + use $K_h = 20$ pci for Stratum 2 clay

MACTEC

MACTEC Engineering and Consulting, Inc.
1606 Ownby Lane
Richmond, VA 23220

JOB NO. 3530-03-1245 SHEET 2 OF 30
PHASE TASK 02
JOB NAME IRIB - Soil Parameters
BY HAB/AJA DATE 12/03/03
CHECKED BY JRW DATE 12/19/03

North Side

Stratum 1
- El. +5 → +0, K_h = 90 pci (Sand above water table) ✓
- El. +0 → -15, K_h = 60 pci (Med. Sand below water table) ✓
- El. -15 → -25, K_h = 125 pci (Dense Sand below water table) ✓

Stratum 2 → El. -25 → -50 K_h = 20 pci (Soft Clay) ✓

Stratum 3
- El. -50 → -63, K_h = 60 pci (Med. Sand below water Table)
- El. -63 → -133, K_h = 125 pci (Dense Sand below water table) ✓

Stratum 4 → El. -133 - 143, K_h = 500 pci (Stiff Clay) ✓

South Side

- El. +5 → +0, K_h = 90 pci (Sand above water table) ✓
- El. +0 → -15, K_h = 60 pci (Med. Sand below water table) ✓
- El. -15 → -30 K_h = 125 pci (Dens Sand below water table) ✓

→ El. -30 → -85 K_h = 20 pci (Soft Clay) ✓

→ El. -85 → -131 K_h = 125 pci (Dense Sand below water table) ✓

El. -131 → -160 K_h = 500 pci (Stiff Clay) ✓

iteration of pile analysis.

Suggested values of the parameter k used for sands are given in Table 3.2. Suggested values of the parameter k used for clays are given in Table 3.3.

Relative Density	Loose	Medium	Dense
Submerged Sand	20 lb/in3 5,430 KPa/m	60 lb/in3 16,300 KPa/m	125 lb/in3 33,900 KPa/m
Sand Above WT	25 lb/in3 6,790 KPa/m	90 lb/in3 24,430 KPa/m	225 lb/i3 61,000 KPa/m

Table 3.2 Soil-Modulus Parameter k for Sands

Clay Type	Avg. Undrained Shear Strength (c_u)	Static	Cyclic
Soft	1.74 - 3.47 psi 250 - 500 psf 12 - 24 KPa	30 pci 8,140 KPa/m	- -
Medium	3.47 - 6.94 psi 500 - 1000 psf 24 - 48 KPa	100 pci 27,150 KPa/m	- -
Stiff	6.94 - 13.9 psi 1000 - 2000 psf 48 - 96 KPa	500 pci 136,000 KPa/m	200 pci 54,300 KPa/m
Very Stiff	13.9 - 27.8 psi 2000 - 4000 psf 96 - 192 KPa	1000 pci 271,000 KPa/m	400 pci 108,500 KPa/m
Hard	27.8 - 55.6 psi 4000 - 8000 psf 192 - 383 KPa	2000 pci 543,000 KPa/m	800 pci 217,000 KPa/m

Table 3.3 Soil-Modulus Parameter k for Clays

c. Undrained Shear Strength

Values of undrained shear strength, c_u, for clays and silts at each depth are entered in standard units of force per unit area. The undrained shear strength is not needed for sand layers. The undrained shear strength is generally taken as half of the uncon-

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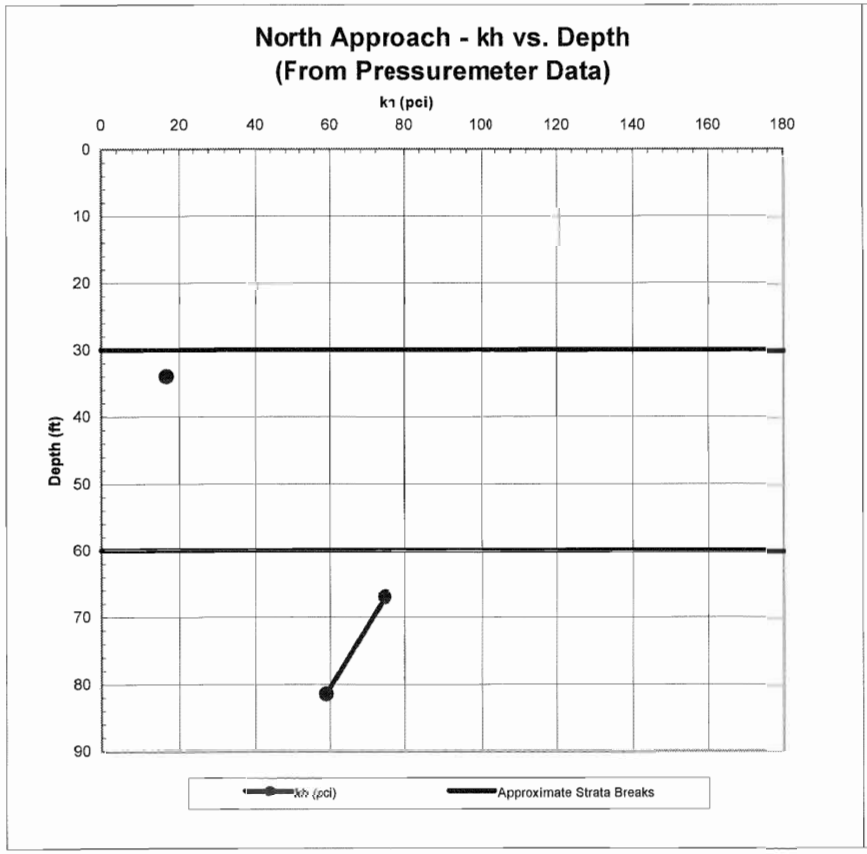
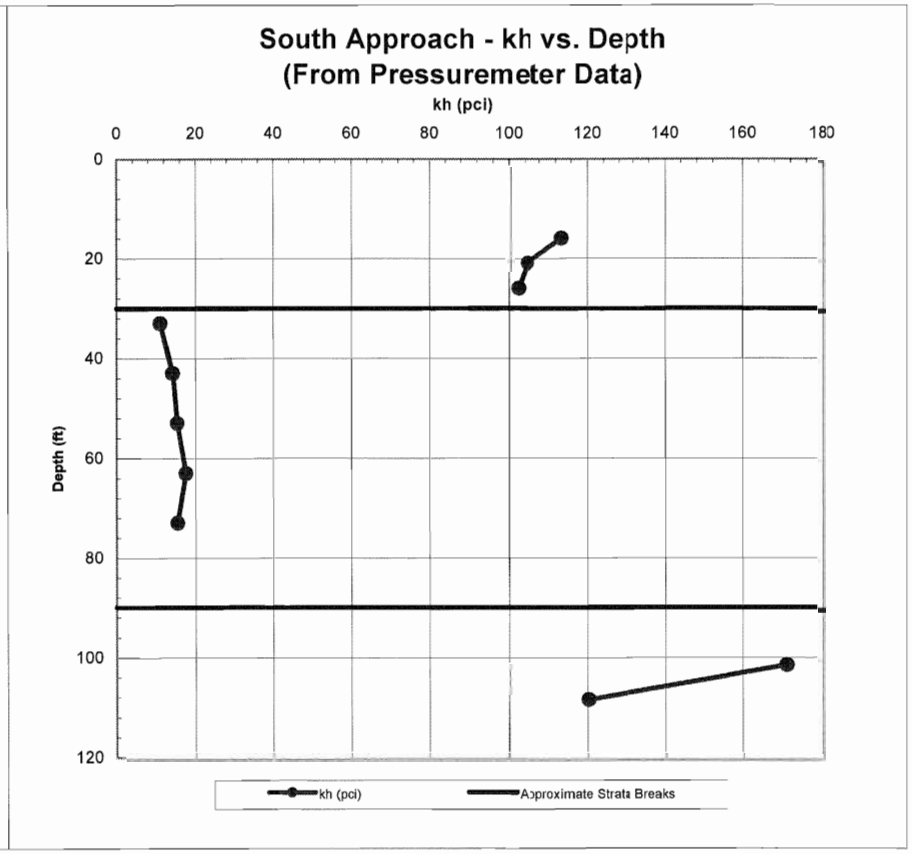

North Approach - kh vs. Depth
(From Pressuremeter Data)
kh (pci)
0 20 40 60 80 100 120 140 160 180
Depth (ft)
0 10 20 30 40 50 60 70 80 90
kh (pci)
Approximate Strata Breaks


South Approach - kh vs. Depth
(From Pressuremeter Data)
kh (pci)
0 20 40 60 80 100 120 140 160 180
Depth (ft)
0 20 40 60 80 100 120
kh (pci)
Approximate Strata Breaks

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MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	22-Jul-03			
roject	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	BI-3			
Test Number	PMT-1			
Depth (Feet)	33	35.00		34.00
Instrument Height	2			
Total Height	35	feet =	11.48	meters
Material	silty clay			
Probe Dia.	B-58 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	elta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.20	0.00	5.00	5.00	5.00
3	0.32	5.00	10.00	5.00	5.00
4	0.51	10.00	15.00	5.00	5.00
5	0.70	15.00	20.00	5.00	5.00
6	0.77	20.00	25.00	5.00	5.00
7	0.90	25.00	30.00	5.00	5.00
8	1.00	30.00	35.00	5.00	5.00
9	1.10	35.00	40.00	5.00	5.00
10	1.20	40.00	45.00	5.00	5.00
11	1.24	45.00	50.00	5.00	5.00
12	1.26	50.00	55.00	5.00	5.00
13	1.32	55.00	60.00	5.00	5.00
14	1.45	65.00	65.00	0.00	5.00
15	1.52	70.00	70.00	0.00	5.00
16	1.58	75.00	75.00	0.00	5.00
17	1.70	80.00	80.00	0.00	5.00
18	1.76	85.00	85.00	0.00	5.00
19	1.80	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n ure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		0		5.00	
1	5.00	5.00		0.15		5.00	
2	10.00	10.00		0.3		5.00	
3	15.00	15.00		0.51		5.00	
4	20.00	20.00		0.82		5.00	
5	25.00	25.00		1.7		5.00	
6	30.00	30.00		4.35		5.00	
7	35.00	35.00		10		5.00	
8	40.00	40.00		17.3		5.00	
	45.00	45.00		23.7			

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.25	0	0			1	0.00	5.00
2	0.26	5	5			2	0.00	5.00
3	0.26	10	10			3	0.00	5.00
4	1.9	15	15			4	0.00	5.10
5	2.25	20.1	20.1			5	0.00	6.50
6	2.45	26.6	26.6			6	0.00	3.40
7	2.55	30	30			7	0.00	5.00
8	2.75	35	35			8	0.00	5.40
9	2.95	40.4	40.4			9	0.00	4.60
10	3.05	45	45			10	0.00	5.00
11	3.1	50	50			11	0.00	-5.00
12	2.26	45	45			12	0.00	-5.00
13	1.92	40	40			13	0.00	-5.00
14	1.6	35	35			14	0.00	5.00
15	2.25	40	40			15	0.00	5.00
16	2.6	45	45			16	0.00	5.00
17	2.95	50	50			17	0.00	5.00
18	3.2	55	55			18	0.00	5.00
19	3.27	60	60			19	0.00	5.00
20	3.5	65	65			20	0.00	5.00
21	3.6	70	70			21	0.00	5.00
22	3.75	75	75			22	0.00	5.00
23	3.8	80	80			23	0.00	5.00
24	3.95	85	85			24	0.00	5.00
25	4.05	90	90			25	0.00	-10.00
26	2.7	80.00	80.00			26	0.00	-10.00
27	2.05	70.00	70.00			27	0.00	-10.00
28	1.7	60.00	60.00			28	0.00	-10.00
29	1.3	50.00	50.00			29	0.00	-11.00
30	0.98	39.00	39.00			30	0.00	-39.00

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MACTEC

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
			Pressure Corrections				Volume Corrections		
1	1.05	-0.24	0.25	1.30	1.54	0.00	25.6	0.004275826	-25.60
2	1.05	-0.17	0.26	1.31	1.48	5.00	25.5	0.004308826	-20.50
3	1.05	-0.11	0.26	1.31	1.41	10.00	25.3	0.004308826	-15.30
4	1.05	-0.09	1.9	2.95	3.03	15.00	28.9	0.009720826	-13.91
5	1.05	-0.03	2.25	3.30	3.33	20.10	29.5	0.010875826	-9.41
6	1.05	0.05	2.45	3.50	3.44	25.60	29.7	0.011535826	-3.11
7	1.05	0.10	2.55	3.60	3.50	30.00	29.8	0.011865826	0.19
8	1.05	0.16	2.75	3.80	3.64	35.00	30	0.012525826	4.99
9	1.05	0.23	2.95	4.00	3.77	40.40	30.2	0.013185826	10.19
10	1.05	0.29	3.05	4.10	3.81	45.00	30.3	0.013515826	14.69
11	1.05	0.35	3.1	4.15	3.79	50.00	30.3	0.013680826	19.69
12	1.05	0.30	2.26	3.31	3.00	45.00	28.9	0.010908826	16.09
13	1.05	0.25	1.92	2.97	2.72	40.00	28.3	0.009786826	11.69
14	1.05	0.19	1.6	2.65	2.46	35.00	27.8	0.008730826	7.19
15	1.05	0.24	2.25	3.30	3.06	40.00	29	0.010875826	10.99
16	1.05	0.30	2.6	3.65	3.35	45.00	29.5	0.012030826	15.49
17	1.05	0.36	2.95	4.00	3.64	50.00	30	0.013185826	19.99
18	1.05	0.42	3.2	4.25	3.83	55.00	30.3	0.014010826	24.69
19	1.05	0.48	3.27	4.32	3.83	60.00	30.3	0.014241826	29.69
20	1.05	0.54	3.5	4.55	4.00	65.00	30.6	0.015000826	34.38
21	1.05	0.61	3.6	4.65	4.04	70.00	30.7	0.015330826	39.28
22	1.05	0.67	3.75	4.80	4.12	75.00	30.8	0.015825826	44.18
23	1.05	0.74	3.8	4.85	4.11	80.00	30.8	0.015990826	49.18
24	1.05	0.80	3.95	5.00	4.19	85.00	30.9	0.016485826	54.08
25	1.05	0.87	4.05	5.10	4.23	90.00	31	0.016815826	58.98
26	1.05	0.76	2.7	3.75	2.98	80.00	28.8	0.012360826	51.19
27	1.05	0.65	2.05	3.10	2.45	70.00	27.8	0.010215826	42.19
28	1.05	0.52	1.7	2.75	2.22	60.00	27.3	0.009060826	32.69
29	1.05	0.40	1.3	2.35	1.95	50.00	26.7	0.007740826	23.29
30	1.05	0.26	0.98	2.03	1.76	39.00	26.2	0.006684826	12.79

Pressuremeter Data Reduction

P_c Net Creep Pressure 11.00
(ba 0kPa)

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	3.03
P_2	3.64
V_1	-13.91
V_2	4.99
V_0	190.00
V_m	-4.46
υ	0.33
ΔP (Bars)	0.60
ΔV (cc)	18.90
E_r (Bars)	16
E_0 (ksf)	32.86

PMT Reload Modulus Calculation

P_1	2.46
P_2	3.79
V_1	7.19
V_2	19.69
V_0	190.00
V_m	13.44
υ	0.33
ΔP (Bars)	1.34
ΔV (cc)	12.50
E_r (Bars)	58
E_r (ksf)	120.87

E/P_l (bars): 0.81

E/P_r (bars): 2.97

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

B =	8	ft
K =	153.73	ksf
k_v =	19.22	ksf
k_h =	11.12	pci

nd: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_0 = 2$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_0 = 3$ for silty soils
$E_r/E_0 = 4$ for sandy/gravelly soils

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MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	22-Jul-03			
Project	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	BI-3			
Test Number	PMT-2			
Depth (Feet)	43	45.00		44.00
Instrument Height	2			
Total Height	45	feet =	14.76	meters
Material	silty clay			
Probe Dia.	B-56 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	elta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.20	0.00	5.00	5.00	5.00
3	0.32	5.00	10.00	5.00	5.00
4	0.51	10.00	15.00	5.00	5.00
5	0.70	15.00	20.00	5.00	5.00
6	0.77	20.00	25.00	5.00	5.00
7	0.90	25.00	30.00	5.00	5.00
8	1.00	30.00	35.00	5.00	5.00
9	1.10	35.00	40.00	5.00	5.00
10	1.20	40.00	45.00	5.00	5.00
11	1.24	45.00	50.00	5.00	5.00
12	1.26	50.00	55.00	5.00	5.00
13	1.32	55.00	60.00	5.00	5.00
14	1.45	65.00	65.00	0.00	5.00
15	1.52	70.00	70.00	0.00	5.00
16	1.58	75.00	75.00	0.00	5.00
17	1.70	80.00	80.00	0.00	5.00
18	1.76	85.00	85.00	0.00	5.00
19	1.80	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n ure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		0		5.00	
1	5.00	5.00		0.15		5.00	
2	10.00	10.00		0.3		5.00	
3	15.00	15.00		0.51		5.00	
4	20.00	20.00		0.82		5.00	
5	25.00	25.00		1.7		5.00	
6	30.00	30.00		4.35		5.00	
7	35.00	35.00		10		5.00	
8	40.00	40.00		17.3		5.00	
	45.00	45.00		23.7			

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.5	0	0			1	0.00	5.00
2	1.02	5	5			2	0.00	5.00
3	1.45	10	10			3	0.00	5.00
4	1.8	15	15			4	0.00	5.00
5	2.23	20	20			5	0.00	5.00
6	2.5	25	25			6	0.00	5.00
7	2.8	30	30			7	0.00	5.00
8	3.1	35	35			8	0.00	5.00
9	3.3	40	40			9	0.00	5.00
10	3.6	45	45			10	0.00	-5.00
11	2.7	40	40			11	0.00	-5.00
12	2.1	35	35			12	0.00	-5.00
13	1.7	30	30			13	0.00	-5.00
14	1.25	25	25			14	0.00	5.00
15	2.1	30	30			15	0.00	5.00
16	2.55	35	35			16	0.00	5.00
17	2.95	40	40			17	0.00	5.00
18	3.3	45	45			18	0.00	5.00
19	3.00	50	50			19	0.00	5.00
20	3.9	55	55			20	0.00	5.00
21	4.1	60	60			21	0.00	5.00
22	4.26	65	65			22	0.00	5.00
23	4.4	70	70			23	0.00	5.00
24	4.52	75	75			24	0.00	5.00
25	4.68	80	80			25	0.00	5.00
26	4.8	85.00	85.00			26	0.00	5.00
27	4.95	90.00	90.00			27	0.00	-10.00
28	3.25	80.00	80.00			28	0.00	-10.00
29	2.49	70.00	70.00			29	0.00	-70.00

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MACTEC

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
	Pressure Corrections					Volume Corrections			
1	1.34	-0.26	0.5	1.84	2.10	0.00	27	0.006086776	-27.01
2	1.34	-0.21	1.02	2.36	2.57	5.00	28.1	0.007802776	-23.11
3	1.34	-0.15	1.45	2.79	2.95	10.00	28.8	0.009221776	-18.81
4	1.34	-0.09	1.8	3.14	3.24	15.00	29.3	0.010376776	-14.31
5	1.34	-0.04	2.23	3.57	3.61	20.00	30	0.011795776	-10.01
6	1.34	0.02	2.5	3.84	3.82	25.00	30.3	0.012686776	-5.31
7	1.34	0.08	2.8	4.14	4.06	30.00	30.7	0.013676776	-0.71
8	1.34	0.14	3.1	4.44	4.30	35.00	31.1	0.014666776	3.89
9	1.34	0.21	3.3	4.64	4.44	40.00	31.3	0.015326776	8.68
10	1.34	0.27	3.6	4.94	4.68	45.00	31.6	0.016316776	13.38
11	1.34	0.22	2.7	4.04	3.82	40.00	30.3	0.013346776	9.69
12	1.34	0.17	2.1	3.44	3.28	35.00	29.4	0.011366776	5.59
13	1.34	0.11	1.7	3.04	2.94	30.00	28.8	0.010046776	1.19
14	1.34	0.05	1.25	2.59	2.54	25.00	28	0.008561776	-3.01
15	1.34	0.10	2.1	3.44	3.34	30.00	29.5	0.011366776	0.49
16	1.34	0.16	2.55	3.89	3.74	35.00	30.2	0.012851776	4.79
17	1.34	0.22	2.95	4.29	4.08	40.00	30.7	0.014171776	9.29
18	1.34	0.27	3.3	4.64	4.37	45.00	31.2	0.015326776	13.78
19	1.34	0.33	3.68	5.02	4.69	50.00	31.7	0.016580776	18.28
20	1.34	0.40	3.9	5.24	4.85	55.00	31.9	0.017306776	23.08
21	1.34	0.46	4.1	5.44	4.99	60.00	32.1	0.017966776	27.88
22	1.34	0.52	4.26	5.60	5.08	65.00	32.2	0.018494776	32.78
23	1.34	0.59	4.4	5.74	5.16	70.00	32.3	0.018956776	37.68
24	1.34	0.65	4.52	5.86	5.21	75.00	32.4	0.019352776	42.58
25	1.34	0.72	4.68	6.02	5.31	80.00	32.5	0.019880776	47.48
26	1.34	0.78	4.8	6.14	5.36	85.00	32.6	0.020276776	52.38
27	1.34	0.84	4.95	6.29	5.45	90.00	32.7	0.020771776	57.28
28	1.34	0.74	3.25	4.59	3.85	80.00	30.4	0.015161776	49.58
29	1.34	0.63	2.49	3.83	3.21	70.00	29.3	0.012653776	40.69

Pressuremeter Data Reduction

P_F Net Creep Pressure 11.00
(ba 0kPa)

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	2.95
P_2	4.44
V_1	-18.81
V_2	8.68
V_0	190.00
V_m	-5.06
υ	0.33
ΔP (Bars)	1.49
ΔV (cc)	27.49
E_0 (Bars)	27
E_0 (ksf)	55.87

PMT Reload Modulus Calculation

P_1	2.54
P_2	4.68
V_1	-3.01
V_2	13.38
V_0	190.00
V_m	5.19
υ	0.33
ΔP (Bars)	2.14
ΔV (cc)	16.39
E_r (Bars)	68
E_r (ksf)	141.25

E/P_l (bars): 1.37

E/P_r (bars): 3.47

P_l/P_r 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

B =	8	ft
K =	196.92	ksf
k_h=	24.62	kcf
k_h=	14.25	pci

$K = k_h(B)$

where: K = Horizontal Spring Constant (pci)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_0 = 2$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_0 = 3$ for silty soils
$E_r/E_0 = 4$ for sandy/gravelly soils

MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	22-Jul-03			
Project	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	BI 3			
Test Number	PMT-3			
Depth (Feet)	53	55.00		54.00
Instrument Height	2			
Total Height	55	feet =	18.04	meters
Material	silty clay			
Probe Dia.	B-58 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.20	0.00	5.00	5.00	5.00
3	0.32	5.00	10.00	5.00	5.00
4	0.51	10.00	15.00	5.00	5.00
5	0.70	15.00	20.00	5.00	5.00
6	0.77	20.00	25.00	5.00	5.00
7	0.90	25.00	30.00	5.00	5.00
8	1.00	30.00	35.00	5.00	5.00
9	1.10	35.00	40.00	5.00	5.00
10	1.20	40.00	45.00	5.00	5.00
11	1.24	45.00	50.00	5.00	5.00
12	1.26	50.00	55.00	5.00	5.00
13	1.32	55.00	60.00	5.00	5.00
14	1.45	65.00	65.00	0.00	5.00
15	1.52	70.00	70.00	0.00	5.00
16	1.58	75.00	75.00	0.00	5.00
17	1.70	80.00	80.00	0.00	5.00
18	1.76	85.00	85.00	0.00	5.00
19	1.80	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n Pressure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		0		5.00	
1	5.00	5.00		0.15		5.00	
2	10.00	10.00		0.3		5.00	
3	15.00	15.00		0.51		5.00	
4	20.00	20.00		0.82		5.00	
5	25.00	25.00		1.7		5.00	
6	30.00	30.00		4.35		5.00	
7	35.00	35.00		10		5.00	
8	40.00	40.00		17.3		5.00	
	45.00	45.00		23.7			

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	1.75	0	0			1	0.00	5.00
2	2.35	5	5			2	0.00	5.00
3	2.8	10	10			3	0.00	5.00
4	3.22	15	15			4	0.00	5.00
5	3.48	20	20			5	0.00	5.00
6	3.75	25	25			6	0.00	5.00
7	4	30	30			7	0.00	5.00
8	4.2	35	35			8	0.00	5.00
9	4.3	40	40			9	0.00	5.00
10	4.5	45	45			10	0.00	-5.00
11	3.7	40	40			11	0.00	-5.00
12	3.2	35	35			12	0.00	-5.00
13	2.77	30	30			13	0.00	5.00
14	3.5	35	35			14	0.00	5.00
15	3.95	40	40			15	0.00	5.00
16	4.3	45	45			16	0.00	5.00
17	4.6	50	50			17	0.00	5.00
18	4.72	55	55			18	0.00	5.00
19	4.9	60	60			19	0.00	5.00
20	5	65	65			20	0.00	5.00
21	5.05	70	70			21	0.00	5.00
22	5.15	75	75			22	0.00	5.00
23	5.25	80	80			23	0.00	5.00
24	5.3	85	85			24	0.00	5.00
25	5.5	90	90			25	0.00	-10.00
26	4.2	80.00	80.00			26	0.00	-10.00
27	3.4	70.00	70.00			27	0.00	-10.00
28	2.9	60.00	60.00			28	0.00	-60.00

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10/30

MACTEC

Pressure Stage	Pressure Corrections: Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Corrections: Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	1.64	-0.30	1.75	3.39	3.69	0.00	30.1	0.011197727	-30.11
2	1.64	-0.25	2.35	3.99	4.24	5.00	31	0.013177727	-26.01
3	1.64	-0.19	2.8	4.44	4.63	10.00	31.6	0.014662727	-21.61
4	1.64	-0.13	3.22	4.86	4.99	15.00	32.1	0.016048727	-17.12
5	1.64	-0.07	3.48	5.12	5.19	20.00	32.4	0.016906727	-12.42
6	1.64	-0.01	3.75	5.39	5.40	25.00	32.6	0.017797727	-7.62
7	1.64	0.06	4	5.64	5.59	30.00	32.9	0.018622727	-2.92
8	1.64	0.12	4.2	5.84	5.72	35.00	33.1	0.019282727	1.88
9	1.64	0.18	4.3	5.94	5.76	40.00	33.1	0.019612727	6.88
10	1.64	0.25	4.5	6.14	5.90	45.00	33.3	0.020272727	11.68
11	1.64	0.19	3.7	5.34	5.15	40.00	32.3	0.017632727	7.68
12	1.64	0.14	3.2	4.84	4.71	35.00	31.7	0.015982727	3.28
13	1.64	0.08	2.77	4.41	4.33	30.00	31.1	0.014563727	-1.11
14	1.64	0.13	3.5	5.14	5.01	35.00	32.1	0.016972727	2.88
15	1.64	0.19	3.95	5.59	5.40	40.00	32.6	0.018457727	7.38
16	1.64	0.25	4.3	5.94	5.69	45.00	33	0.019612727	11.98
17	1.64	0.31	4.6	6.24	5.93	50.00	33.3	0.020602727	16.68
18	1.64	0.38	4.72	6.36	5.99	55.00	33.4	0.020998727	21.58
19	1.64	0.44	4.9	6.54	6.10	60.00	33.6	0.021592727	26.38
20	1.64	0.50	5	6.64	6.14	65.00	33.6	0.021922727	31.38
21	1.64	0.57	5.05	6.69	6.12	70.00	33.6	0.022087727	36.38
22	1.64	0.64	5.15	6.79	6.16	75.00	33.6	0.022417727	41.38
23	1.64	0.70	5.25	6.89	6.19	80.00	33.7	0.022747727	46.28
24	1.64	0.77	5.3	6.94	6.18	85.00	33.6	0.022912727	51.38
25	1.64	0.83	5.5	7.14	6.31	90.00	33.8	0.023572727	56.18
26	1.64	0.72	4.2	5.84	5.12	80.00	32.3	0.019282727	47.68
27	1.64	0.60	3.4	5.04	4.44	70.00	31.3	0.016642727	38.68
28	1.64	0.48	2.9	4.54	4.07	60.00	30.7	0.014992727	29.29

Pressuremeter Data Reduction

P_E [illegible]eep Pressure 11.00
(ba[illegible] [illegible]0kPa)

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	3.69
P_2	5.19
V_1	-30.11
V_2	-12.42
V_0	190.00
V_m	-21.26
υ	0.33
ΔP (Bars)	1.50
ΔV (cc)	17.69
E_0 (Bars)	30
E_0 (ksf)	79.37

PMT Reload Modulus Calculation

P_1	4.33
P_2	5.90
V_1	-1.11
V_2	11.68
V_0	190.00
V_m	5.28
υ	0.33
ΔP (Bars)	1.56
ΔV (cc)	12.79
E_r (Bars)	63
E_r (ksf)	132.48

E/P_l (bars): 1.95

E/P_r (bars): 3.25

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_0 = 2$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_0 = 3$ for silty soils
$E_r/E_0 = 4$ for sandy/gravelly soils

B =	8	ft
K =	211.86	ksf
k_h =	26.48	kcf
k_h =	15.33	pci

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11/30

MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	22-Jul-03			
Project	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	BI 3			
Test Number	PMT-4			
Depth (Feet)	63	65.00		64.00
Instrument Height	2			
Total Height	65	feet =	21.33	meters
Material	silty clay			
Probe Dia.	B-58 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.20	0.00	5.00	5.00	5.00
3	0.32	5.00	10.00	5.00	5.00
4	0.61	10.00	15.00	5.00	5.00
5	0.70	15.00	20.00	5.00	5.00
6	0.77	20.00	25.00	5.00	5.00
7	0.90	25.00	30.00	5.00	5.00
8	1.00	30.00	35.00	5.00	5.00
9	1.10	35.00	40.00	5.00	5.00
10	1.20	40.00	45.00	5.00	5.00
11	1.24	45.00	50.00	5.00	5.00
12	1.26	50.00	55.00	5.00	5.00
13	1.32	55.00	60.00	5.00	5.00
14	1.45	65.00	65.00	0.00	5.00
15	1.52	70.00	70.00	0.00	5.00
16	1.58	75.00	75.00	0.00	5.00
17	1.70	80.00	80.00	0.00	5.00
18	1.76	85.00	85.00	0.00	5.00
19	1.80	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n Pressure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		0		5.00	
1	5.00	5.00		0.15		5.00	
2	10.00	10.00		0.3		5.00	
3	15.00	15.00		0.51		5.00	
4	20.00	20.00		0.82		5.00	
5	25.00	25.00		1.7		5.00	
6	30.00	30.00		4.35		5.00	
7	35.00	35.00		10		5.00	
8	40.00	40.00		17.3		5.00	
	45.00	45.00		23.7			

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	2	0	0			1	0.00	5.00
2	2.5	5	5			2	0.00	5.00
3	3.05	10	10			3	0.00	5.00
4	3.3	15	15			4	0.00	5.00
5	3.75	20	20			5	0.00	5.00
6	4	25	25			6	0.00	5.00
7	4.25	30	30			7	0.00	5.00
8	4.45	35	35			8	0.00	5.00
9	4.65	40	40			9	0.00	5.00
10	4.75	45	45			10	0.00	-5.00
11	3.85	40	40			11	0.00	-5.00
12	3.27	35	35			12	0.00	-5.00
13	2.7	30	30			13	0.00	5.00
14	3.25	35	35			14	0.00	5.00
15	4	40	40			15	0.00	5.00
16	4.5	45	45			16	0.00	5.00
17	4.75	50	50			17	0.00	5.00
18	5	55	55			18	0.00	5.00
19	5.1	60	60			19	0.00	5.00
20	5.25	65	65			20	0.00	5.00
21	5.4	70	70			21	0.00	5.00
22	5.5	75	75			22	0.00	5.00
23	5.5	80	80			23	0.00	5.00
24	5.6	85	85			24	0.00	5.00
25	5.7	90	90			25	0.00	-10.00
26	4.25	80.00	80.00			26	0.00	-10.00
27	3.5	70.00	70.00			27	0.00	-10.00
28	2.8	60.00	60.00			28	0.00	-60.00

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MACTEC

Pressure Corrections | **Volume Corrections**

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	1.94	-0.31	2	3.94	4.25	0.00	31	0.013008677	-31.01
2	1.94	-0.26	2.5	4.44	4.70	5.00	31.7	0.014658677	-26.71
3	1.94	-0.20	3.05	4.99	5.19	10.00	32.4	0.016473677	-22.42
4	1.94	-0.14	3.3	5.24	5.38	15.00	32.6	0.017298677	-17.62
5	1.94	-0.08	3.75	5.69	5.77	20.00	33.1	0.018783677	-13.12
6	1.94	-0.02	4	5.94	5.96	25.00	33.4	0.019608677	-8.42
7	1.94	0.05	4.25	6.19	6.15	30.00	33.6	0.020433677	-3.62
8	1.94	0.11	4.45	6.39	6.28	35.00	33.8	0.021093677	1.18
9	1.94	0.17	4.65	6.59	6.42	40.00	33.9	0.021753677	6.08
10	1.94	0.24	4.75	6.69	6.45	45.00	34	0.022083677	10.98
11	1.94	0.19	3.85	5.79	5.61	40.00	32.9	0.019113677	7.08
12	1.94	0.13	3.27	5.21	5.08	35.00	32.2	0.017199677	2.78
13	1.94	0.07	2.7	4.64	4.57	30.00	31.5	0.015318677	-1.52
14	1.94	0.13	3.25	5.19	5.06	35.00	32.2	0.017133677	2.78
15	1.94	0.18	4	5.94	5.76	40.00	33.1	0.019608677	6.88
16	1.94	0.24	4.5	6.44	6.20	45.00	33.7	0.021258677	11.28
17	1.94	0.30	4.75	6.69	6.39	50.00	33.9	0.022083677	16.08
18	1.94	0.37	5	6.94	6.57	55.00	34.1	0.022908677	20.88
19	1.94	0.43	5.1	7.04	6.61	60.00	34.2	0.023238677	25.78
20	1.94	0.50	5.25	7.19	6.70	65.00	34.3	0.023733677	30.68
21	1.94	0.56	5.4	7.34	6.78	70.00	34.4	0.024228677	35.58
22	1.94	0.63	5.5	7.44	6.82	75.00	34.4	0.024558677	40.58
23	1.94	0.69	5.5	7.44	6.75	80.00	34.3	0.024558677	45.68
24	1.94	0.76	5.6	7.54	6.79	85.00	34.4	0.024888677	50.58
25	1.94	0.82	5.7	7.64	6.82	90.00	34.4	0.025218677	55.57
26	1.94	0.71	4.25	6.19	5.48	80.00	32.8	0.020433677	47.18
27	1.94	0.59	3.5	5.44	4.85	70.00	31.9	0.017958677	38.08
28	1.94	0.47	2.8	4.74	4.27	60.00	31	0.015648677	28.98

Pressuremeter Data Reduction

P_F [illegible]ep Pressure 11.00
(ba[illegible] [illegible]0kPa)

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	4.25
P_2	5.77
V_1	-31.01
V_2	-13.12
V_0	190.00
V_m	-22.07
υ	0.33
ΔP (Bars)	1.52
ΔV (cc)	17.89
E_0 (Bars)	38
E_0 (ksf)	79.02

PMT Reload Modulus Calculation

P_1	4.57
P_2	6.45
V_1	-1.52
V_2	10.98
V_0	190.00
V_m	4.73
υ	0.33
ΔP (Bars)	1.89
ΔV (cc)	12.49
E_r (Bars)	78
E_r (ksf)	163.34

E/P_l (bars): 1.94

E/P_r (bars): 4.01

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_0 = 2$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_0 = 3$ for silty soils
$E_r/E_0 = 4$ for sandy/gravelly soils

B =	8	ft
K =	242.36	ksf
k_h =	30.30	kcf
k_h =	17.53	pci

MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	22-Jul-03
Project	Indian River Inlet
Location	Dewey Beach, DE
Borehole	BI-3
Test Number	PMT-5
Depth (Feet)	73 75.00 74.00
Instrument Height	2
Total Height	75 feet = 24.61 meters
Material	silty clay
Probe Dia.	B-58 mm

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.20	0.00	5.00	5.00	5.00
3	0.32	5.00	10.00	5.00	5.00
4	0.51	10.00	15.00	5.00	5.00
5	0.70	15.00	20.00	5.00	5.00
6	0.77	20.00	25.00	5.00	5.00
7	0.90	25.00	30.00	5.00	5.00
8	1.00	30.00	35.00	5.00	5.00
9	1.10	35.00	40.00	5.00	5.00
10	1.20	40.00	45.00	5.00	5.00
11	1.24	45.00	50.00	5.00	5.00
12	1.26	50.00	55.00	5.00	5.00
13	1.32	55.00	60.00	5.00	5.00
14	1.45	65.00	65.00	0.00	5.00
15	1.52	70.00	70.00	0.00	5.00
16	1.58	75.00	75.00	0.00	5.00
17	1.70	80.00	80.00	0.00	5.00
18	1.76	85.00	85.00	0.00	5.00
19	1.80	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n Pressure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		0		5.00	
1	5.00	5.00		0.15		5.00	
2	10.00	10.00		0.3		5.00	
3	15.00	15.00		0.51		5.00	
4	20.00	20.00		0.82		5.00	
5	25.00	25.00		1.7		5.00	
6	30.00	30.00		4.35		5.00	
7	35.00	35.00		10		5.00	
8	40.00	40.00		17.3		5.00	
	45.00	45.00		23.7			

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	2.6	0	0			1	0.00	5.00
2	3.1	5	5			2	0.00	5.00
3	3.5	10	10			3	0.00	5.00
4	3.9	15	15			4	0.00	5.00
5	4.22	20	20			5	0.00	5.00
6	4.45	25	25			6	0.00	5.00
7	4.6	30	30			7	0.00	5.00
8	4.8	35	35			8	0.00	5.00
9	4.9	40	40			9	0.00	5.00
10	5.15	45	45			10	0.00	5.00
11	5.25	50	50			11	0.00	-5.00
12	4.45	45	45			12	0.00	-5.00
13	3.85	40	40			13	0.00	-5.00
14	3.4	35	35			14	0.00	5.00
15	4.24	40	40			15	0.00	5.00
16	4.7	45	45			16	0.00	5.00
17	5.05	50	50			17	0.00	5.00
18	5.25	55	55			18	0.00	5.00
19	5.45	60	60			19	0.00	5.00
20	5.6	65	65			20	0.00	5.00
21	5.68	70	70			21	0.00	5.00
22	5.76	75	75			22	0.00	5.00
23	5.9	80	80			23	0.00	5.00
24	6.05	85	85			24	0.00	5.00
25	6.1	90	90			25	0.00	-10.00
26	4.65	80.00	80.00			26	0.00	-10.00
27	3.85	70.00	70.00			27	0.00	-10.00
28	3.25	60.00	60.00			28	0.00	-60.00

MACTEC

Pressure Corrections | Volume Corrections

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	2.24	-0.33	2.6	4.84	5.17	0.00	32.3	0.015974627	-32.32
2	2.24	-0.27	3.1	5.34	5.61	5.00	32.9	0.017624627	-27.92
3	2.24	-0.21	3.5	5.74	5.95	10.00	33.4	0.018944627	-23.42
4	2.24	-0.15	3.9	6.14	6.29	15.00	33.8	0.020264627	-18.82
5	2.24	-0.09	4.22	6.46	6.55	20.00	34.1	0.021320627	-14.12
6	2.24	-0.03	4.45	6.69	6.72	25.00	34.3	0.022079627	-9.32
7	2.24	0.04	4.6	6.84	6.81	30.00	34.4	0.022574627	-4.42
8	2.24	0.10	4.8	7.04	6.94	35.00	34.6	0.023234627	0.38
9	2.24	0.16	4.9	7.14	6.98	40.00	34.6	0.023564627	5.38
10	2.24	0.23	5.15	7.39	7.16	45.00	34.8	0.024389627	10.18
11	2.24	0.29	5.25	7.49	7.20	50.00	34.8	0.024719627	15.10
12	2.24	0.24	4.45	6.69	6.45	45.00	34	0.022079627	10.98
13	2.24	0.18	3.85	6.09	5.91	40.00	33.3	0.020099627	6.68
14	2.24	0.12	3.4	5.64	5.52	35.00	32.8	0.018614627	2.18
15	2.24	0.17	4.24	6.48	6.31	40.00	33.8	0.021386627	6.18
16	2.24	0.23	4.7	6.94	6.71	45.00	34.3	0.022904627	10.68
17	2.24	0.30	5.05	7.29	7.00	50.00	34.6	0.024059627	15.38
18	2.24	0.36	5.25	7.49	7.13	55.00	34.8	0.024719627	20.18
19	2.24	0.42	5.45	7.69	7.27	60.00	34.9	0.025379627	25.07
20	2.24	0.49	5.6	7.84	7.35	65.00	35	0.025874627	29.97
21	2.24	0.55	5.68	7.92	7.37	70.00	35	0.026138627	34.97
22	2.24	0.62	5.76	8.00	7.38	75.00	35.1	0.026402627	39.87
23	2.24	0.68	5.9	8.14	7.46	80.00	35.1	0.026864627	44.87
24	2.24	0.75	6.05	8.29	7.55	85.00	35.2	0.027359627	49.77
25	2.24	0.81	6.1	8.34	7.53	90.00	35.2	0.027524627	54.77
26	2.24	0.70	4.65	6.89	6.19	80.00	33.7	0.022739627	46.28
27	2.24	0.58	3.85	6.09	5.51	70.00	32.8	0.020099627	37.18
28	2.24	0.46	3.25	5.49	5.03	60.00	32.1	0.018119627	27.88

Pressuremeter Data Reduction

P_c [illegible]ep Pressure 11.00
(ba[illegible] [illegible]0kPa)

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	5.17
P_2	6.55
V_1	-32.32
V_2	-14.12
V_0	190.00
V_m	-23.22
υ	0.33
ΔP (Bars)	1.38
ΔV (cc)	18.19
E_0 (Bars)	34
E_0 (ksf)	70.36

PMT Reload Modulus Calculation

P_1	5.52
P_2	7.20
V_1	2.18
V_2	15.18
V_0	190.00
V_m	8.68
υ	0.33
ΔP (Bars)	1.68
ΔV (cc)	12.99
E_r (Bars)	68
E_r (ksf)	142.69

E/P_l (bars): 1.73

E/P_r (bars): 3.50

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_0 = 2$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_0 = 3$ for silty soils
$E_r/E_0 = 4$ for sandy/gravelly soils

B =	8	ft
K =	213.05	ksf
k_h =	26.63	kcf
k_h =	**15.41**	**pci**

MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	20-Jul-03			
Project	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	BI-10			
Test Number	PMT-6			
Depth (Feet)	34	36.00		35.00
Instrument Height	2			
Total Height	36	feet =	11.81	meters
Material	silty clay			
Probe Dia.	B-58 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	elta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.05	5.00	5.00	0.00	5.00
3	0.20	10.00	10.00	0.00	5.00
4	0.26	15.00	15.00	0.00	5.00
5	0.35	20.00	20.00	0.00	5.00
6	0.40	25.00	25.00	0.00	5.00
7	0.43	30.00	30.00	0.00	5.00
8	0.50	35.00	35.00	0.00	5.00
9	0.60	40.00	40.00	0.00	5.00
10	0.68	45.00	45.00	0.00	5.00
11	0.73	50.00	50.00	0.00	5.00
12	0.75	55.00	55.00	0.00	10.00
13	0.80	65.00	65.00	0.00	5.00
14	0.95	70.00	70.00	0.00	5.00
15	0.90	75.00	75.00	0.00	5.00
16	0.92	80.00	80.00	0.00	5.00
17	1.03	85.00	85.00	0.00	5.00
18	1.08	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n sure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		0		5.00	
1	5.00	5.00		0.15		5.00	
2	10.00	10.00		0.25		5.00	
3	15.00	15.00		0.3		5.00	
4	20.00	20.00		0.55		5.00	
5	25.00	25.00		1		5.00	
6	30.00	30.00		2.15		5.00	
7	35.00	35.00		5.2		5.00	
8	40.00	40.00		16.75		5.00	
9	45.00	45.00		23		5.00	
10	50.00	50.00		29.4			

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	2.6	0	0			1	0.00	5.00
2	3.1	5	5			2	0.00	5.00
3	3.5	10	10			3	0.00	5.00
4	3.9	15	15			4	0.00	5.00
5	4.22	20	20			5	0.00	5.00
6	4.45	25	25			6	0.00	5.00
7	4.6	30	30			7	0.00	5.00
8	4.8	35	35			8	0.00	5.00
9	4.9	40	40			9	0.00	5.00
10	5.15	45	45			10	0.00	5.00
11	5.26	50	50			11	0.00	-5.00
12	4.45	45	45			12	0.00	-5.00
13	3.85	40	40			13	0.00	-5.00
14	3.4	35	35			14	0.00	5.00
15	4.24	40	40			15	0.00	5.00
16	4.7	45	45			16	0.00	5.00
17	5.05	50	50			17	0.00	5.00
18	5.25	55	55			18	0.00	5.00
19	5.45	60	60			19	0.00	5.00
20	5.6	65	65			20	0.00	5.00
21	5.68	70	70			21	0.00	5.00
22	5.76	75	75			22	0.00	5.00
23	5.9	80	80			23	0.00	5.00
24	6.05	85	85			24	0.00	5.00
25	6.1	90	90			25	0.00	-10.00
26	4.65	80.00	80.00			26	0.00	-10.00
27	3.85	70.00	70.00			27	0.00	-10.00
28	3.25	60.00	60.00			28	0.00	-60.00

MACTEC

Pressure Stage	Pressure Corrections: Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	Volume Corrections: System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	1.08	-0.24	2.6	3.68	3.91	0.00	25.4	0.012129421	-25.41
2	1.08	-0.18	3.1	4.18	4.36	5.00	26.2	0.013779421	-21.21
3	1.08	-0.13	3.5	4.58	4.70	10.00	26.7	0.015099421	-16.72
4	1.08	-0.07	3.9	4.98	5.04	15.00	27.3	0.016419421	-12.32
5	1.08	-0.01	4.22	5.30	5.30	20.00	27.7	0.017475421	-7.72
6	1.08	0.06	4.45	5.53	5.47	25.00	27.9	0.018234421	-2.92
7	1.08	0.12	4.6	5.68	5.56	30.00	28	0.018729421	1.98
8	1.08	0.18	4.8	5.88	5.69	35.00	28.2	0.019389421	6.78
9	1.08	0.25	4.9	5.98	5.73	40.00	28.3	0.019719421	11.68
10	1.08	0.31	5.15	6.23	5.92	45.00	28.6	0.020544421	16.38
11	1.08	0.37	5.25	6.33	5.95	50.00	28.6	0.020874421	21.38
12	1.08	0.32	4.45	5.53	5.20	45.00	27.5	0.018234421	17.48
13	1.08	0.27	3.85	4.93	4.66	40.00	26.7	0.016254421	13.28
14	1.08	0.21	3.4	4.48	4.26	35.00	26	0.014769421	8.99
15	1.08	0.26	4.24	5.32	5.06	40.00	27.3	0.017541421	12.68
16	1.08	0.32	4.7	5.78	5.46	45.00	27.9	0.019059421	17.08
17	1.08	0.38	5.05	6.13	5.75	50.00	28.3	0.020214421	21.68
18	1.08	0.44	5.25	6.33	5.89	55.00	28.5	0.020874421	26.48
19	1.08	0.50	5.45	6.53	6.02	60.00	28.7	0.021534421	31.28
20	1.08	0.57	5.6	6.68	6.11	65.00	28.8	0.022029421	36.18
21	1.08	0.63	5.68	6.76	6.12	70.00	28.8	0.022293421	41.18
22	1.08	0.70	5.76	6.84	6.14	75.00	28.9	0.022557421	46.08
23	1.08	0.76	5.9	6.98	6.21	80.00	29	0.023019421	50.98
24	1.08	0.83	6.05	7.13	6.30	85.00	29.1	0.023514421	55.88
25	1.08	0.89	6.1	7.18	6.28	90.00	29.1	0.023679421	60.88
26	1.08	0.79	4.65	5.73	4.94	80.00	27.1	0.018894421	52.88
27	1.08	0.67	3.85	4.93	4.26	70.00	26	0.016254421	43.98
28	1.08	0.55	3.25	4.33	3.78	60.00	25.2	0.014274421	34.79

Pressuremeter Data Reduction

P_E [illegible]eep Pressure 11.00
(b[illegible] 0kPa)

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	3.91
P_2	5.30
V_1	-25.41
V_2	-7.72
V_0	190.00
V_m	-16.56
υ	0.33
ΔP (Bars)	1.39
ΔV (cc)	17.69
E_0 (Bars)	36
E_0 (ksf)	75.59

PMT Reload Modulus Calculation

P_1	4.26
P_2	5.95
V_1	8.99
V_2	21.38
V_0	190.00
V_m	15.18
υ	0.33
ΔP (Bars)	1.69
ΔV (cc)	12.39
E_r (Bars)	74
E_r (ksf)	155.22

E/P_l (bars): 1.86

E/P_r (bars): 3.81

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_{0=2}$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_{0=3}$ for silty soils
$E_r/E_{0=4}$ for sandy/gravelly soils

B =	8	ft
K =	230.81	ksf
k_h =	28.85	kcf
k_h =	**16.70**	**pci**

17/30

MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	15-Oct-03			
Project	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	BH 10			
Test Number	PM2-1			
Depth (Feet)	16	83.50		49.75
Instrument Height	2			
Total Height	18	feet =	5.91	meters
Material	sand			
Probe Dia.	B-58 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.10	5.00	5.00	0.00	5.00
3	0.23	10.00	10.00	0.00	5.00
4	0.30	15.00	15.00	0.00	5.00
5	0.35	20.00	20.00	0.00	5.00
6	0.50	25.00	25.00	0.00	5.00
7	0.55	30.00	30.00	0.00	5.00
8	0.60	35.00	35.00	0.00	5.00
9	0.65	40.00	40.00	0.00	5.00
10	0.70	45.00	45.00	0.00	5.00
11	0.75	50.00	50.00	0.00	5.00
12	0.80	55.00	55.00	0.00	5.00
13	0.85	60.00	60.00	0.00	5.00
14	0.95	65.00	65.00	0.00	5.00
15	1.00	70.00	70.00	0.00	5.00
16	1.05	75.00	75.00	0.00	5.00
17	1.12	80.00	80.00	0.00	5.00
18	1.20	85.00	85.00	0.00	5.00
19	1.25	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n Pressure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		-0.01		5.00	
1	5.00	5.00		0.2		5.00	
2	10.00	10.00		0.75		5.00	
3	15.00	15.00		1.7		5.00	
4	20.00	20.00		3.1		5.00	
5	25.00	25.00		5.75		5.00	
6	30.00	30.00		10.75		5.00	
7	35.00	35.00		17.75		2.00	
8	37.00	37.00		20.25		-37.00	

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.4	0	0			1	0.00	5.00
2	1.75	5	5			2	0.00	5.00
3	3.1	10	10			3	0.00	5.00
4	4.3	15	15			4	0.00	5.00
5	5.45	20	20			5	0.00	5.00
6	6.5	25	25			6	0.00	5.00
7	7.4	30	30			7	0.00	5.00
8	8.3	35	35			8	0.00	5.00
9	9.1	40	40			9	0.00	5.00
10	9.95	45	45			10	0.00	5.00
11	10.6	50	50			11	0.00	-5.00
12	5.1	45	45			12	0.00	-5.00
13	2.6	40	40			13	0.00	-5.00
14	1.5	35	35			14	0.00	5.00
15	3.6	40	40			15	0.00	5.00
16	6.15	45	45			16	0.00	5.00
17	8.28	50	50			17	0.00	5.00
18	9.85	55	55			18	0.00	5.00
19	10.9	60	60			19	0.00	5.00
20	11.6	65	65			20	0.00	5.00
21	12.2	70	70			21	0.00	5.00
22	12.75	75	75			22	0.00	5.00
23	13.25	80	80			23	0.00	5.00
24	13.75	85	85			24	0.00	5.00
25	14.3	90	90			25	0.00	

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MACTEC

Pressure Corrections | **Volume Corrections**

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	0.54	0.02	0.4	0.94	0.92	0.00	6	0.003094711	-6.00
2	0.54	-0.02	1.75	2.29	2.31	5.00	14	0.007549711	-9.01
3	0.54	-0.06	3.1	3.64	3.70	10.00	22	0.012004711	-12.01
4	0.54	-0.02	4.3	4.84	4.86	15.00	24	0.015964711	-9.02
5	0.54	0.03	5.45	5.99	5.96	20.00	25	0.019759711	-5.02
6	0.54	0.09	6.5	7.04	6.95	25.00	25.5	0.023224711	-0.52
7	0.54	0.15	7.4	7.94	7.79	30.00	26	0.026194711	3.97
8	0.54	0.20	8.3	8.84	8.64	35.00	27	0.029164711	7.97
9	0.54	0.25	9.1	9.64	9.39	40.00	28	0.031804711	11.97
10	0.54	0.30	9.95	10.49	10.18	45.00	29	0.034609711	15.97
11	0.54	0.36	10.6	11.14	10.78	50.00	30	0.036754711	19.96
12	0.54	0.36	5.1	5.64	5.28	45.00	25	0.018604711	19.98
13	0.54	0.49	2.6	3.14	2.65	40.00	10	0.010354711	29.99
14	0.54	0.32	1.5	2.04	1.72	35.00	18	0.006724711	16.99
15	0.54	0.32	3.6	4.14	3.82	40.00	23	0.013654711	16.99
16	0.54	0.35	6.15	6.69	6.34	45.00	25.5	0.022069711	19.48
17	0.54	0.39	8.28	8.82	8.42	50.00	27	0.029098711	22.97
18	0.54	0.43	9.85	10.39	9.95	55.00	29	0.034279711	25.97
19	0.54	0.47	10.9	11.44	10.96	60.00	31	0.037744711	28.96
20	0.54	0.53	11.6	12.14	11.61	65.00	32	0.040054711	32.96
21	0.54	0.58	12.2	12.74	12.16	70.00	33	0.042034711	36.96
22	0.54	0.63	12.75	13.29	12.66	75.00	34	0.043849711	40.96
23	0.54	0.70	13.25	13.79	13.09	80.00	33.75	0.045499711	46.20
24	0.54	0.76	13.75	14.29	13.53	85.00	34	0.047149711	50.95
25	0.54	0.82	14.3	14.84	14.02	90.00	34.5	0.048964711	55.45

Pressuremeter Data Reduction

P_E [illegible]ep Pressure 11.00
(ba[illegible] [illegible]0kPa)

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	3.70
P_2	8.64
V_1	-12.01
V_2	7.97
V_0	190.00
V_m	-2.02
υ	0.33
ΔP (Bars)	4.94
ΔV (cc)	19.98
E_p (Bars)	124
E_0 (ksf)	256.08

PMT Reload Modulus Calculation

P_1	1.72
P_2	8.44
V_1	16.99
V_2	22.97
V_0	190.00
V_m	19.98
υ	0.33
ΔP (Bars)	6.72
ΔV (cc)	5.98
E_r (Bars)	628
E_r (ksf)	1310.90

E/P_l (bars): 6.34

E/P_r (bars): 32.19

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_0 = 2$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_0 = 3$ for silty soils
$E_r/E_0 = 4$ for sandy/gravelly soils

B =	8	ft
K =	1568.98	ksf
k_h =	196.12	kcf
k_h =	113.50	pci

MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	15-Oct-03			
Project	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	BII 19			
Test Number	PM2-2			
Depth (Feet)	21			21.00
Instrument Height	2			
Total Height	23	feet =	7.55	meters
Material	sand			
Probe Dia.	B-58 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.10	5.00	5.00	0.00	5.00
3	0.23	10.00	10.00	0.00	5.00
4	0.30	15.00	15.00	0.00	5.00
5	0.35	20.00	20.00	0.00	5.00
6	0.50	25.00	25.00	0.00	5.00
7	0.55	30.00	30.00	0.00	5.00
8	0.60	35.00	35.00	0.00	5.00
9	0.65	40.00	40.00	0.00	5.00
10	0.70	45.00	45.00	0.00	5.00
11	0.75	50.00	50.00	0.00	5.00
12	0.80	55.00	55.00	0.00	5.00
13	0.85	60.00	60.00	0.00	5.00
14	0.95	65.00	65.00	0.00	5.00
15	1.00	70.00	70.00	0.00	5.00
16	1.05	75.00	75.00	0.00	5.00
17	1.12	80.00	80.00	0.00	5.00
18	1.20	85.00	85.00	0.00	5.00
19	1.25	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n Pressure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		-0.01		5.00	
1	5.00	5.00		0.2		5.00	
2	10.00	10.00		0.75		5.00	
3	15.00	15.00		1.7		5.00	
4	20.00	20.00		3.1		5.00	
5	25.00	25.00		5.75		5.00	
6	30.00	30.00		10.75		5.00	
7	35.00	35.00		17.75		2.00	
8	37.00	37.00		20.25		-37.00	

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.65	0	0			1	0.00	5.00
2	2.2	5	5			2	0.00	5.00
3	3.7	10	10			3	0.00	5.00
4	5.1	15	15			4	0.00	5.00
5	6.4	20	20			5	0.00	5.00
6	7.45	25	25			6	0.00	5.00
7	8.55	30	30			7	0.00	5.00
8	9.5	35	35			8	0.00	5.00
9	10.3	40	40			9	0.00	5.00
10	11.25	45	45			10	0.00	5.00
11	11.9	50	50			11	0.00	10.00
12	12.1	60	60			12	0.00	5.00
13	13	65	65			13	0.00	5.00
14	13.8	70	70			14	0.00	5.00
15	14.25	75	75			15	0.00	5.00
16	15.1	80	80			16	0.00	5.00
17	15.75	85	85			17	0.00	5.00
18	16.2	90	90			18	0.00	

MACTEC

Pressure Corrections | **Volume Corrections**

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	0.69	-0.09	0.65	1.34	1.43	0.00	14.4	0.004412686	-14.40
2	0.69	-0.10	2.2	2.89	2.99	5.00	19.7	0.009527686	-14.71
3	0.69	-0.07	3.7	4.39	4.46	10.00	22.8	0.014477686	-12.81
4	0.69	-0.04	5.1	5.79	5.83	15.00	25.1	0.019097686	-10.12
5	0.69	0.00	6.4	7.09	7.08	20.00	26.8	0.023387686	-6.82
6	0.69	0.05	7.45	8.14	8.08	25.00	28	0.026852686	-3.03
7	0.69	0.10	8.55	9.24	9.13	30.00	29.2	0.030482686	0.77
8	0.69	0.16	9.5	10.19	10.03	35.00	30.1	0.033617686	4.87
9	0.69	0.21	10.3	10.99	10.77	40.00	30.8	0.036257686	9.16
10	0.69	0.27	11.25	11.94	11.67	45.00	31.6	0.039392686	13.36
11	0.69	0.33	11.9	12.59	12.26	50.00	32.1	0.041537686	17.86
12	0.69	0.46	12.1	12.79	12.33	60.00	32.2	0.042197686	27.76
13	0.69	0.51	13	13.69	13.17	65.00	32.9	0.045167686	32.05
14	0.69	0.57	13.8	14.49	13.92	70.00	33.5	0.047807686	36.45
15	0.69	0.63	14.25	14.94	14.30	75.00	33.8	0.049292686	41.15
16	0.69	0.69	15.1	15.79	15.10	80.00	34.4	0.052097686	45.55
17	0.69	0.75	15.75	16.44	15.69	85.00	34.8	0.054242686	50.15
18	0.69	0.81	16.2	16.89	16.08	90.00	35.1	0.055727686	54.84

Pressuremeter Data Reduction

P_E ...eep Pressure 11.00
(ba... ...0kPa)

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	4.46
P_2	11.67
V_1	-12.81
V_2	13.36
V_0	190.00
V_m	0.27
υ	0.33
ΔP (Bars)	7.21
ΔV (cc)	26.18
E_0 (Bars)	130
E_0 (ksf)	291.11

Reload Modulus correlated from ROCTEST Manual

E_r/E_0 = 4.00

E_r (ksf) 1164.44

E/P_l (bars): 7.15

E/P_r (bars): 0.05

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

B =	8	ft
K =	1455.55	ksf
k_h =	181.94	kcf
k_h =	105.29	pci

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_0 = 2$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_0 = 3$ for silty soils
$E_r/E_0 = 4$ for sandy/gravelly soils

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MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	15-Oct-03			
Project	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	BH-19			
Test Number	PM2-3			
Depth (Feet)	26			26.00
Instrument Height	2			
Total Height	28	feet =	9.19	meters
Material	sand			
Probe Dia.	B-58 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	elta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.10	5.00	5.00	0.00	5.00
3	0.23	10.00	10.00	0.00	5.00
4	0.30	15.00	15.00	0.00	5.00
5	0.35	20.00	20.00	0.00	5.00
6	0.50	25.00	25.00	0.00	5.00
7	0.55	30.00	30.00	0.00	5.00
8	0.60	35.00	35.00	0.00	5.00
9	0.65	40.00	40.00	0.00	5.00
10	0.70	45.00	45.00	0.00	5.00
11	0.75	50.00	50.00	0.00	5.00
12	0.80	55.00	55.00	0.00	5.00
13	0.85	60.00	60.00	0.00	5.00
14	0.95	65.00	65.00	0.00	5.00
15	1.00	70.00	70.00	0.00	5.00
16	1.05	75.00	75.00	0.00	5.00
17	1.12	80.00	80.00	0.00	5.00
18	1.20	85.00	85.00	0.00	5.00
19	1.25	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n ssure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		-0.01		5.00	
1	5.00	5.00		0.2		5.00	
2	10.00	10.00		0.75		5.00	
3	15.00	15.00		1.7		5.00	
4	20.00	20.00		3.1		5.00	
5	25.00	25.00		5.75		5.00	
6	30.00	30.00		10.75		5.00	
7	35.00	35.00		17.75		2.00	
8	37.00	37.00		20.25		-37.00	

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	1	0	0			1	0.00	5.00
2	2.45	5	5			2	0.00	5.00
3	4	10	10			3	0.00	5.00
4	5.45	15	15			4	0.00	5.00
5	6.75	20	20			5	0.00	5.00
6	8	25	25			6	0.00	5.00
7	9.15	30	30			7	0.00	5.00
8	10.15	35	35			8	0.00	5.00
9	11.2	40	40			9	0.00	5.00
10	12	45	45			10	0.00	5.00
11	13.05	50	50			11	0.00	10.00
12	13.25	60	60			12	0.00	5.00
13	14.35	65	65			13	0.00	5.00
14	15.3	70	70			14	0.00	5.00
15	16.2	75	75			15	0.00	5.00
16	17	80	80			16	0.00	5.00
17	17.6	85	85			17	0.00	5.00
18	18.3	90	90			18	0.00	

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MACTEC

Pressure Corrections

Volume Corrections

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	0.84	-0.12	1	1.84	1.96	0.00	16.6	0.006060661	-16.61
2	0.84	-0.11	2.45	3.29	3.40	5.00	20.7	0.010845661	-15.71
3	0.84	-0.09	4	4.84	4.92	10.00	23.7	0.015960661	-13.72
4	0.84	-0.05	5.45	6.29	6.33	15.00	25.8	0.020745661	-10.82
5	0.84	0.00	6.75	7.59	7.59	20.00	27.4	0.025035661	-7.43
6	0.84	0.04	8	8.84	8.79	25.00	28.8	0.029160661	-3.83
7	0.84	0.09	9.15	9.99	9.89	30.00	29.9	0.032955661	0.07
8	0.84	0.15	10.15	10.99	10.84	35.00	30.9	0.036255661	4.06
9	0.84	0.20	11.2	12.04	11.84	40.00	31.8	0.039720661	8.16
10	0.84	0.26	12	12.84	12.58	45.00	32.4	0.042360661	12.56
11	0.84	0.31	13.05	13.89	13.57	50.00	33.2	0.045825661	16.75
12	0.84	0.44	13.25	14.09	13.64	60.00	33.3	0.046485661	26.65
13	0.84	0.50	14.35	15.19	14.69	65.00	34.1	0.050115661	30.85
14	0.84	0.56	15.3	16.14	15.58	70.00	34.7	0.053250661	35.25
15	0.84	0.61	16.2	17.04	16.42	75.00	35.3	0.056220661	39.64
16	0.84	0.67	17	17.84	17.16	80.00	35.8	0.058860661	44.14
17	0.84	0.73	17.6	18.44	17.70	85.00	36.2	0.060840661	48.74
18	0.84	0.79	18.3	19.14	18.34	90.00	36.6	0.063150661	53.34

Pressuremeter Data Reduction

P. eep Pressure (bu. .00kPa) 11.00

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	6.33
P_2	12.58
V_1	-10.82
V_2	12.56
V_0	190.00
V_m	0.87
υ	0.33
ΔP (Bars)	6.24
ΔV (cc)	23.38
P_0 (Bars)	130
E_0 (ksf)	283.20

Reload Modulus correlated from ROCTEST Manual

E_r/E_0 = 4.00

E_r (ksf) 1132.79

E/P_l (bars): 6.95

E/P_r (bars): 0.05

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

B =	8	ft
K =	1415.99	ksf
k_h=	177.00	kcf
k_h=	102.43	pci

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_{0=2}$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_{0=3}$ for silty soils
$E_r/E_{0=4}$ for sandy/gravelly soils

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MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	15-Oct-03			
Project	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	DII-10			
Test Number	PM2-4			
Depth (Feet)	101.5			101.50
Instrument Height	2			
Total Height	103.5	feet =	33.96	meters
Material	sand			
Probe Dia.	B-58 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.10	5.00	5.00	0.00	5.00
3	0.23	10.00	10.00	0.00	5.00
4	0.30	15.00	15.00	0.00	5.00
5	0.35	20.00	20.00	0.00	5.00
6	0.50	25.00	25.00	0.00	5.00
7	0.55	30.00	30.00	0.00	5.00
8	0.60	35.00	35.00	0.00	5.00
9	0.65	40.00	40.00	0.00	5.00
10	0.70	45.00	45.00	0.00	5.00
11	0.75	50.00	50.00	0.00	5.00
12	0.80	55.00	55.00	0.00	5.00
13	0.85	60.00	60.00	0.00	5.00
14	0.95	65.00	65.00	0.00	5.00
15	1.00	70.00	70.00	0.00	5.00
16	1.05	75.00	75.00	0.00	5.00
17	1.12	80.00	80.00	0.00	5.00
18	1.20	85.00	85.00	0.00	5.00
19	1.25	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n Pressure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		-0.01		5.00	
1	5.00	5.00		0.2		5.00	
2	10.00	10.00		0.75		5.00	
3	15.00	15.00		1.7		5.00	
4	20.00	20.00		3.1		5.00	
5	25.00	25.00		5.75		5.00	
6	30.00	30.00		10.75		5.00	
7	35.00	35.00		17.75		2.00	
8	37.00	37.00		20.25		-37.00	

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	1.25	0	0			1	0.00	5.00
2	4.5	5	5			2	0.00	5.00
3	9	10	10			3	0.00	5.00
4	12.35	15	15			4	0.00	5.00
5	15.55	20	20			5	0.00	5.00
6	18.5	25	25			6	0.00	5.00
7	21.25	30	30			7	0.00	5.00
8	23.6	35	35			8	0.00	5.00
9	25	40	40			9	0.00	5.00
10	28	45	45			10	0.00	5.00
11	29.2	50	50			11	0.00	10.00
12	32.1	60	60			12	0.00	5.00
13	33	65	65			13	0.00	5.00
14	34	70	70			14	0.00	5.00
15	34.8	75	75			15	0.00	5.00
16	36.1	80	80			16	0.00	5.00
17	37	85	85			17	0.00	5.00
18	37.8	90	90			18	0.00	

MACTEC

Pressure Corrections

Volume Corrections

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	3.09	-0.21	1.25	4.34	4.55	0.00	23	0.014329586	-23.01
2	3.09	-0.20	4.5	7.59	7.80	5.00	27.7	0.025054586	-22.73
3	3.09	-0.20	9	12.09	12.29	10.00	32.1	0.039904586	-22.14
4	3.09	-0.17	12.35	15.44	15.61	15.00	34.7	0.050959586	-19.75
5	3.09	-0.13	15.55	18.64	18.77	20.00	36.8	0.061519586	-16.86
6	3.09	-0.09	18.5	21.59	21.68	25.00	38.6	0.071254586	-13.67
7	3.09	-0.04	21.25	24.34	24.38	30.00	40	0.080329586	-10.08
8	3.09	0.01	23.6	26.69	26.68	35.00	41.2	0.088084586	-6.29
9	3.09	0.07	25	28.09	28.02	40.00	41.9	0.092704586	-1.99
10	3.09	0.12	28	31.09	30.98	45.00	43.2	0.102604586	1.70
11	3.09	0.17	29.2	32.29	32.12	50.00	43.7	0.106564586	6.19
12	3.09	0.29	32.1	35.19	34.90	60.00	44.9	0.116134586	14.98
13	3.09	0.35	33	36.09	35.74	65.00	45.2	0.119104586	19.68
14	3.09	0.41	34	37.09	36.68	70.00	45.6	0.122404586	24.28
15	3.09	0.47	34.8	37.89	37.42	75.00	45.9	0.125044586	28.97
16	3.09	0.53	36.1	39.19	38.66	80.00	46.3	0.129334586	33.57
17	3.09	0.59	37	40.09	39.50	85.00	46.7	0.132304586	38.17
18	3.09	0.66	37.8	40.89	40.24	90.00	46.9	0.134944586	42.97

Pressuremeter Data Reduction

P_E [illegible]ep Pressure 11.00
(ba[illegible] [illegible]0kPa)

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	15.61
P_2	38.66
V_1	-19.75
V_2	33.57
V_0	190.00
V_m	6.91
υ	0.33
ΔP (Bars)	23.05
ΔV (cc)	53.32
P_E (Bars)	220
E_0 (ksf)	472.92

Reload Modulus correlated from ROCTEST Manual

E_r/E_0 = 4.00

E_r (ksf) 1891.68

E/P_l (bars): 11.61

E/P_r (bars): 0.05

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

B =	8	ft
K =	2364.60	ksf
k_h =	295.58	kcf
k_h =	171.05	pci

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_{0=2}$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_{0=3}$ for silty soils
$E_r/E_{0=4}$ for sandy/gravelly soils

MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	15-Oct-03			
Project	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	BII-19			
Test Number	PM2-5			
Depth (Feet)	108.5			108.50
Instrument Height	2			
Total Height	110.5	feet =	36.25	meters
Material	silty clay			
Probe Dia.	B-58 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	alta {(Vc(n+1))-Vcn} cc
1	0.00	0.00	0.00	0.00	5.00
2	0.10	5.00	5.00	0.00	5.00
3	0.23	10.00	10.00	0.00	5.00
4	0.30	15.00	15.00	0.00	5.00
5	0.35	20.00	20.00	0.00	5.00
6	0.50	25.00	25.00	0.00	5.00
7	0.55	30.00	30.00	0.00	5.00
8	0.60	35.00	35.00	0.00	5.00
9	0.65	40.00	40.00	0.00	5.00
10	0.70	45.00	45.00	0.00	5.00
11	0.75	50.00	50.00	0.00	5.00
12	0.80	55.00	55.00	0.00	5.00
13	0.85	60.00	60.00	0.00	5.00
14	0.95	65.00	65.00	0.00	5.00
15	1.00	70.00	70.00	0.00	5.00
16	1.05	75.00	75.00	0.00	5.00
17	1.12	80.00	80.00	0.00	5.00
18	1.20	85.00	85.00	0.00	5.00
19	1.25	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n Pressure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0.00	0.00		-0.01		5.00	
1	5.00	5.00		0.2		5.00	
2	10.00	10.00		0.75		5.00	
3	15.00	15.00		1.7		5.00	
4	20.00	20.00		3.1		5.00	
5	25.00	25.00		5.75		5.00	
6	30.00	30.00		10.75		5.00	
7	35.00	35.00		17.75		2.00	
8	37.00	37.00		20.25		-37.00	

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	d Vol-By Pass 30 seconds .02 cc	Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	3.5	0	0			1	0.00	5.00
2	6.55	5	5			2	0.00	5.00
3	10.2	10	10			3	0.00	5.00
4	13.25	15	15			4	0.00	5.00
5	15.95	20	20			5	0.00	5.00
6	18	25	25			6	0.00	5.00
7	20.2	30	30			7	0.00	5.00
8	21.75	35	35			8	0.00	5.00
9	23.15	40	40			9	0.00	5.00
10	24.15	45	45			10	0.00	5.00
11	25	50	50			11	0.00	10.00
12	26.6	60	60			12	0.00	5.00
13	27.2	65	65			13	0.00	5.00
14	28.2	70	70			14	0.00	5.00
15	28.2	75	75			15	0.00	5.00
16	29	80	80			16	0.00	5.00
17	29.8	85	85			17	0.00	5.00
18	30.2	90	90			18	0.00	

MACTEC

Pressure Corrections | **Volume Corrections**

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.0131* volume+.0937 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	3.30	-0.26	3.5	6.80	7.06	0.00	26.8	0.022444751	-26.82
2	3.30	-0.24	6.55	9.85	10.09	5.00	30.1	0.032509751	-25.13
3	3.30	-0.21	10.2	13.50	13.71	10.00	33.3	0.044554751	-23.34
4	3.30	-0.18	13.25	16.55	16.73	15.00	35.5	0.054619751	-20.55
5	3.30	0.13	15.95	19.25	19.38	20.00	37.2	0.063529751	-17.26
6	3.30	-0.08	18	21.30	21.38	25.00	38.4	0.070294751	-13.47
7	3.30	-0.03	20.2	23.50	23.53	30.00	39.6	0.077554751	-9.68
8	3.30	0.02	21.75	25.05	25.03	35.00	40.4	0.082669751	-5.48
9	3.30	0.08	23.15	26.45	26.37	40.00	41.1	0.087289751	-1.19
10	3.30	0.14	24.15	27.45	27.31	45.00	41.5	0.090589751	3.41
11	3.30	0.20	25	28.30	28.10	50.00	41.9	0.093394751	8.01
12	3.30	0.32	26.6	29.90	29.58	60.00	42.6	0.098674751	17.30
13	3.30	0.38	27.2	30.50	30.12	65.00	42.8	0.100654751	22.10
14	3.30	0.44	28.2	31.50	31.06	70.00	43.2	0.103954751	26.70
15	3.30	0.51	28.2	31.50	30.99	75.00	43.2	0.103954751	31.70
16	3.30	0.57	29	32.30	31.73	80.00	43.5	0.106594751	36.39
17	3.30	0.63	29.8	33.10	32.47	85.00	43.9	0.109234751	40.99
18	3.30	0.69	30.2	33.50	32.81	90.00	44	0.110554751	45.89

Pressuremeter Data Reduction

P_F Creep Pressure (bars) (100kPa) 11.00

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	16.73
P_2	30.12
V_1	-20.55
V_2	22.10
V_0	190.00
V_m	0.77
υ	0.33
ΔP (Bars)	13.39
ΔV (cc)	42.65
E_0 (Bars)	159
E_0 (ksf)	332.74

Reload Modulus correlated from ROCTEST Manual

E_r/E_0 = 4.00

E_r (ksf) 1330.95

E/P_l (bars): 8.17

E/P_r (bars): 0.05

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

B =	8	ft
K =	1663.69	ksf
k_h=	207.96	kcf
k_h=	120.35	pci

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_0 = 2$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_0 = 3$ for silty soils
$E_r/E_0 = 4$ for sandy/gravelly soils

MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	3-Nov-03
Project	Indian River Inlet
Location	Dewey Beach, DE
Borehole	BII-22
Test Number	PM2-6
Depth (Feet)	67
Instrument Height	3
Total Height	70 feet = 22.97 meters
Material	sand
Probe Dia.	B-58 mm

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	0.15	0.00	0.00	0.00	5.00
2	0.3	5.00	5.00	0.00	5.00
3	0.35	10.00	10.00	0.00	5.00
4	0.4	15.00	15.00	0.00	5.00
5	0.4	20.00	20.00	0.00	5.00
6	0.45	25.00	25.00	0.00	5.00
7	0.5	30.00	30.00	0.00	5.00
8	0.57	35.00	35.00	0.00	5.00
9	0.65	40.00	40.00	0.00	5.00
10	0.7	45.00	45.00	0.00	5.00
11	0.75	50.00	50.00	0.00	5.00
12	0.77	55.00	55.00	0.00	5.00
13	0.8	60.00	60.00	0.00	5.00
14	0.85	65.00	65.00	0.00	5.00
15	0.92	70.00	70.00	0.00	5.00
16	0.98	75.00	75.00	0.00	5.00
17	1	80.00	80.00	0.00	5.00
18	1.05	85.00	85.00	0.00	5.00
19	1.15	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n Pressure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0	0		0		5.00	
1	5	5		0.23		5.00	
2	10	10		0.45		5.00	
3	15	15		0.7		5.00	
4	20	20		1.05		5.00	
5	25	25		1.68		5.00	
6	30	30		2.8		5.00	
7	35	35		5		5.00	
8	40	40		9.35		5.00	
9	45	45		15.3		5.00	
10	50	50		22.1		2.30	
11	52.3	52.3		25		-52.30	

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	1.6	0	0			1	0.00	5.00
2	3.35	5	5			2	0.00	5.00
3	5.25	10	10			3	0.00	5.00
4	7.1	15	15			4	0.00	5.00
5	8.72	20	20			5	0.00	5.00
6	10.2	25	25			6	0.00	5.00
7	11.5	30	30			7	0.00	5.00
8	12.6	35	35			8	0.00	5.00
9	13.6	40	40			9	0.00	5.00
10	14.9	45	45			10	0.00	5.00
11	15.75	50	50			11	0.00	5.00
12	16.75	55	55			12	0.00	5.00
13	17.5	60	60			13	0.00	5.00
14	18.25	65	65			14	0.00	5.00
15	19	70	70			15	0.00	5.00
16	19.7	75	75			16	0.00	5.00
17	20.2	80	80			17	0.00	5.00
18	20.85	85	85			18	0.00	5.00
19	21.25	90	90			19	0.00	-90.00

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MACTEC

Pressure Corrections

Volume Corrections

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.01* volume+.2185 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	2.09	-0.08	1.6	3.69	3.77	0.00	30	0.012181652	-30.01
2	2.09	-0.09	3.35	5.44	5.53	5.00	35.7	0.017956652	-30.72
3	2.09	-0.06	5.25	7.34	7.40	10.00	37.5	0.024226652	-27.52
4	2.09	-0.03	7.1	9.19	9.22	15.00	39.5	0.030331652	-24.53
5	2.09	0.00	8.72	10.81	10.81	20.00	41.5	0.035677652	-21.54
6	2.09	0.04	10.2	12.29	12.25	25.00	42.5	0.040561652	-17.54
7	2.09	0.08	11.5	13.59	13.51	30.00	43.8	0.044851652	-13.84
8	2.09	0.13	12.6	14.69	14.57	35.00	44.2	0.048481652	-9.25
9	2.09	0.17	13.6	15.69	15.52	40.00	45	0.051781652	-5.05
10	2.09	0.21	14.9	16.99	16.78	45.00	46	0.056071652	-1.06
11	2.09	0.25	15.75	17.84	17.60	50.00	47.2	0.058876652	2.74
12	2.09	0.29	16.75	18.84	18.55	55.00	48	0.062176652	6.94
13	2.09	0.34	17.5	19.59	19.25	60.00	48.1	0.064651652	11.84
14	2.09	0.38	18.25	20.34	19.96	65.00	49	0.067126652	15.93
15	2.09	0.42	19	21.09	20.67	70.00	49.8	0.069601652	20.13
16	2.09	0.46	19.7	21.79	21.33	75.00	51	0.071911652	23.93
17	2.09	0.51	20.2	22.29	21.78	80.00	51.1	0.073561652	28.83
18	2.09	0.55	20.85	22.94	22.39	85.00	51.5	0.075706652	33.42
19	2.09	0.60	21.25	23.34	22.74	90.00	51.6	0.077026652	38.32

Pressuremeter Data Reduction

P_E [illegible]ep Pressure 11.00
(ba[illegible] [illegible]0kPa)

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	7.40
P_2	15.44
V_1	-27.52
V_2	11.95
V_0	190.00
V_m	-7.79
υ	0.33
ΔP (Bars)	8.04
ΔV (cc)	39.47
E_0 (bars)	99
E_0 (ksf)	206.23

Reload Modulus correlated from ROCTEST Manual

E_r/E_0 = 4.00

E_r (ksf)	824.91

E/P_1 (bars): 5.06

E/P_f (bars): 0.05

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reactions (k_h):

R =	8	ft
K =	1031.14	ksf
k_h =	128.89	kcf
k_h =	74.59	pci

$K = k_h(B)$

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: $K = E_0 + E_r$ for non-displacement piles (Briaud, 1992, pp. 137)
$E_r/E_{0=2}$ for clay soils (ROCTEST Technical Note, pp. 39)
$E_r/E_{0=3}$ for silty soils
$E_r/E_{0=4}$ for sandy/gravelly soils

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MACTEC

Pressuremeter Test Data

Drill Method	Rotary Tricone and Bentonite Slurry
Pressure Loss Calibration	
Volume Loss Calibration No.	LP-3
Probe Sheath	Metal
Operator	S. Clark

Date	3-Nov-03			
roject	Indian River Inlet			
Location	Dewey Beach, DE			
Borehole	DII-22			
Test Number	PM2-7			
Depth (Feet)	81.5	83.50		82.50
Instrument Height	3			
Total Height	84.5	feet =	27.72	meters
Material	sand			
Probe Dia.	B-58 mm			

P Calibration Data Unconfined

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Delta V (dn-cn) creep cc	elta {(Vc(n+1))-Vcn} cc
1	0.15	0.00	0.00	0.00	5.00
2	0.3	5.00	5.00	0.00	5.00
3	0.35	10.00	10.00	0.00	5.00
4	0.4	15.00	15.00	0.00	5.00
5	0.4	20.00	20.00	0.00	5.00
6	0.45	25.00	25.00	0.00	5.00
7	0.5	30.00	30.00	0.00	5.00
8	0.57	35.00	35.00	0.00	5.00
9	0.65	40.00	40.00	0.00	5.00
10	0.7	45.00	45.00	0.00	5.00
11	0.75	50.00	50.00	0.00	5.00
12	0.77	55.00	55.00	0.00	5.00
13	0.8	60.00	60.00	0.00	5.00
14	0.85	65.00	65.00	0.00	5.00
15	0.92	70.00	70.00	0.00	5.00
16	0.98	75.00	75.00	0.00	5.00
17	1	80.00	80.00	0.00	5.00
18	1.05	85.00	85.00	0.00	5.00
19	1.15	90.00	90.00	0.00	

V Calibration Data Confined in Steel Pipe

a n .sure Stage	b Vol 30 sec cc	c Vol 60 sec cc	d Reading-By-Pass 60 sec. .02 cc	e Pressure bars (100 kPa)	Delta V (cn-bn) creep cc	Delta {(Vc(n+1))-Vcn} cc	Delta {(Vc(n+1))-Vcn} cc
0	0	0		0		5.00	
1	5	5		0.23		5.00	
2	10	10		0.45		5.00	
3	15	15		0.7		5.00	
4	20	20		1.05		5.00	
5	25	25		1.68		5.00	
6	30	30		2.8		5.00	
7	35	35		5		5.00	
8	40	40		9.35		5.00	
9	45	45		15.3		5.00	
10	50	50		22.1		2.30	
11	52.3	52.3		25		-52.30	

Pressuremeter Test Data

n Pressure Stage	a Pressure Bars	b Vol 30 sec. cc	c Vol 60 sec cc	Vol-By Pass 30 seconds .02 cc	d Vol-By Pass 60 seconds .02 cc	n Pressure Stage	Delta V (dn-cn) creep cc	Delta {(Vc(n+1))-Vcn} cc
1	2.25	0	0			1	0.00	5.00
2	4.25	5	5			2	0.00	5.00
3	6.2	10	10			3	0.00	5.00
4	7.75	15	15			4	0.00	5.00
5	9	20	20			5	0.00	5.00
6	10	25	25			6	0.00	5.00
7	11.05	30	30			7	0.00	5.00
8	12	35	35			8	0.00	5.00
9	12.75	40	40			9	0.00	5.00
10	13.5	45	45			10	0.00	5.00
11	14.2	50	50			11	0.00	5.00
12	15	55	55			12	0.00	5.00
13	15.75	60	60			13	0.00	5.00
14	16.3	65	65			14	0.00	5.00
15	16.85	70	70			15	0.00	5.00
16	17.35	75	75			16	0.00	5.00
17	17.75	80	80			17	0.00	5.00
18	18.5	85	85			18	0.00	5.00
19	19.3	90	90			19	0.00	-90.00

MACTEC

Pressure Corrections

Volume Corrections

Pressure Stage	Water Column γh +.075 (bars) (100 Kpa)	Membranes' Inertia Pressure = 0.01* volume+.2185 Delta P	Applied Hydraulic Pressure (bars) (100 Kpa)	Columns K+M (bars) (100 Kpa)	Corrected Pressure (bars) (100 Kpa)	Volume Reading c.c.	System Expansion	BW Casing Expansion .0033 cc/bar	Corrected Volume
1	2.52	-0.10	2.25	4.77	4.88	0.00	32	0.01575628	-32.02
2	2.52	-0.09	4.25	6.77	6.87	5.00	36	0.02235628	-31.02
3	2.52	-0.06	6.2	8.72	8.79	10.00	38	0.02879128	-28.03
4	2.52	-0.03	7.75	10.27	10.31	15.00	40	0.03390628	-25.03
5	2.52	0.00	9	11.52	11.52	20.00	41.5	0.03803128	-21.54
6	2.52	0.05	10	12.52	12.48	25.00	42	0.04133128	-17.04
7	2.52	0.10	11.05	13.57	13.48	30.00	42.2	0.04479628	-12.24
8	2.52	0.13	12	14.52	14.39	35.00	43.5	0.04793128	-8.55
9	2.52	0.18	12.75	15.27	15.10	40.00	44	0.05040628	-4.05
10	2.52	0.22	13.5	16.02	15.80	45.00	44.5	0.05288128	0.45
11	2.52	0.27	14.2	16.72	16.45	50.00	44.7	0.05519128	5.24
12	2.52	0.31	15	17.52	17.22	55.00	46	0.05783128	8.94
13	2.52	0.36	15.75	18.27	17.92	60.00	46.1	0.06030628	13.84
14	2.52	0.40	16.3	18.82	18.42	65.00	46.5	0.06212128	18.44
15	2.52	0.44	16.85	19.37	18.94	70.00	48	0.06393628	21.94
16	2.52	0.49	17.35	19.87	19.30	75.00	48.2	0.06558628	26.73
17	2.52	0.53	17.75	20.27	19.74	80.00	48.3	0.06690628	31.63
18	2.52	0.58	18.5	21.02	20.45	85.00	49	0.06938128	35.93
19	2.52	0.63	19.3	21.82	21.20	90.00	49.2	0.07202128	40.73

Pressuremeter Data Reduction

P_f [illegible]eep Pressure (ba[illegible] [illegible]0kPa) 11.00

Limit Pressure Calculation

Annular Volume cc	20.00
V_0 Probe cc	190.00
Limit Pressure Volume cc	230.00
P_L Net Limit Pressure (100 kPa)	19.50

PMT Initial Modulus Calculation

P_1	8.36
P_2	15.94
V_1	-28.03
V_2	19.95
V_0	190.00
V_m	-4.04
υ	0.33
ΔP (Bars)	7.58
ΔV (cc)	47.98
E_0 (Bars)	78
E_0 (ksf)	163.22

Reload Modulus correlated from ROCTEST Manual

E_r/E_0 = 4.00

E_r (ksf) 652.87

E/P_l (bars): 4.01

Pf/Pl 0.56

Coefficient of Horizontal Subgrade Reaction (k_h):

R =	8	ft
K =	816.09	ksf
k_h=	102.01	kcf
k_h=	**59.03**	**pci**

K = k_h(B)

where: K = Horizontal Spring Constant (psi)
k_h = Coefficient of Horizontal Subgrade Reaction (pci)
B = Pile Diameter (in)

and: K = E_0 +E_r for non-displacement piles (Briaud, 1992, pp. 137)
E_r/E_0 = 2 for clay soils (ROCTEST Technical Note, pp. 39)
E_r/E_0 = 3 for silty soils
E_r/E_0 = 4 for sandy/gravelly soils

ε_{50}

50% STRAIN

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Knoxville, TN 37921-5904

Strain at 50% of Max. Stress ε_{50}

For Clay Layer (Stratum 2)

$\varepsilon_{50} = 0.02$ for soft clay ✓
From L-pile manual

For Sand layers

The ε_{50} value is not used in sand models

Lower clay layer (Stratum 4)

Value for Stiff Clay from L-pile manual
$\varepsilon_{50} = 0.005$ ✓

2/2

fined compressive strengths.

d. Internal Friction (Degrees)

Values of the angle of internal friction, ϕ, for sands and/or silts at each soil depth are entered in degrees. Internal friction angle is not needed for clay and rock layers.

e. Strain

Values of strain at 50% of the maximum stress, ε_{50}, for clays and/or silts at each soil depth are entered in standard units of strain. Strain value is not needed for sand layers. Reference values are provided in Tables 3.3 and 3.4 below.

Consistency of Clay	ε_{50}
Soft	0.020
Medium	0.010
Stiff	0.005

Table 3.4 Values of ε_{50} for Clays

Avgerage Undrained Shear Strength (kPa)	ε_{50}
50-100	0.007
100-200	0.005
300-400	0.004

Table 3.5 Values of ε_{50} for Stiff Clays

If soil test data are available, the user may enter the value based on the stress-strain curves measured in the soil laboratory. The *p-y* curves for weak rocks need a strain parameter, k_{rm}, which is equivalent to ε_{50}. It will be described in the section of k_{rm} for

G
SHEAR MODULUS

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Shear Modulus - G -

- Use the field Shear Wave Velocities to calculate the Shear Modulus.

- The following equation was used to calculate the shear modulus (See attached shear wave velocity graphs.)

$$G = \rho_T \cdot V_s^2$$

Where:

G = Shear modulus

ρ_T = total mass density

$= \frac{\gamma_T}{g}$

Where: γ_T = total unit wt.

g = gravitational acceleration = 32.2 ft/s^2

V_s = Shear Wave Velocity

ConeTec Shear Wave Velocity data reduction sheet

Hole: CII-13 North Side Near pier Location
Location: Indian River Bridge
Cone: AD139
Date: 9/30/2003
Source: Hammer & Beam

Source depth:	0.00 m
Source offset:	0.60 m

Tip Depth (m)	Geophone Depth(m)	Travel Path (m)	Interval time (ms)	Velocity (m/s)	Velocity (ft/s)	Interval Depth (m)	Interval Depth (ft)
1.80	1.60	1.71	13.51	126.5	415.0	0.80	2.62
2.80	2.60	2.67	7.34	130.7	428.9	2.10	6.89
3.80	3.60	3.65	6.95	141.2	463.2	3.10	10.17
4.80	4.60	4.64	7.14	138.6	454.6	4.10	13.45
5.80	5.60	5.63	5.83	170.3	558.9	5.10	16.73
6.80	6.60	6.63	5.45	182.6	599.1	6.10	20.01
7.80	7.60	7.62	4.14	240.7	789.6	7.10	23.29
8.80	8.60	8.62	4.13	241.5	792.2	8.10	26.57
9.80	9.60	9.62	4.33	230.4	756.0	9.10	29.86
10.80	10.60	10.62	5.45	183.2	600.9 X	10.10	33.14
11.80	11.60	11.62	6.76	147.7	1 484.6	11.10	36.42
12.80	12.60	12.61	7.52	132.8	2 435.7	12.10	39.70
13.80	13.60	13.61	7.52	132.8	3 435.8	13.10	42.98
14.80	14.60	14.61	7.52	132.9	4 435.9	14.10	46.26
15.80	15.60	15.61	7.65	130.6	5 428.5	15.10	49.54
16.80	16.60	16.61	7.03	142.1	6 466.4	16.10	52.82
17.80	17.60	17.61	7.45	134.1	7 440.1	17.10	56.10
18.80	18.60	18.61	7.03	142.2	8 466.4	18.10	59.38
19.80	19.60	19.61	4.55	219.7	720.7 X	19.10	62.66
20.80	20.60	20.61	3.51	284.8	934.3	20.10	65.94
21.80	21.60	21.61	3.52	284.0	931.7	21.10	69.22
22.80	22.60	22.61	3.51	284.8	934.4	22.10	72.51
23.80	23.60	23.61	3.52	284.0	931.7	23.10	75.79
24.80	24.60	24.61	3.10	322.5	1058.0	24.10	79.07
25.40	25.20	25.21	1.86	322.5	1058.0	24.90	81.69

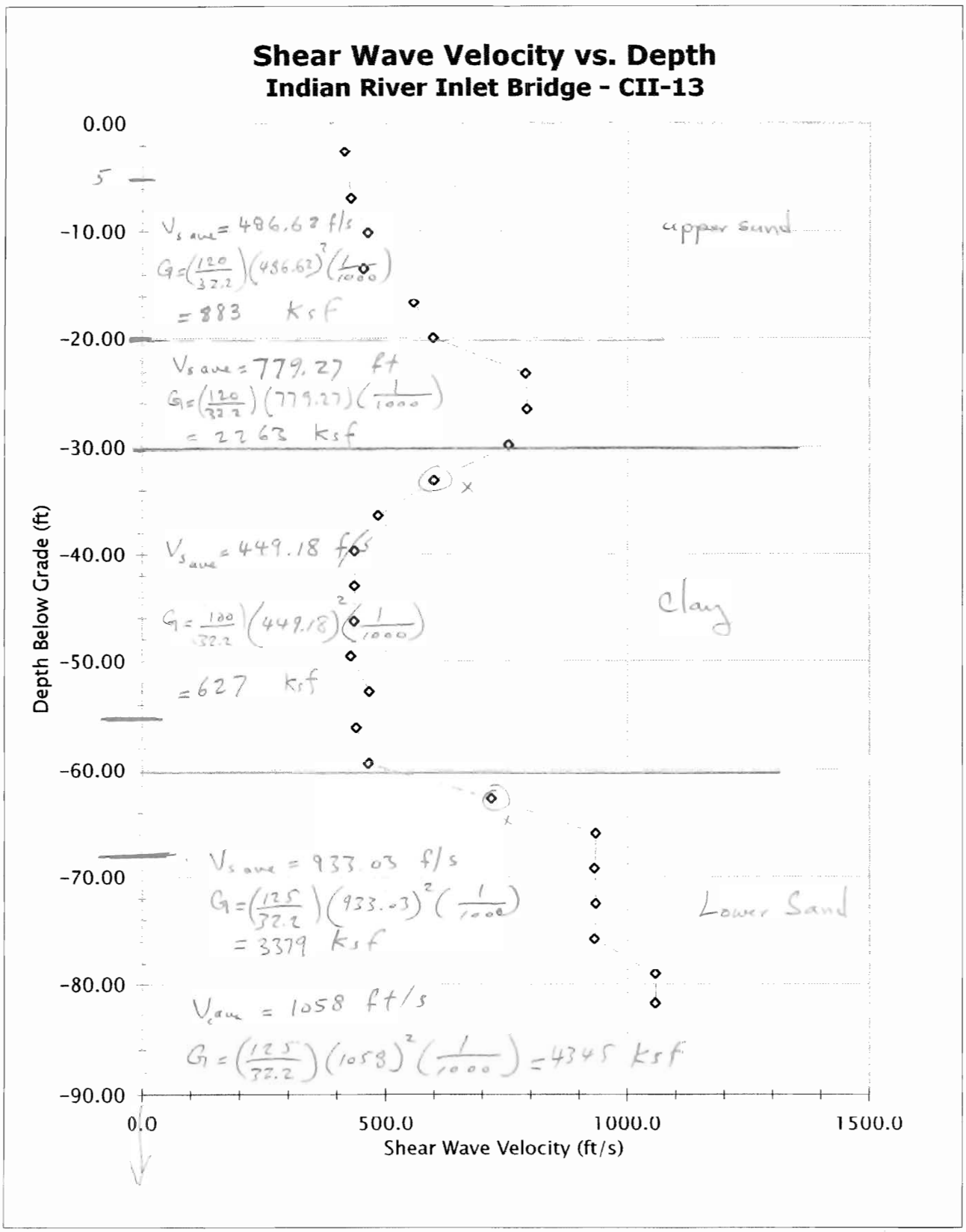
Sand

Clay

Sand

933.03
974.7

NS


Shear Wave Velocity vs. Depth
Indian River Inlet Bridge - CII-13
Depth Below Grade (ft)
Shear Wave Velocity (ft/s)
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
-80.00
-90.00
0.0
500.0
1000.0
1500.0
5
$V_{s\,ave}$ = 486.62 f/s
$G = \left(\frac{120}{32.2}\right)(486.62)^2\left(\frac{1}{1000}\right)$
= 883 ksf
$V_{s\,ave}$ = 779.27 ft
$G = \left(\frac{120}{32.2}\right)(779.27)\left(\frac{1}{1000}\right)$
= 2263 ksf
$V_{s\,ave}$ = 449.18 f/s
$G = \frac{120}{32.2}(449.18)^2\left(\frac{1}{1000}\right)$
= 627 ksf
$V_{s\,ave}$ = 933.03 f/s
$G = \left(\frac{125}{32.2}\right)(933.03)^2\left(\frac{1}{1000}\right)$
= 3379 ksf
$V_{s\,ave}$ = 1058 ft/s
$G = \left(\frac{125}{32.2}\right)(1058)^2\left(\frac{1}{1000}\right)$ = 4345 ksf
upper sand
clay
Lower Sand

✓

ConeTec Shear Wave Velocity data reduction sheet

Hole: CII-12 South Side Near Pier Location
Location: Indian River Bridge
Cone: AD139
Date: 10/1/2003
Source: Hammer & Beam

Source depth:	0.00 m
Source offset:	0.60 m

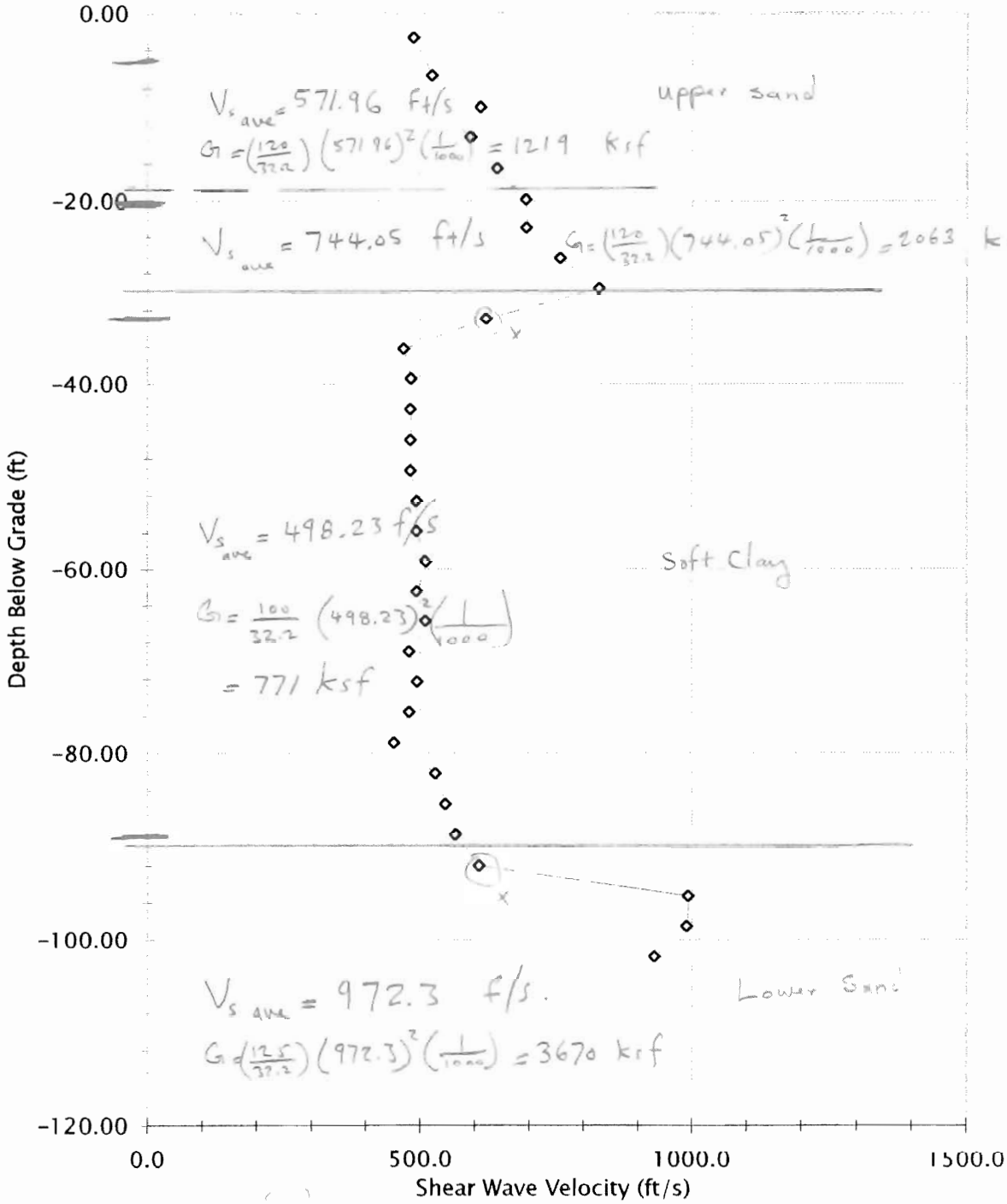
Tip Depth (m)	Geophone Depth(m)	Travel Path (m)	Interval time (ms)	Velocity (m/s)	Velocity (ft/s)	Interval Depth (m)	Interval Depth (ft)
1.75	1.55	1.66	11.16	148.9	488.6	0.78	2.54
2.75	2.55	2.62	6.01	159.3	522.7	2.05	6.73
3.75	3.55	3.60	5.26	186.4	611.7	3.05	10.01
4.75	4.55	4.59	5.46	181.1	594.3	4.05	13.29
5.75	5.55	5.58	5.07	195.8	642.5	5.05	16.57
6.75	6.55	6.58	4.70	211.7	694.6	6.05	19.85
7.75	7.55	7.57	4.70	212.0	695.5	7.05	23.13
8.75	8.55	8.57	4.32	230.8	757.3	8.05	26.41
9.75	9.55	9.57	3.95	252.6	828.8	9.05	29.69
10.75	10.55	10.57	5.26	189.8	622.6	10.05	32.97
11.75	11.55	11.57	6.96	143.5	470.7	11.05	36.25
12.75	12.55	12.56	6.76	147.7	484.7	12.05	39.53
13.75	13.55	13.56	6.77	147.6	484.1	13.05	42.81
14.75	14.55	14.56	6.77	147.6	484.2	14.05	46.10
15.75	15.55	15.56	6.77	147.6	484.2	15.05	49.38
16.75	16.55	16.56	6.62	151.0	495.2	16.05	52.66
17.75	17.55	17.56	6.61	151.2	496.0	17.05	55.94
18.75	18.55	18.56	6.41	155.9	511.5	18.05	59.22
19.75	19.55	19.56	6.62	151.0	495.3	19.05	62.50
20.75	20.55	20.56	6.41	155.9	511.6	20.05	65.78
21.75	21.55	21.56	6.82	146.6	480.9	21.05	69.06
22.75	22.55	22.56	6.62	151.0	495.4	22.05	72.34
23.75	23.55	23.56	6.82	146.6	480.9	23.05	75.62
24.75	24.55	24.56	7.24	138.1	453.0	24.05	78.90
25.75	25.55	25.56	6.20	161.2	529.0	25.05	82.18
26.75	26.55	26.56	6.00	166.6	546.7	26.05	85.46
27.75	27.55	27.56	5.79	172.7	566.5	27.05	88.75
28.75	28.55	28.56	5.38	185.8	609.7	28.05	92.03
29.75	29.55	29.56	3.30	303.0	994.0	29.05	95.31
30.75	30.55	30.56	3.31	302.1	991.0	30.05	98.59
31.75	31.55	31.56	3.52	284.0	931.9	31.05	101.87

0-19 Sand
19-30
30-60 Clay
60-102 Sand

SS

5/5

Shear Wave Velocity vs. Depth
Indian River Inlet Bridge - CII-12



✓

υ
POISSON'S RATIO

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Poisson's Ratio:

Soft clay layer (saturated)

Values given in references:

TVA: $\mu = 0.45 - 0.5$

Bowles: $\mu = 0.4 - 0.5$

Foundation Handbook: $\mu = 0.5$

→ use $\mu = 0.45$ → Stratum 2 CLAY ✓

Sand Layers

values of μ given in references:

TVA: $\mu = 0.34$ for loose sand
$\mu = 0.32$ for dense sand

Bowles: $\mu = 0.2 - 0.4$ for dense sand

Foundation Handbook: $\mu = 0.3 - 0.35$ for sand

→ Use: $\mu = 0.32$ ✓ for medium sand, → (N.S. El. +5 → -15), (N.S. El. -50 → -63), (S.S. El. +5 → -15)

$\mu = 0.30$ ✓ for dense sand → (N.S. El. -15 → -25), (N.S. El. -63 → -133), (S.S. El. -15 → -30), (S.S. El. -85 → -131)

Lower Clay Layer: stiff clay (Stratum 4)

Bowles: $\mu = 0.4 - 0.5$
TVA $\mu = 0.45 - 0.5$ } for saturated clay

→ use $\mu = 0.40$ ✓

V. Dense Sand

$\mu = 0.3$ ✓

TABLE 4

Typical Values for Poisson's Ratio

Type of Soil	μ
Clay, saturated	0.45 - 0.50
Clay, soft	0.40
Clay, medium	0.36
Compacted earthfill	0.35
Silt	0.32 - 0.35
Sand, loose	0.34
Sand, dense	0.32
Gravel, dense	0.30
Crushed stone, dense	0.28

(from Ref 7.3)

TABLE 5

Typical Values for Modulus of Elasticity

Type of Soil	E_s (ksf)
Clay, very soft	7.0 - 58.0
Clay, soft	29.0 - 86.0
Clay, medium	86.0 - 170.0
Clay, hard	140.0 - 360.0
Clay, sandy	570.0 - 860.0
Compacted earthfill	200.0 - 250.0 → 1,386 - 1,736 psi
Silt	43.0 - 430.0
Sand, silty	140.0 - 430.0
Sand, loose	220.0 - 500.0
Sand, dense	1,000.0 - 1,700.0
Crushed stone, dense	1,500.0 → 10,100 ± psi
Sand and gravel, dense	2,000.0 - 4,000.0

(from Ref 7.3)

$E_{CONCRETE} \cong 3,000,000$ psi

$E_{STEEL} \cong 29,000,000$ psi

Table 2-3. Typical range of values for the static stress-strain modulus E_s for selected soils. Field values depend on stress history, water content, density, etc.

Soil	E_s ksi	E_s kg/cm^2
Clay		
Very soft	0.05–0.4	3–30
Soft	0.2–0.6	20–40
Medium	0.6–1.2	45–90
Hard	1–3	70–200
Sandy	4–6	300–425
Glacial fill	1.5–22	100–1,600
Loess	2–8	150–600
Sand		
Silty	1–3	50–200
Loose	1.5–3.5	100–250
Dense	7–12	500–1,000
Sand and gravel		
Dense	14–28	800–2,000
Loose	7–20	500–1,400
Shales	20–2,000	1,400–14,000
Silt	0.3–3	20–200

fer to

(*d*)

when

(*e*)

ation

2-17)

lated

(*f*)

Table 2-4. Typical range of values for Poisson's ratio μ

Type of soil	μ
Clay, saturated	0.4–0.5
Clay, unsaturated	0.1–0.3
Sandy clay	0.2–0.3
Silt	0.3–0.35
Sand (dense)	0.2–0.4
Coarse (void ratio = 0.4–0.7)	0.15
Fine-grained (void ratio = 0.4–0.7)	0.25
Rock	0.1–0.4 (depends somewhat on type of rock)
Loess	0.1–0.3
Ice	0.36
Concrete	0.15

Foundation Engineering Handbook

4/4

TABLE 2.41 TYPICAL VALUES OF PARAMETER *A*. (From Bjerrum (Lambe, 1962) and Wu (1966).)

Soil Type	*Parameter A (at failure)*
Sensitive clay	1.2–2.5
Normal consolidated clays	0.7–1.3
Overconsolidated clays	0.3–0.7
Heavily overconsolidated sandy clays	−0.5–0.0
Very loose fine sand	2.0–3.0
Medium fine sand	0.0
Dense fine sand	−0.3
Loess	−0.2

Skempton (1954) proposed a method for evaluating the pore pressure for both saturated and partially saturated soil as

$$\Delta u = B[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)] \qquad (2.47)$$

in which

Δu = change in pore pressure due to increased stresses
A, B = pore-pressure parameters
$\Delta\sigma_1, \Delta\sigma_3$ = change in major and minor principal stresses
$\Delta\sigma_1 - \Delta\sigma_3$ = deviator stress

The parameter B ranges from 0 for dry soil to 1.0 for saturated soil. The parameter A is mainly dependent on the type of soil and its previous stress history; typical values are given in Table 2.41.

The values of A and B can be measured experimentally in both laboratory and field. (For more discussion see Lambe (1962) and Lambe and Whitman (1969)).

5. Sensitivity

Most clays lose a portion of their strength and stiffness when remolded. The main cause of this phenomenon may be reorientation of particles into less favorable positions. If the clay regains a portion of its strength with elapsed time, the phenomenon is referred to as *thixotropy*.

The sensitivity of a soil to remolding is measured by the ratio of undisturbed strength to remolded strength as defined by Terzaghi (1944). Commonly, the unconfined compression test is used. From the point of view of their sensitivity to remolding, clays may conveniently be classified as follows (Skempton, 1952; Bjerrum, 1954):

Sensitivity	Classification
< 2	insensitive
2–4	moderately sensitive
4–8	sensitive
8–16	very sensitive
16–32	slightly quick
32–64	medium quick
> 64	quick

The sensitivity of most clays ranges from 2 to 4, that of peat from 1.5 to 10, and for marine clays from 1.6 to 26.

6. Tensile Strength

Tensile strength data are useful to predict the cracking behavior of earth dams, highway pavement and stabilized soil structures. For its determination, a simple test method called the *double-punch test* may be used (Fang and Chen, 1971, 1972). This test uses two steel disks centered on both top and bottom surfaces of a cylindrical soil specimen; load is then applied on the disks until the specimen reaches failure. The tensile strength is computed by the following formula:

$$\sigma_t = \frac{P}{\pi(KbH - a^2)} \qquad (2.48)$$

in which σ_t = tensile strength, P = load, b = radius of the specimen, a = radius of disk, H = height of specimen, K = constant = 1.0. A height-diameter ratio of the specimen varying from 0.8 to 1.2 and a ratio of the diameter of the specimen to the diameter of the disk varying from 0.2 to 0.3 are suitable for the test.

7. Piezometers

Piezometers are used to measure the hydrostatic or excess water pressures in the pores of saturated soils. Information on these neutral stresses is important in the study of bearing capacity, earth pressure, settlement, and stability of slopes. There are four basic types of piezometers available commercially: open standpipe, hydraulic, pneumatic, and electric. These are discussed in Chapters 1, 6, and 11.

8. Poisson's Ratio and Young's Modulus

Poisson's ratio and Young's modulus are discussed in Chapters 4 and 19. The ranges of typical values of Poisson's ratio for various soils is shown in Table 2.42, and for Young's modulus of foundation rocks and soils in Tables 2.7 and 19.5 (Chapter 19). Indirect measurements of Young's modulus from Dutch cone and undrained shear tests are discussed in Chapter 4.

TABLE 2.42 RANGE OF POISSON'S RATIO. (From Barkan (1962) and others.)

Soil Type	*Poisson's Ratio*
Clay, saturated	0.50
Clay with sand and silt	0.30–0.42
Clay, unsaturated	0.35–0.40
Loess	0.44
Sandy soil	0.15–0.25
Sand	0.30–0.35

9. Field Shear Measurements

The vane test is commonly used for determination of the undrained shear strength of clay. The test basically consists of placing a four bladed vane in the undisturbed soil and rotating it from the surface to determine the torsional force required to cause a cylindrical surface to be sheared by the vane; this force is then converted to a unit shearing resistance of the cylindrical surface. For computing the shear strength from the vane test, the following equation is used:

$$S_u = \frac{6}{7}\frac{M}{\pi D^3} \qquad (2.49)$$

where

S_u = undrained shear strength

STRATUM 2
SETTLEMENT PARAMETERS

OCR

$C_{\varepsilon c}$

C_{cr}

C_v

C_u

C_α

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1606 Ownby Lane
Richmond, VA 23220

JOB NO. 3530-03-1245 SHEET 1 OF 2
PHASE TASK 02
JOB NAME IRIB - Soil Parameters
BY AJA DATE 12/23/03
CHECKED BY JRW DATE 12/24/03

Purpose: Estimate Consolidation Parameters for Stratum 2 clay.

Method: Use Laboratory consolidation test data

Solution Compression Ratios ($C_{\varepsilon c}$ + $C_{\varepsilon c}$)

→ from lab test sheets, $C_{\varepsilon c}$ → max = 0.33, min = 0.14, Avg = 0.216

$C_{\varepsilon r}$ → max = 0.033, min = 0.014, Avg = 0.023

↳ use values from BI-3 (40'-42') as representative:

$C_{\varepsilon c}$ = 0.208 ✓ say 0.21 $C_{\varepsilon r}$ = 0.022 ✓

Over-Consolidation Ratio (OCR)

→ from Lab tests, OCR, max = 1.7, min = ~~0.11~~ BAD DATA UNREALISTIC

↳ Several test show OCR < 1.0 (i.e. disturbance)

→ from Lab Index tests, Avg L.L = 55 (liquid limit)
Avg N.M. = 52 (Natural moisture)

↳ Due to low blowcounts, Index test data + Consolidation test data, Stratum 2 appears to be Normally Consolidated → Assume OCR = 1.0 ✓

Coefficient of Consolidation (C_v)

→ from Laboratory Consolidation tests

e4/ist C_v → max = 72 in²/day, min = 4.32 in²/day
Avg C_v = 21.4 in²/day

↳ Most tests range from ~ 7-14 in²/day

→ use value from BI-3 (40-42') as representative

→ C_v = 7.2 in²/day ✓

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JOB NO. 3530-03-1245 SHEET 2 OF 2
PHASE TASK 02
JOB NAME IRIB - Soil Parameters
BY AJA DATE 12/23/03
CHECKED BY JRW DATE 12/24/03

Coefficient of horizontal Consolidation

→ from lab test on horizontal trimmed sample from BI-7 (41.5'-43.3')

→ $C_h \sim 4-8$ in²/day.

→ from CPT PWP dissipation Tests

→ $C_h \sim 13-190$ in²/day

- Due to likely sample disturbance on Horizontally trimmed sample, use values of C_h from CPT testing

→ Assume C_h is approximately 2X C_v

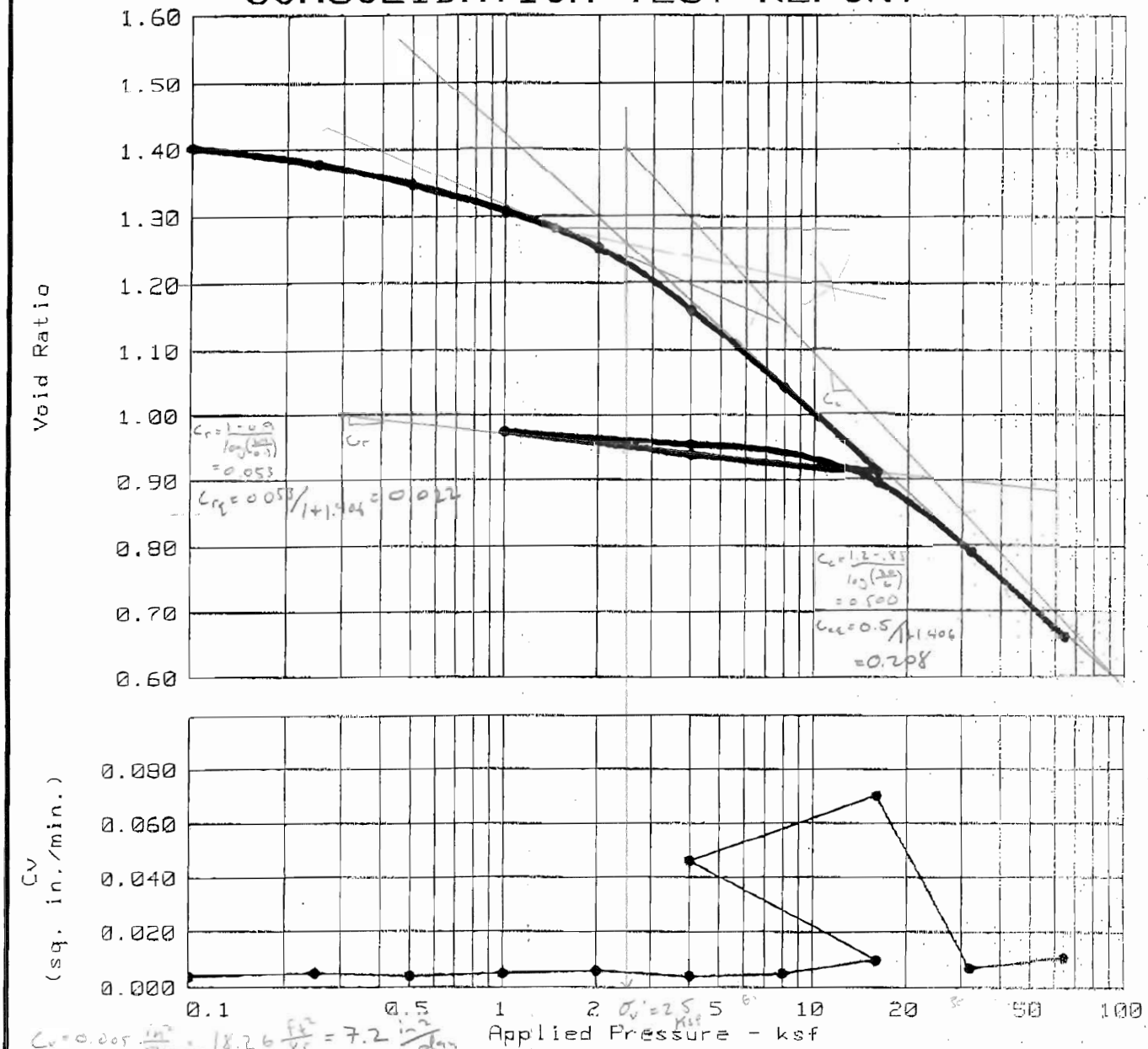
so → $C_h = 14.4$ in²/day ✓

Coefficient of Secondary Compression

→ From Lab consolidation tests, C_α, max = 0.007, min = 0.001
Avg = 0.0037, = 0.004

use $C_\alpha = 0.004$ in design ✓

CONSOLIDATION TEST REPORT



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp.Gr.	Initial void ratio
87.8 %	45.7 %	72.9			2.700	1.4060

TEST RESULTS	MATERIAL DESCRIPTION
Cc = 0.5 Cr = 0.053 σp' = 2.5 OCR ~ 1 Cv = 0.005 Cα = 0.003 @ 4 ksf	Cv = 0.005 in²/min × 1440 in²/day @ 5 ksf = 7.2 in²/day

Project No.: 3530-03-1245 Phase 01
Project: Indian River Inlet Bridges
Location: Boring BI-3 @ 40' - 42'

Date: 9/3/03

CONSOLIDATION TEST REPORT

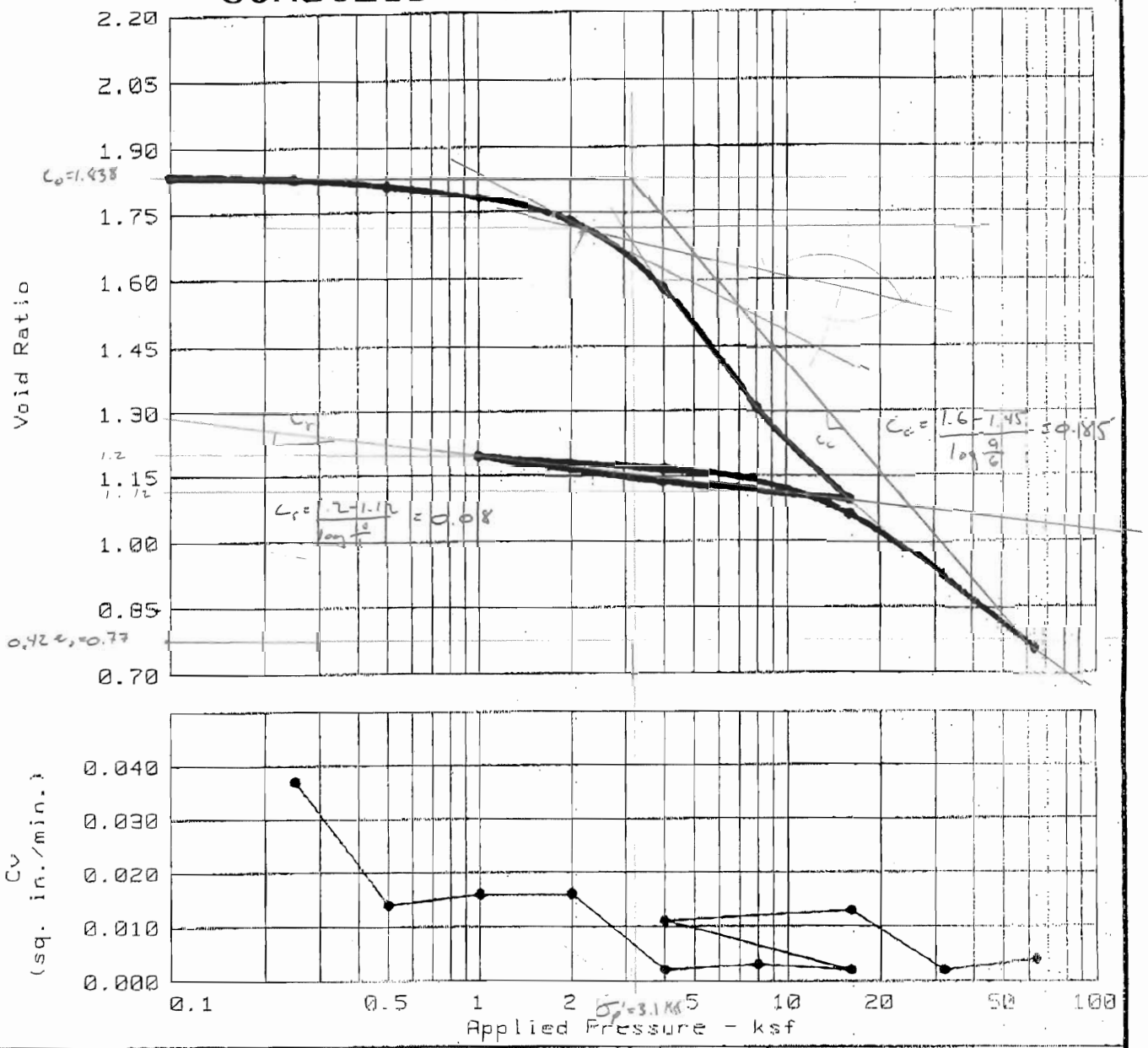
LAW ENGINEERING & ENVIRONMENTAL SERVICES, INC.

Remarks:

PRELIMINARY
Subject to Final Review

Fig. No. 1 1

CONSOLIDATION TEST REPORT



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp.Gr.	Initial void ratio
88.6 %	60.3 %	61.2			2.700	1.0379

TEST RESULTS

C_c = 0.85 $C_{c\alpha}$ = 0.85/(1+1.838) = 0.3

C_r = 0.08 $C_{r\alpha}$ = 0.08/(1+1.838) = 0.028

MATERIAL DESCRIPTION

C_v = 0.007 in²/min X 1440 in²/day @4 ksf = 10.08 in²/day

Project No.: 3530-03-1245 Phase 01
Project: Indian River Inlet Bridges
Location: Boring BI-3 @ 60' - 62'

Date: 9/3/03 C_α @ 4 ksf = 0.007

Remarks:

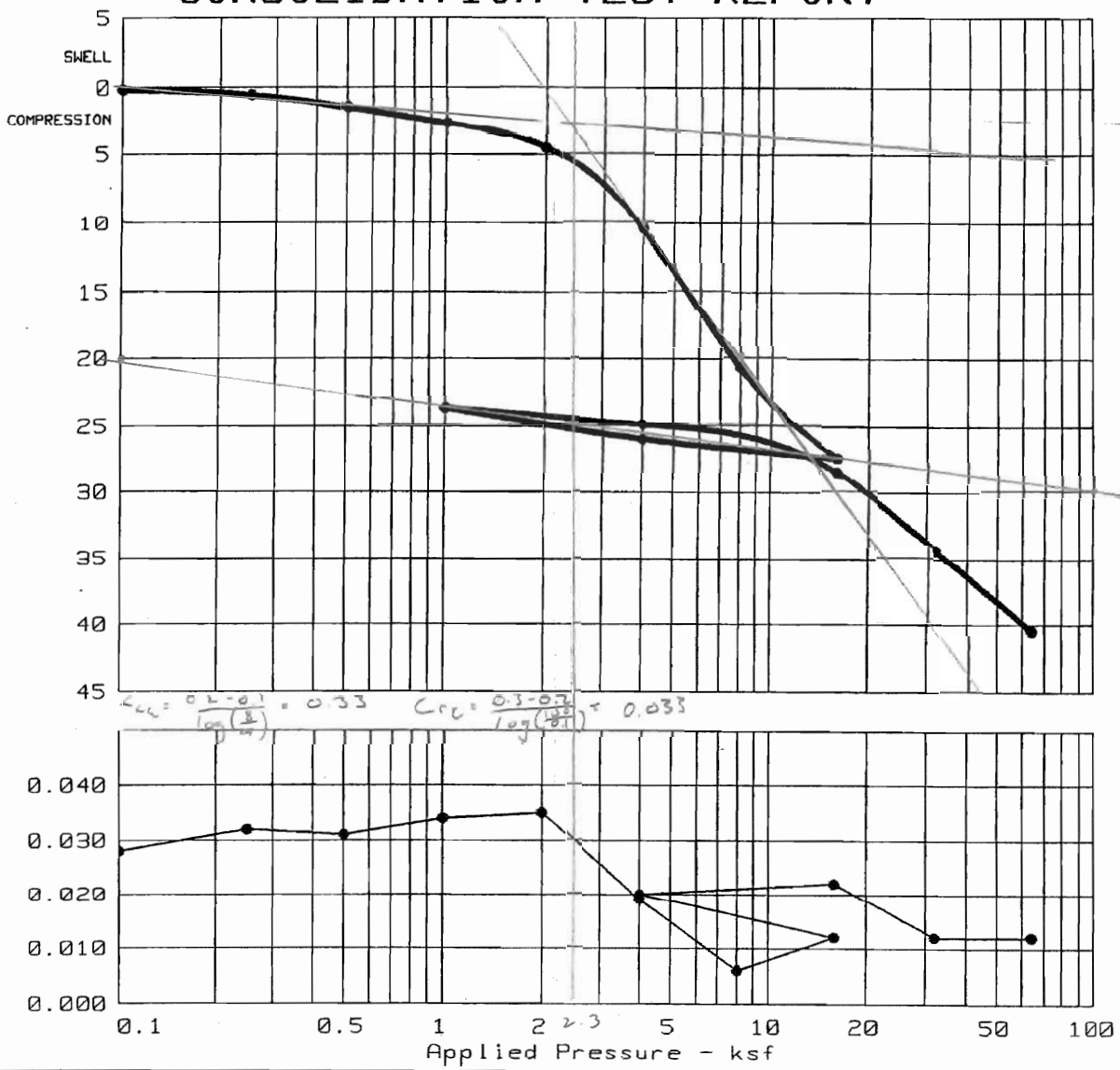
PRELIMINARY
Subject to Final Review

CONSOLIDATION TEST REPORT

LAW ENGINEERING & ENVIRONMENTAL SERVICES, INC.

Fig. No. 1.1

CONSOLIDATION TEST REPORT



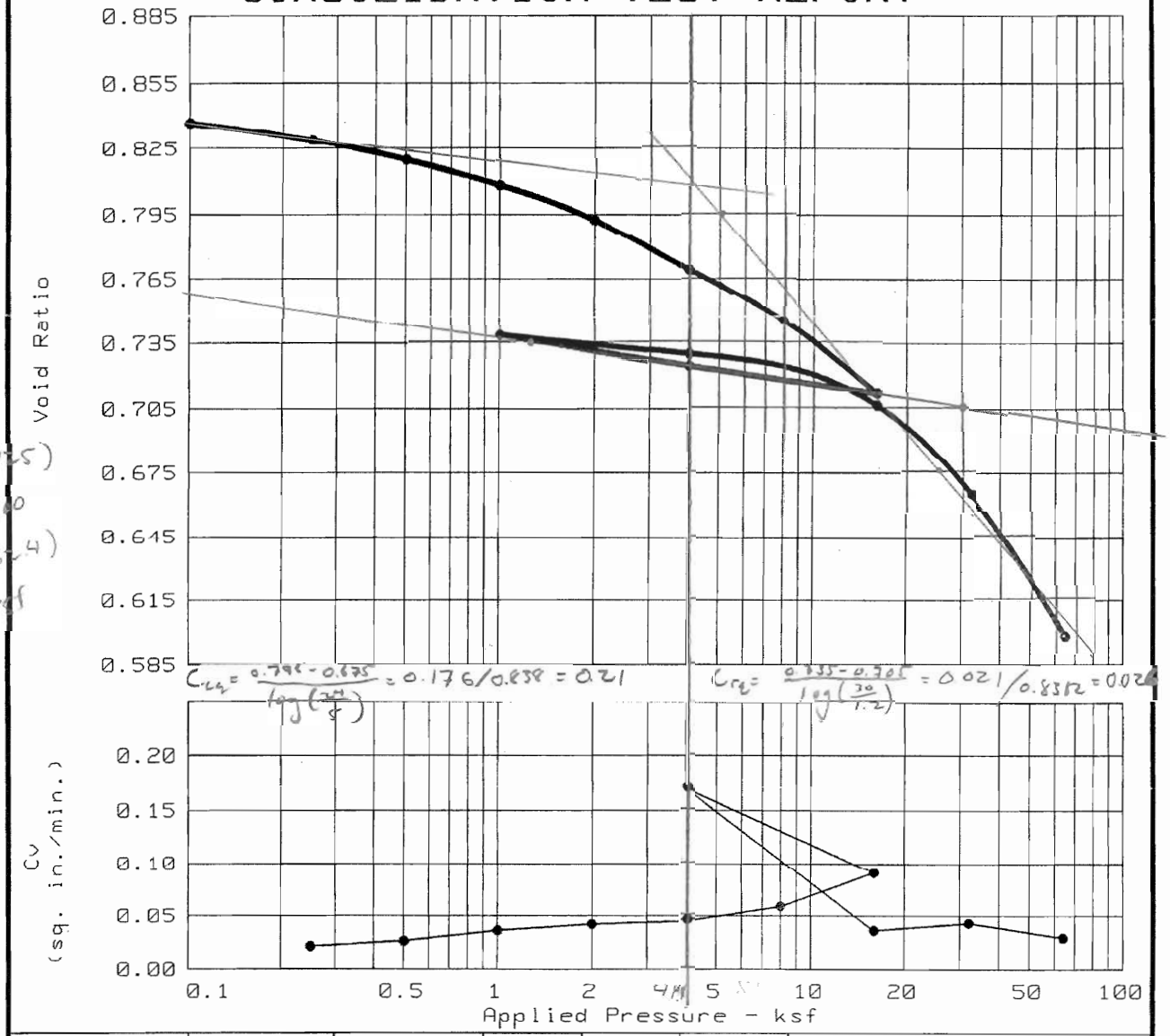
$C_{cc} = \frac{0.2-0.1}{\log(\frac{2}{1})} = 0.33$ $C_{rc} = \frac{0.3-0.2}{\log(\frac{1.5}{0.1})} = 0.033$

$P_o = 30(125) + 1(100) - 6(62.4) = 2,230$ psf

Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp.Gr.	Initial void ratio
73.4 %	55.9 %	61.2	46	24	2.700	2.0590

TEST RESULTS	MATERIAL DESCRIPTION
$C_v = 0.01 \frac{in^2}{min} \cdot \frac{525600}{144} = 36.5 \frac{ft^2}{yr} = 14.4 \, in^2/day$	Grayish brown lean CLAY Class: (CL)
Project No.: 3530-03-1245 Phase 01 Project: Indian River Inlet Bridges Location: Boring BI-9 @ 30' - 32' Date: 9/29/03 C_α @ 4 ksf = 0.005	Remarks: 4/29/05
CONSOLIDATION TEST REPORT LAW ENGINEERING & ENVIRONMENTAL SERVICES, INC.	Fig. No. 1 1

CONSOLIDATION TEST REPORT



$P_o = 30 \times (1.5) + (4)100 - 29(62.4) = 2350$ psf

$C_{c_2} = \frac{0.795 - 0.675}{\log\left(\frac{24}{8}\right)} = 0.176/0.858 = 0.21$

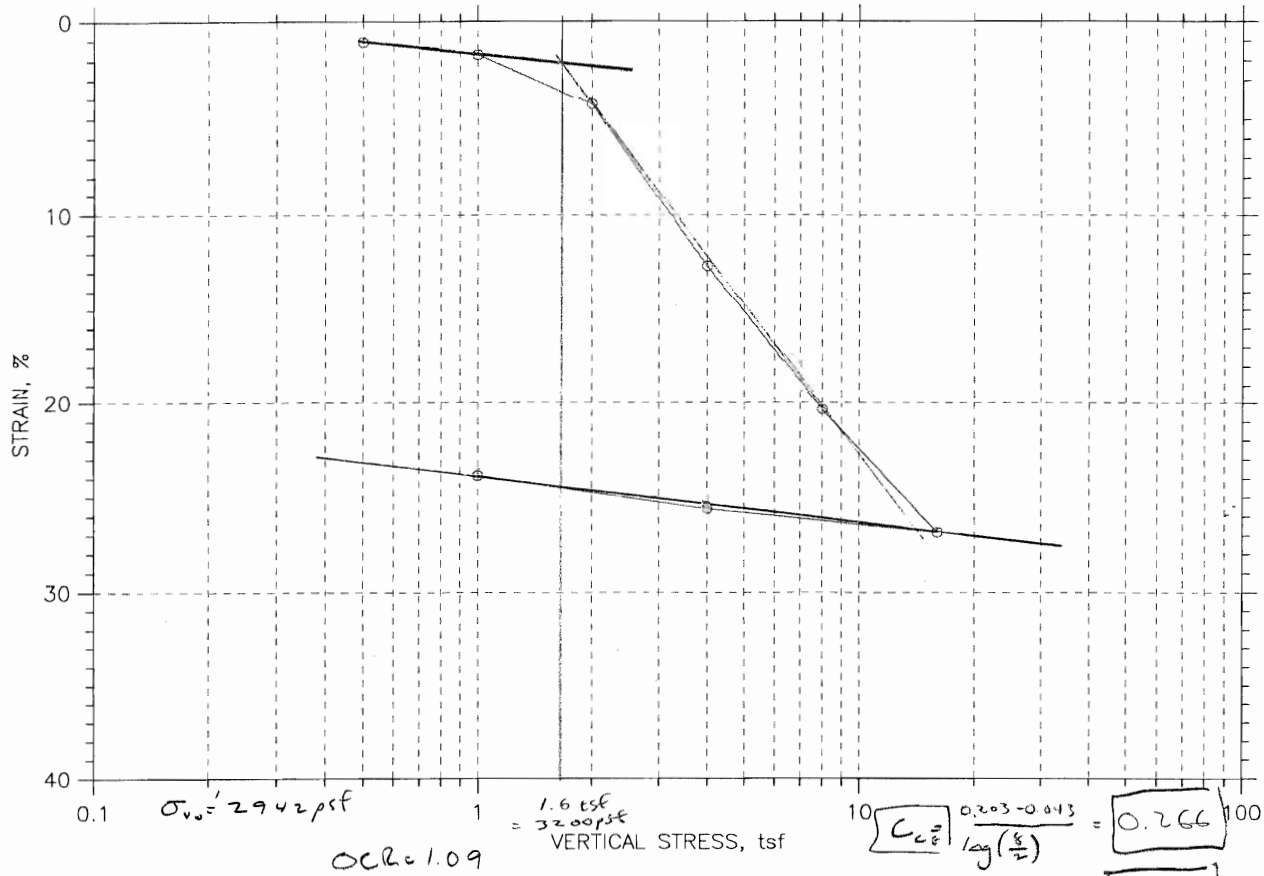
$C_{c_1} = \frac{0.735 - 0.705}{\log\left(\frac{30}{1.2}\right)} = 0.021/0.8512 = 0.02$

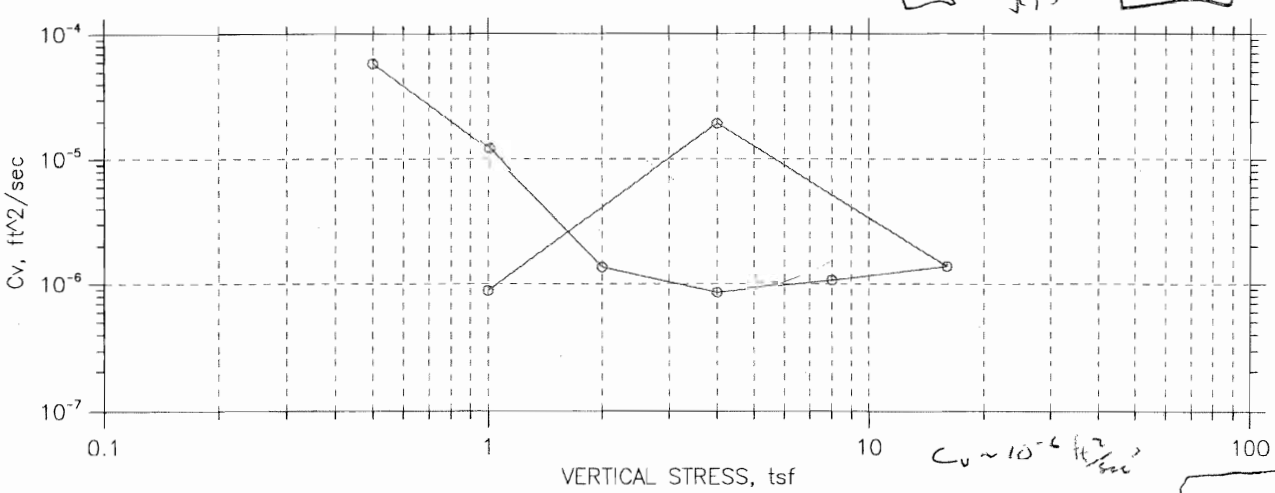
Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp.Gr.	Initial void ratio
89.5 %	27.8 %	93.3	39	18	2.700	0.8382

TEST RESULTS	MATERIAL DESCRIPTION
$C_v = 0.05 \frac{in^2}{min} \cdot \frac{52560}{144} = 18.25 \frac{ft^2}{min}$ $= 0.05 \frac{in^2}{min} \times \frac{1440 min}{day} = 72 \frac{in^2}{day}$	Dark gray lean CLAY Class: (CL)
Project No.: 3530-03-1245 Phase 02 Project: Indian River Inlet Bridges Location: Boring BII-9 @ 33.5' - 35' Date: 12/22/03 C_α @ 4 ksf = 0.001	Remarks: 14/23/03
CONSOLIDATION TEST REPORT LAW ENGINEERING & ENVIRONMENTAL SERVICES, INC.	Fig. No. 1 1

CONSOLIDATION TEST DATA

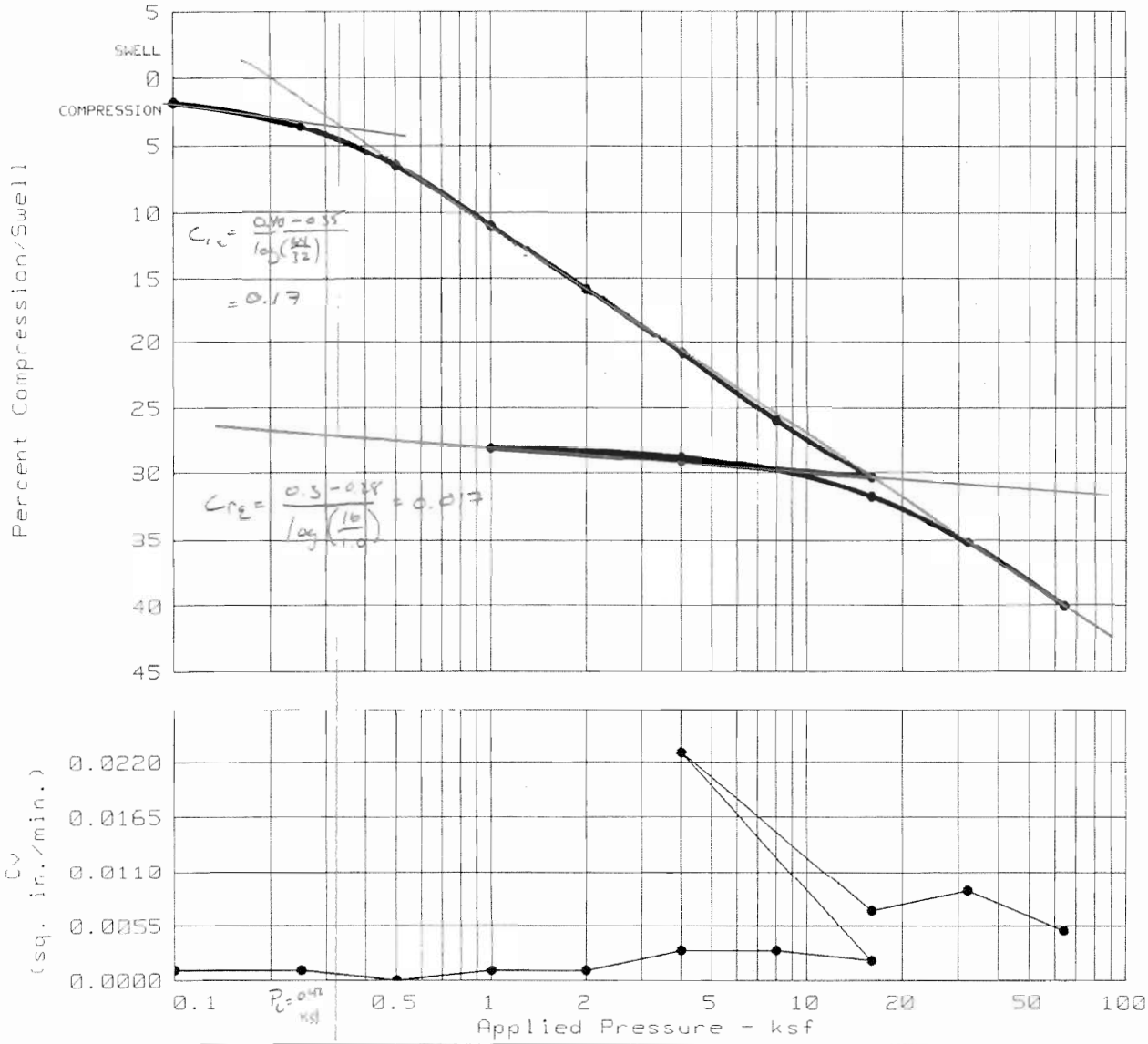
SUMMARY REPORT





Project: Indian River Inlet Bridge	Location: Sussex County, Delaware	Project No.: LB1952
Boring No.: BII-12	Tested By: MLT	Checked By: JAC
Sample No.: 9697	Test Date: 11-21-03	Depth: 49-51'
Test No.: UII-2	Sample Type: 3 inch Tube	Elevation: Not given
Description: Gray, FAT CLAY (CH)		
Remarks: None.		

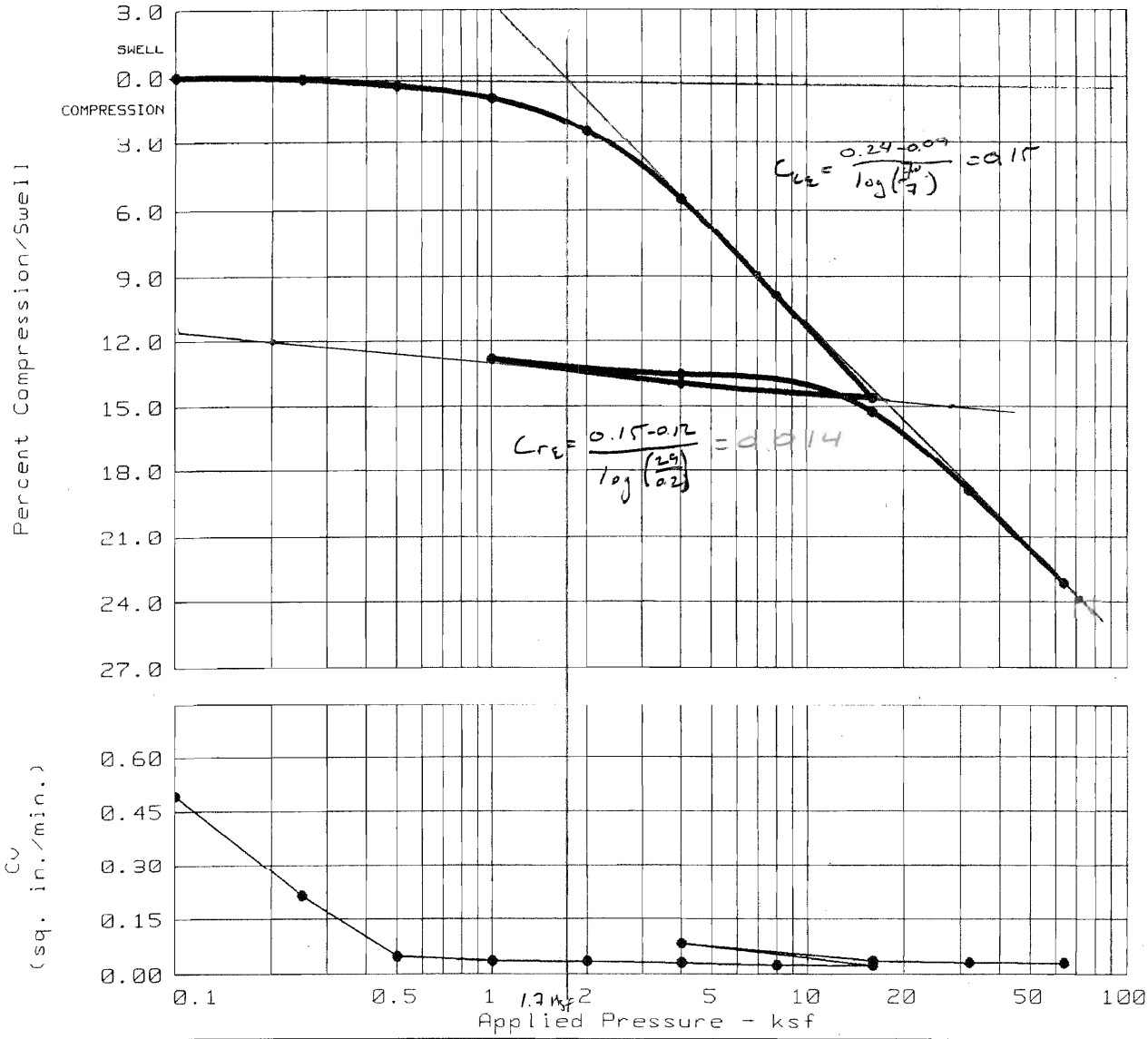
CONSOLIDATION TEST REPORT



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp.Gr.	Initial void ratio
90.6 %	61.5 %	62.4	51	21	2.700	1.8309

TEST RESULTS	MATERIAL DESCRIPTION
$C_v = \sim 0.003\ in^2/min \times \frac{1440\ min}{1\ day} = 4.32\ in^2/min$ @ 4 ksf	Dark gray elastic SILT (MH)
Project No.: 3530-03-1245 Phase 02 Project: Indian River Inlet Bridges Location: Boring BII-14 @ 73' - 75' Date: 12/16/03 C_α @ 4 ksf = 0.006	Class: (MH) Remarks: [illegible] 12/16/03
CONSOLIDATION TEST REPORT LAW ENGINEERING & ENVIRONMENTAL SERVICES, INC.	Fig. No. 1 1

CONSOLIDATION TEST REPORT

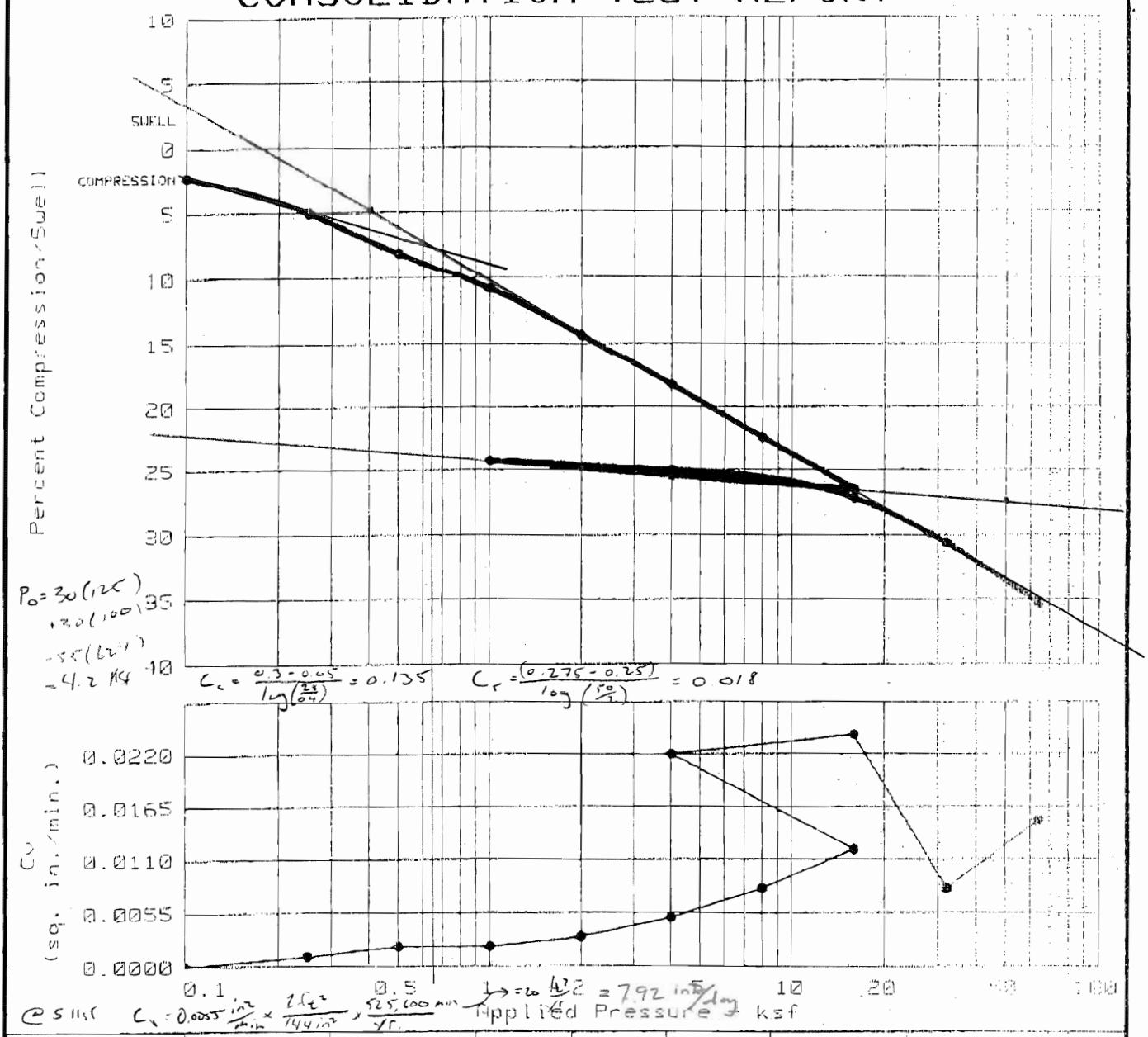


$P_o = 60(125) + 10(100) - 35(62.4) = 6300$ psf

Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp.Gr.	Initial void ratio
82.4 %	36.3 %	80.3	32	11	2.700	1.1901

TEST RESULTS	MATERIAL DESCRIPTION
$C_v \sim 0.03 \frac{in^2}{min} \times 1440 \frac{min}{day} = 43.2$	Dark gray lean CLAY Class: (CL)
Project No.: 3530-03-1245 Phase 02 Project: Indian River Inlet Bridges Location: Boring BTI-17 @ 69' - 71' Date: 11/18/03 C_α @ 4 ksf = 0.002	Remarks: 11/4/03
CONSOLIDATION TEST REPORT LAW ENGINEERING & ENVIRONMENTAL SERVICES, INC.	Fig. No. 1 1

CONSOLIDATION TEST REPORT



$P_o = 30(125) + 30(100) + 55(62.4) = 4.2$ ksf

$C_c = \frac{0.3 - 0.05}{\log(\frac{2.3}{0.4})} = 0.135$ $C_r = \frac{(0.275 - 0.25)}{\log(\frac{10}{1})} = 0.018$

@ 5 ksf $C_v = 0.0055 \frac{in^2}{min} \times \frac{12 ft^2}{144 in^2} \times \frac{525{,}600 min}{yr} \rightarrow = 20 \frac{ft^2}{yr} = 7.92 \frac{in^2}{day}$

Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp.Gr.	Initial void ratio
71.0 %	45.5 %	75.8			2.700	1.7388

TEST RESULTS	MATERIAL DESCRIPTION

Project No.: 3530-03-1245 Phase 02
Project: Indian River Inlet Bridges
Location: Boring BII-18 @ 60' - 62'

Date: 12/1/03 C_α @ 4 ksf = 0.002

Remarks:

CONSOLIDATION TEST REPORT

LAW ENGINEERING & ENVIRONMENTAL SERVICES, INC.

Fig. No. 11

MACTEC

PROJECT NAME Indian River Inlet Bridge PROJECT NO. 3530-03-1245.02

BY: AJA DATE 8/28/2003 CHECKED BY CEB DATE 12/12/03

Calculations for Coefficient of Horizontal Consolidation from CPT Data

Material Parameters of Soft Clay Layer

Vs =	480 ft/s	G_{max} (psf) =	715528.0
γ_T =	100 pcf	I_R =	2385
Su =	300 psf		
a_c =	1.4 in		

Boring	Depth (ft)	GWL(ft)	Umin	Umax	u_{eq} (ft)	u_0 (ft)	u_f (ft)	u_{50} (ft)	T_{50} (sec)	T_{50} (days)	c_h (in^2/day)
CII-07	48.06	3	92.54	149	45.06	103.94	47.48	97.03	1410	0.016319	29.4
CII-09	68.08	3	143.98	227.6	65.08	162.52	78.9	146.34	2495	0.028877	16.6
CII-10	55.12	3	108.73	175.8	52.12	123.68	56.61	113.96	2415	0.027951	17.2
CII-11	40.35	3	53.64	175	37.35	137.65	16.29	106.18	218	0.002523	190.3
CII-11	70.05	3	151.67	250.32	67.05	183.27	84.62	158.69	3230	0.037384	12.8
CII-13	40.03	3	83.35	166.64	37.03	129.61	46.32	101.84	1155	0.013368	35.9

~ 2x C_v

Mean = 50.4

St. Dev. = 69.1

Lunne, Powell + Robertson - "Cone Penetration Testing in Geotechnical Practice" (1997)

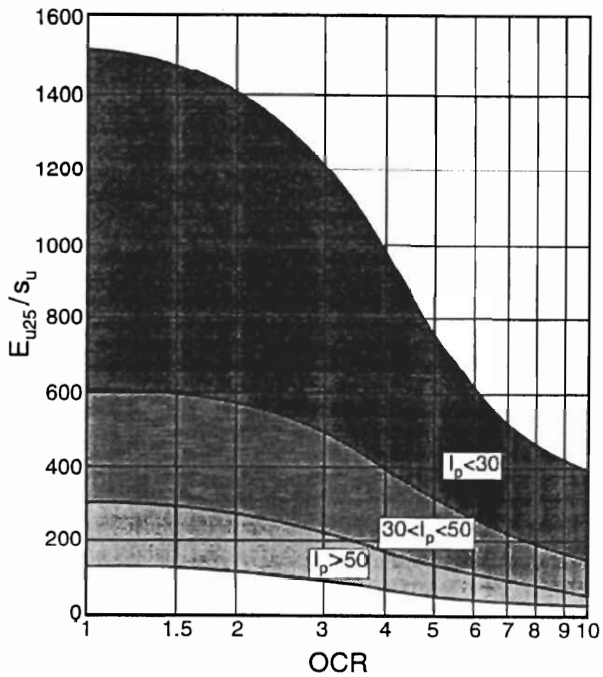


Figure 5.36 Stiffness ratio, E/s_u, as function of OCR (after Duncan and Buchignani, 1976).

Figure 5.37a shows typical dissipation curves for a soft clay (Bothkennar clay) plotted on a logarithmic time scale. The results vary with the filter position. For interpretation it is best to normalize the pore pressure relative to the initial pore pressure at the beginning of dissipation, u_i, and the equilibrium *in situ* pore pressure u_o. The normalized excess pore pressure, U, at time t, is thus expressed as:

$$U = \frac{u_t - u_o}{u_i - u_o} \tag{5.33}$$

where:

u_t = the pore pressure at time t

u_i = initial pore pressure at $t = 0$

u_o = *in situ* pore pressure before penetration.

The results of Figure 5.37a are replotted in normalized form in Figure 5.37b.

Over the last 10 to 15 years, theoretical and semi-empirical solutions have been developed for deriving the coefficient of consolidation from pore pressure dissipation data.

Table 5.9 presents an overview of the main solutions available to calculate the coefficient of consolidation from piezocone dissipation data.

Torstensson (1975, 1977) developed an interpretation model based on cavity expansion theories. Initial pore pressures were computed assuming an elasto-plastic soil model and spherical or cylindrical cavity expansion theory, as shown in Table 5.9. Torstensson then used linear uncoupled one-dimensional consolidation to compute the dissipation of pore pressures.

Torstensson suggested that the coefficient of consolidation should be interpreted at 50% dissipation from the following formula:

$$c = \frac{T_{50}}{t_{50}} \cdot r_o^2 \tag{5.34}$$

where the time factor T_{50} is found from the theoretical solutions, t_{50} is the measured time for 50% dissipation and r_o = penetrometer radius (cylindrical model) or equivalent penetrometer radius for spherical model.

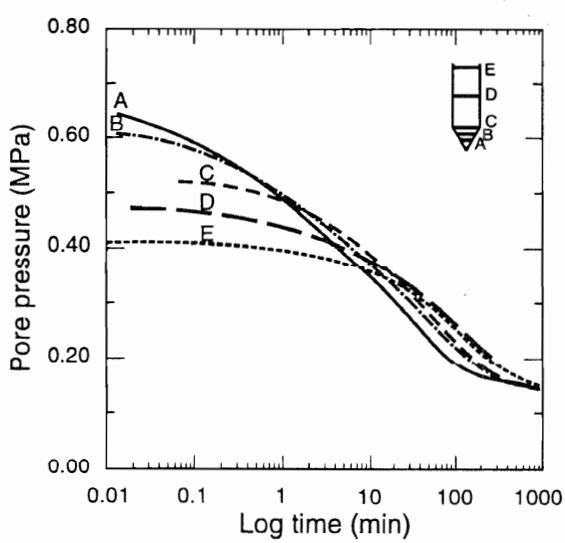


Figure 5.37a Dissipation test results from Bothkennar.

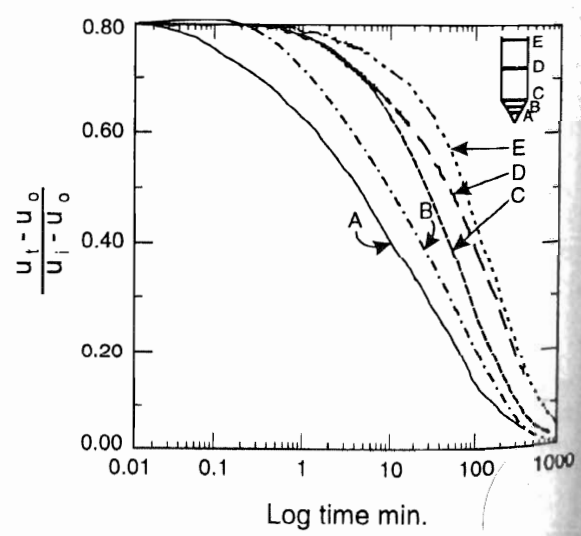


Figure 5.37b Normalized dissipation test data from Bothkennar.

Table 5.9 Available solutions to calculate the coefficient of consolidation from piezocone dissipation tests

Author	Cavity type	Soil model	Initial pore pressure, Δu_1	Consolidation	Remarks
Søderberg (1962)	Cylindrical, radius R	Elastoplastic	$\frac{\Delta u}{\Delta u_1} = \frac{R}{r}$	1-D	Not in use
Torstensson (1975, 1977)	Cylindrical/spherical	Elastoplastic	$\Delta u_1 = 2s_u \ln(r_p/r)$ $\Delta u_1 = 4s_u \ln(r_p/r)$	1-D	
Randolph & Wroth (1979)	Cylindrical	Elastoplastic	As Torstensson's	1-D	= Equiv. to Torstensson
Battaglio *et al.* (1981)	Cylindrical/spherical	Elastoplastic	Same as Torstensson	1-D	Fits entire curve
Senneset *et al.* (1982)	Cylindrical	Elastoplastic	Same as Torstensson	1-D	= Equiv. to Torstensson
Levadoux & Baligh (1985)	Piezocone model	Non-linear $I_r = 500$	From strain path method	2-D	Most comprehensive work
Gupta & Davidson (1986)	Piezocone model	Elastoplastic	Modified cavity expansion, some dissipation	Linear axisymmetric	
Soarès *et al.* (1987)	Piezocone model	Non-linear	Corrected by visual examination and regression analysis	2-D	
Houlsby and Teh (1988)	Piezocone model	Non-linear I_r varies	Predicted by large strain finite element analysis and strain path method	2-D	Extension of Levadoux and Baligh (1985)

u = pore pressure; s_u = undrained shear strength; r = radial distance; r_p = radius of plastic zone; $I_r = G/s_u$ = rigidity index.

The selection of the appropriate model depends on the location of the porous element. The spherical solution may be most applicable if the filter element is located somewhere on the conical part. If the filter is located somewhere on the cylindrical shaft some distance away from the cone the cylindrical solution will be the most applicable.

A comprehensive study on pore pressure dissipation has been performed by Levadoux and Baligh (1980, 1986) and Baligh and Levadoux (1980, 1986) who proposed an interpretation method after evaluating predictions of dissipation tests in Boston Blue Clay (BBC).

Levadoux and Baligh used the strain path method (Baligh, 1985) to predict the initial pore pressure distribution for normally consolidated Boston Blue Clay with rigidity index, $I_r = 500$. A finite element method was used for the subsequent coupled and uncoupled linear isotropic consolidation analysis.

Some important conclusions from the study of Baligh and Levadoux (1986) were:

1. The simple uncoupled solutions provide reasonably accurate predictions of the dissipation process.
2. Consolidation is taking place predominantly in the recompression mode for dissipation less than 50%.
3. Initial distribution of excess pore pressures around the probe has a significant influence on the dissipation process.
4. Dissipation is predominantly in the horizontal direction.

Houlsby and Teh (1988) proposed an interpretation based on the results of large strain finite element analyses of the penetration pore pressures, and a finite difference analysis of the dissipation pore pressure. They used an approach similar to the Levadoux-Baligh theory but included the effect of varying the rigidity index, I_r ($= G/s_u$). Houlsby and Teh suggested using a modified dimensionless time factor, T^* given in Table 5.10, defined as follows:

$$T^* = \frac{c_h \cdot t}{r^2 \sqrt{I_r}} \tag{5.35}$$

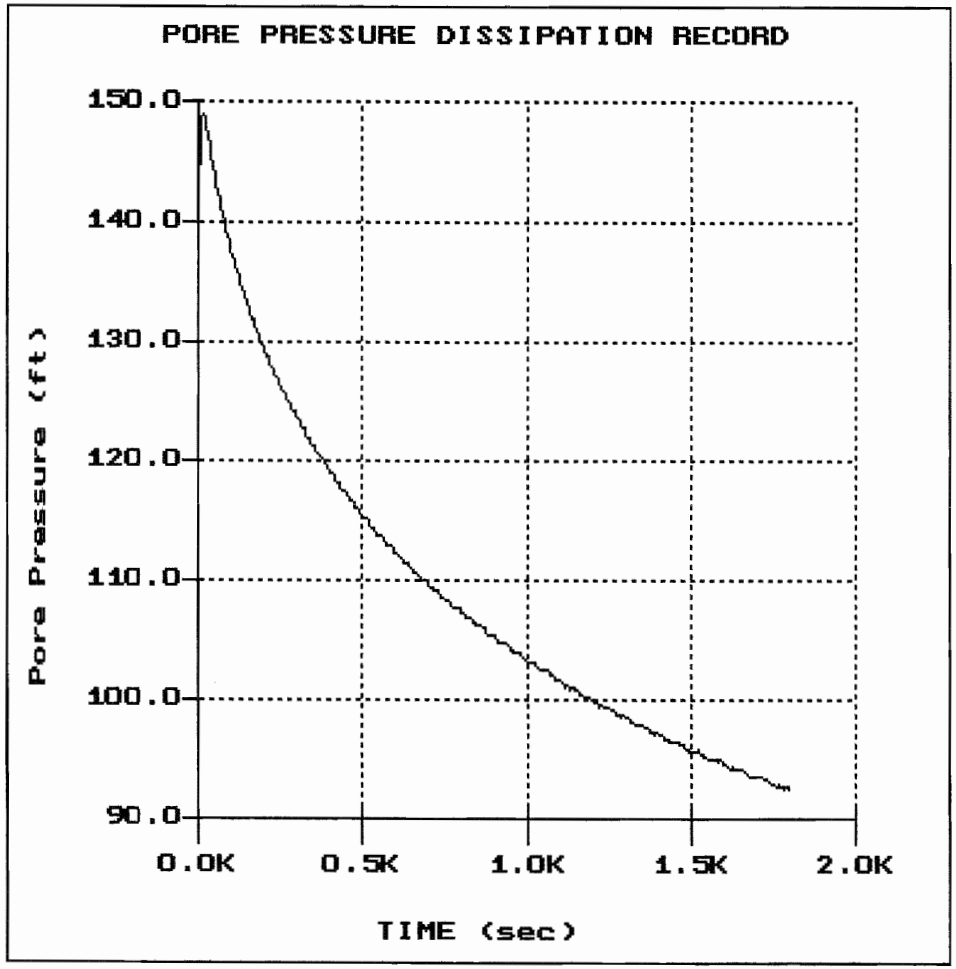
Table 5.10 Modified time factors T^* from consolidation analysis (from Houlsby and Teh, 1988)

	Location			
Degree of consolidation	Cone (u_1)	Cylindrical extension above cone base (u_2)	Five radii above cone base	Ten radii above cone base
20%	0.014	0.038	0.294	0.378
30%	0.032	0.078	0.503	0.662
40%	0.063	0.142	0.756	0.995
50%	0.118	0.245	1.11	1.458
60%	0.226	0.439	1.65	2.139
70%	0.463	0.804	2.43	3.238
80%	1.04	1.60	4.10	5.24

MACTEC

Hole:CII-07
Location:Indian River Br.

Cone:20 Ton AD139
Date:10:01:03 14:26

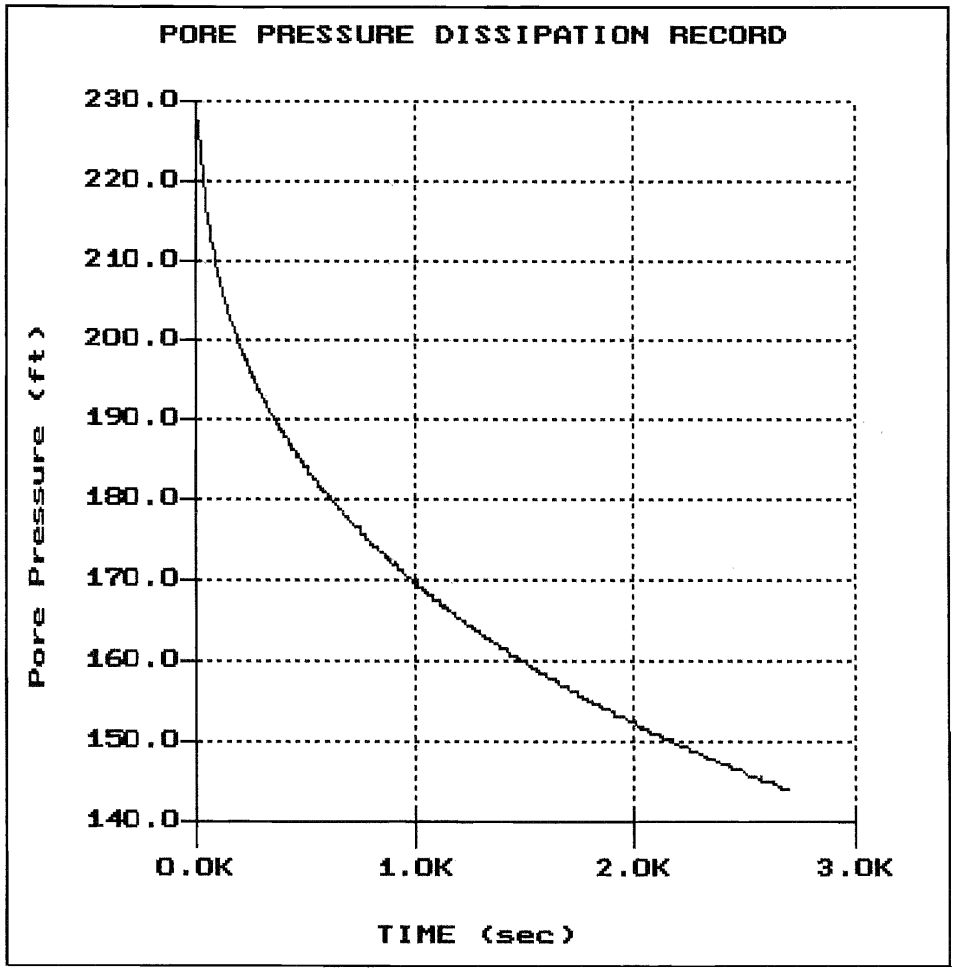


File: 762CP007.PPD
Depth (m): 14.65
(ft): 48.06
Duration : 1800.0s
U-min: 92.54 1800.0s
U-max: 149.00 15.0s

MACTEC

Hole:CII-09
Location:Indian River Br.

Cone:20 Ton AD139
Date:10:01:03 16:01

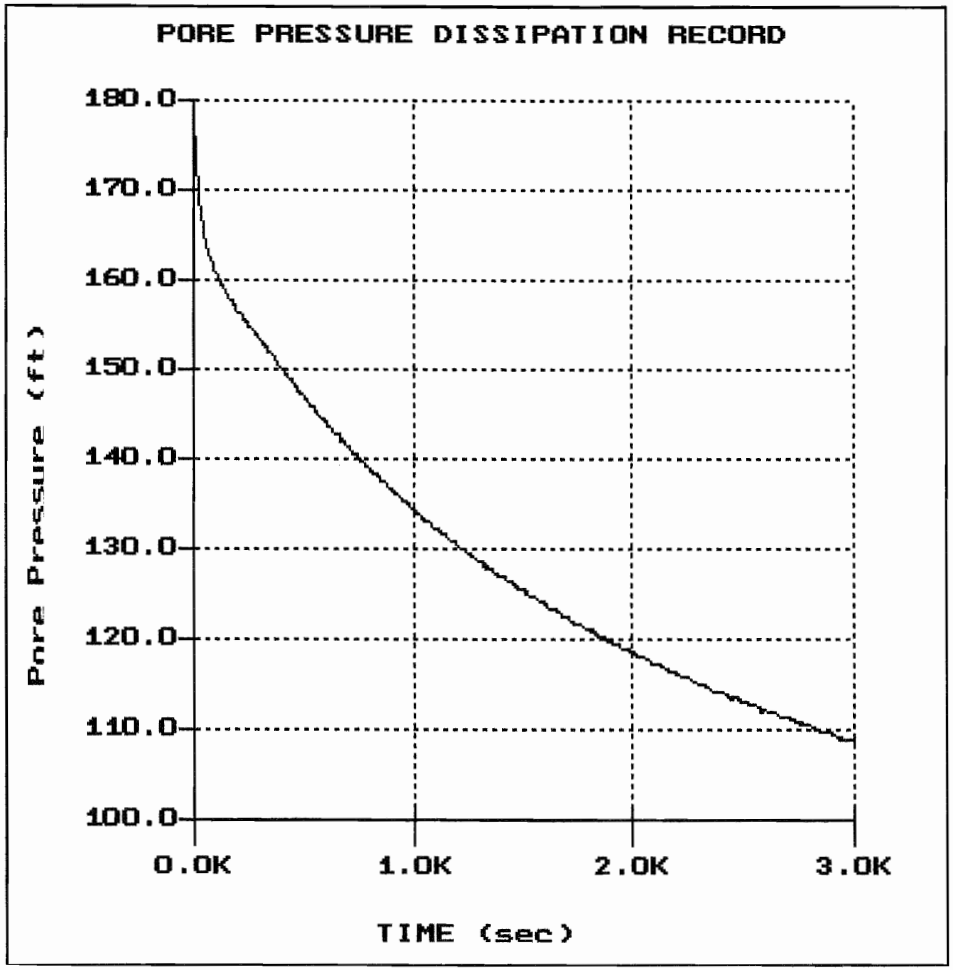


File: 762CP009.PPD
Depth (m): 20.75
(ft): 68.08
Duration : 2700.0s
U-min: 143.98 2700.0s
U-max: 227.60 5.0s

MACTEC

Hole:CII-10
Location:Indian River Br.

Cone:20 Ton AD139
Date:10:01:03 12:30

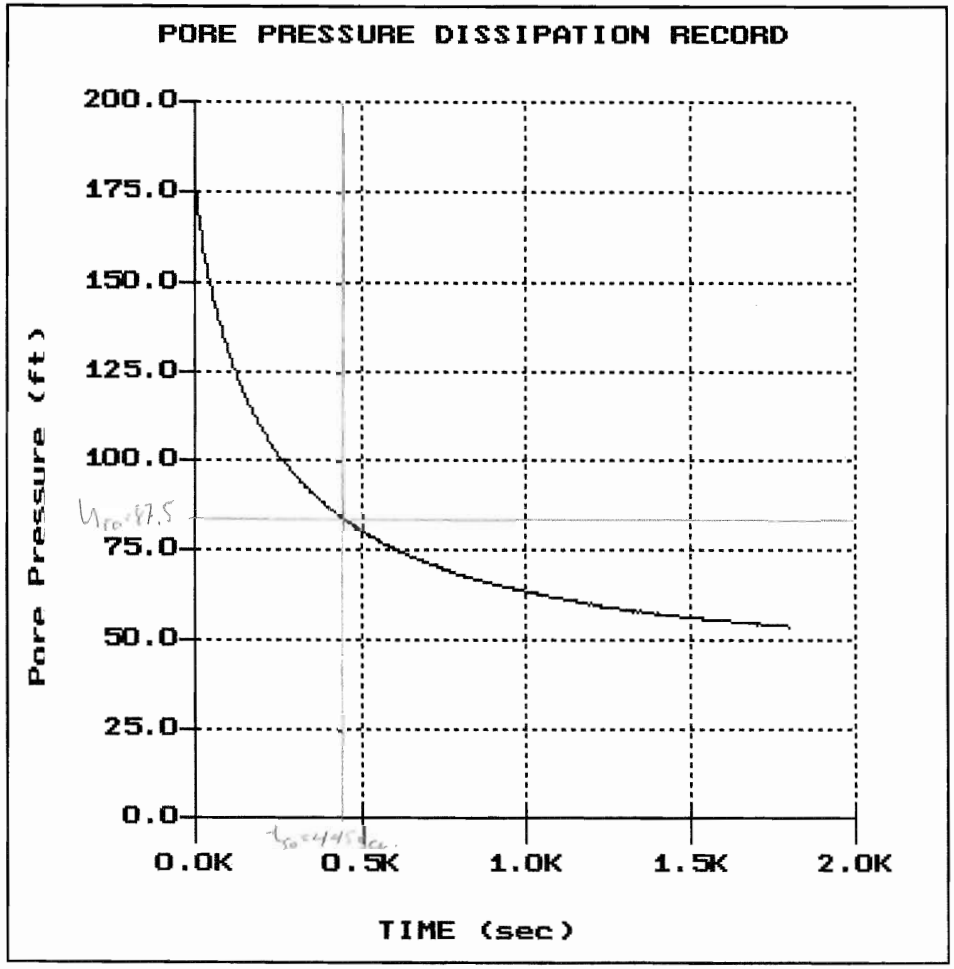


File: 762CP010.PPD
Depth (m): 16.80
(ft): 55.12
Duration : 3000.0s
U-min: 108.73 3000.0s
U-max: 175.80 10.0s

MACTEC

Hole:CII-11
Location:Indian River Br.

Cone:20 Ton AD139
Date:10:01:03 09:50



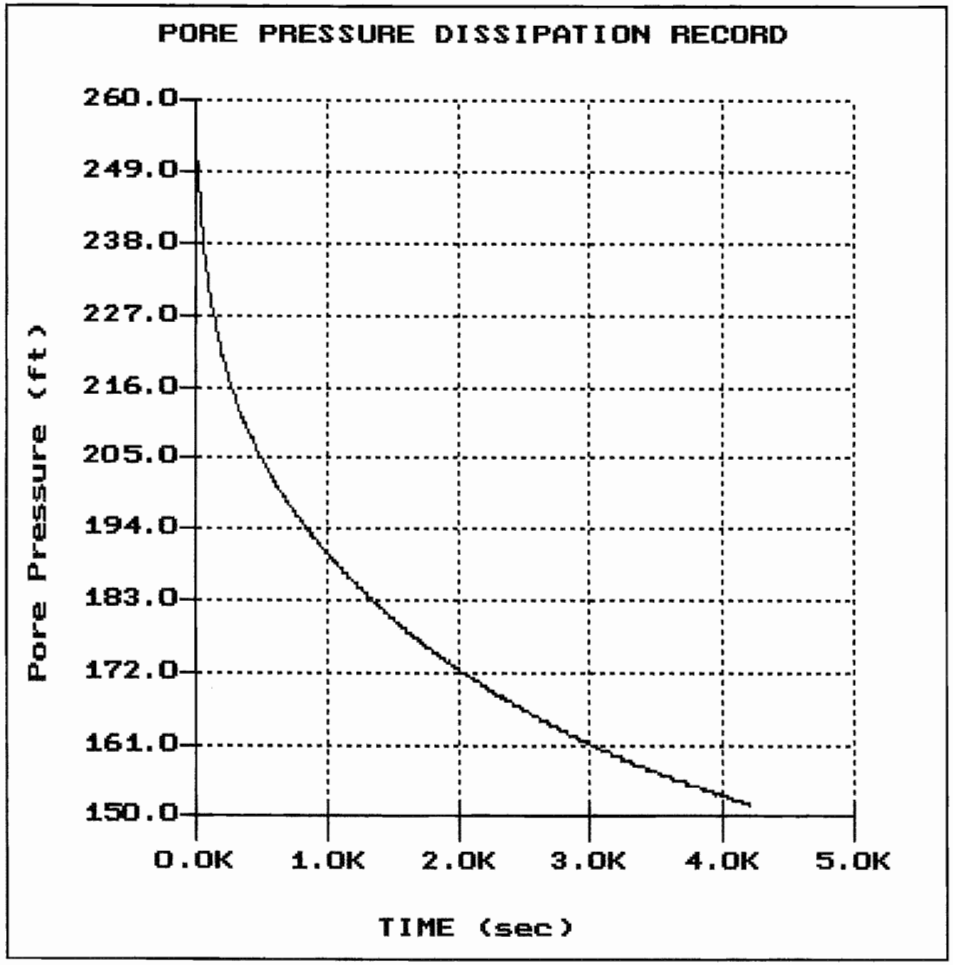
File: 762CP011.PPD
Depth (m): 12.30
(ft): 40.35
Duration : 1800.0s
U-min: 53.64 1800.0s
U-max: 175.00 5.0s

@ 40.52'
q_t = 82 tsf
σ_v = 2.47 tsf
u_2 =

MACTEC

Hole:CII-11
Location:Indian River Br.

Cone:20 Ton AD139
Date:10:01:03 09:50

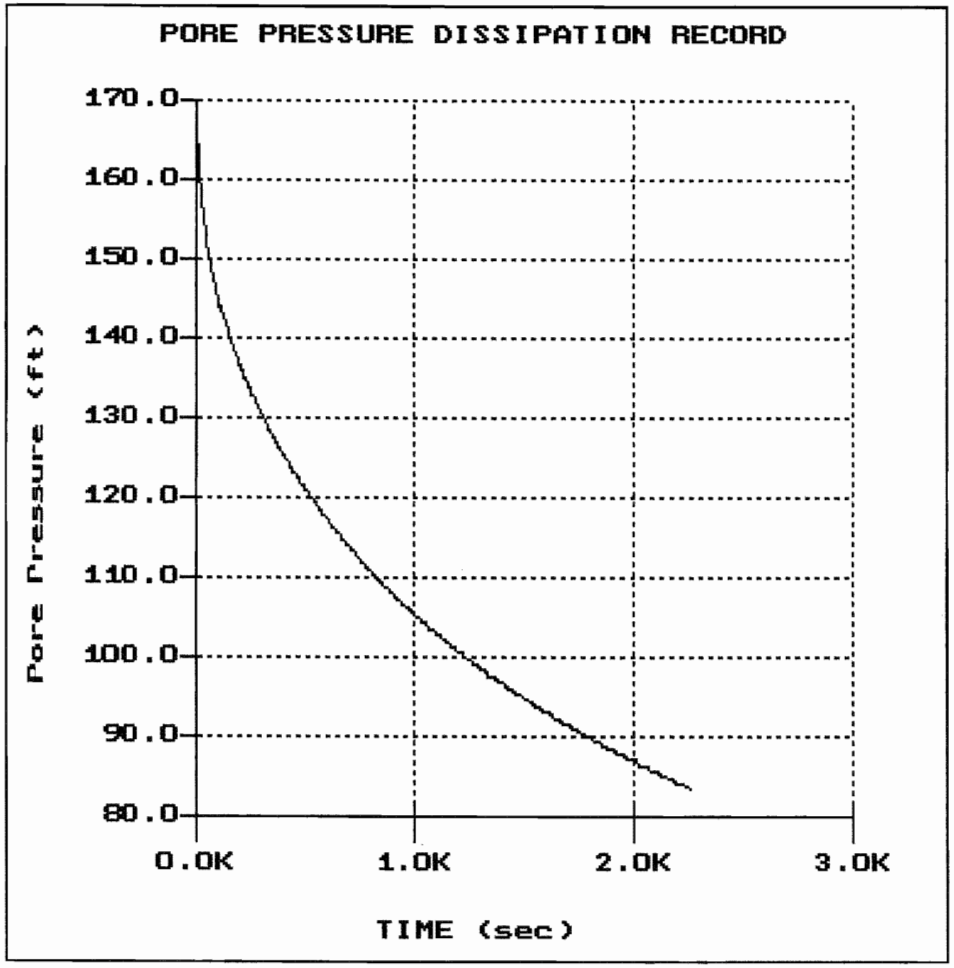


File: 762CP011.PPD
Depth (m): 21.35
(ft): 70.05
Duration : 4200.0s
U-min: 151.67 4200.0s
U-max: 250.32 10.0s

MACTEC

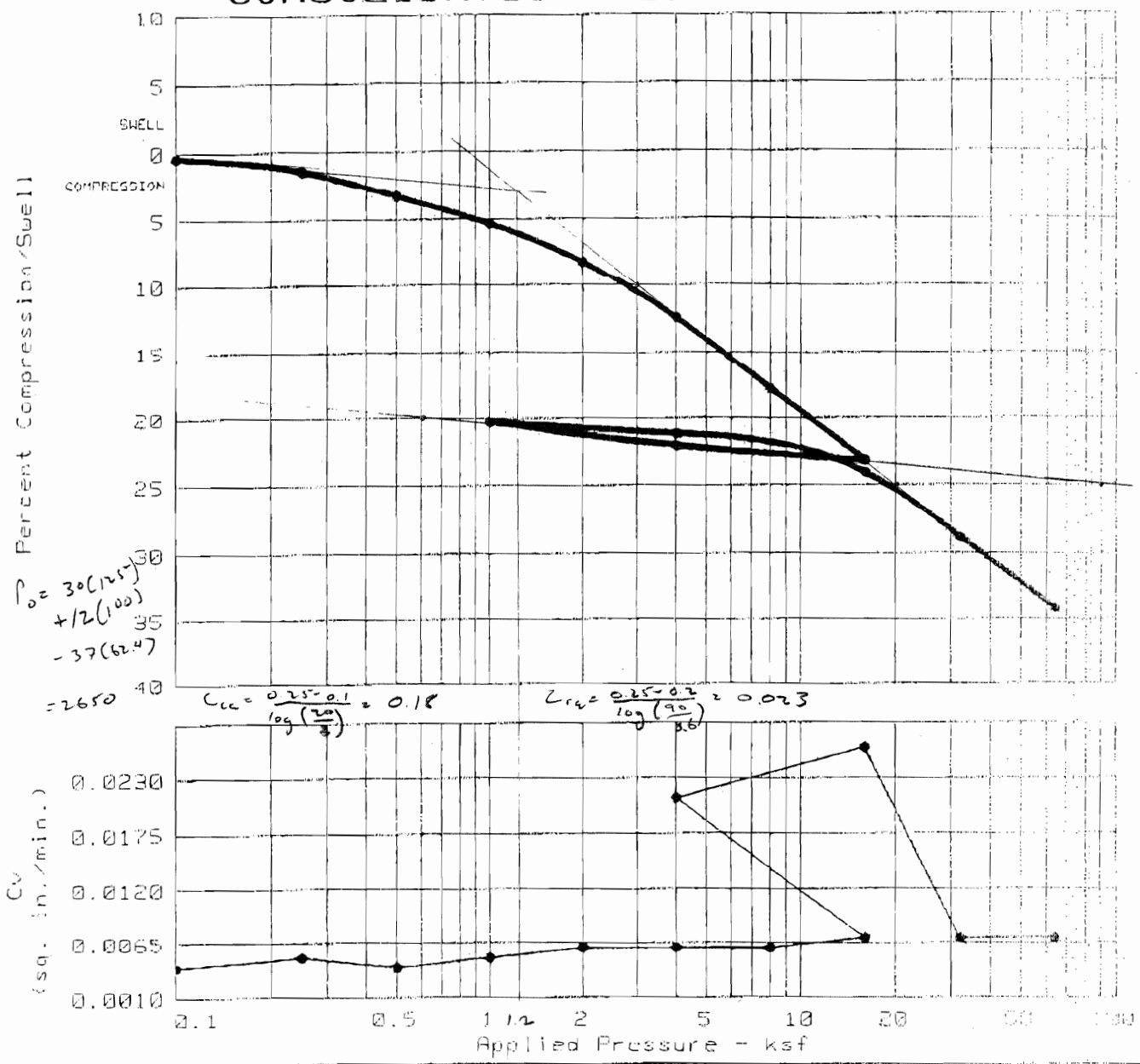
Hole:CII-13
Location:Indian River Br.

Cone:20 Ton AD139
Date:09:30:03 12:03



File: 762CP013.PPD
Depth (m): 12.20
(ft): 40.03
Duration : 2250.0s
U-min: 83.35 2245.0s
U-max: 166.64 0.0s

CONSOLIDATION TEST REPORT



Natural Saturation	Natural Moisture	Dry Dens. (pcf)	LL	PI	Sp.Gr.	Initial vois ratio
89.1 %	51.5 %	67.1	59	24	2.700	1.561

TEST RESULTS	MATERIAL DESCRIPTION
C_α @ 4 ksf = 0.004 → N/A (Horizontal)	$\sqrt{t}$ → $C_v = 0.006\ in^2/min \times 1440 = 8.64\ in^2/day$ @ 4 ksf
Project No.: 3530-03-1245 Phase 01 Project: Indian River Inlet Bridges Location: Boring ~~BI-17~~ @ 41.5' - 43.3' BI-7 Horizontal Date: 11/19/03	$\log(t)$ → $C_v = 0.003\ in^2/min \times 1440 = 4.32\ in^2/day$ Remarks:
CONSOLIDATION TEST REPORT LAW ENGINEERING & ENVIRONMENTAL SERVICES, INC.	Fig. No. 1

STRATUM 3
SETTLEMENT PARAMETERS

E (modulus)

MACTEC

MACTEC Engineering and Consulting
5 Ownby Lane
Richmond, VA 23220

PURPOSE: Estimate modulus values for drilled shaft settlement analysis using FHWA Equivalent Raft Method

ASSUMPTIONS:

SOLUTION: Use methods described in FHWA *Drilled Shafts: Construction Procedures and Design Methods (FHWA-IF-99-025).*

1. Estimate Modulus values for different Stratum

Stratum 3 Sands: North Pier:

Elevation (ft):	Depth (ft):	Avg. N60:	E'bi		
-50 to -133	55 to 138	$N_{60} := 48$	$E_{bi} := 146.2\,ksf \cdot (N_{60})^{0.5}$	$E_{bi} = 1013\,ksf$	use Ebi = 1000 ksf
-138 to -155	143 to 160	$N_{60} := 15$	$E_{bi} := 146.2 \cdot ksf \cdot (N_{60})^{0.5}$	$E_{bi} = 566\,ksf$	use Ebi = 500 ksf

Stratum 3 Sands: South Pier:

Elevation (ft):	Depth (ft):	Avg. N60:	E'bi		
-85 to -131	90 to 136	$N_{60} := 45$	$E_{bi} := 146.2 \cdot ksf \cdot (N_{60})^{0.5}$	$E_{bi} = 981\,ksf$	use Ebi = 1000 ksf
-135 to -145	140 to 150	$N_{60} := 15$	$E_{bi} := 146.2 \cdot ksf \cdot (N_{60})^{0.5}$	$E_{bi} = 566\,ksf$	use Ebi = 500 ksf

Note: Values correspond reasonably well with those recommended by Bowles (1996):

Bowles (1996) gives range for modulus values of: Sands: Loose: 200 - 500 ksf
Dense: 1000 - 1620 ksf

Silty Sands: 100 - 400 ksf

Gravelly Sands: Loose: 1000 - 3000 ksf
Dense: 2000 - 4000 ksf

Correlations from Bowles (1996) for: Gravelly Sands: Es (KPa) = 600*(N+6) + 2000 (for N > 15 bpf)
= 600*(45+6)+2000 = 34400 KPa ~ 700 ksf

Es (KPa) = 1200*(N+6) (for all gravelly sands)
= 1200*(45+6) = 64800 KPa ~ 1350 ksf

Clayey Sands: Es (KPa) = 320*(N+15)
= 320*(15+15) = 9600 KPa ~ 200 ksf

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Modulus Range

JOB NO. 3530-03-1245		SHEET 1	OF 2
PHASE Eng		TASK 03	
JOB NAME IRIB			
BY AJA		DATE 6/8/04	
CHECKED BY CEB		DATE 6/10/04	

Purpose: Estimate Range of Modulus values for Sand below Arch Base Foundation elements:

Method: Use Correlations + tabulated values in Various References listed below.

Solution:

Parameter		Values of Correlation	Reference
Initial Modulus	E_d / p_a	Med Dense sand: 200-500 → E_d = 400-1000 ksf Dense Sand: 500-1000 → E_d = 1000-2000 ksf (for p_a = 2 ksf)	EPRI (1990) Table 5-5
Secant Modulus	E/p_a	Sands w/ Fines: N_{60} ~ 45 bpf in upper stratum III, ~ 20 bpf in lower stratum III $E/p_a = 5 \cdot N_{60}$ → $E = 2 \cdot 5 \cdot 45 = 450$ ksf, $= 2 \cdot 5 \cdot 20 = 200$ ksf Clean NC Sands: $E/p_a = 10 \cdot N_{60}$ → $E = 2 \cdot 10 \cdot 45 = 900$ ksf, $= 2 \cdot 10 \cdot 20 = 400$ ksf Clean OC Sands: $E/p_a = 15 \cdot N_{60}$ → $E = 2 \cdot 15 \cdot 45 = 1350$ ksf, $= 2 \cdot 15 \cdot 20 = 600$ ksf	EPRI (1990) Eqs. 5-26a-c
Young's Modulus	E_{ds}:	$E_{ds} = \alpha \cdot q_c$, $\alpha = 1.5-2.5$ q_c @ IRIB = 400-700 ksf So: E_{ds} = 600 ksf - 1750 ksf	EPRI (1990)
Young's Modulus	E_s (Avg along c. dus of shaft) E_b (Avg below p.k t.p.)	Med. Dense / Dense E_s = 8,000 psi - 16,000 psi = 1150 ksf - 2300 ksf E_b = 5-10 times E_s	Poulos & Davis (1990) Table 5.3

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JOB NO. 3530-03-1245 SHEET 2 OF 2
PHASE TASK 03
JOB NAME IRB
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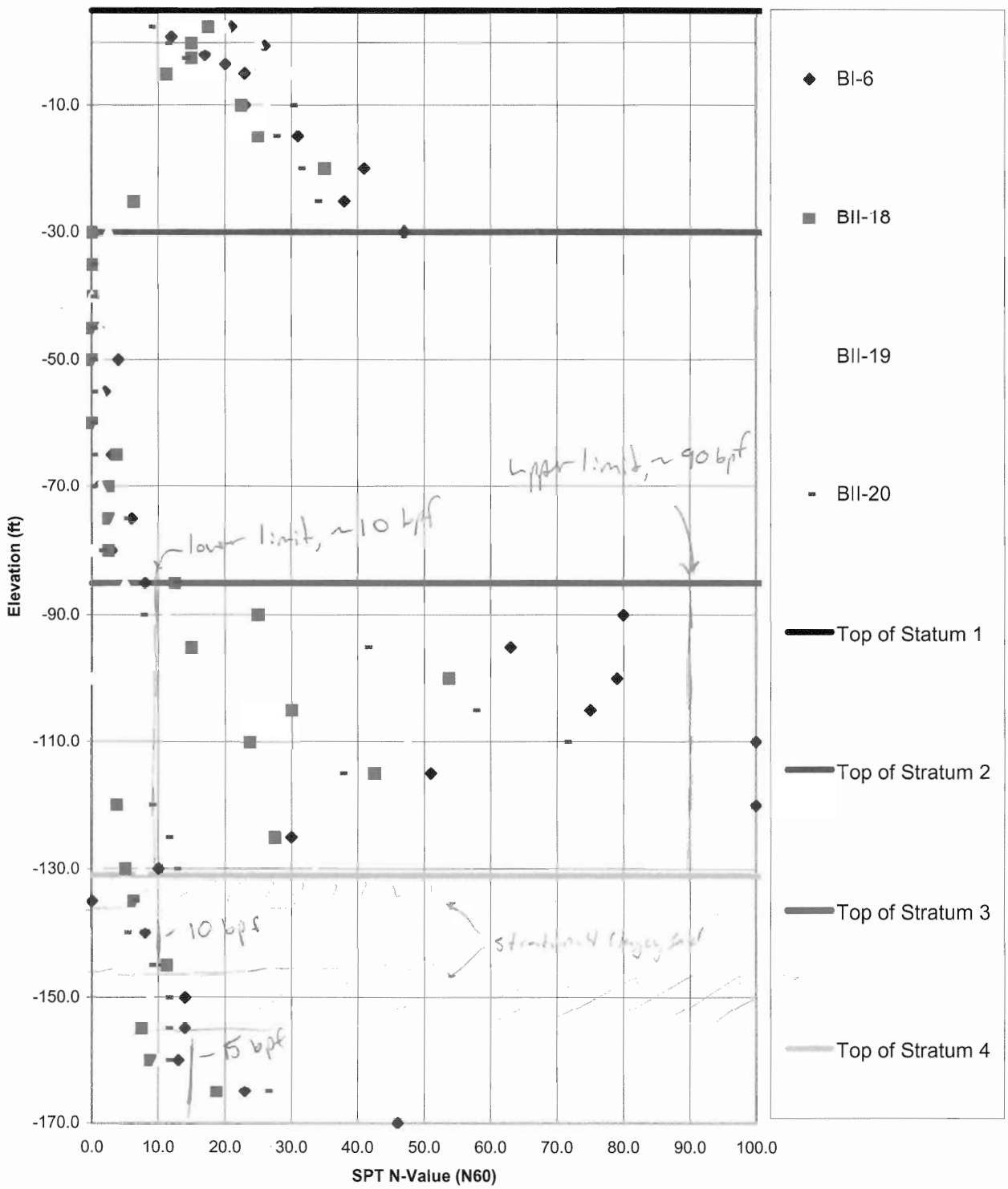
CHECKED BY CEB DATE 6/10/02

Parameter	Values of Correlation	Reference
E_s (Kpa) (N.C. Sandy)	for N = 45 in upper stratum III N = 20 in lower stratum III	
	★ $E_s = 500(N+15)$ upper III = 500(45+15) = 30,000 Kpa ~ 625 Ksf Lower III = 500(20+15) = 17,500 Kpa ~ 365 Ksf	
	★ $E_s = 7000\sqrt{N}$ upper III = $7000\sqrt{45}$ = 46957 Kpa ~ 980 Ksf lower III = $7000\sqrt{20}$ = 31305 Kpa ~ 650 Ksf	
E_s (Kpa) (saturated sand)	★ $E_s = 250(N+15)$ upper III = 250(45+15) = 15000 Kpa ~ 315 Ksf lower III = 250(20+15) = 8750 Kpa ~ 180 Ksf	→ Bowles (1996) Table 5-6
E_s (Kpa) (Gravelly Sand)	★ $E_s = 1200(N+6)$ upper III = 1200(45+6) = 61200 Kpa ~ 1280 Ksf lower III = 1200(20+6) = 31200 Kpa ~ 650 Ksf	
	★ $E_s = 600(N+6) + 2000$ upper III = 600(45+6) + 2000 = 32,600 Kpa ~ 680 Ksf lower III = 600(20+6) + 2000 = 17,600 Kpa ~ 370 Ksf	

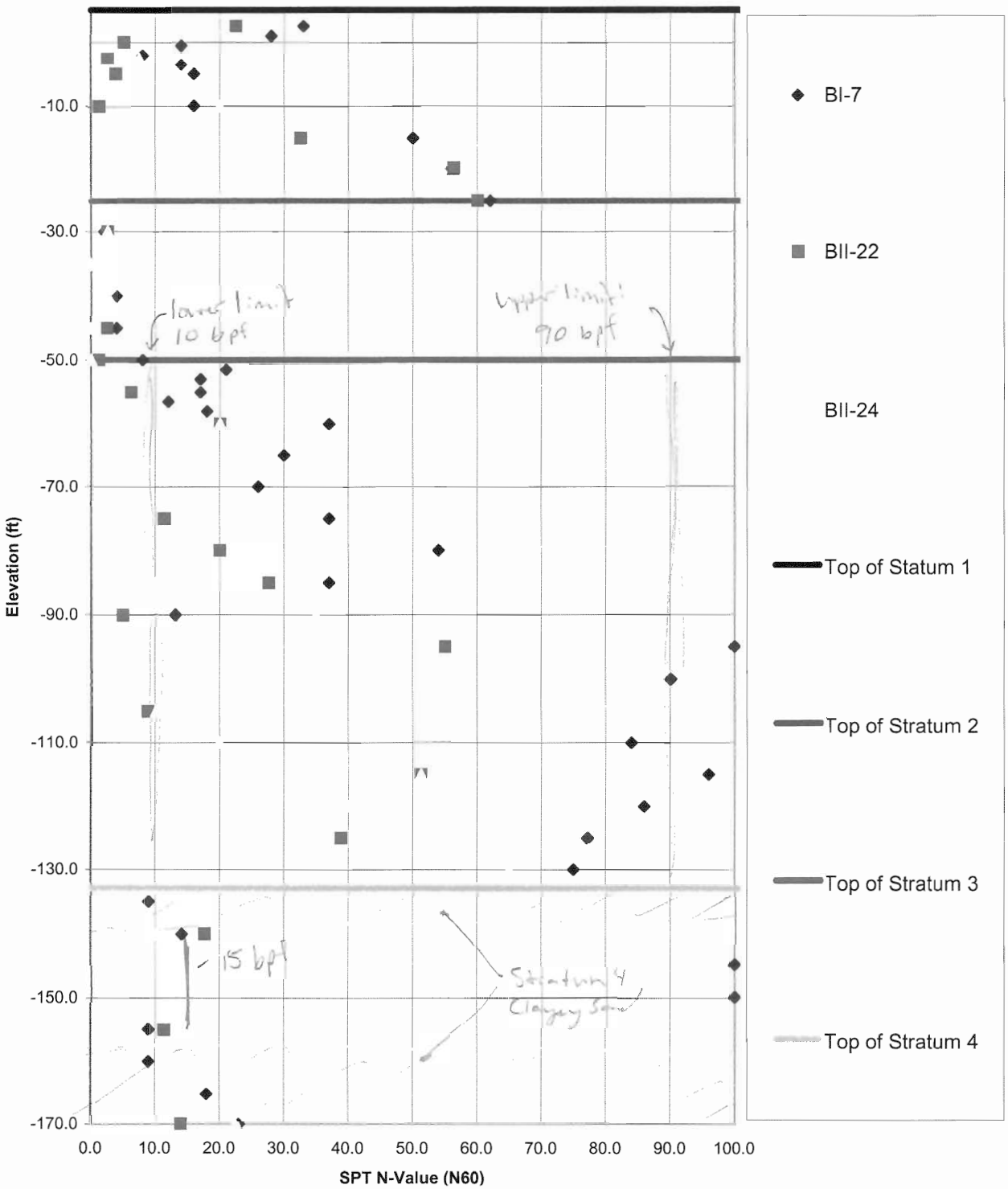
Summary

	Upper Stratum III	Lower Stratum III
Range of E:	315 – 2300 Ksf	180 – 1150 Ksf
Value used in Analysis	1000 Ksf	500 Ksf.

SPT vs. Depth Near South Pier



SPT vs. Depth Near North Pier



STRATUM 4
SETTLEMENT PARAMETERS

OCR

$C_{\varepsilon c}$

C_{cr}

C_{v}

C_{u}

C_{α}

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JOB NO. 3530-03-1245 SHEET 1 OF 2
PHASE 02 TASK ENG
JOB NAME IRIB
BY AJA DATE 3/10/04
CHECKED BY JRW DATE 4/2/04

Purpose: Estimate Over Consolidation Ratio of Stratum 4 Clayey Sand

Method: Use Lab + SPT Data along with published correlations to estimate OCR

Assumptions:

Solution: (1) Summarize Lab Data:

	Boring	Depth	NMC%	LL	PL	%-200
Stage I -	BI-6	143.5-145	19.5	24	12	55
	BI-7	143.5-145	16.4	23	14	46
	BI-7	163.5-165	19.7	23	15	32
Stage II -	BII-18	138.5-140	24.2	31	18	
	BII-18	143.5-145	19.9	27	15	28
	BII-18	158.5-160	27.7			83
	BII-18	163.5-165	30	32	20	
	BII-19	138.5-140	24.4	32	19	
	BII-19	143.5-145	20.8			41.3
	BII-19	148.5-150	22.9	51	21	
	BII-19	153.5-155	27.3			93.8
	BII-19	163.5-165	23.6	2	18	
	BII-19	168.5-170	15.6			43.8
	BII-22	143.5-145	19.0	23	14	52.9
	BII-22	160-162	69.1	65	28	
	Average Values		25.7	32	18	53

(2) Distinguish Stratigraphy:

Based on Review of actual samples + Laboratory data plots (Attached) the more Clayey portions of Strata 4 occur at the following Depths/Elevations:

	Depth / Elevation (FE)	Approximate Range of N-values
North Pier/Abutment:	138 / -133 to 143/-138	8 - 15
	160 / -155 to 175/-170	8 - 25
South Pier/Abutment:	136/-131 to 140/-135	0 - 10 (most between 7 + 10)
	150 / -145 to 160/-155	8 - 15

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JOB NO. 3530-03-1245 SHEET 2 OF 2
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BY AJA DATE 3/10/04
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(3) Estimate OCR:

- Based on Natural moisture + Plasticity Data, the clayey portions of Stratum 4 Appear to be moderately over-consolidated:

Avg. LL	Avg NM%	Avg PL
32	25.7	18

- Laboratory Consolidation Test shows signs of disturbance, so use correlative Equations with SPT N-value.

→ From EPRI (1990) Figure 3-18 shows equation for correlating SPT N-value with OCR for Cohesive Soils.

→ $OCR = 0.58 \cdot N \cdot \left(\frac{P_a}{\sigma_{vo}'}\right)$

where N in clayey portions of Stratum 4 Ranges approximately: according to values presented on previous page.
: $P_a \sim 1$ tsf, $\sigma_{vo}' \sim 4-5$ tsf

	Depth / Elevation	Approximate N-value	Range of OCR (Fig 3-18)	Design OCR
→ North Pier/Abut.:	138/-133 to 143/-138	8-15	1.2-2.2	1.25
	160/-155 to 175/-170	8-25	1.2-3.6	1.5
→ South Pier/Abut:	136/-131 to 140/-135	~7-10	1.0-1.5	1.25
	150/-145 to 160/-155	8-15	1.2-2.2	1.5

(4) Summary: Use OCR values Ranging from 1.25-1.5 for Pier/Abutment Settlement calculations. ✓

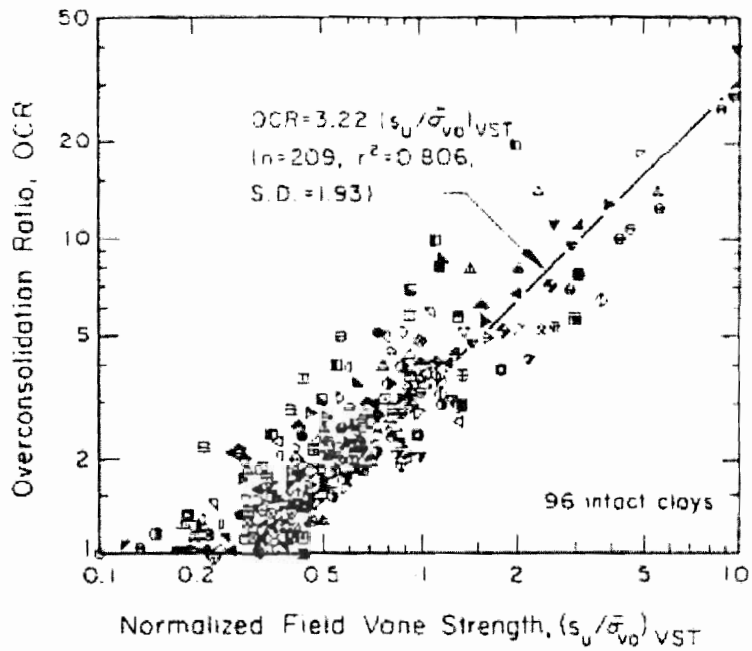


Figure 3-17. OCR Correlated with VST s_u

Source: Based on Mayne and Mitchell (9), p. 152.

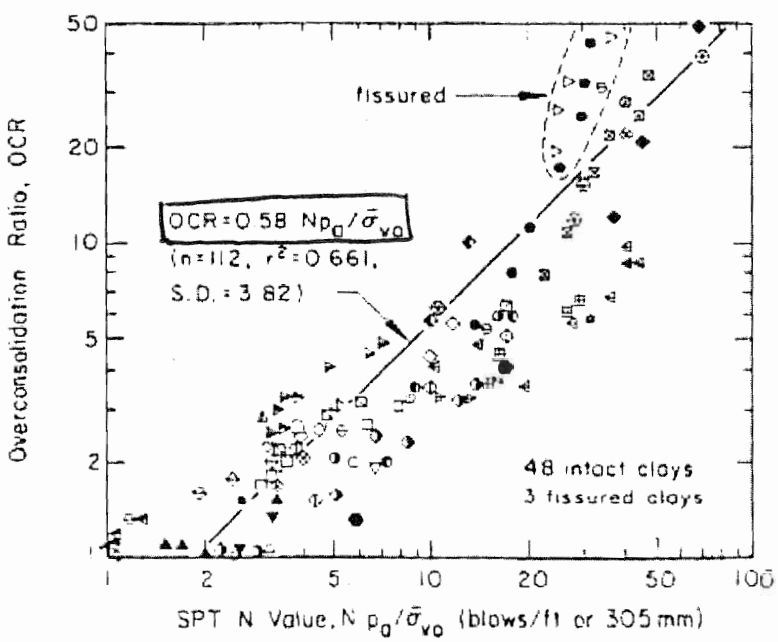
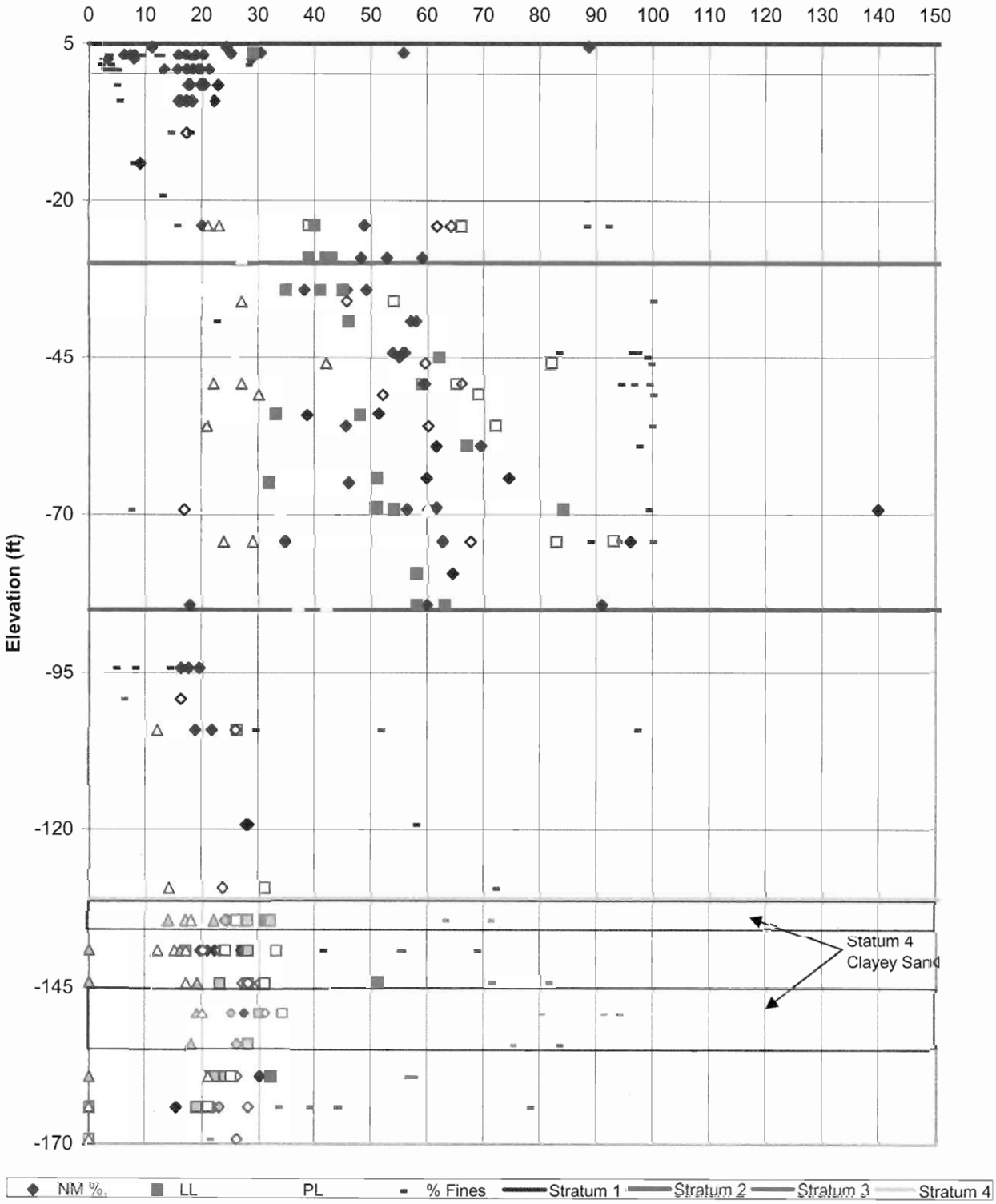


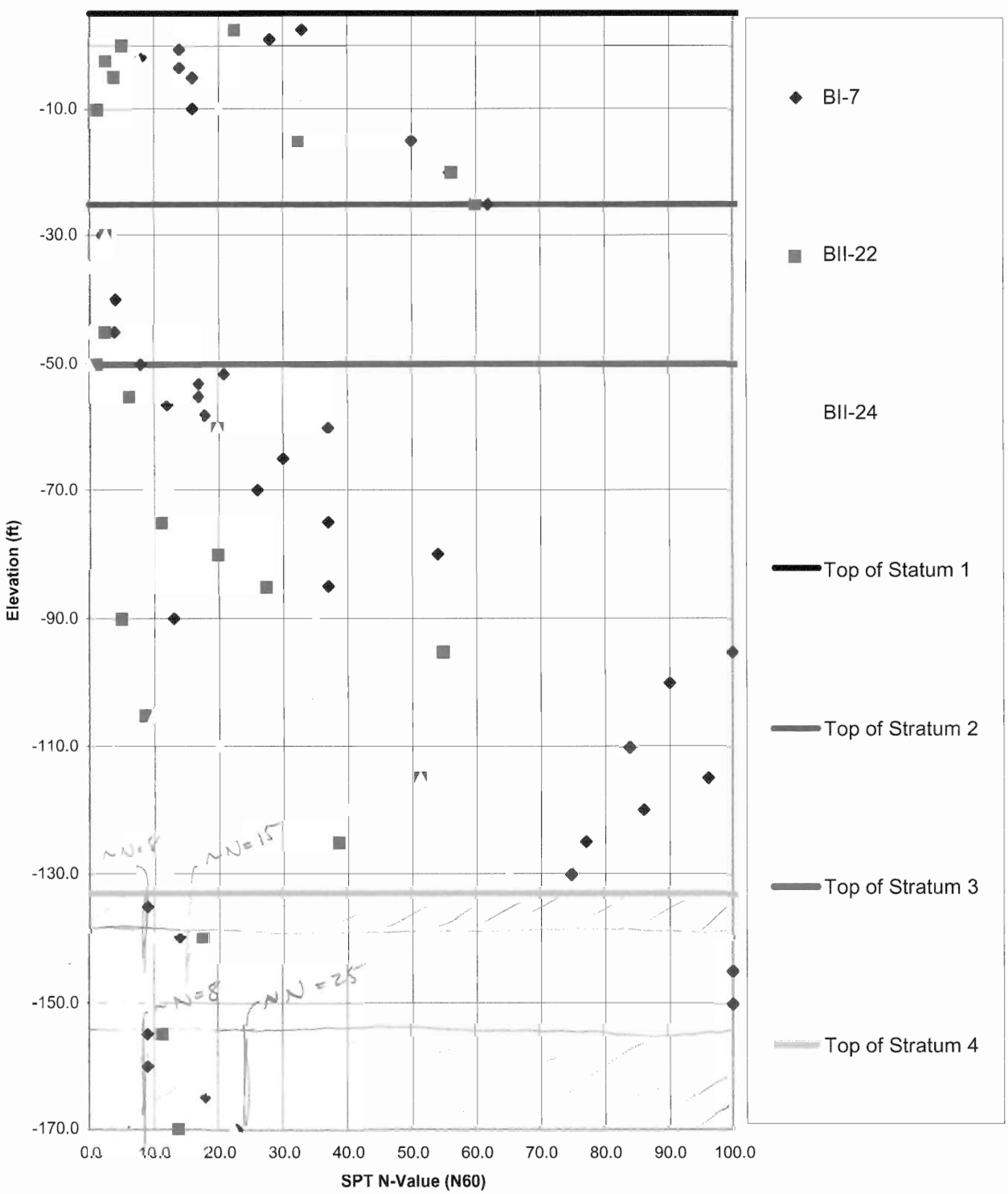
Figure 3-18. OCR Correlated with SPT N

Source: Based on Mayne and Kemper (11), p. 143, and others (12)

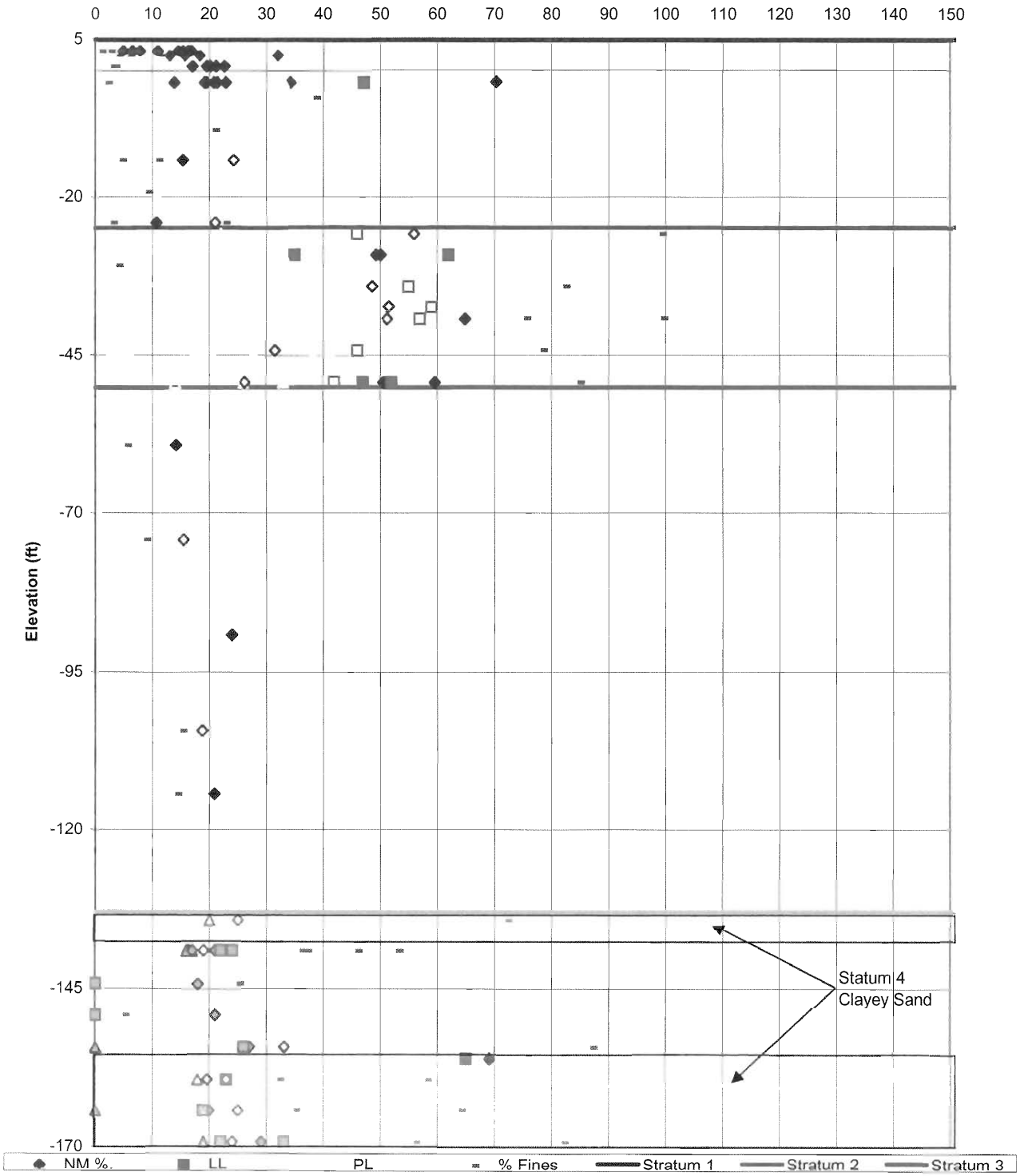
Lab Data vs. Depth (South Approach)



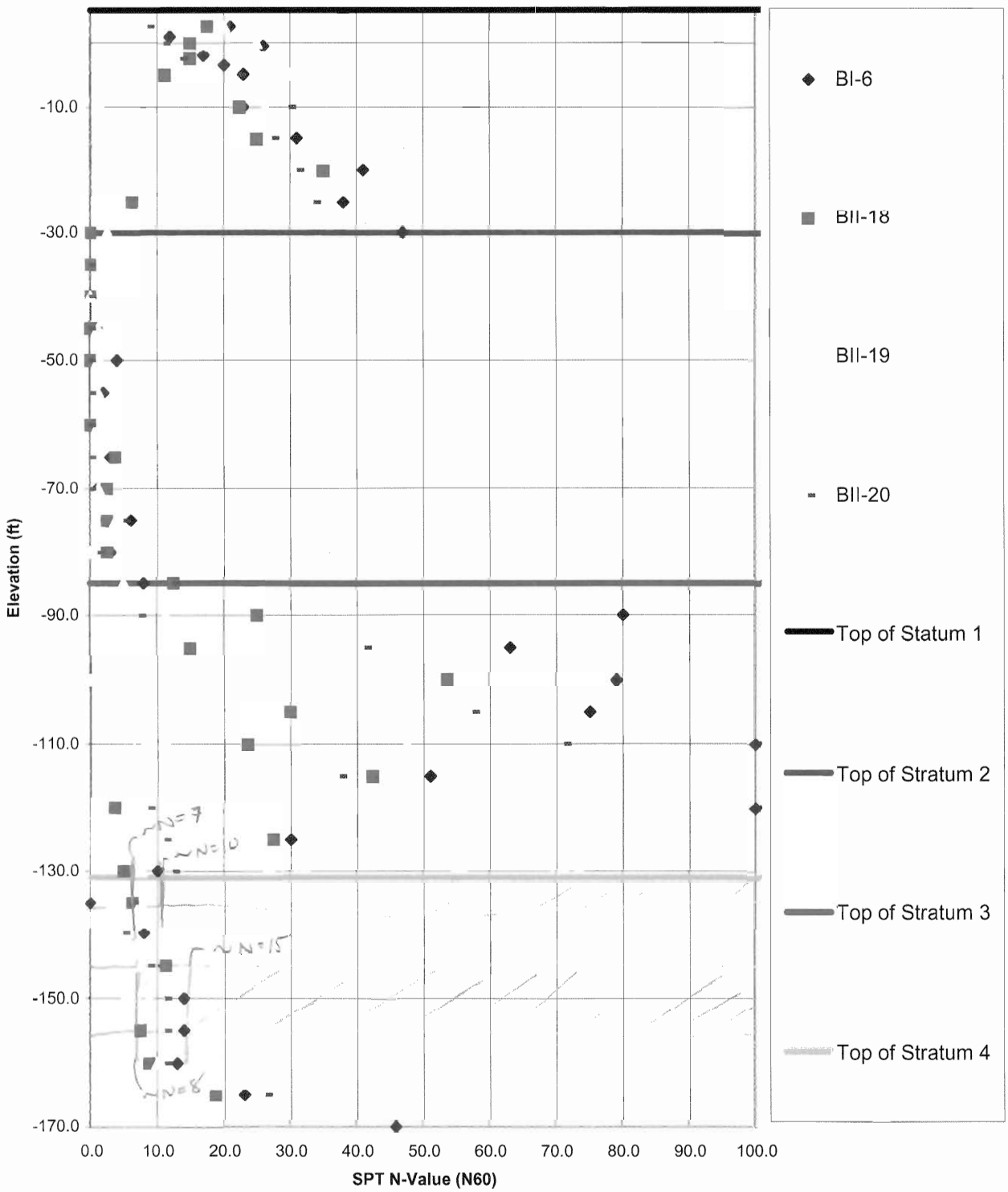
SPT vs. Depth Near North Pier



Lab Data vs. Depth (North Approach)



SPT vs. Depth Near South Pier



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JOB NO. 3530-03-1245.03 SHEET 1 OF 1
JOB NAME IRIB PHASE.TASK
BY AJA DATE 2/23/04
CHECKED BY CEB DATE 4/30/04

Estimate Settlement Paramters of Stratum 4: Assume: $LL := 32$ $PI := 14$ $w_n := 26$ $\gamma_T := 115 \cdot pcf$

Estimate Compression Index:

$C_{c\varepsilon 1} := 0.009 \cdot w_n + 0.002 \cdot LL - 0.1$ (Azzouz et al., 1976) $C_{c\varepsilon 1} = 0.198$

$C_{c\varepsilon 2} := 0.006 \cdot (LL - 9)$ (Azzouz et al., 1976) $C_{c\varepsilon 2} = 0.138$

$C_{c\varepsilon 3} := \frac{(LL - 13)}{109}$ (Mayne, 1980) $C_{c\varepsilon 3} = 0.174$ Use: $C_{c\varepsilon} := 0.15$

Estimate Range for Recompression Index:

$C_{rmax} := 0.2 C_{c\varepsilon}$ $C_{rmax} = 0.03$

$C_{rmin} := 0.02 \cdot C_{c\varepsilon}$ $C_{rmin} = 0.003$

Use: $C_{r\varepsilon} := 0.1 \cdot C_{c\varepsilon}$ $C_{r\varepsilon} = 0.015$

*Note: Correlative equations from references calculate Cc & Cr (i.e. void ratio based compression indices). Values calculated and used in analyses were conservatively assumed to be equal to the compression ratios (i.e. strain based compression ratios). This is conservative as the compression indices are divided by (1+eo) to calculate the compression ratios.

√

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JOB NO. 3530-03-1245 SHEET 1 OF 1
PHASE TASK 02
JOB NAME IRIB - Soil Parameters
BY AJA DATE 12/29/03
CHECKED BY JRW DATE 3/10/04

Purpose: Estimate Coefficient of Consolidation for Stratum 4 Sandy Clays

Method: Use Lab. consolidation test data in conjunction with published correlations with index test data

Solution: From Lab Consolidation test at BII-18, 143.5-145

→ $C_v \sim 375$ in²/day → but sample shows disturbance.

From EPRI Manual, Correlation with w_L(%) gives range of ~ 70-300 in²/day for C_v (at $w_L \sim 30\%$ for Stratum 4)

→ Assume Stratum 4 will consolidate Rapidly. No estimate of C_v is necessary. ✓

EPRI Manual, Kulhawy & Mayne, 1990

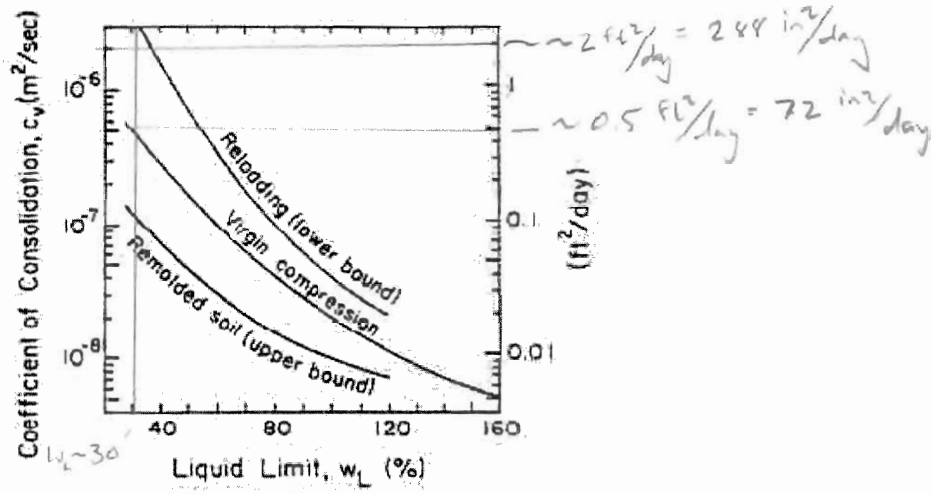

Figure 6-15. c_v versus w_L

Source: NAVFAC (21), p. 7.1-144.

Correlations with CPT and DMT Results

Several of the recent in-situ tests, particularly the piezocone and dilatometer, have been utilized to give field estimates of horizontal permeability (k_h) and horizontal coefficient of consolidation (c_{vh}) in clays. The basic equation for the horizontal coefficient of consolidation is:

$$c_{vh} = T\ R^2/t \qquad (6\text{-}16)$$

in which T = time factor, R = equivalent cavity (piezocone) radius, and t = time to achieve desired degree of excess pore water stress dissipation. The approach is based on cavity expansion theory, and therefore it depends on the rigidity index of the soil ($I_r = G/s_u$, in which G = shear modulus and s_u = undrained shear strength).

Figure 6-16 gives the piezocone time factors. Most commonly, the dissipation test is conducted for a period of time (t) that will allow 50 percent dissipation of the original insertion excess pore water stress (Δu). The time factor corresponding to this dissipation time then is introduced into Equation 6-16 to compute the coefficient of consolidation. Cylindrical theory would be used for a pore water sensor behind the tip, while spherical theory would be used for a sensor at the tip.

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JOB NO. 3530-03-1245 SHEET 1 OF 1
PHASE TASK 02
JOB NAME IRIB - Soil Parameters
BY AJA DATE 12/29/04
CHECKED BY JRW DATE 3/10/04

Purpose: Estimate the Coefficient of Secondary compression of Stratum 4 Sandy Clays.

Method: Use Lab consolidation Test data along with published information on Coefficient of Secondary compression

Solution: → From Lab test - C_α = 0.0012 - 0.0013 (Sheets Attached)

→ from EPRI Manual, C_α for Over Consolidated Soils, is usually between 0.001 - 0.0005.

↳ Assume C_α for Stratum 4 = 0.0013. ✓

EPRI Manual, Kulhawy + Mayne, 1990

time, as shown below:

$$C_{\alpha\epsilon} = \partial\epsilon/\partial \log t \tag{6-18}$$

$$C_{\alpha e} = \partial e/\partial \log t \tag{6-19}$$

For a wide variety of clays, $C_{\alpha\epsilon}$ has been correlated to the natural water content, as shown in Figure 6-18. Based on this figure, the following was suggested for NC clay:

$$C_{\alpha\epsilon} \approx 0.0001\ w_n \tag{6-20}$$

Examination of available data indicates that $0.0005 < C_{\alpha\epsilon} < 0.001$ for most OC clays.

For NC clays, the ratio of the coefficient of secondary compression to the compression index ($C_{\alpha e}/C_c = C_{\alpha\epsilon}/CR$) is relatively constant for a given soil. Table 6-3 lists $C_{\alpha e}/C_c$ for a variety of clays. On the average, the value of $C_{\alpha e}/C_c$ is 0.04 ± 0.01 for the inorganic clays and silts. For the organic clays and silts, the value averages 0.05 ± 0.01. For the peats, the value averages 0.075 ± 0.01. This constant also is applicable for inorganic OC clays that have $C_{\alpha e}/C_{ur}$ equal

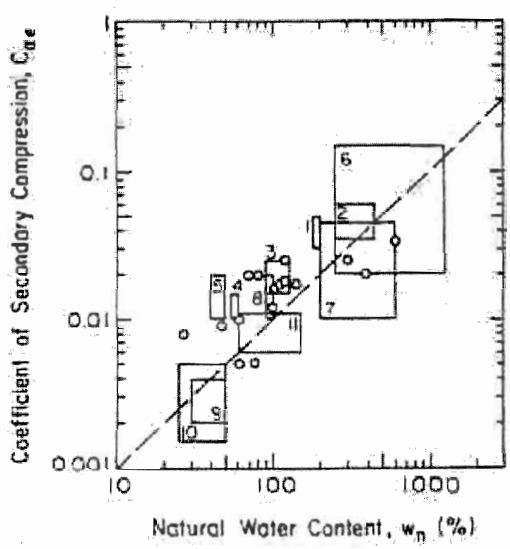
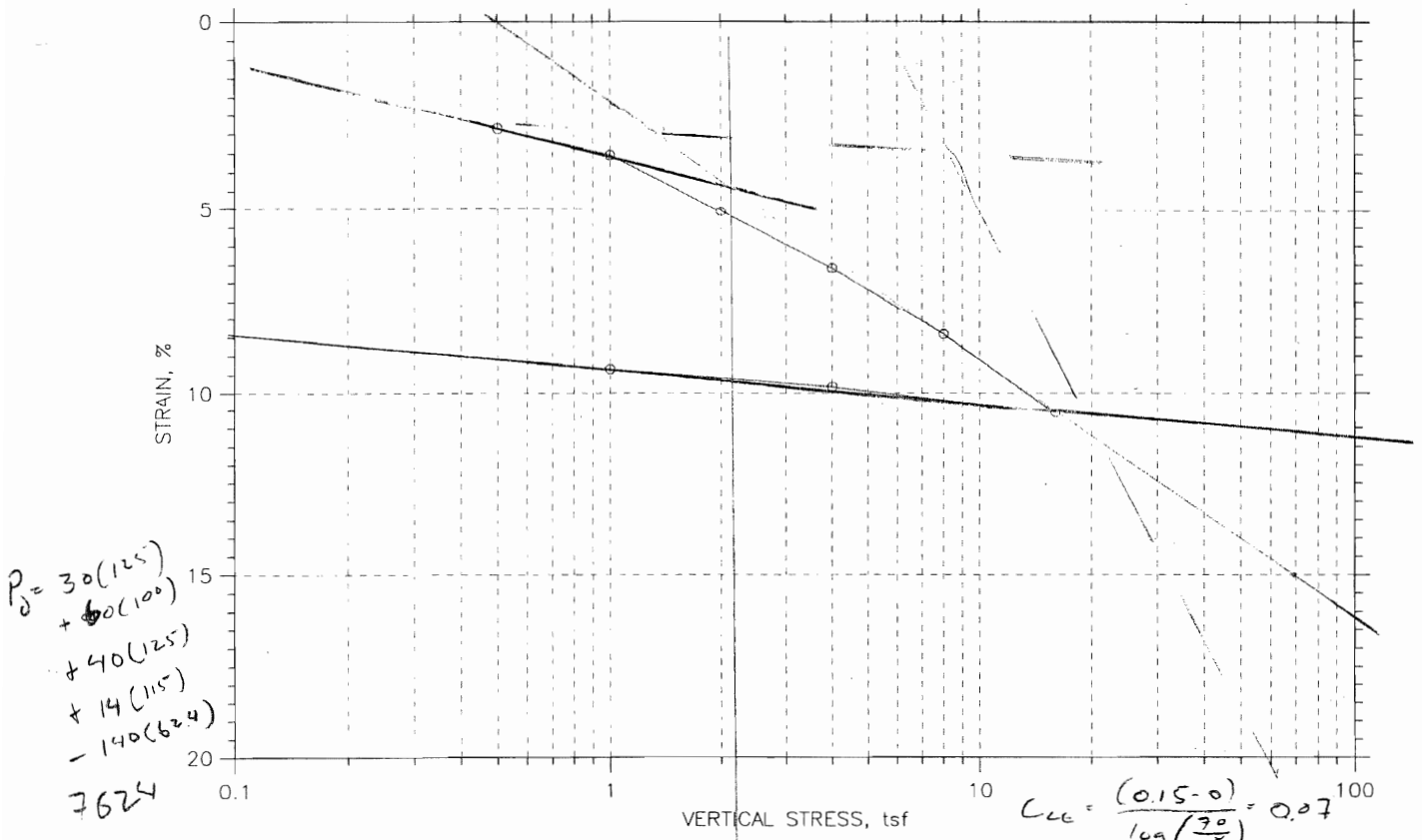


Figure 6-18. Coefficient of Secondary Compression versus Water Content for NC Clays

Source: Mesri (24), p. 125.

CONSOLIDATION TEST DATA

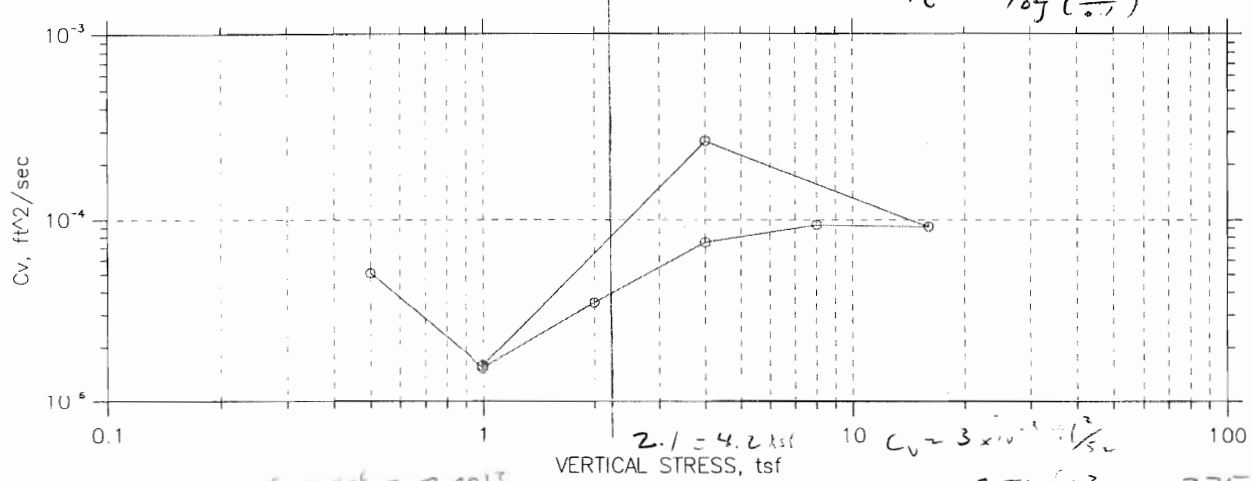
SUMMARY REPORT



P_o = 30(125) + 60(100) + 40(125) + 14(115) − 140(62.4) = 7624

$C_{cc} = \frac{(0.15-0)}{\log\left(\frac{7.0}{0.5}\right)} = 0.07$

$C_{rc} = \frac{0.113-0.095}{\log\left(\frac{100}{0.1}\right)} = 0.006$



2.1 = 4.2 ksf

$C_v \approx 3 \times 10^{-3}$ ft²/sec = 950 ft²/yr = 375 in²/day ✓

C_α @ 2 ksf = 4 ksf = 0.0013

Project: Indian River Inlet Bridge	Location: Sussex County, Delaware	Project No.: LB1952
Boring No.: BII 18	Tested By: MLT	Checked By: JAC
Sample No.: 9698	Test Date: 11-21-03	Depth: 143.5-145
Test No.: UII-6	Sample Type: 3 inch Tube	Elevation: Not given
Description: Gray, CLAYEY SAND (SC)		
Remarks: Material possibly disturbed. Refer to VGS shelby tube log BII-18 and digital photographs BII-18 a & b.		

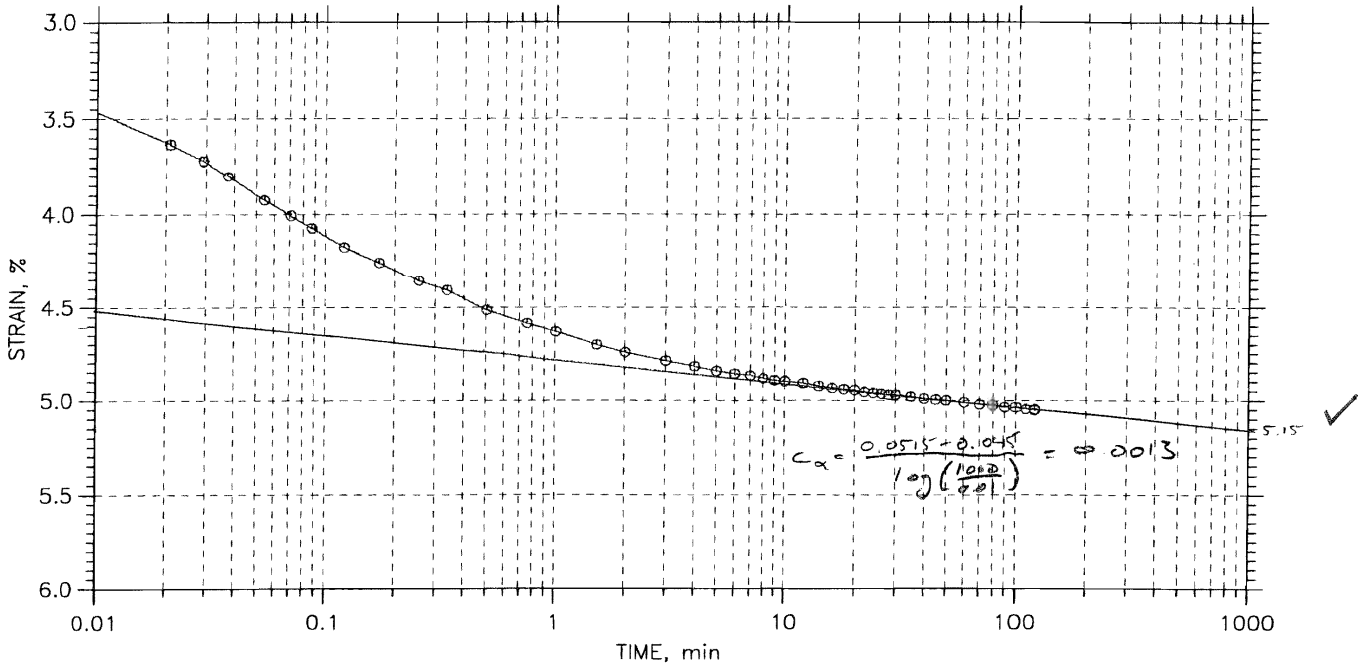
Tue, 02-DEC-2003 11:00:24

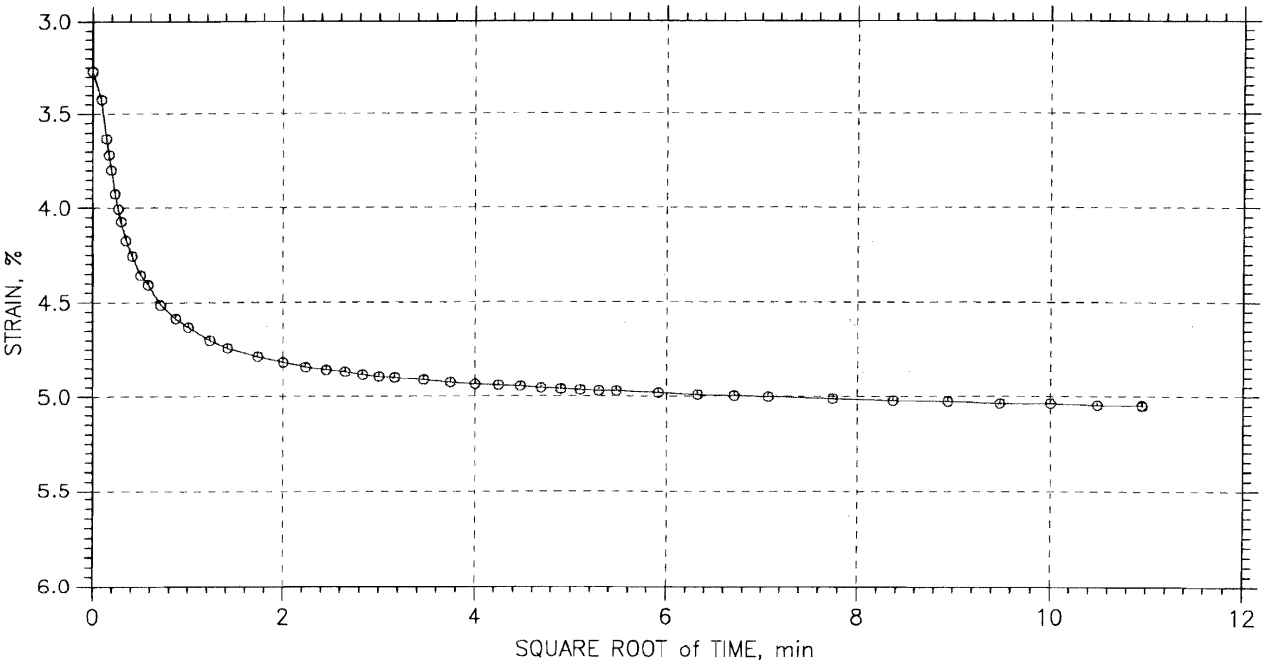
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 3 of 8

Stress: 2. tsf





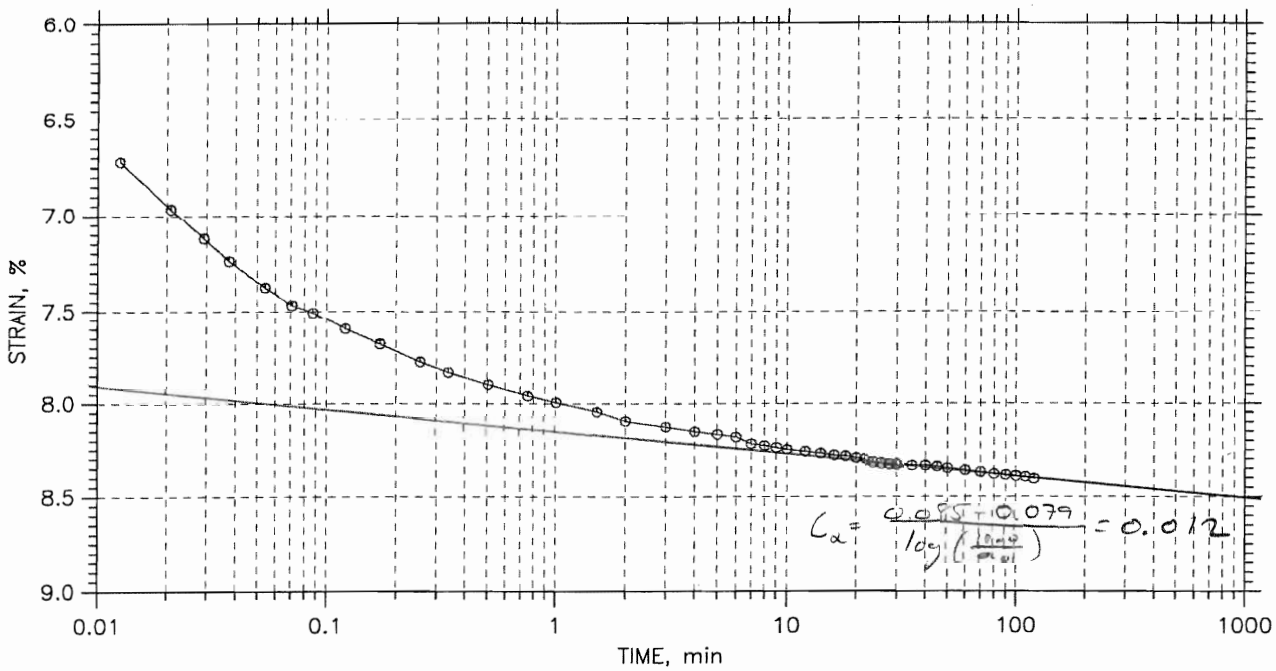
Project: Indian River Inlet Bridge	Location: Sussex County, Delaware	Project No.: LB1952
ring No.: BII-18	Tested By: MLT	Checked By: JAC
Sample No.: 9698	Test Date: 11-21-03	Depth: 143.5-145
Test No.: UII-6	Sample Type: 3 inch Tube	Elevation: Not given
Description: Gray, CLAYEY SAND (SC)		
Remarks: Material possibly disturbed. Refer to VGS shelby tube log BII-18 and digital photographs BII-18 a & b.		

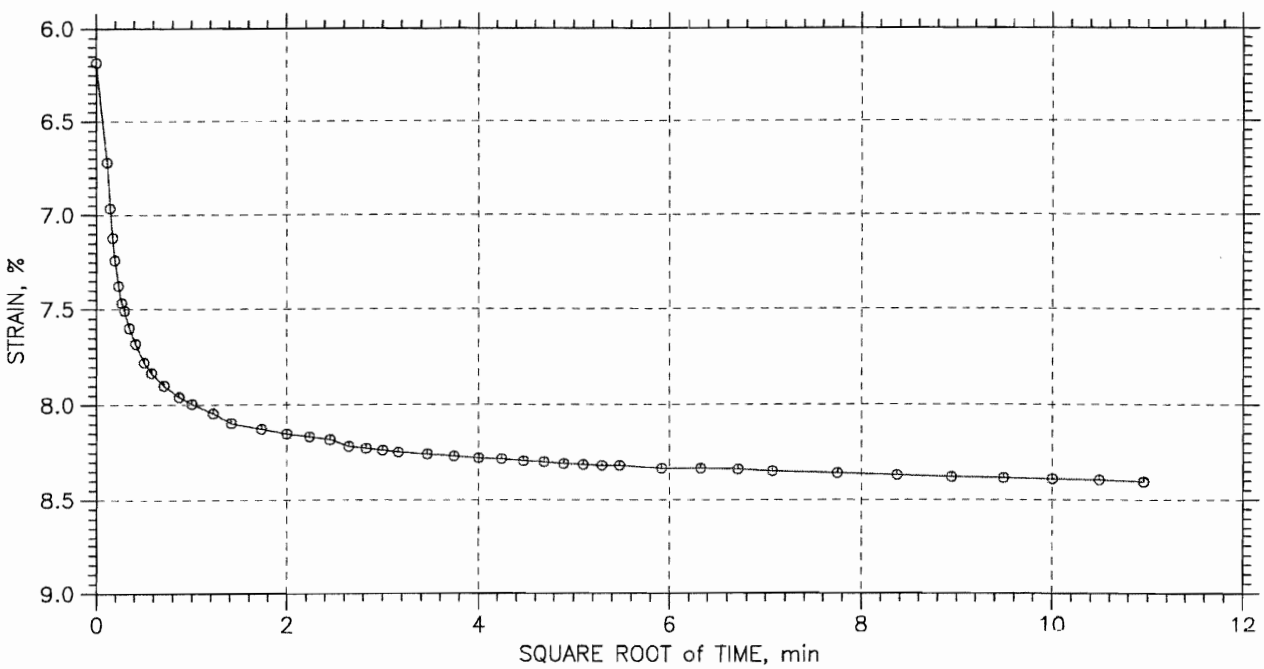
CONSOLIDATION TEST DATA

TIME CURVES

Constant Load Step: 5 of 8

Stress: 8. tsf





Project: Indian River Inlet Bridge	Location: Sussex County, Delaware	Project No.: LB1952
Boring No.: BII-18	Tested By: MLT	Checked By: JAC
Sample No.: 9698	Test Date: 11-21-03	Depth: 143.5-145
Test No.: UII-6	Sample Type: 3 inch Tube	Elevation: Not given
Description: Gray, CLAYEY SAND (SC)		
Remarks: Material possibly disturbed. Refer to VGS shelby tube log BII-18 and digital photographs BII-18 a & b.		

e. 02-DEC-2003 11:00:25