LOUISIANA DEPARTMENT OF

TRANSPORTATION AND DEVELOPMENT

PILE CAPACITY GUIDE

Pavement & Geotechnical Design Section - 2001

Pile Capacity Guide

COLUMN	DESCRIPTION	METRIC	US
1	Top elevation of soil strata Given on boring log sheet	m	ft
2	Bottom elevation of soil strata Given on boring log sheet	m	ft
3	Soil Strata Thickness, T (1) - (2)	m	ft
4	Soil Cohesion ($c = q_u / 2$) q_u given on boring log sheet	kN/m^2	tsf
5	Soil Friction Angle, ϕ Obtained from SPT or given $\delta = \phi$	deg	deg
6	Wet Soil Unit Weight, γ_{wet} (on log sheet)if not, use .060 TSF	kN/m^3	tcf
7	Submerged Soil Unit Weight, γ_{sub} [(6) - (γ_{H_2O})] $\gamma_{H_2O} = 9.807\ kN/m^3$ $\gamma_{H_2O} = 0.0312\ ton/ft^3$	kN/m^3	tcf
8	Thickness * Soil Unit Weight, T * γ (3) * (For Soils Above the Water Table Use (6) (For Soils Below the Water Table Use (7)	kN/m^2	tsf
9	Effective Vertical Overburden Pressure at the Soil Strata Interface of Depth Z, σ'_v Σ rows in (8)	kN/m^2	tsf
10	Average Effective Vertical Overburden Pressure for Each Soil Strata, σ'_{avg} (10) = $[[(9)_{Row} + (9)_{Row-1}] / 2] + (9)_{Row-1}$	kN/m^2	tsf
11	Coefficient of Lateral Stress, K PPC & Timber K = 1.3 Steel Pipe & Step-Tapered K = 1.0	---	---
12	Tan ϕ, tangent of (5)	---	---
13	σ'_{avg}KTanϕ, (10) * (11) * (12)	kN/m^2	tsf
14	Friction Limit, f_{lim} SEE FIGURE 2	kN/m^2	tsf
15	Limiting Pile/Soil Adhesion for Cohesive Soils, C_a Figure 2A/2B Type A = concrete , Type B = steel	kN/m^2	tsf

PILE DATA

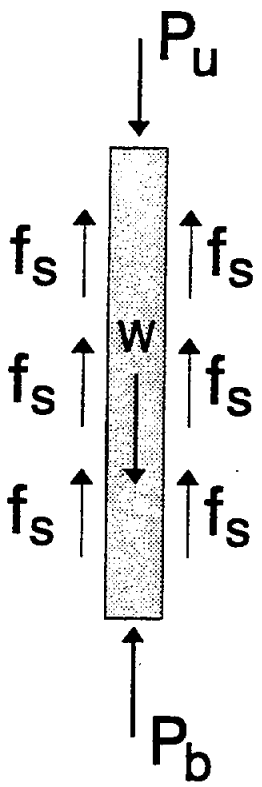
	Timber	14"Sq.	16"Sq.	18"Sq.	24"Sq.	14"Rd.	16"Rd.	18"Rd.
Pile Perimeter,P (Sq. Ft./Ft.)	2.62	4.66	5.32	6.0	8.0	3.66	4.18	4.71
Tip Area, A_{tip}	-	1.36	1.76	2.25	4.0	1.06	1.38	1.77

Pile Capacity Guide

COLUMN	DESCRIPTION	METRIC	US
16	Pile Surface Contact Area for Each Soil Strata, A_s (p) * (3) pile perimeter * depth	m^2	ft^2
17	Frictional Shear Stress, q_s Cohesive: $q_s = c_a$, (15) Cohesionless: q_s = Use the lesser value of (13) or (14)	kN/m^2	tsf
18	Frictional Resistance, f_s (16) * (17)	kN	tons
19	Ultimate Skin Resistance, P_f Σ (18) for each soil strata	kN	tons
20	Bearing Capacity Factor, N_q Figure 7	---	---
21	Alpha Coefficient, α Figure 6	---	---
22	Bearing Pressure in Cohesionless Soils, $(\alpha * N_q * \sigma_v)$ [(21) * (20) * (9)]	kN/m^2	tsf
23	Maximum Unit Pile Point Resistance for cohesionless soils Fig. 8-A, 8-B	kN/m^2	tsf
24	Cohesive Bearing Pressure (see fig. 9) [(4)*N_c + (9)] for D/B>4, N_c=9 (ZERO FOR COHESIONLESS SOILS)	kN/m^2	tsf
25	Bearing Pressure for Cohesionless Soils, q_{rb} pick smaller of (22) & (23) for cohesionless soils	kN/m^2	tsf
26	Ultimate Bearing Resistance, P_{rb} (25) or (24)* A_{tip} See Pile Data for A_{tip}	kN	tons
27	TOTAL Resistance, P_u (19) + $(26)_{Row+1}$	kN	tons

Figure 1

STATIC PILE CAPACITY FORCE DIAGRAM



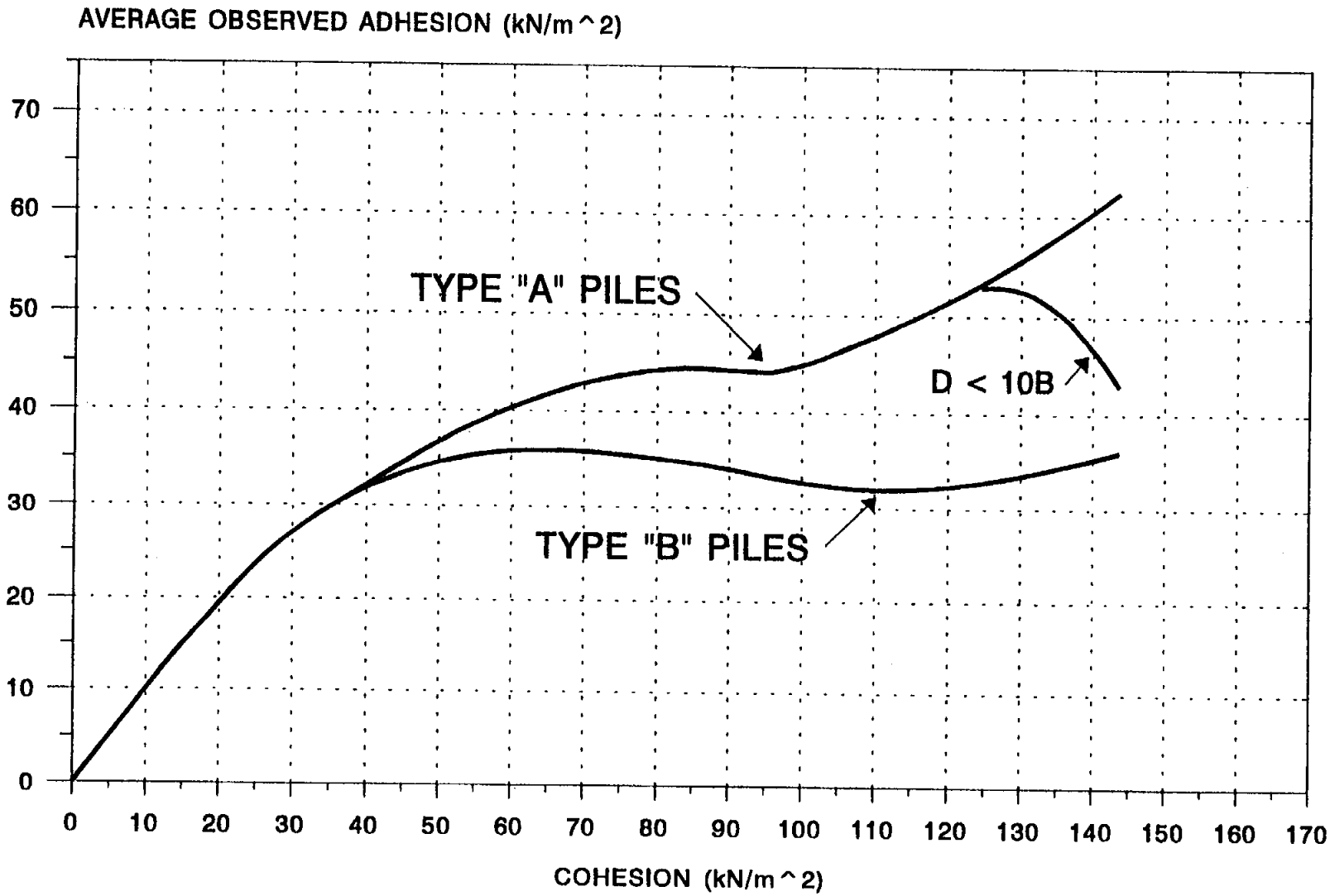
$$P_u = P_f + P_b - W \quad \text{(Equ. 1)}$$

Figure 2

FRICTION LIMITS, f_{lim}

SOIL TYPE	CONCRETE PILE	STEEL PILE
Clean Sand	1.00	0.75
Silty Sand	0.75	0.65
Clean Silt	0.60	0.50
Sandy Clay, Clayey Silt	0.40	0.40

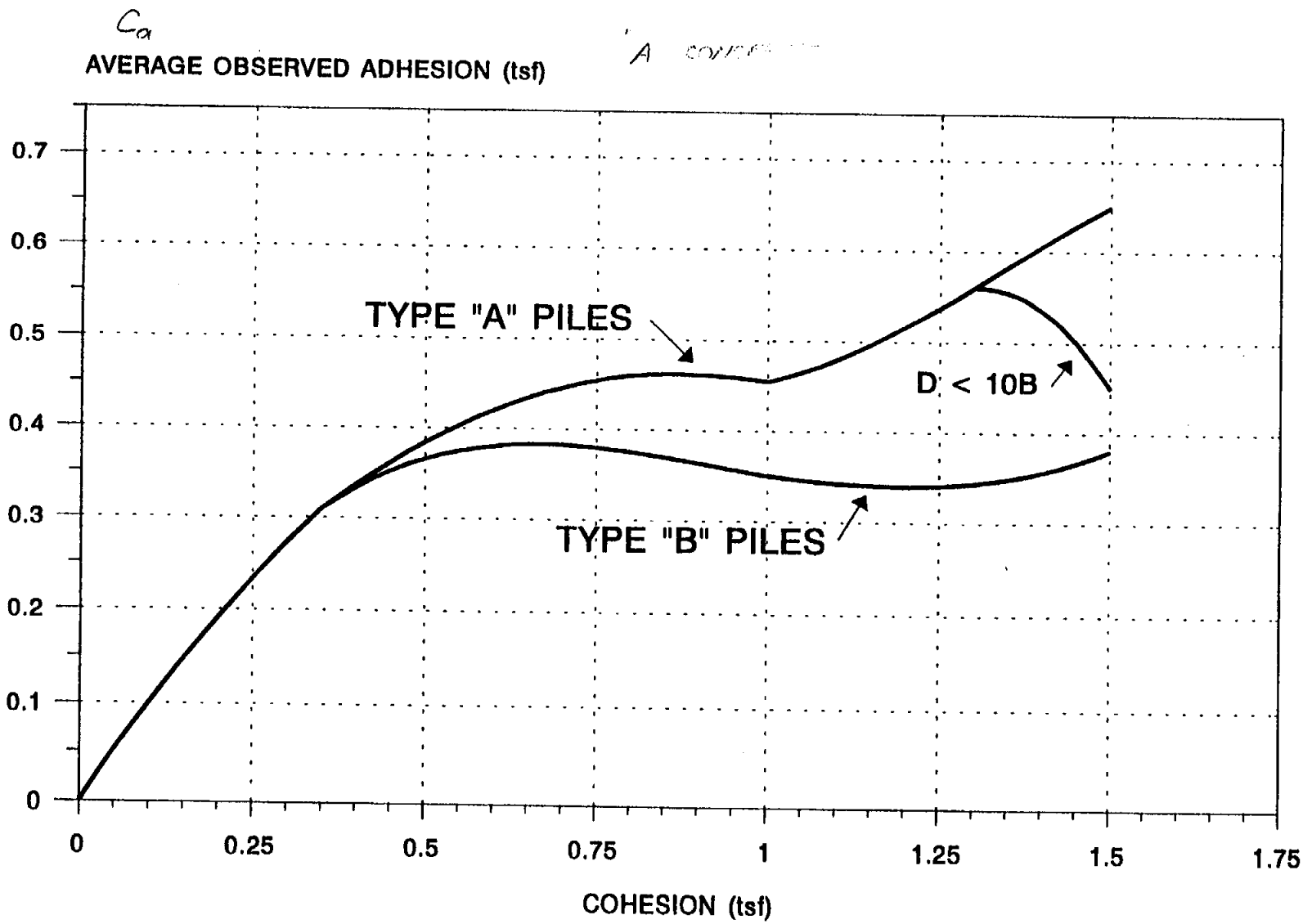
LIMITING ADHESION FOR SOFT TO STIFF CLAYS (TOMLINSON)



LA DOTD-PAVEMNET & GEOTECHNICAL DESIGN
PILELOAD PROGRAM
FIGURE 2-A

METRIC

LIMITING ADHESION FOR SOFT TO STIFF CLAYS (TOMLINSON)



DOTD-PAVEMENT & GEOTECHNICAL DESIGN
PILELOAD PROGRAM
FIGURE 2-B

U.S SYSTEM

FIGURE 3-A METRIC

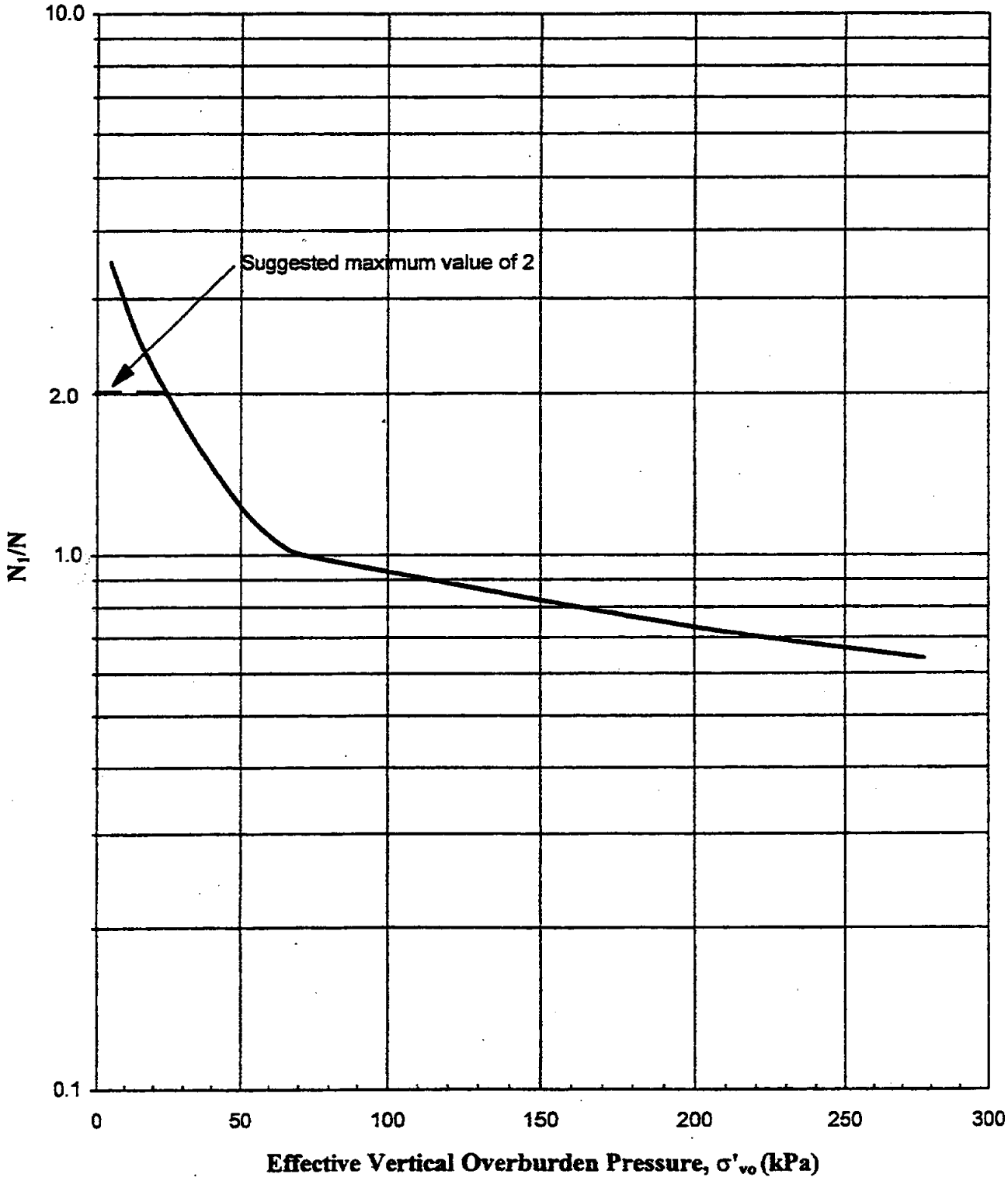
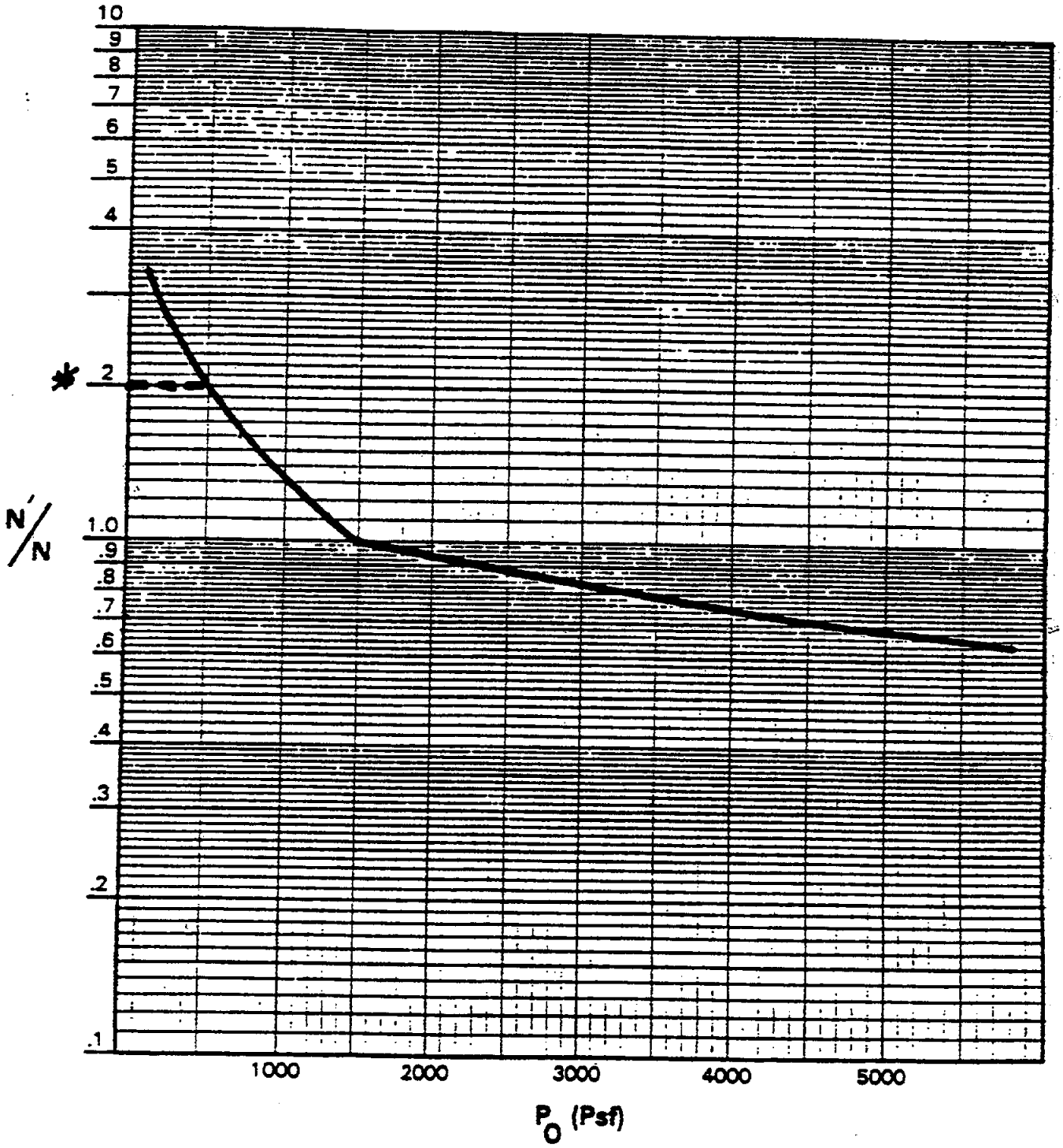


Figure 9-2: Relationship to Correct SPT N-values for Overburden Pressure (Bazaraa, 1967)

FIGURE 3-B U.S. SYSTEM

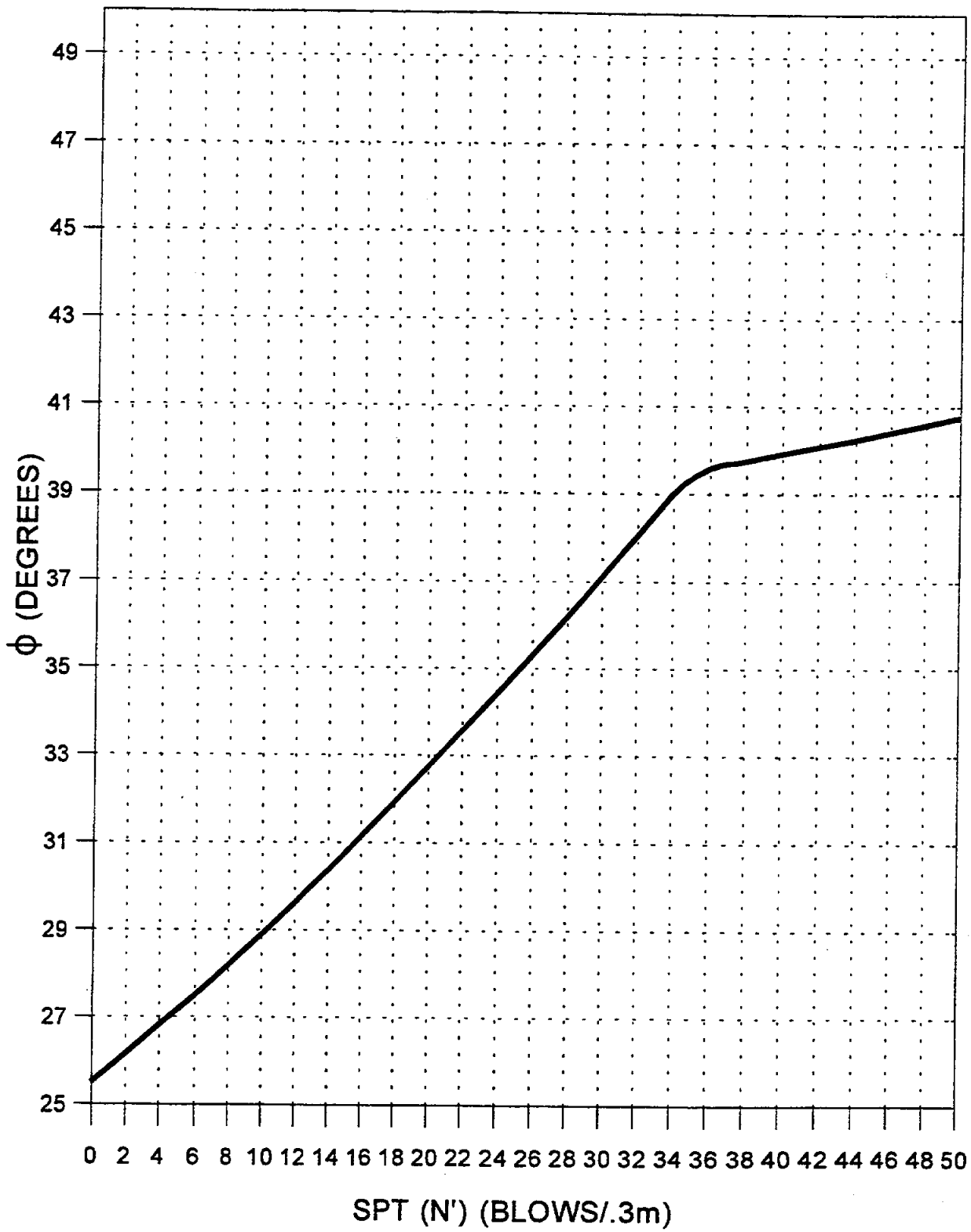


Where: N' = Corrected SPT Blow Count
N = SPT value
P_o = Existing effective vertical overburden pressure
* = Suggested Maximum Value

Reference: Based on 1967, Bazaraa, The Use of Standard Penetration Test for Estimating Settlement of Shallow Foundation on Sand.

FIGURE 12 ***CORRECTING SPT (N) BLOW COUNTS***

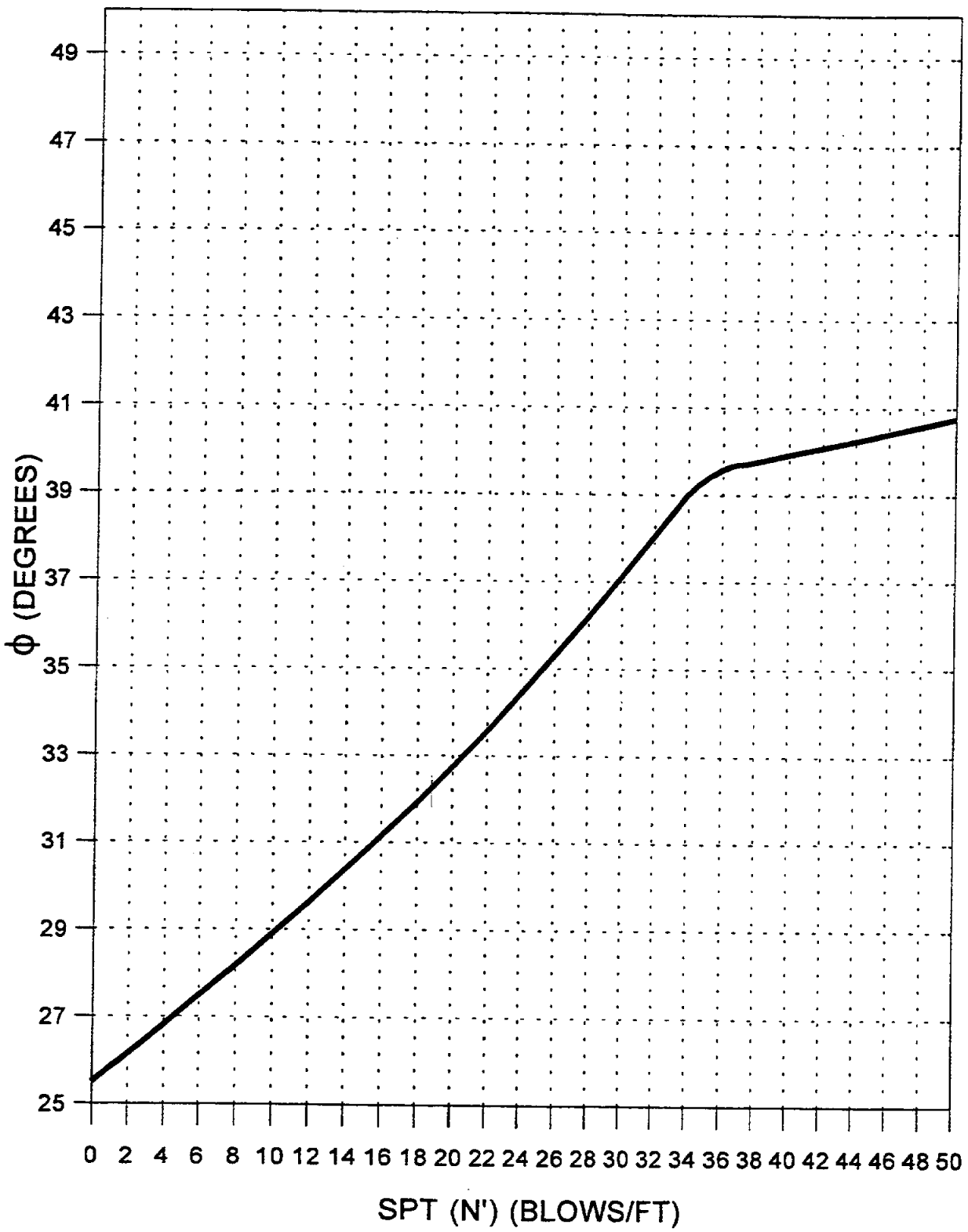
ϕ vs.SPT (N')



LA DOTD-PAVEMENT & GEOTECHNICAL DESIGN
P ELOAD PROGRAM
FIGURE 4-A

METRIC

Φ vs.SPT (N')

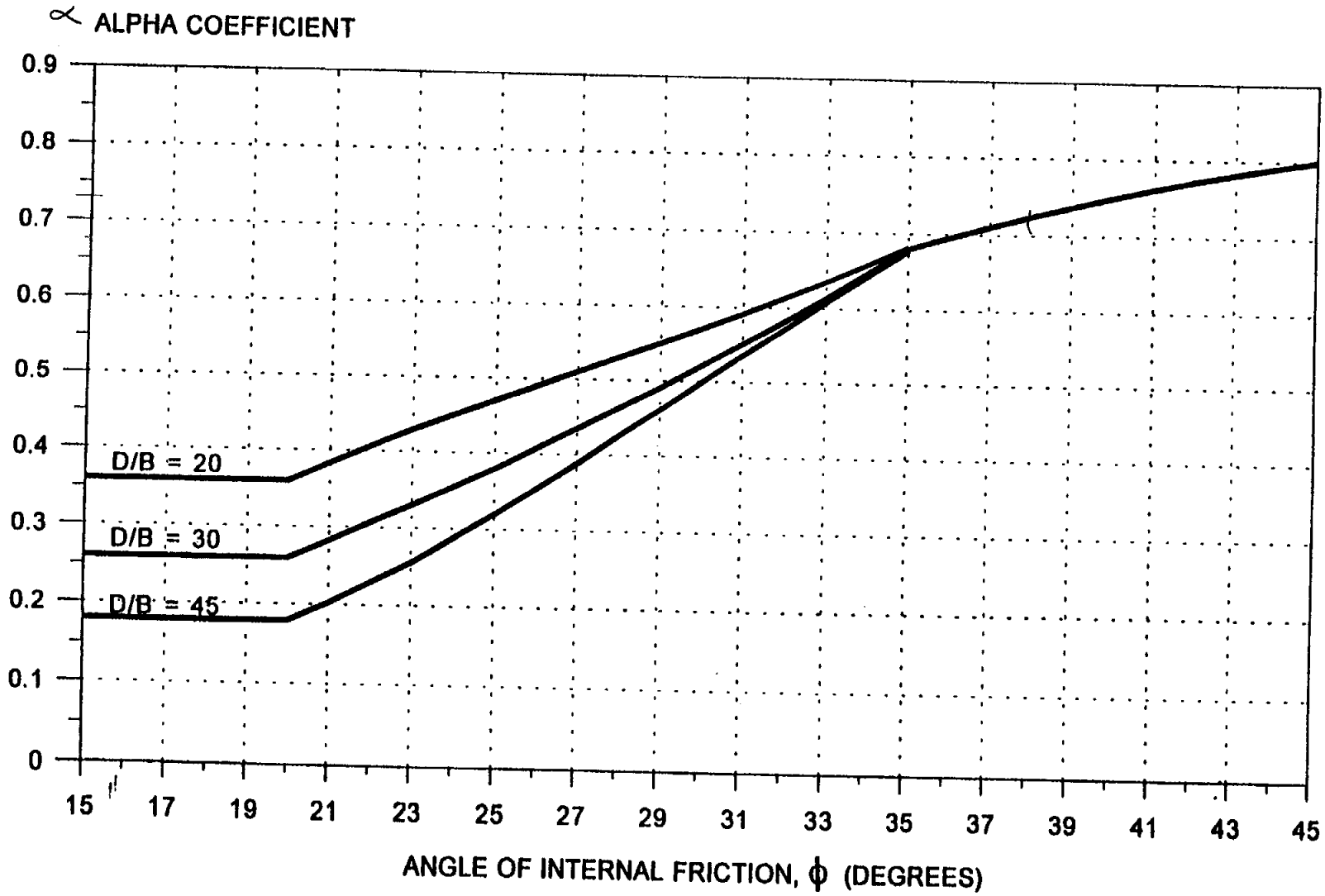


DOTD-PAVEMENT & GEOTECHNICAL DESIGN
ELOAD PROGRAM
URE 4-B

U.S. SYSTEM

RELATIONSHIP BETWEEN ALPHA COEFFICIENT AND FRCTIONAL ANGLE FOR COHESIONLESS SOILS

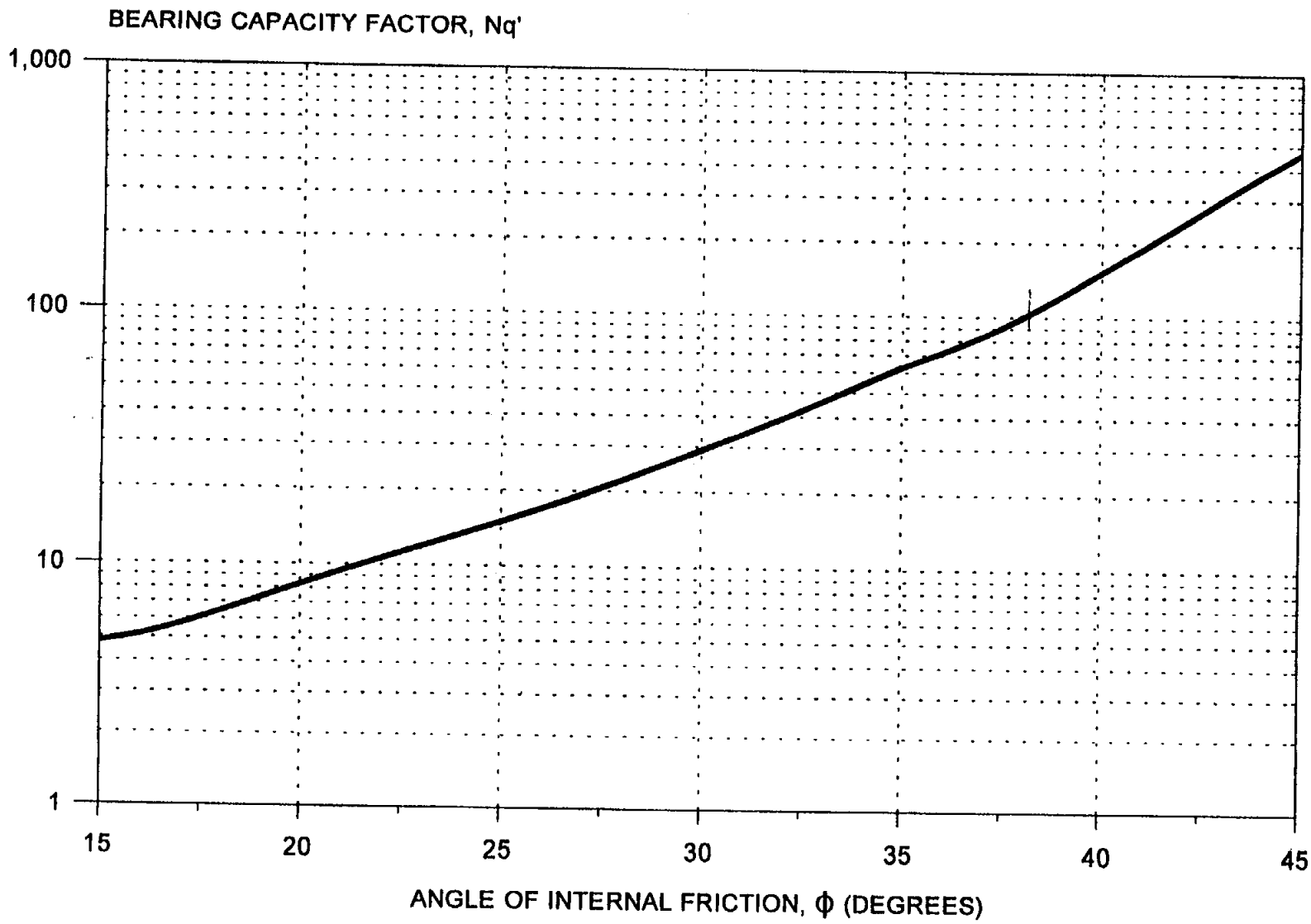
(MODIFIED BOWLES, 1977)



LA DOTD-PAVEMENT & GEOTECHNICAL DESIGN
PILELOAD PROGRAM
FIGURE 6

METRIC & U.S. SYSTEMS

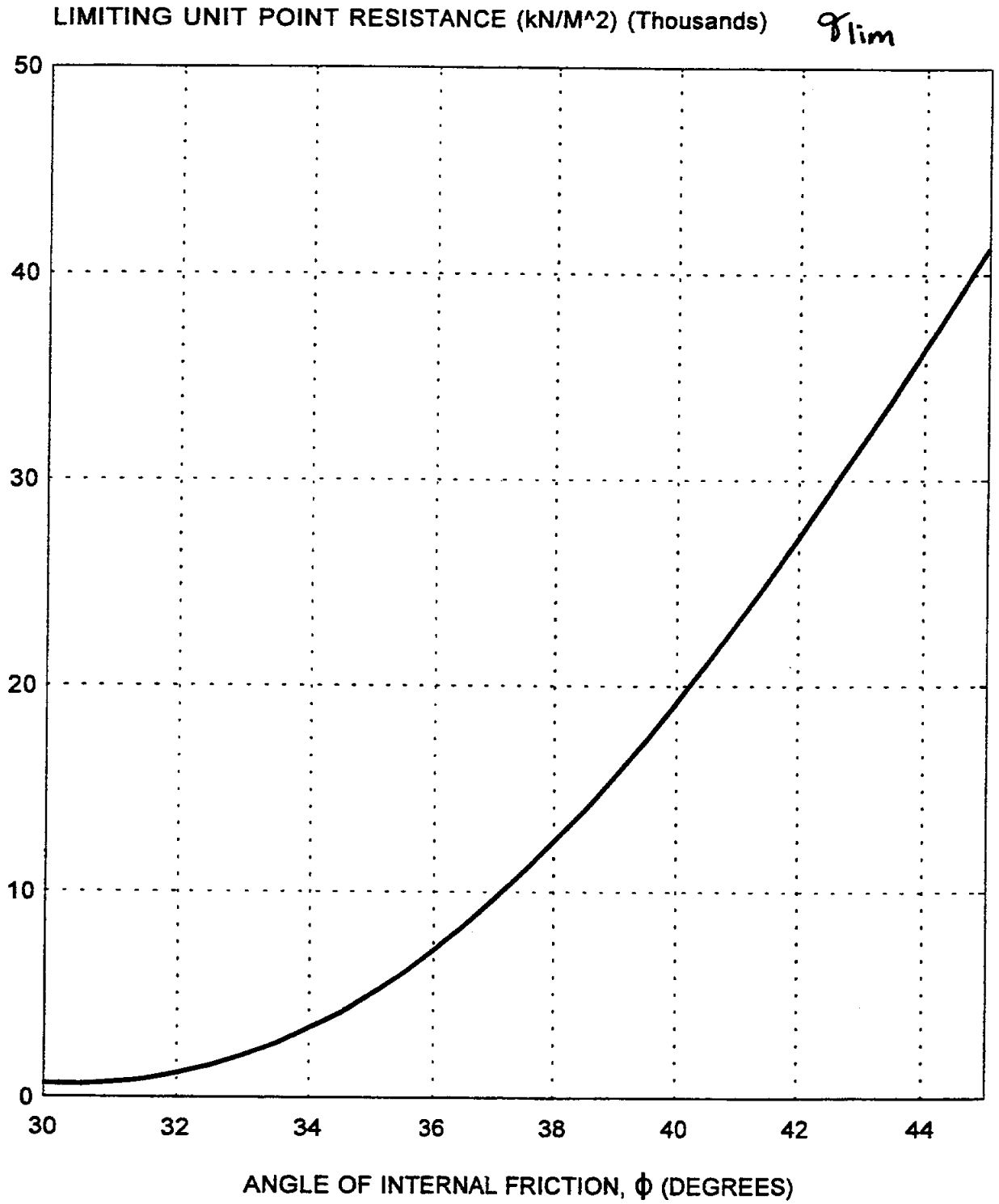
ESTIMATING BEARING CAPACITY FACTORS Nq'
(MODIFIED BOWLES, 1977)



LA DOTD-PAVEMENT & GEOTECHINCAL
PILELOAD PROGRAM
FIGURE 7

METRIC & U.S. SYSTEMS

RELATIONSHIP BETWEEN MAXIMUM UNIT PILE POINT RESISTANCE AND FRICTION ANGLE FOR COHENSIONLESS SOILS

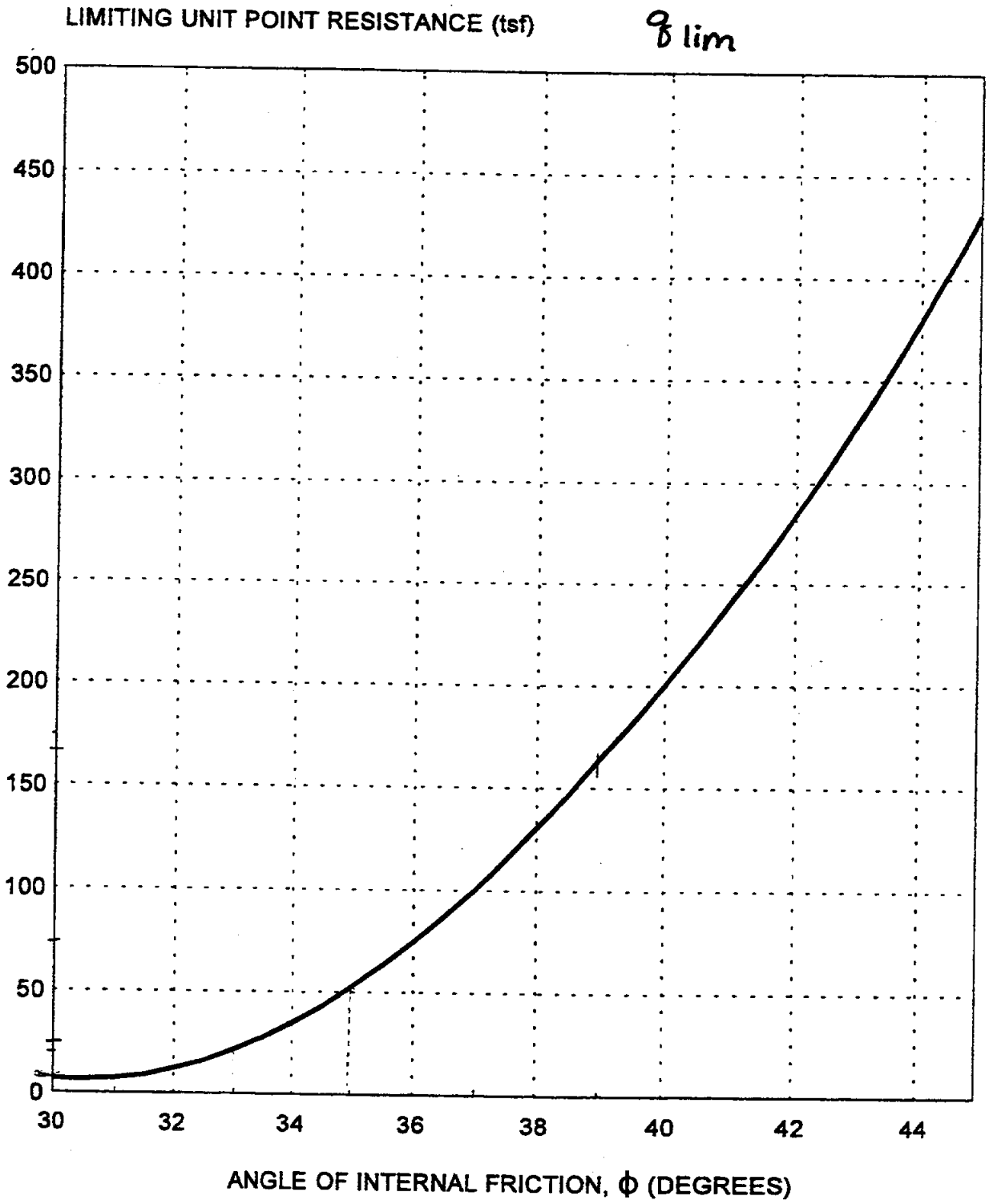


29° –
30° –
31° –
32° –
33° –
34° –
35° –
36° –
37° –

→TD-PAVEMENT & GEOTECHNICAL
ILELOAD PROGRAM
1 URE 8-A

METRIC

RELATIONSHIP BETWEEN MAXIMUM UNIT PILE POINT RESISTANCE AND FRICTION ANGLE FOR COHENSIONLESS SOILS



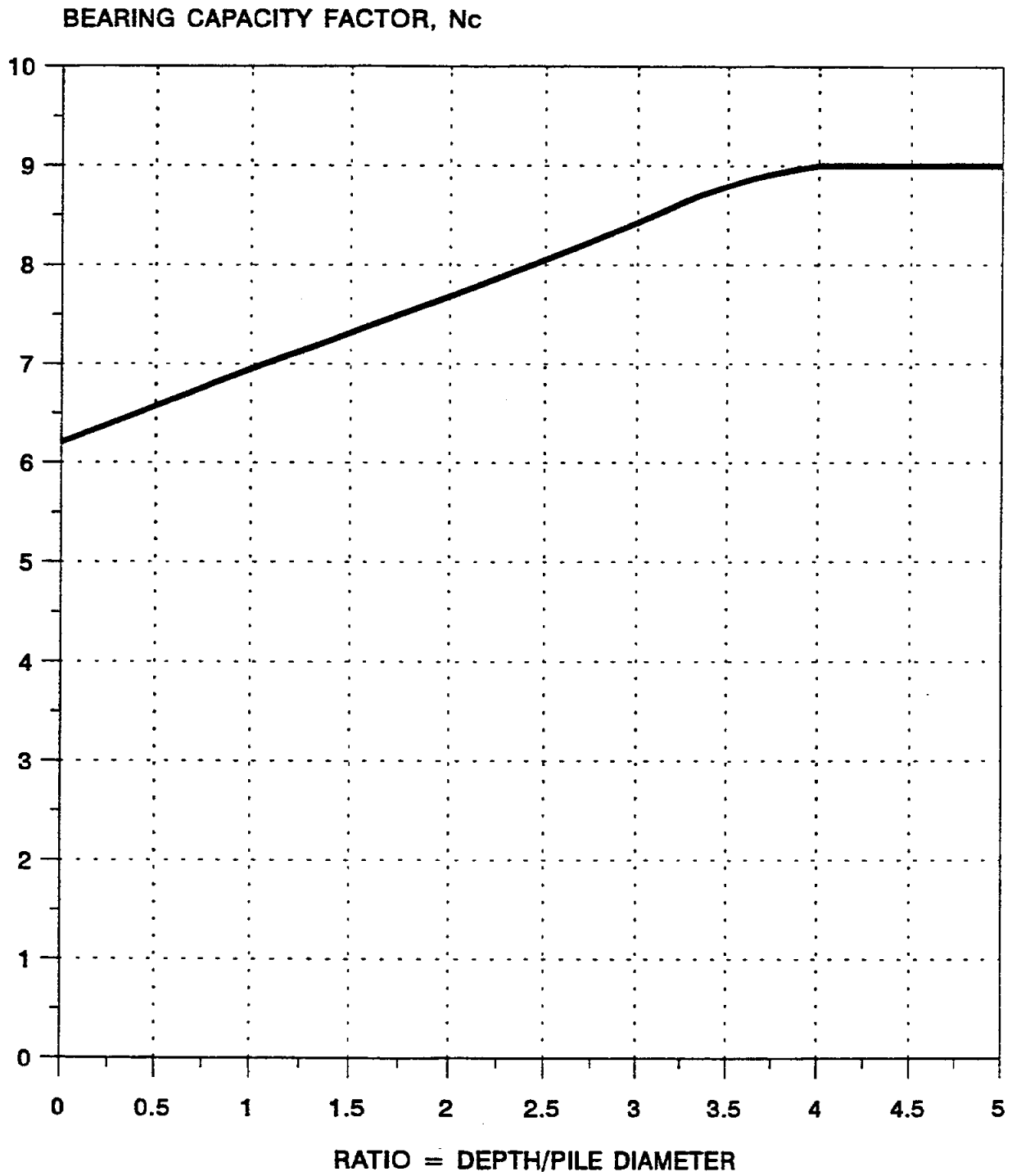
OTD-PAVEMENT & GEOTECHNICAL DESIGN
ELOAD PROGRAM
GURE 8-B

29° - 6.8
30° - 7.0
31° - 7.1
32° - 12.0
33° - 20.0
34° - 40.0
35° - 65.0
36° - 75.0
37° - 100.0
38° - 130.0

U.S. SYSTEM

39° - 165.0
40° - 200.0

BEARING CAPACITY FACTOR, Nc
FOR FOUNDATIONS IN CLAY
(SKEMPTON, 1951)



LADOTD-PAVEMENT & GEOTECHNICAL DESIGN
P ELOAD PROGRAM
FIGURE 9

METRIC & U.S. SYSTEM

PILE CAPACITY

EXAMPLE CALCULATIONS

PILE CAPACITY

FRICTIONAL RESISTANCE | $P_f = \Sigma f_s \cdot$ PILE surface Area

$$f_s = \underbrace{C_a}_{\text{cohesive soils}} + \underbrace{K \cdot \sigma_o' \cdot \tan \phi}_{\text{SANDS \& SILTS}}$$

(f_s → TSF; C_a ← adhesion)

(CLAYS) C_a = limiting pile/soil adhesion for cohesive soils. FIGURE 2-B, (Tomlinson curves)

(SANDS)

Pile Type		
prestressed Concrete piles, P.P.C.	> Type "A",	$K = 1.3$ (SAND)
Timber Piles		
Steel Pipe Piles	> Type "B",	$K = 1.0$ (SAND)
Step Tapered Piles		

σ_o' = Effective Overburden pressure - To middle of SAND LAYER (use γ_{SUB}, $\gamma_{SUB} = \gamma_{WET} - \gamma_{WATER}$)

To Get ϕ: (GIVEN SPT Value N_{field}) (SANDS)

use effective vertical Overburden Pressure, σ_o', FIG. 9-2, GET N'/N, Then Get ϕ From FIG. 4-B (using N') ($N'_{corr} = N_{field} \cdot$ value)

FRICTION LIMIT - (SANDS)

$$f_s = K \cdot \sigma_o' \cdot \tan \phi \le f_{lim} \qquad \phi \approx \delta = \text{SOIL-PILE FRICTION ANGLE}$$

(EQ. 8.33, p. 454, DAS)

where f_{lim} is the following:

SOIL DESCRIPTION	TYPE "A" Pile (f_{lim})	Type "B" Pile (f_{lim})
Clean Sand	1.00 TSF	.75 TSF
Clean Silt / Fine Sand	.75 TSF	.65 TSF
CL. SAND / CL. Silt	.40 TSF	.40 TSF
SA. SILT	.60 TSF	

BEARING RESISTANCE $P_b = q_b \cdot$ Tip Area

Ultimate Bearing Pressure (q_b)

AT END OF PILE

$$q_b = \underbrace{c N_c}_{\text{Cohesive Soils}} + \underbrace{\sigma_o' \alpha N_q}_{\text{SANDS \& SILTS}}$$

CLAYS:

- C = soil cohesion ($c = q_u/2$)
- $N_c = 9$, Skempton's factors, if $\frac{\text{Depth}}{\text{Pile Diam.}} < 4$, use FIG. 9 to get N_c

SANDS:

- σ_o' = Effective Overburden Pressure - (bottom of pile) or middle (avg) of layer under pile end.
- α = depth / width ratio : FIG. 6
- N_q = Bearing Capacity Factor : FIG. 7 - Bowles - 1977

$$q_b = \sigma_o' \alpha N_q \leq \text{MAX. Unit Pile Point Resistance}$$

(FIG. 8-B) (Meyerhof, 1976)

$P_b = (q_b \cdot \text{TIP AREA})$

Ultimate Pile Capacity:

$$P_{ULT} = P_f + P_b$$

$$P_{ULT(ALLOWABLE)} = \frac{P_{ULT}}{F.S.}$$

USE F.S = 2.0 for Test Piles
F.S. = 3.0 No Test Piles - "ON System"

Pile Capacity Worksheet "EXAMPLE"

PARISH: LASALLE
ROUTE: BAYOU FUNNY LOUIS
BORING: L2
STATION:
LOCATION:

PILE TYPE: 14" P.P.C.
PILE LENGTH:

DES. LOAD (DL): 55.0
(2.5x DL): 138.0 TONS

PILE PERIMETER (p): 4.67 ft.
AREA OF PILE TIP (A_{tip}): 1.361 ft^2

SHEET 1 OF 1
ENGINEER: R.J.J.
DATE: 2-15-95

Column / Row	Soil Strata 1 Elevation Top	2 Elevation Bot.	3 T	Soil Properties 4 c	5 $\delta=\phi$	6 γ_{wet}	7 γ_{sub}	Cohesionless Friction 8 $T\times\gamma$	9 σ'_v	10 σ'_{avg}	11 K	12 Tan δ	13 $\sigma'_{avg}K\tan\delta$	14 f_{lim}	Cohesive Friction 15 Ca	Friction Resistance 16 A_s	17 q_s	18 f_s	19 P_f	Cohesionless Bearing 20 N_q	21 α	22 $\alpha N_q\sigma'_v$	23 q_{lim}	Cohesive Bearing 24 $cN_c+\sigma'_v$	Bearing Resistance 25 q_{rb}	26 P_{rb}	Tot 27 P_u
1	79.6	76.6	3		37°	.06	.028	.084	.084	.042	1.3	.75	.041	.40	—	14.01	.041	.57	.57	90	.70	5.3	100.0		5.3	7.2	
2	76.6	65.6	11		29°	.06	.028	.308	.392	.238	1.3	.55	.170	.75	—	51.37	.170	8.73	9.31	29	.54	6.1	6.8		6.1	8.3	
3	65.6	62.6	3		31°	.06	.028	.084	.476	.434	1.3	.60	.338	.75	—	14.01	.338	4.74	14.0	34	.55	8.9	7.1		7.1	9.6	
4	62.6	57.6	5		32°	.06	.028	.14	.616	.546	1.3	.62	.44	.75	—	23.3	.44	10.27	24.27	40	.56	13.8	12.0		12.0	16.3	
5	57.6	52.6	5		37°	.06	.028	.14	.756	.686	1.3	.75	.669	.75	—	23.3	.669	15.62	39.89	90	.70	47.6	100.0		47.6	64.8	80
6	52.6	47.6	5		34°	.06	.028	.14	.896	.826	1.3	.67	.719	.75	—	23.3	.72	16.81	56.70	56	.60	30.1	40.0		30.1	40.9	66
7	47.6	42.6	5		31°	.06	.028	.14	1.036	.966	1.3	.60	.753	.75	—	23.3	.75	17.50	74.20	34	.52	18.3	7.1		7.1	9.7	90
8	42.6	37.6	5		32°	.06	.028	.14	1.176	1.106	1.3	.62	.891	.75	—	23.3	.75	17.50	91.70	40	.54	25.4	12.0		12.0	16.3	204
9	37.6	32.6	5		37°	.06	.028	.14	1.316	1.246	1.3	.75	1.215	.75	—	23.3	.75	17.50	109.2	90	.70	82.9	100.0		82.9	112.8	114
10	32.6	27.6	5	.30		.06	.028	.14	1.456						.27	23.3	.27	6.30	115.5	—				4.16	5.6	118.
11	27.6	22.6	5	.10		.06	.028	.14	1.596						.10	23.3	.10	2.33	117.8	—				2.50	3.4	129.
12	22.6	17.6	5	.75		.06	.028	.14	1.736						.45	23.3	.45	10.51	128.3	—				8.49	11.6	141.
13	17.6	12.6	5	.85		.06	.028	.14	1.876						.45	23.3	.45	10.51	138.8	—				9.53	12.9	151.
14	12.6	7.6	5	.85		.06	.028	.14	2.016						.45	23.3	.45	10.51	149.3	—				9.66	13.1	
15																											
16																											
17																											
18																											
19																											
20																											

ADJUSTED P_u FOR WEIGHT OF PILE: $P_{ULT\,ADJ} = P_u - W_{TOTAL}$

$W_{TOP} = \gamma_{TOP} * A_{tip} * L$

$W_{BOT} = \gamma_{TOP} * A_{tip} * L$

$W = W + W$

"OPTIONAL"

$L = 20$ ft.

$L =$

$W_{TOP} = 150 \frac{lb}{ft^3} \times 1.361\ ft^2 \times 20\ ft.$

$W_{TOP} = 4{,}083\ lb = 2.0$ TONS

$W_{TOTAL} = 6.0$ TONS

$W_{BOT} = 87.6 \frac{lb}{ft^3} \times 1.361\ ft^2 \times 67\ ft.$

$W_{BOT} = 4.0$ TONS

$P_{ULT\,ADJ} = 152 - 6.0 = \underline{146.0 \text{ TONS}}$