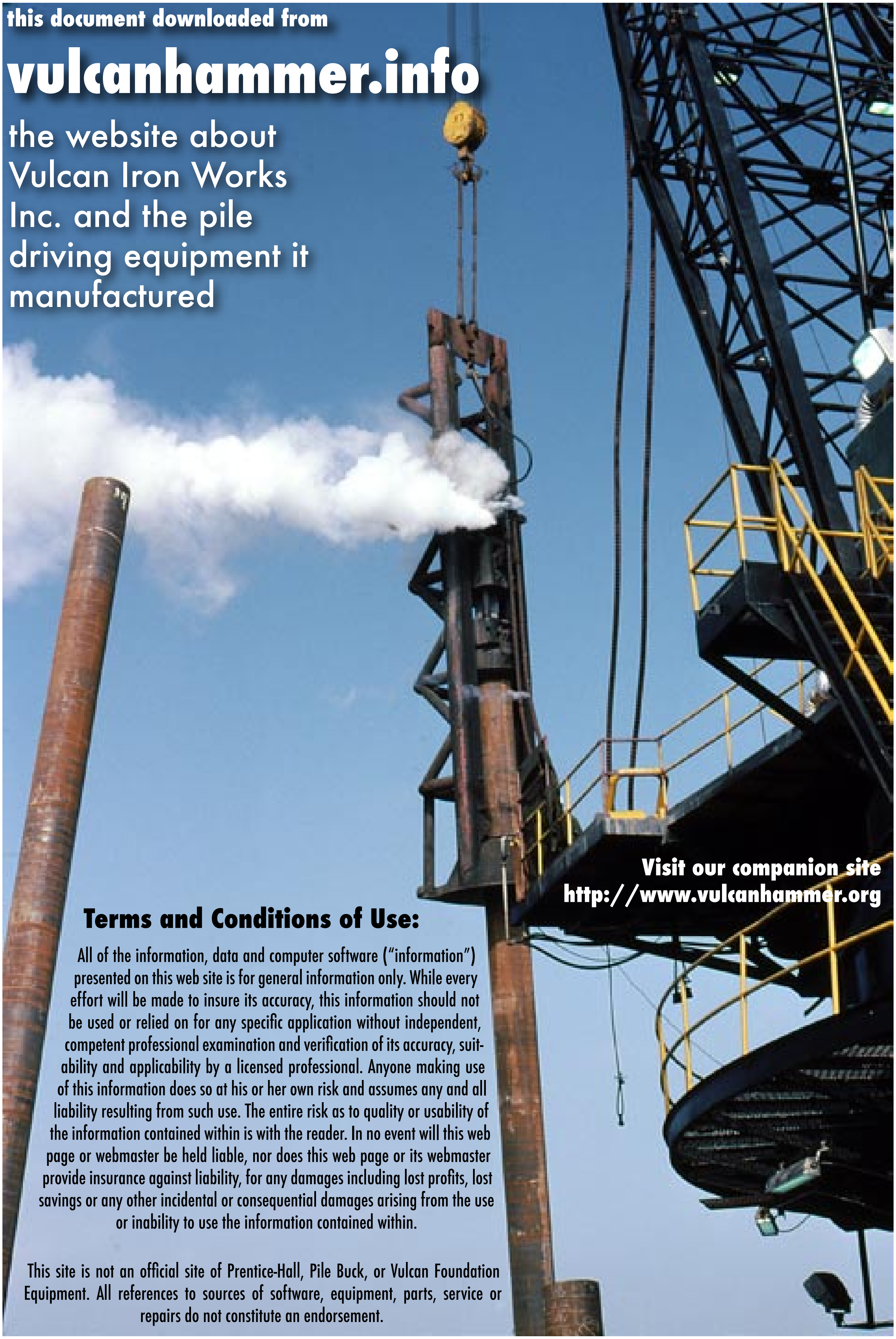

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DESIGN OF DEEP FOUNDATIONS

D. Michael Holloway
Woodward-Clyde Consultants
San Francisco, CAL

DEEP FOUNDATIONS
October 8-9, 1980

SIGNIFICANT EVENTS
PILE FOUNDATION PROJECT

EXPLORATION TESTING

- Two Phase Program

PRELIMINARY DESIGN RECOMMENDATIONS

- Estimate Structural Loads, Tolerable Settlements
- Select Candidate Pile(s) and Configuration(s)
- Estimate Capacity, Settlement, Deflection
- Estimate Required Penetration/Installation Criteria
- Develop Indicator Pile Driving and Load Testing Program

INDICATOR PILE INSTALLATION

- Initial Driving
- Restrike
- Dynamic Measurements

LOAD TESTING

- Axial
- Lateral

INTERPRETATION OF FIELD DATA

- Refusal Conditions
- Ultimate Pile Capacities, Settlement, Group Effects
- Correlation of Dynamic Measurements with Analyses
- Load Transfer Behavior Characterization

FINAL DESIGN RECOMMENDATIONS

CONSTRUCTION MONITORING, INSPECTION, MODIFICATION

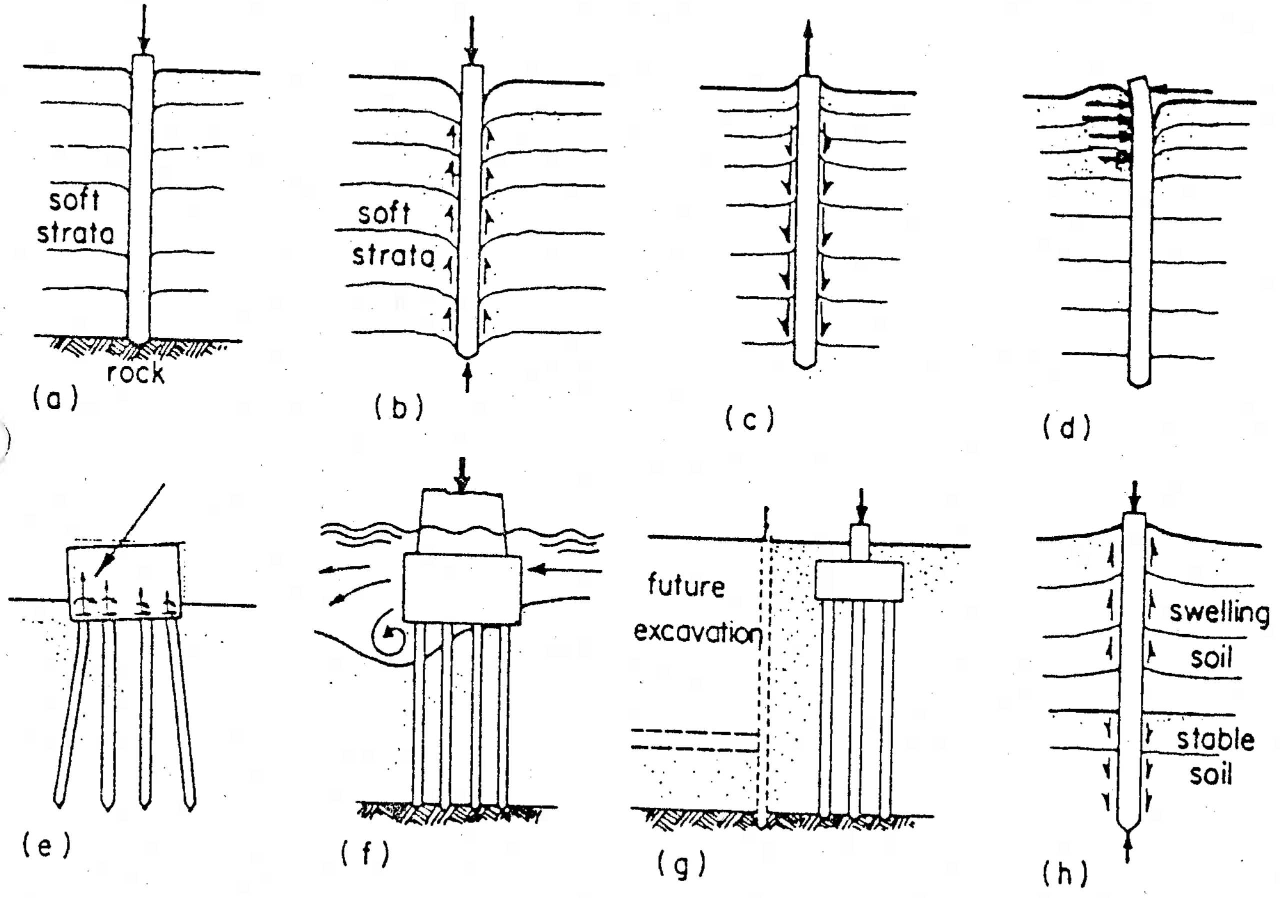


Figure 1. Situations in which piles may be needed. (Vesić, 1977)

TABLE 1

PRINCIPAL ADVANTAGES AND DISADVANTAGES OF DIFFERENT PILE TYPES

PILE TYPE	ADVANTAGES	DISADVANTAGES
Timber	Easy to handle or cut-off. Relatively inexpensive material. Readily available (USA). Naturally tapered.	Decay above water table, especially in marine environment. Limited in size and bearing capacity. Prone to damage by hard driving. Difficult to extend. Noisy to drive.
Steel	Easy to handle, cut off, extend. Available in any length or size. Can penetrate hard strata, boulders, soft rock. Convenient to combine with steel superstructure.	Subject to corrosion, require protection in marine environment. Flexible H-piles may deviate from axis of driving. Relatively expensive material. Noisy to drive.
Concrete: Precast	Durability in almost any environment. Convenient to combine with concrete superstructure.	Cumbersome to handle and drive. Difficult to cut off or extend. Noisy to drive.
Cast-in-place: Casing left in ground	Allows inspection before concreting. Easy to cut off or extend.	Casing cannot be re-used. Thin casing may be damaged by impact or soil pressure.
Casing withdrawn or no casing	No storage space required. Can be finished at any elevation. Can be made before excavation. Some types allow larger displacements in weaker soils. Some types have no driving operation suitable where noise and vibration are prohibited (downtown).	In soft soils shaft may be squeezed by soil cave-in. In case of heavy compaction of concrete previously completed piles may be damaged. If concrete is placed too fast there is danger of creation of a void.

(Vesić, 1977)

DEEP FOUNDATION
BEARING CAPACITY EQUATION

$$Q_{ULT} = Q_p + Q_s$$

$$Q_s = \int f_s \, dA_s$$

SHAFT RESISTANCE

$$Q_p = q_o A_p$$

POINT RESISTANCE

UNIT POINT BEARING CAPACITY

$$q_o = cN_c^* + \bar{\sigma}_v N_q^*$$

N_c^* , N_q^* – – Dimensionless factors for deep foundations that depend at least on ϕ

$$N_c^* = (N_q^* - 1) \cot \phi$$

where ϕ = Constant

UNIT SHAFT RESISTANCE

$$f_s = C_a + \bar{\sigma}_N \tan \delta$$

C_a = adhesion

$\bar{\sigma}_N$ = effective normal stress @ shaft

δ = interface friction angle

Vesić

$$\bar{\sigma}_v N_q^* = \bar{\sigma}_o N_\sigma$$

where $N_\sigma(\phi, I_{rr})$

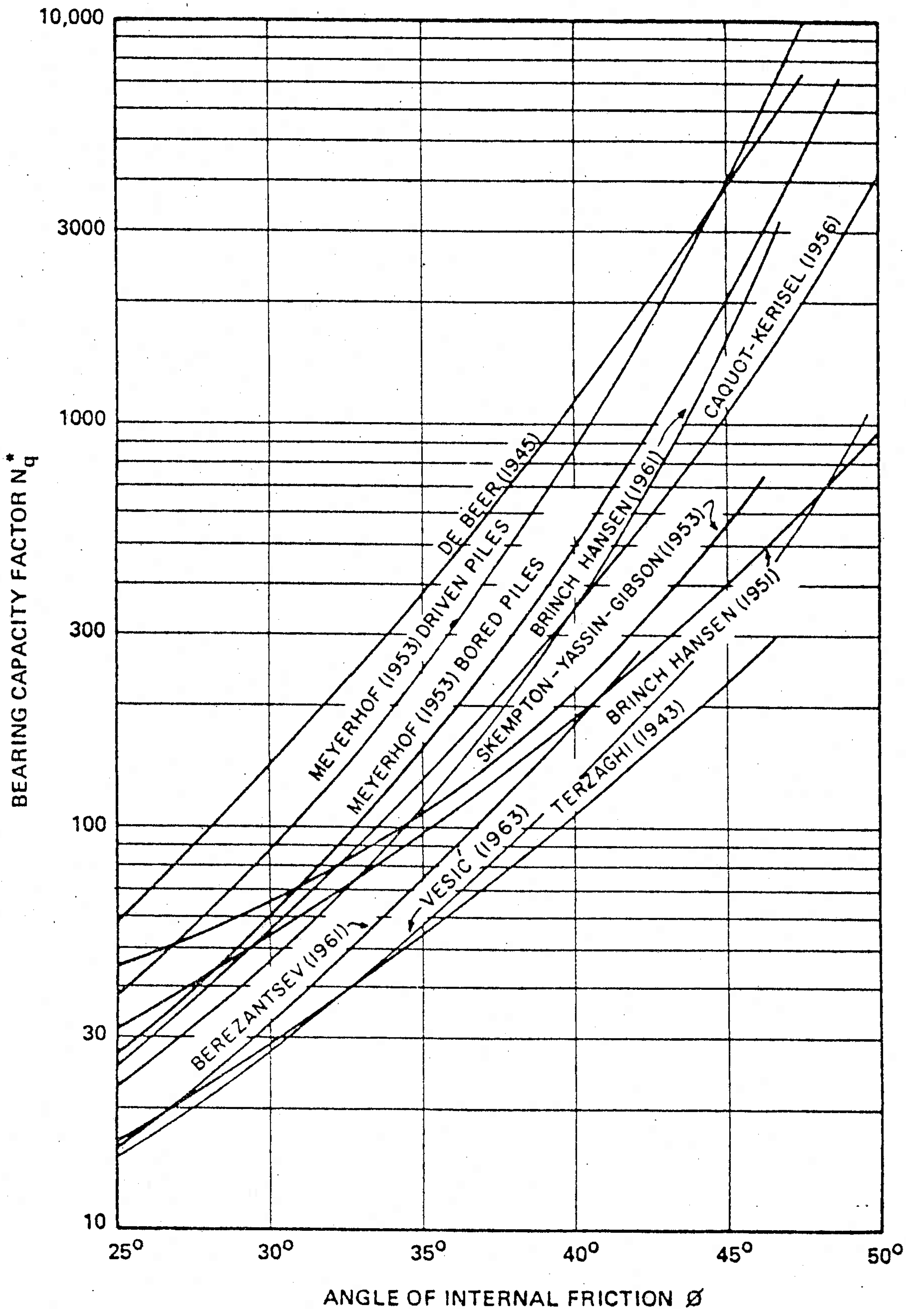
$\bar{\sigma}_o$ = mean effective insitu normal stress @ point

I_{rr} = Rigidity Index (c, ϕ, G, Δ)

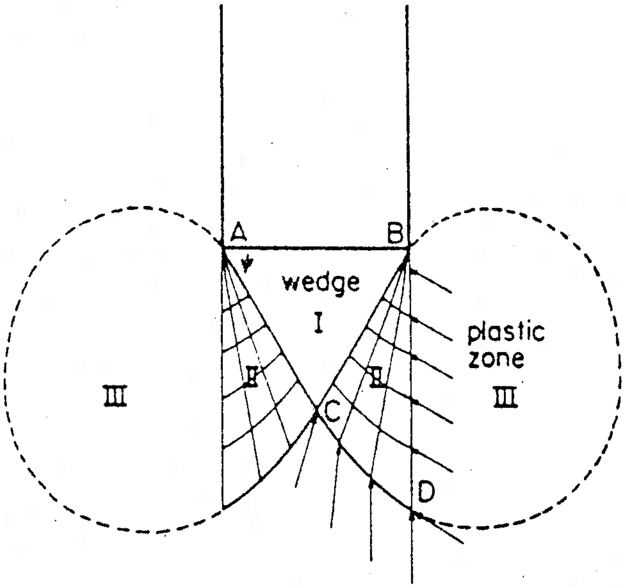
for quartz sands the approximate value is

$$N_q^* = (1 + \tan\phi)\, e^{\pi \tan\phi} \tan^2(45 + \phi/2)$$

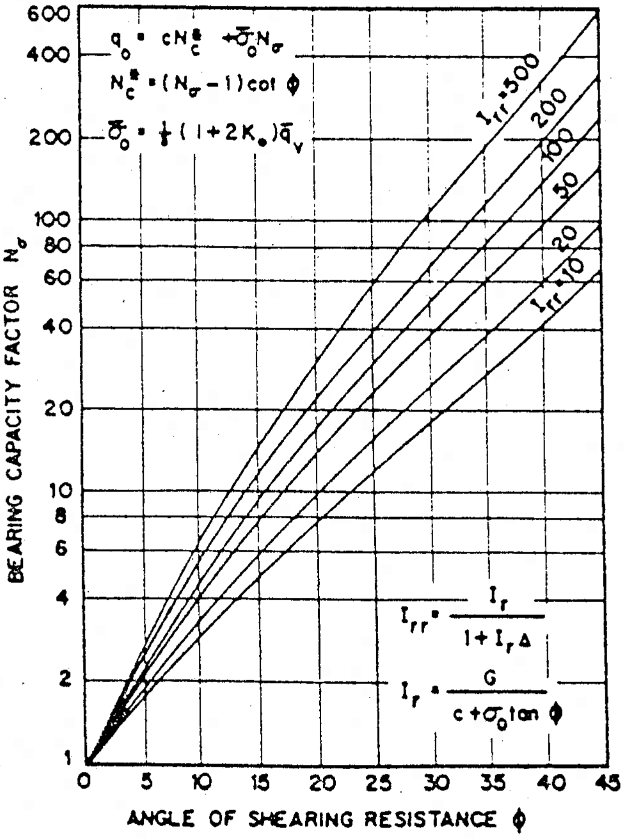
where $\phi = \phi(\bar{\sigma}_o)$


BEARING CAPACITY FACTOR N_q^*
10,000
3000
1000
300
100
30
10
25°
30°
35°
40°
45°
50°
ANGLE OF INTERNAL FRICTION Ø
DE BEER (1945)
MEYERHOF (1953) DRIVEN PILES
MEYERHOF (1953) BORED PILES
BRINCH HANSEN (1961)
CAQUOT-KERISEL (1956)
SKEMPTON-YASSIN-GIBSON (1953)
BRINCH HANSEN (1951)
TERZAGHI (1943)
VESIC (1963)
BEREZANTSEV (1961)

(Vesic, 1965)



(Vesić, 1977)


$q_o = cN_c^* + \bar{\sigma}_o N_\sigma$
$N_c^* = (N_\sigma - 1)\cot\phi$
$\bar{\sigma}_o = \frac{1}{3}(1+2K_o)\bar{q}_v$
$I_{rr} = 500$
200
100
50
20
$I_{rr} = 10$
$I_{rr} = \frac{I_r}{1 + I_r \Delta}$
$I_r = \frac{G}{c + \sigma_o \tan\phi}$
BEARING CAPACITY FACTOR N_σ
1
2
4
6
8
10
20
40
60
80
100
200
400
600
ANGLE OF SHEARING RESISTANCE ϕ
0
5
10
15
20
25
30
35
40
45

(Vesic', 1977)

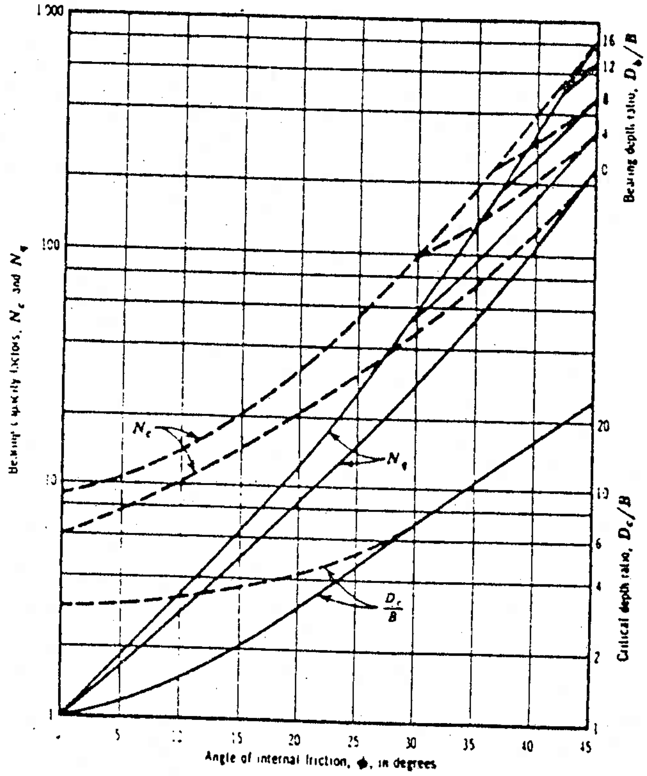
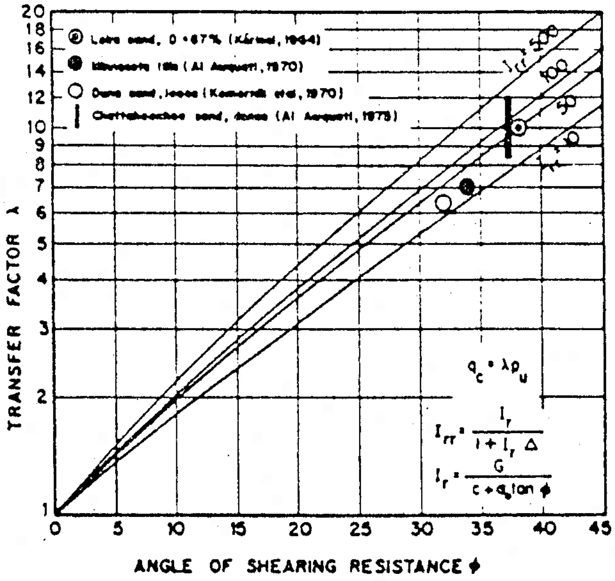


FIG. 1.—Bearing Capacity Factors and Critical Depth Ratios for Driven Piles

(Meyerhof, 1976)


20
18
16
14
12
10
9
8
7
6
5
4
3
2
1
TRANSFER FACTOR λ
0
5
10
15
20
25
30
35
40
45
ANGLE OF SHEARING RESISTANCE φ
Loire sand, D = 67% (Kérisel, 1964)
Minnesota silt (Al Awqati, 1970)
Dune sand, loose (Komornik et al, 1970)
Chattahoochee sand, dense (Al Awqati, 1975)
$I_{rr} = 500$
100
50
$I_{rr} = 10$
$q_c = \lambda p_u$
$I_{rr} = \frac{I_r}{1 + I_r \Delta}$
$I_r = \frac{G}{c + q_o \tan \phi}$

(Vesić, 1977)

Common Assumptions
Shaft Resistance in Sand

$$\bar{\sigma}_N = K_s \, \bar{\sigma}_v$$

$$K_A \le K_s \le K_p$$

← Bored Driven →

$$\frac{\delta}{\phi} \text{ or } \frac{\tan \delta}{\tan \phi} \le 1$$

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Common Assumptions — Shaft Resistance in NC Clay

BETA

$$f_s = \beta \ \bar{\sigma}_v$$

$$\beta = (1 - \sin\phi)\tan\phi$$ (BURLAND)

$$\beta = \frac{\sin\phi\cos\phi}{1 + \sin^2\phi}$$ (VESIĆ)

LAMBDA

$$f_s^{avg} = \lambda\,(\bar{\sigma}_o + 2s_u)_{avg}$$ (VIJAYVERGIYA and FOCHT)

ALPHA

$$f_s = \alpha\ s_u$$ (TOMLINSON et al)

ALPHA (α)

$$f_s = \alpha \cdot S_u$$

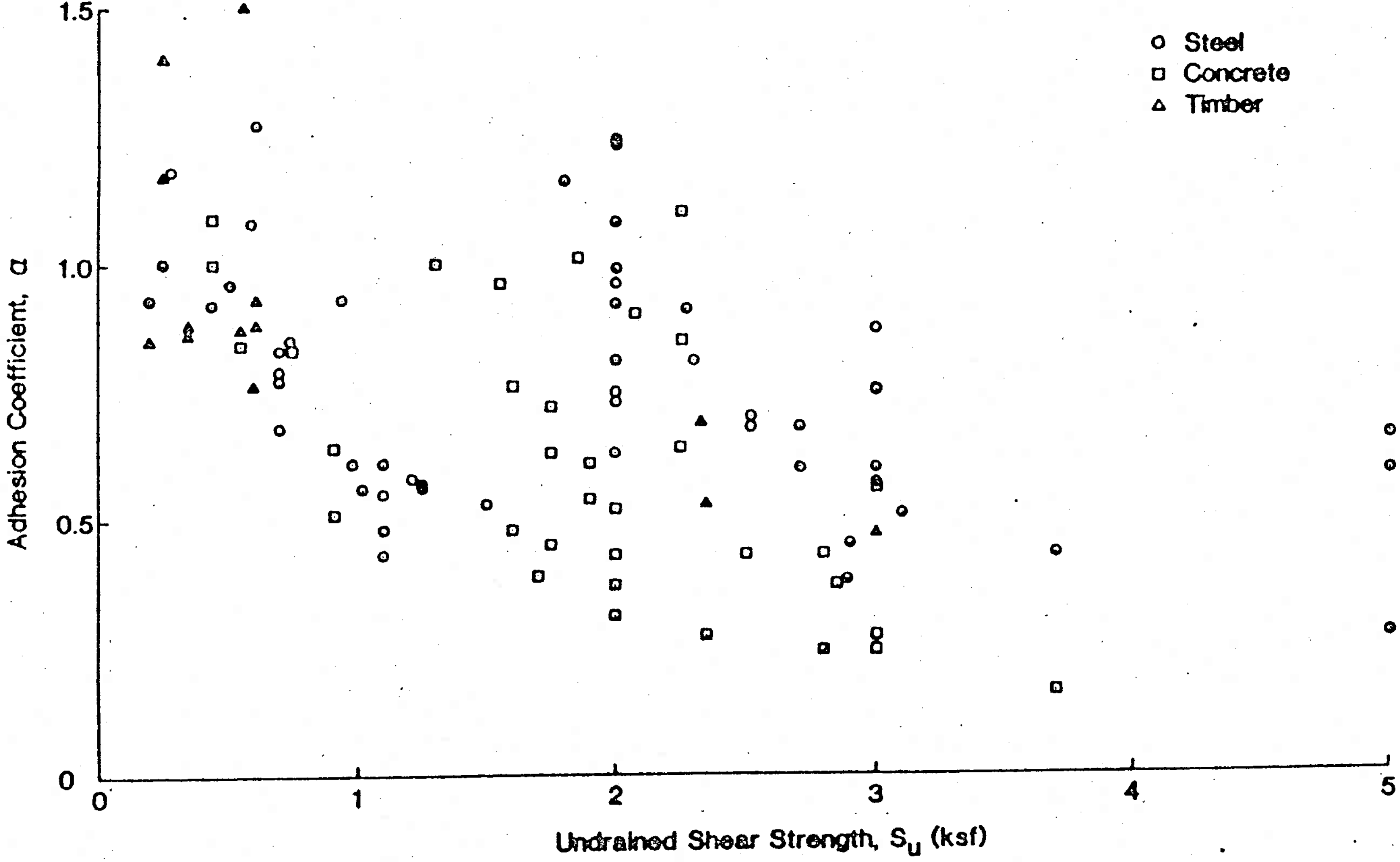
Basis of Development : Observational Data

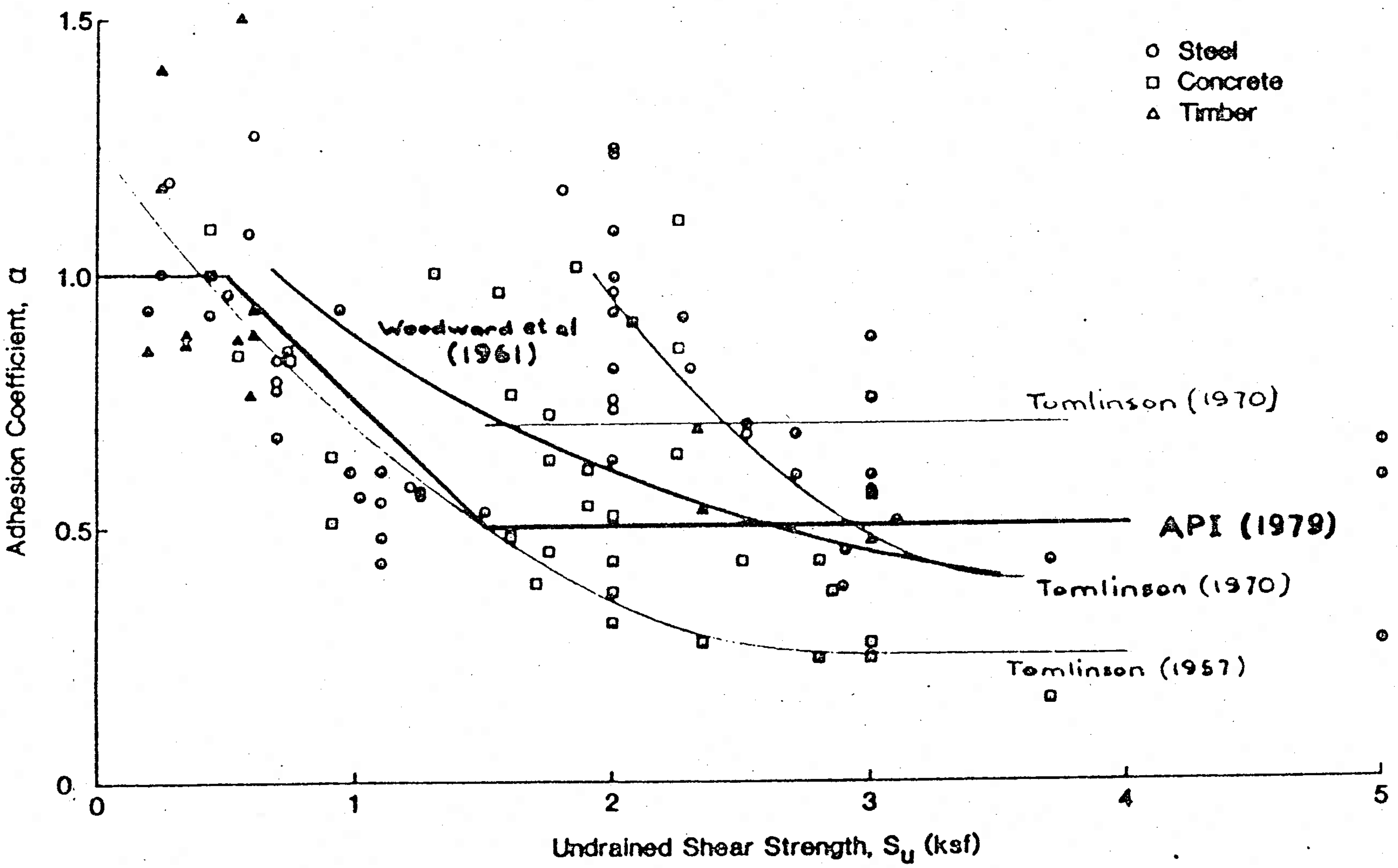
- **Pile Load Tests**
- **Undrained Strength**

Parameters :

a) Undrained Shear Strength Profile
   - typically Unconfined Compression

b) Adhesion Coefficient , α
?


Steel
Concrete
Timber
1.5
1.0
0.5
0
Adhesion Coefficient, α
0
1
2
3
4
5
Undrained Shear Strength, S_u (ksf)


Steel
Concrete
Timber
Woodward et al (1961)
Tomlinson (1970)
API (1979)
Tomlinson (1970)
Tomlinson (1957)
Adhesion Coefficient, α
1.5
1.0
0.5
0.
0
1
2
3
4
5
Undrained Shear Strength, S_u (ksf)

LAMBDA (λ)

$$f_s = \lambda(\bar{\sigma}_v + 2S_u)$$

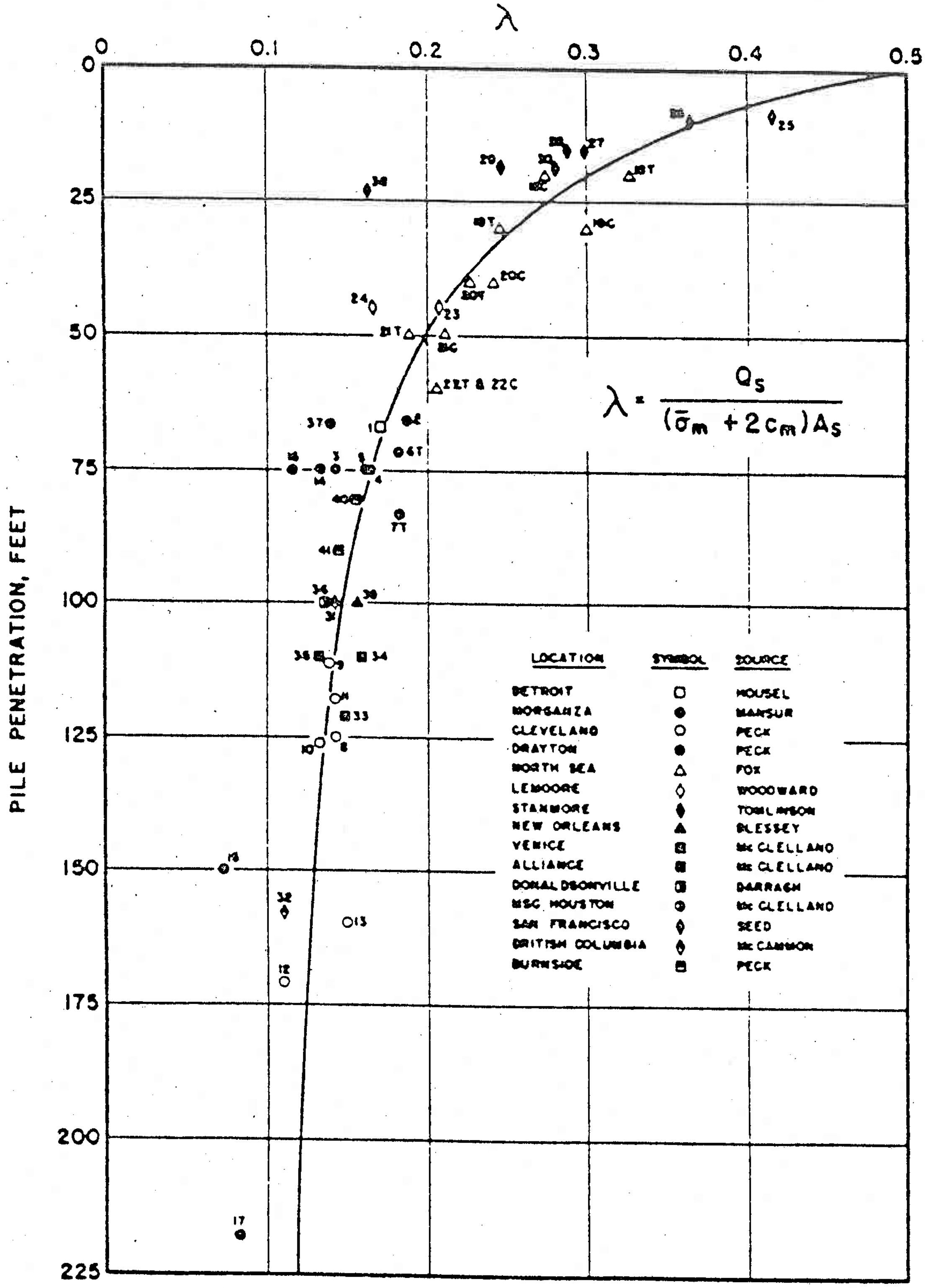
(Vijayvergiya & Focht, 1972)

Basis of Development : Observational Data

- Pile Load Tests on Steel Pipe Piles
- Undrained Strength (notably Unconfined Compression and Miniature Vane)

Parameters :

- Vertical Effective Stress Profile
- Undrained Strength Profile
- λ -vs- Penetration Depth
  ?



FRICTIONAL CAPACITY COEFFICIENT, λ, vs. PILE PENETRATION
(0 to 225 Feet)

BETA (β)

$$f_s = \beta \cdot \bar{\sigma}_v$$

Basis of Development : Concept that f_s is a Normal Stress dependent frictional quantity.

- Burland / Meyerhof
- Vesić / Parry & Swain
- General Effective Stress (using Critical State Concepts)

  Esrig, Kirby et. al.

BETA (β) continued ...

Parameters :

a) Vertical Effective Stress Profile

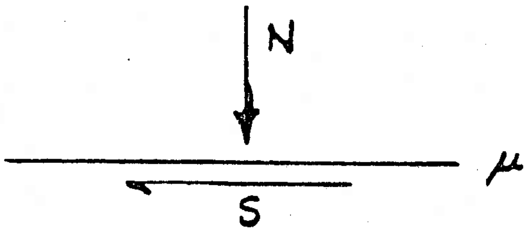
b) Stress History

c) Soil - Pile Interface Friction Angle
   - use $\delta \approx \phi'$

d) Lateral Stress Coefficient
   - use $K \approx 1 - \sin \phi'$ for N.C. Clay

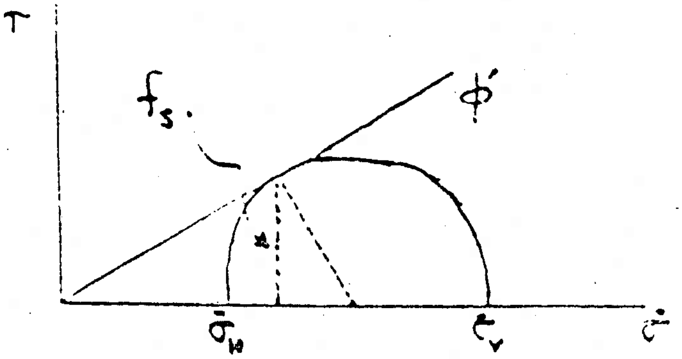
BURLAND / MEYERHOF

$$\beta = K \tan \delta$$



VESIĆ / PARRY & SWAIN

$$\beta = \frac{\sin \phi' \cos \phi'}{1 + \sin^2 \phi'}$$



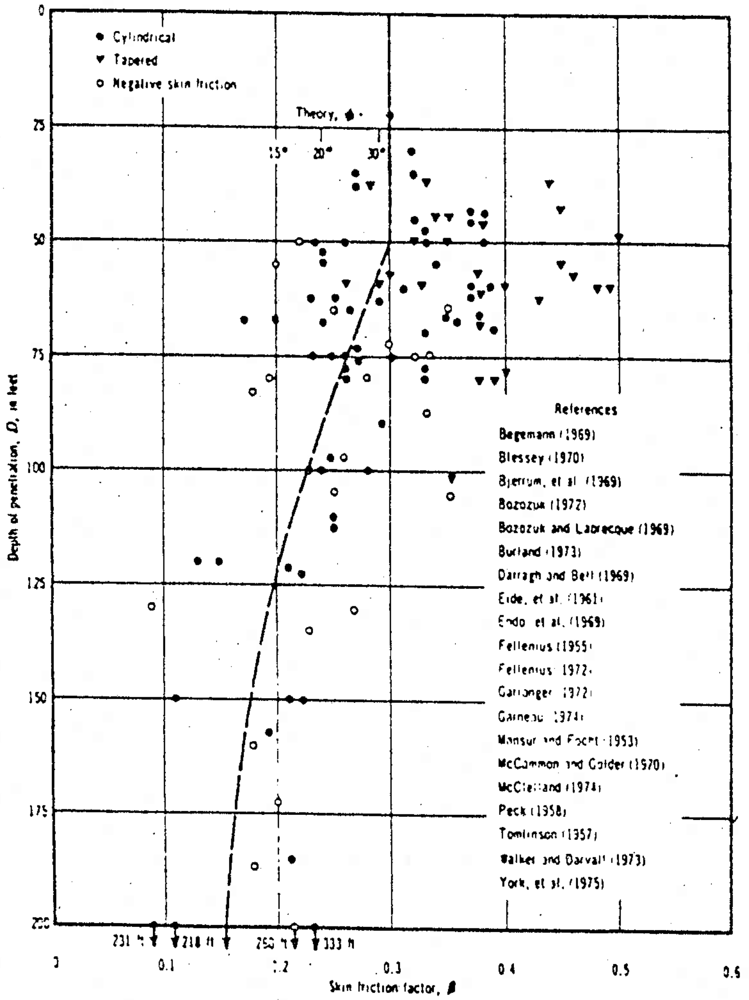
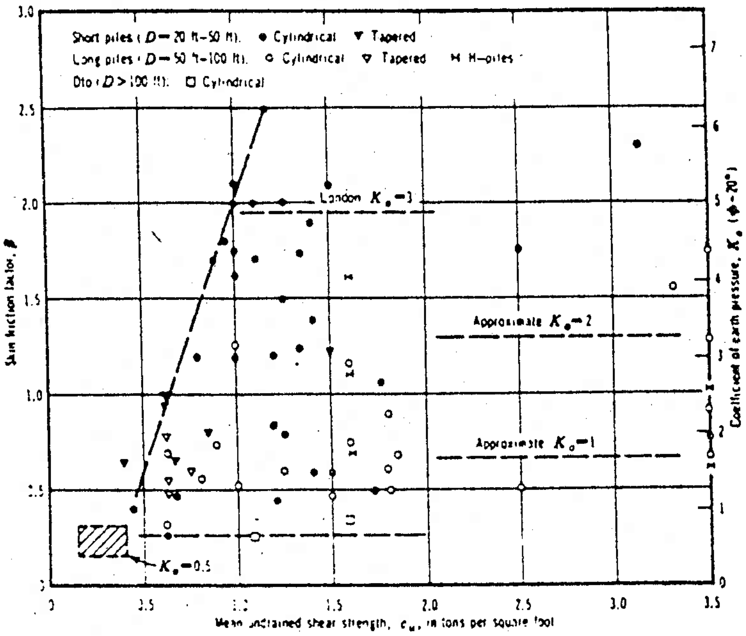


FIG. 13.—Positive and Negative Skin Friction Factors of Driven Piles in Soft and Medium Clays (1 ft = 0.305 m)

(Meyerhof, 1976)



References

B[illegible]ager (1959)	Ostenfeld, et al. (1968)
Burland (1973)	Peck (1958)
Clark and Meyerhof (1973)	Schlitt (1951)
Fellenius and Samson (1975)	Sherman (1969)
F[illegible], et al. (1970)	Stermac, et al. (1969)
Kerisel (1964)	Tomlinson (1957) and (1971)
Meyerhof and Murdock (1953)	Woodward, et al. (1961)

FIG. 14.—Skin Friction Factor of Driven Piles in Stiff Clay (1 tsf = 95.8 kN/m²)

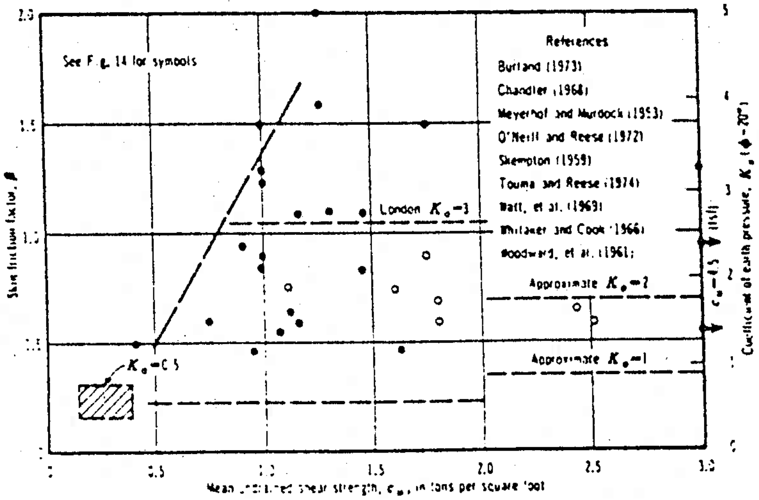
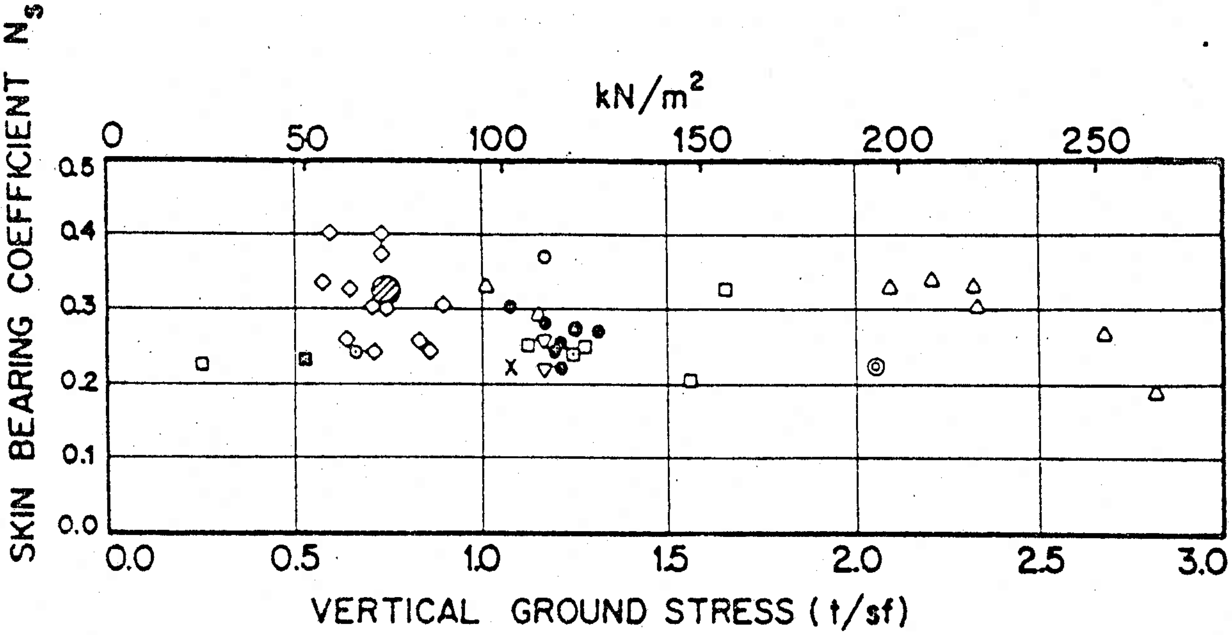


FIG. 15.—Skin Friction Factor of Bored Piles in Stiff Clay (1 tsf = 95.8 kN/m²)

(Meyerhof, 1976)



⊙Detroit	Housel, 1950	○ Lemoore	Woodward, 1961
●Morganza	Mansur, 1956	▨ Khorramshahr	Hutchinson & Jensen, 1968
■San Francisco	Seed & Reese, 1957	⊡ Donaldsonville	Darragh, 1969
△Cleveland, Burnside	Peck, 1958	◎ British Columbia	McCammon, 1970
◇Drammen	Eide et al., 1961	X New Orleans	Blessey, 1970
▽Drayton	Peck, 1961	□ Misc. Locations	McClelland Engrs.

Figure 14. Observed values of skin bearing-capacity factor N_s in normally consolidated clays.

(Vesić, 1977)

PILE CAPACITY ESTIMATES FROM INSITU TESTS

	CPT	PMT	SPT
Unit Point Resistance, q_o	$\approx q_c$	$\lambda \rho_u$ $\lambda(\phi, I_{rr})$ (VESIĆ)	$\beta \bar{N}$ (tsf) $\bar{N} = N; \leq 15$ $\bar{N} = 15 + \frac{1}{2}(N-15);$ $\bar{N} > 15$ (MEYERHOF)
Unit Shaft Resistance, f_s	$\approx \psi f_c$ $\psi = 1$, electric cone $0.5 < \psi < 1$, dutch cone ρq_c	—	$\bar{N}/50$ (tsf) or use ρq_o
Comments	Consider scale effects; reduce f_s for bored piles		β varies w/ soil type; ≈ 2 for sat. clay ≈ 4 for sand

Type	Dia.	Length ft.	Soil type	Location	Source
□ ■ steel H	14	191 219	silt	Tappan Zee, N.Y.	Yang 1956
△ steel pipe	6	22	soft clay	San Francisco	Seed & Reese, 1957
▲ steel pipe	12	60	soft clay	Michigan	Housel 1958
◎ ⊙ precast concrete	14	40 56	soft boulder clay	Horten Quay	Bjerrum et al., 1958
◉ ● ○ steel pipe	24	242 316 300	soft to stiff clay	Eugene Island	McClelland, 1969 Stevens, 1974 ---- (theoretical prediction)

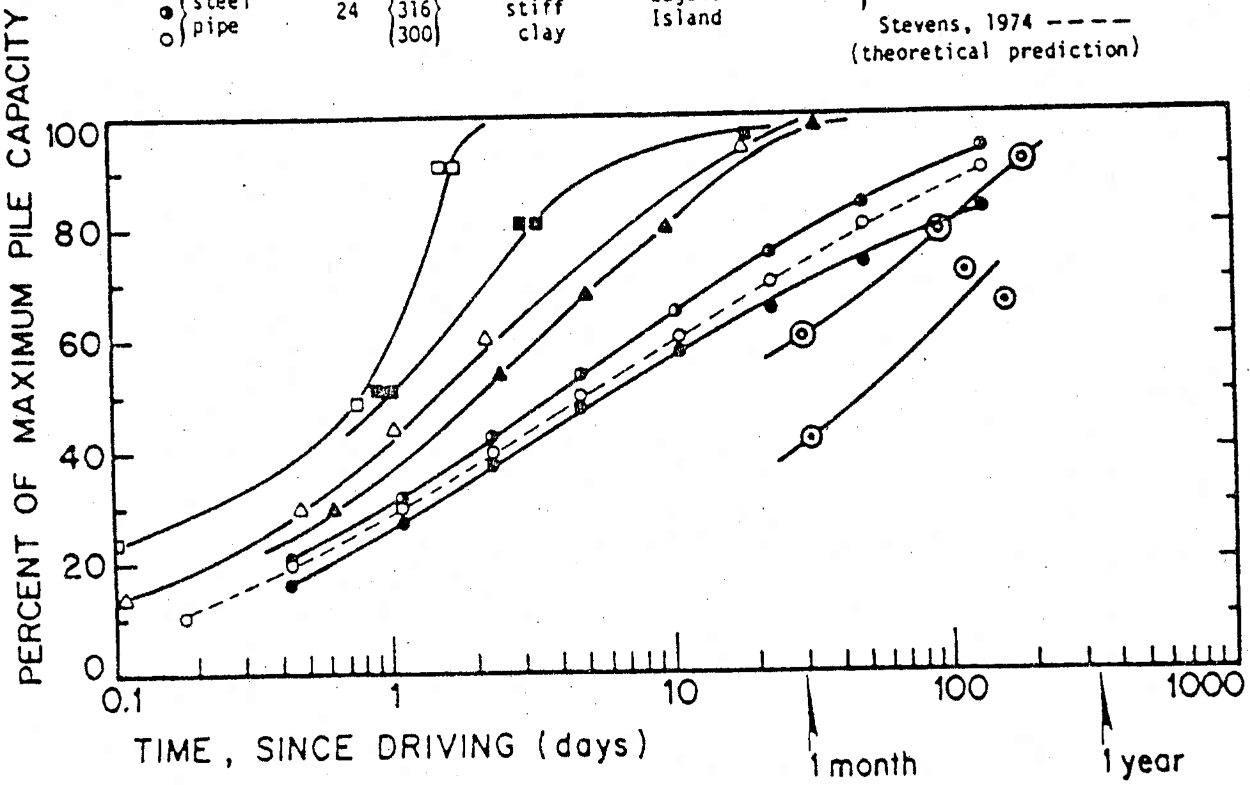
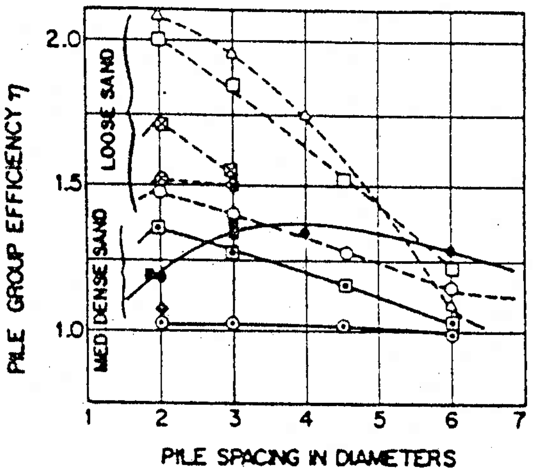


Figure 13. Field data on increase of bearing capacity with time for friction piles in clay. (Vesić, 1977)

PILE GROUP EFFICIENCY FACTORS

BEARING CAPACITY $\eta = \dfrac{\bar{Q}}{\Sigma Q}$

SETTLEMENT $\rho = \dfrac{\bar{W}}{W} \approx \sqrt{\dfrac{\bar{B}}{B}}$



SYMBOL	NO. OF PILES IN GROUP	PILE DIAMETER	PENETRATION IN BEARING STRATUM (DIA)	SOIL TYPE	SOURCE
△	4	4"	20	LOOSE SAND	KÉZDI (1957)
● ■	4 9	4"	15	MED. DENSE SAND	VESIĆ (1968)
◆	4	6"	3	DENSE SAND OVERLAIN BY LOOSE SAND	VESIĆ (1968)
○ □	4 9	1.4"	15	LOOSE SAND	TEJCHMAN (1973)
⊙ ⊡	4 9	1.4"	15	MED. DENSE SAND	TEJCHMAN (1973)
⊗ ⊠	4 9	12"	20	LOOSE SAND	KISHIDA (1967)

Figure 35. Observed efficiencies of square pile groups in sand.

(Vesić, 1977)

TABLE 2

RULES FOR DETERMINATION OF ULTIMATE LOAD

1. *Limiting total settlement*
   (a) Absolute 1.0 in. (Holland, New York City Code)
   (b) Relative 10% of pile tip diameter (England)
2. *Limiting plastic settlement*
   0.25 in. (AASHTO)
   0.33 in. (Magnel)
   0.50 in. (Boston Code)
3. *Limiting ratio plastic settlement/elastic settlement*
   1.5 (Christiani and Nielsen)
4. Maximum ratio $\frac{\text{elastic settlement increment}}{\text{plastic settlement increment}}$
   (Széchy, 1961, Ref. 25)
5. *Limiting ratio settlement/load*
   (a) Total 0.01 in./ton (California, Chicago)
   (b) Incremental 0.03 in./ton (Ohio)
   0.05 in./ton (Raymond Co.)
6. *Limiting ratio plastic settlement/load*
   (a) Total 0.01 in./ton (New York City Code)
   (b) Incremental 0.03 in./ton (Raymond Co.)
7. Maximum ratio $\frac{\text{settlement increment}}{\text{load increment}}$
   (Vesić, 1963, Ref. 26)
8. *Maximum curvature of log w/log Q line*
   (De Beer, 1967, Ref. 27)
9. *Van der Veen postulate*

$$w = \beta \ln\left(1 - \frac{Q}{Q_{max}}\right)$$

(Van der Veen, 1953, Ref. 23)

TABLE 3

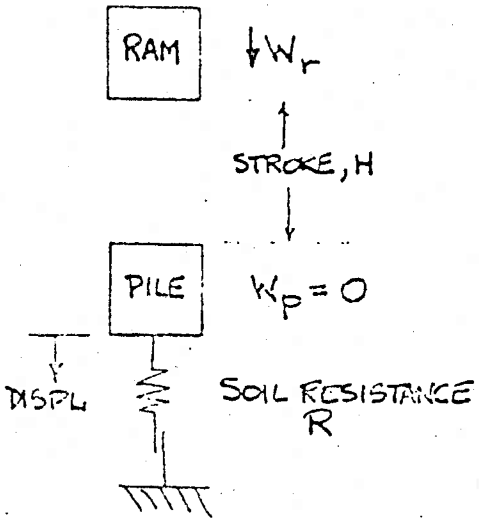
EXPERIMENTAL VALUES OF N_q^* IN SAND

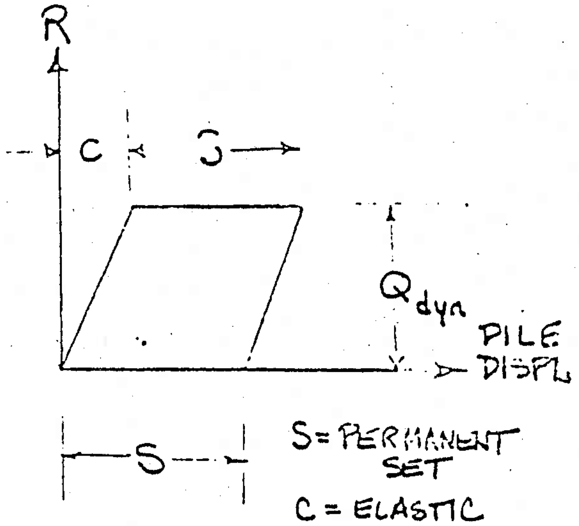
SAND COMPACTNESS	RELATIVE DENSITY (%)	N_q^* DRIVEN PILES	N_q^* BORED PILES
Very dense	>80	60–200	40–80
Dense	60–80	40–80	20–40
Medium	40–60	25–60	10–30
Loose	<40	20–30	5–15

Source: Figure 11 and other records. Higher values apply to shorter piles.

(Vesić, 1977)

ENGINEERING NEWS FORMULA





S = PERMANENT SET
C = ELASTIC QUAKE

ASSUMPTIONS

1. NEWTONIAN (POINT MASS) IMPACT
2. MASSLESS PILE & SOIL
3. RAM ENERGY TRANSFERRED FULLY TO PILE (ALL USEFUL WORK ON SOIL RESISTANCE)
4. OVERALL SOIL RESISTANCE AS AN ELASTIC-PLASTIC "SPRING WITH FULL REBOUND

$$W_r H = Q_{dyn} (c/2 + s)$$

5. ALLOWABLE LOAD $Q_a = Q_{dyn}/6$.

SOLVING FOR Q_a WITH H IN FT AND C,S IN IN.

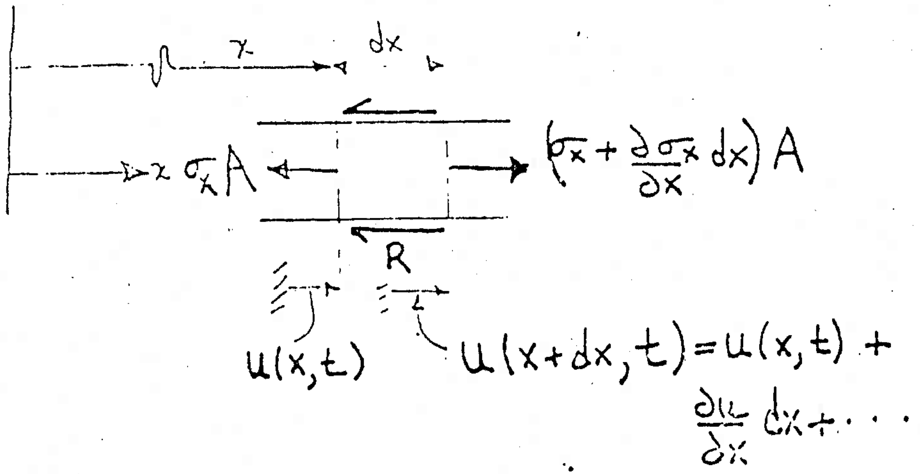
$$Q_a = \frac{12}{6} \frac{W_r H}{(c/2 + S)} = \frac{2 W_r H}{(c/2 + S)}$$

The Wave Equation Versus Energy Formulae, (Forcka, 1970)

	Varieties						
	Pile Impedance or Area	Hammer Cushion	Pile Cushioning Effect	Soil Resistance Distribution	Hammer Energy	Ram Velocity	Drivehead Weight
1. Engineering News					X		
2. Modified Engineering News	U				X		
3. Gow	U				X		
4. Vulcan Iron Works	U				X		
5. Bureau of Yards and Docks					X		
6. Rankine	X			X	X		
7. Dutch	U				X		
8. Ritter	U				X		
9. Eytelwein	U				X		
10. Navy-McKay	U				X		
11. Sanders					X		
12. Gates					X		
13. Danish	X				X		
14. Janbu	X				X		
15. Hiley	X			X	X		
16. Redtenbacker	X			X	X		
17. Pacific Coast Uniform Building Code	X				X		
18. Canadian National Building Code	X			X	X		
19. Olson and Flaate					X		
Wave Equation Analysis	X	X	X	X	X	X	X

Legend: Blank Space - variable not accounted for
U - variable unsatisfactorily accounted for
X - variable accounted for

ROD: FREE BODY DIAGRAM



u(x,t) = DISPLACEMENT OF A POINT ON THE ROD, L

$\sigma_x(x,t)$ = STRESS AT A POINT ALONG THE ROD, F/L^2

R(x,t) = RESISTANCE AT A POINT ALONG THE ROD, F/L

A(x) = CROSS SECTION AREA AT X, L^2

$\rho(x)$ = MASS DENSITY AT X, M/L^3

<u>ROD ELEMENT EQUILIBRIUM</u> $\Sigma \bar{F} = m \bar{a}$

$$\left[-\sigma_x + \sigma_x + \frac{\partial \sigma_x}{\partial x} dx\right] A - R\,dx = (\rho A\,dx) \frac{\partial^2 u}{\partial t^2}$$

General D. Eq.

$$A \frac{\partial \sigma_x}{\partial x} - R = \rho A \frac{\partial^2 u}{\partial t^2}$$

ONE-DIMENSIONAL
EQUILIBRIUM
EQUATION

TYPICAL ASSUMPTIONS

1 HOOKEAN SOLID (INFINITESIMAL (ROD) STRAINS)

$$\sigma_x = E\,\varepsilon_x = E\,\frac{\partial u}{\partial x}$$

$E = E(x)$, YOUNG'S MODULUS, F/L^2

THE DIFFERENTIAL (WAVE) EQUATION

$$A\,\frac{\partial}{\partial x}\left(E\,\frac{\partial u}{\partial x}\right) - R = \rho\,A\,\frac{\partial^2 u}{\partial t^2}$$

INITIAL CONDITIONS

$$u(x,t)\Big|_{t_0} = u_0(x)$$

$$\frac{\partial u}{\partial x}(x,t)\Big|_{t_0} = \dot{u}_0(x)$$

$$\left\{\, R(x,t)\Big|_{t_0} = R_0(x) \right\}$$

BOUNDARY CONDITIONS

$u(x,t)$ or $\dfrac{\partial u}{\partial x}(x,t)$ at $x = 0$

$u(x,t)$ or $\dfrac{\partial u}{\partial x}(x,t)$ at $x = L$

GENERAL PROBLEM

2. HOMOGENEOUS ROD (E, ρ ARE CONSTANTS)

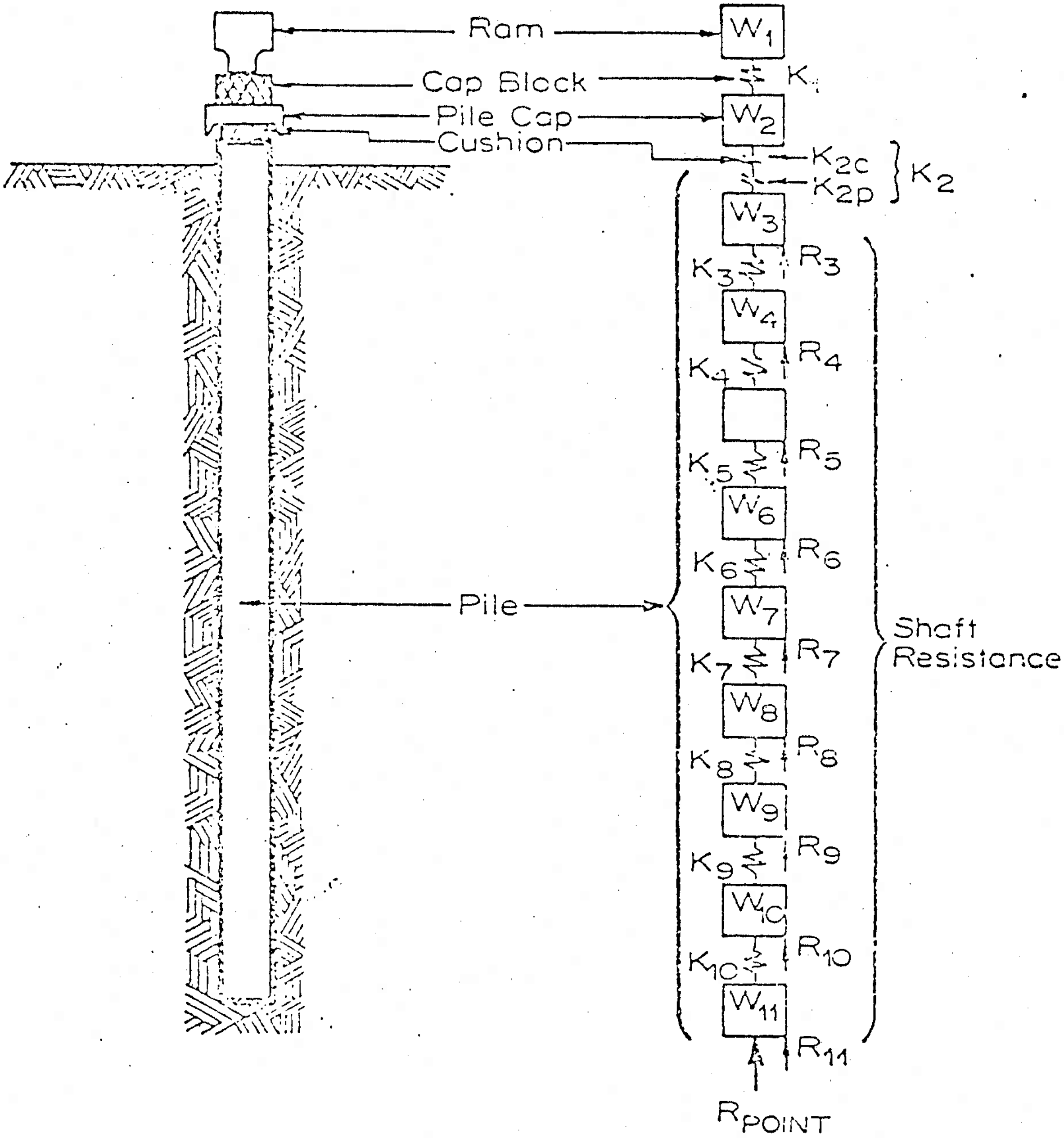
$$\frac{E}{\rho}\frac{\partial^2 u}{\partial x^2} - \frac{R}{A\rho} = \frac{\partial^2 u}{\partial t^2}$$

3. ROD FREELY SUSPENDED ($\cancelto{0}{R}$)

$$\frac{E}{\rho}\frac{\partial^2 u}{\partial x^2} = \frac{\partial^2 u}{\partial t^2}$$

where $\dfrac{E}{\rho} = c^2$

and c = VELOCITY OF WAVE PROPAGATION (a measurable quantity)



Discrete Element Model of Hammer-Pile-Soil System.

SMITH'S ALGORITHM

LUMPED PARAMETER (DISCRETE ELEMENT) MODEL

ELEMENT EQUILIBRIUM EQUATION NEST

$$D_m = [u(m,n+1)] = v_m(12\Delta t)$$

$$C_m = [u(m,n+1) - u(m+1,n+1)] = D_m - D_{m+1}$$

$$F_m = C_m K_m$$

$$Z_m = F_{m-1} - F_m - R_m$$

$$V_m = v_m + Z_m \frac{\Delta t\, g}{W_m}$$

These combine as

$$D_m = 2d_m - d_m^*$$

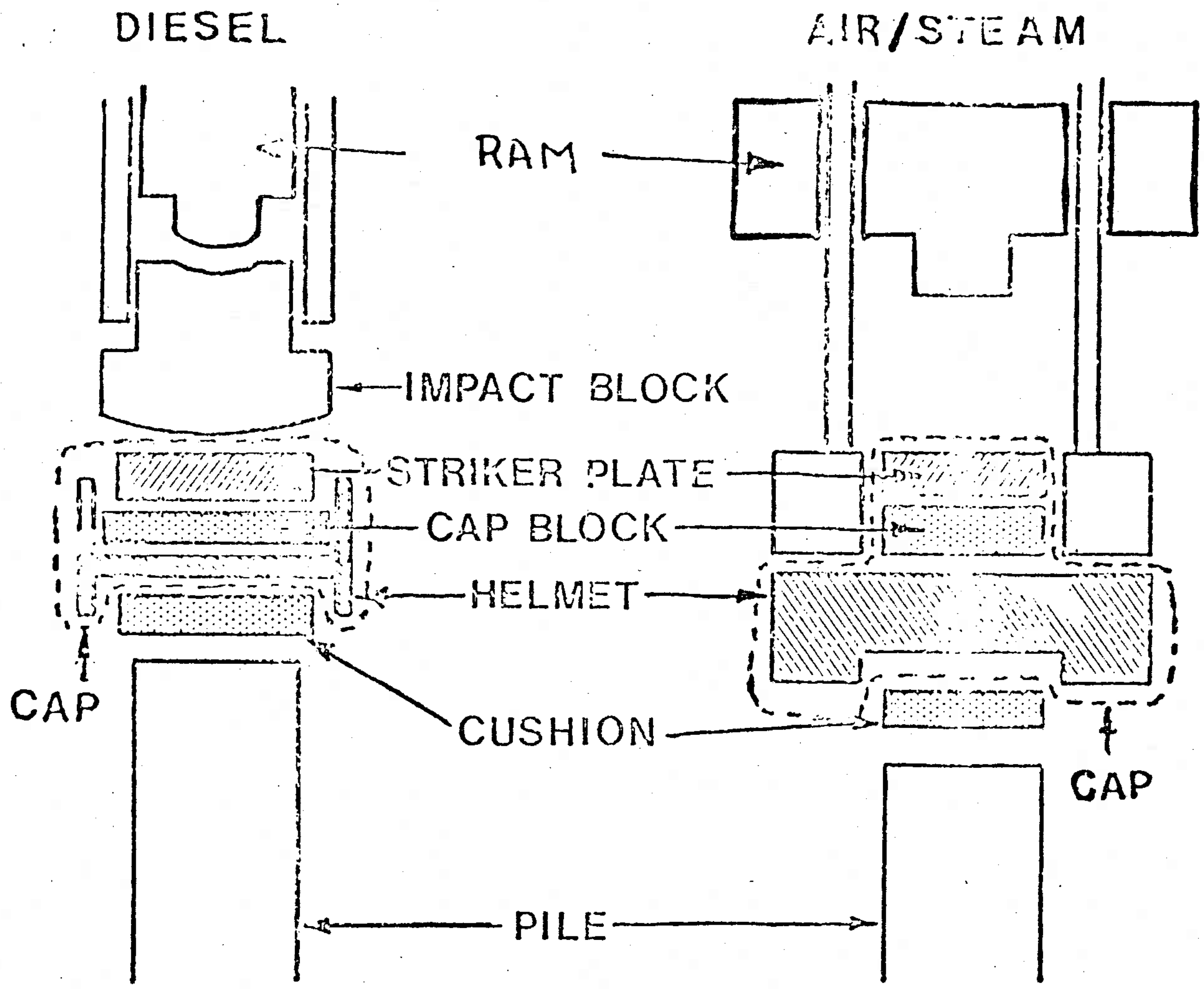
$$+ \frac{12g(\Delta t)^2}{W_m}\Big[(d_{m-1} - d_m)K_{m-1} - (d_m - d_{m+1})K_m - R_m\Big]$$

NOTATION: 1. SUBSCRIPT m DENOTES ELEMENT NUMBER

2. UPPER CASE LETTER DENOTES CURRENT (n+1) TIME INTERVAL; LOWER CASE, PREVIOUS TIME INTERVAL (n); ASTERISK DENOTES (n-1) TIME INTERVAL.

D = DISPLACEMENT
C = SPRING COMPRESSION
F = SPRING FORCE

Z = RESULTANT FORCE
V = VELOCITY
K = SPRING CONSTANT



HAMMER ASSEMBLY TERMINOLOGY
from the WEAP USER'S GUIDE

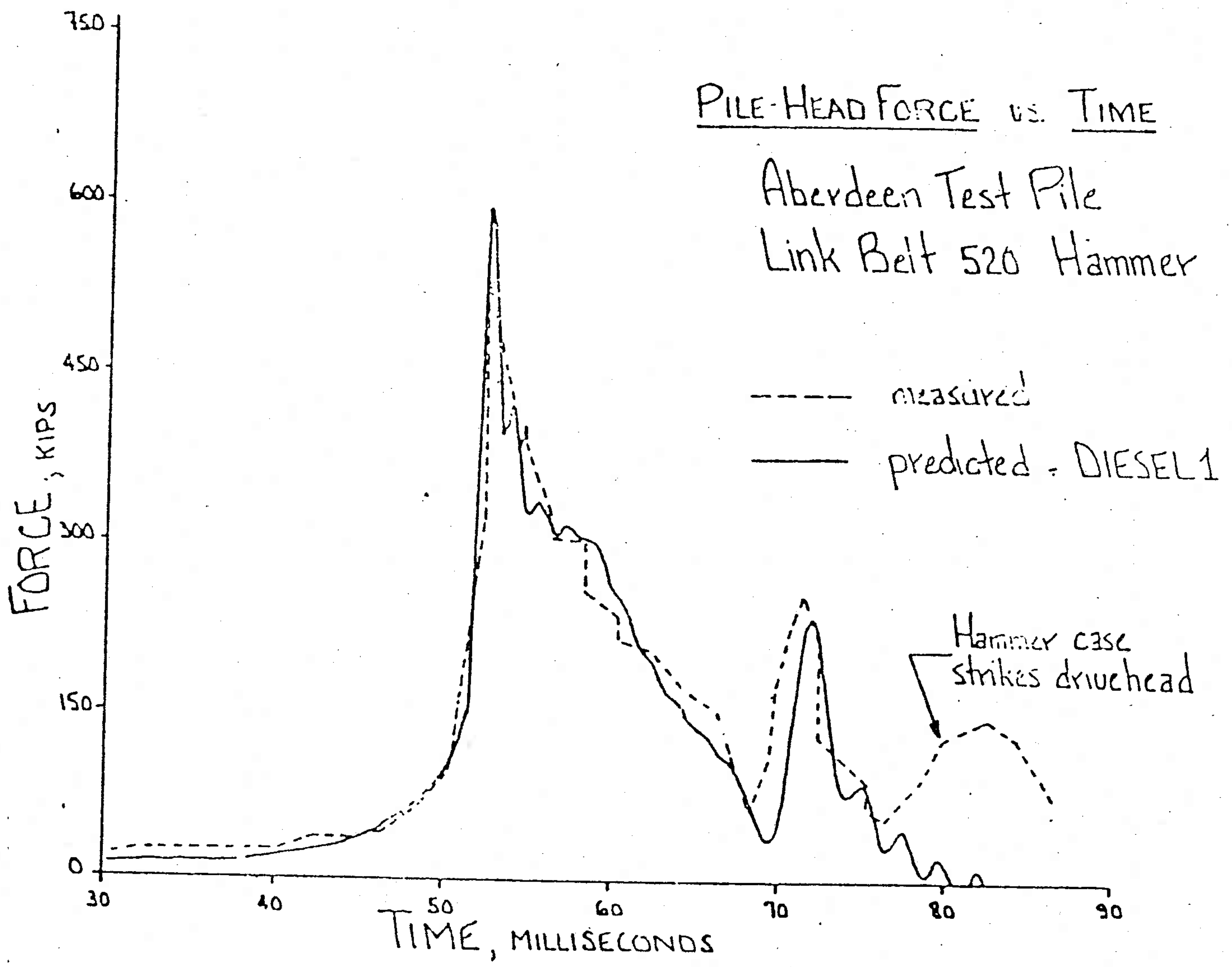
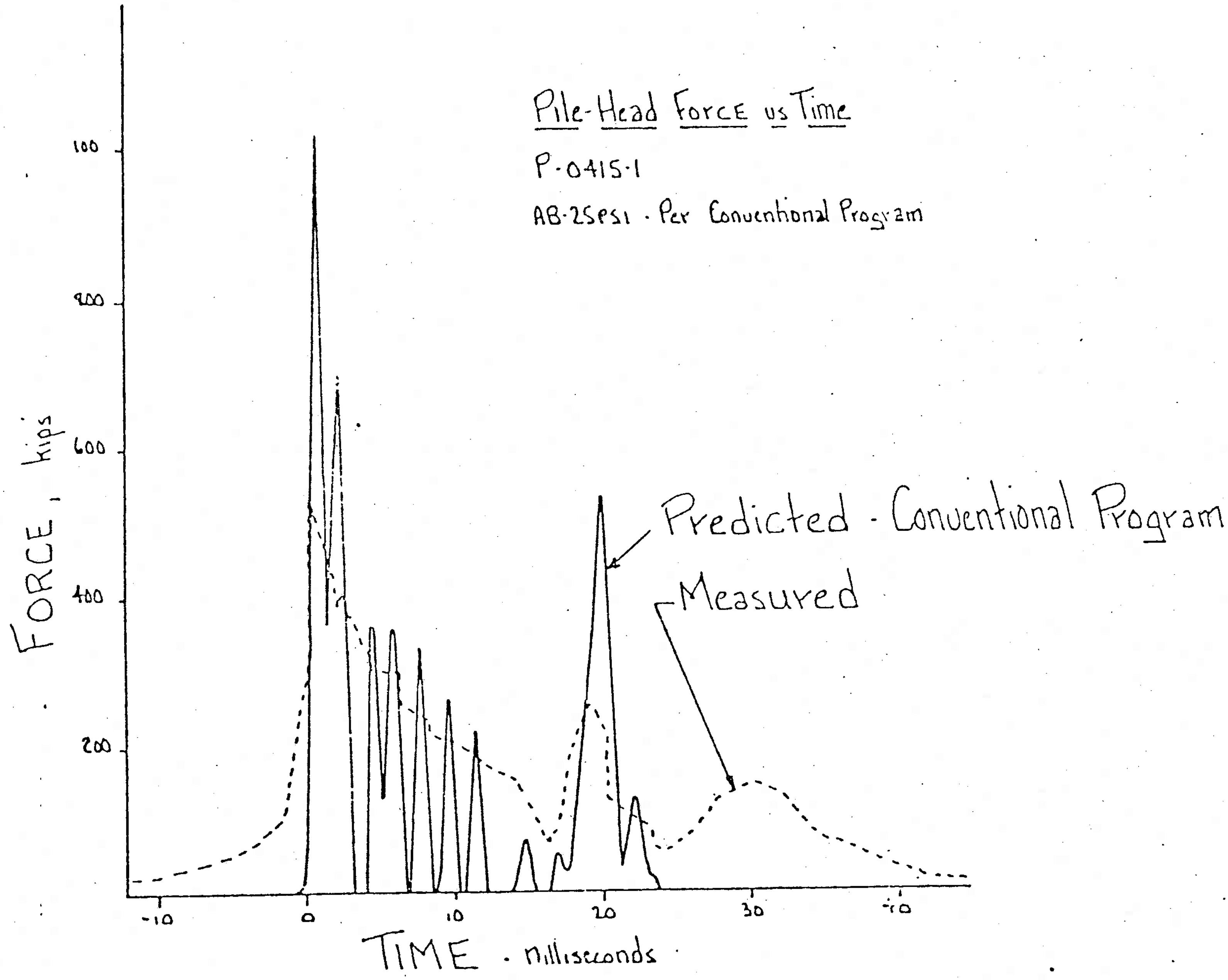


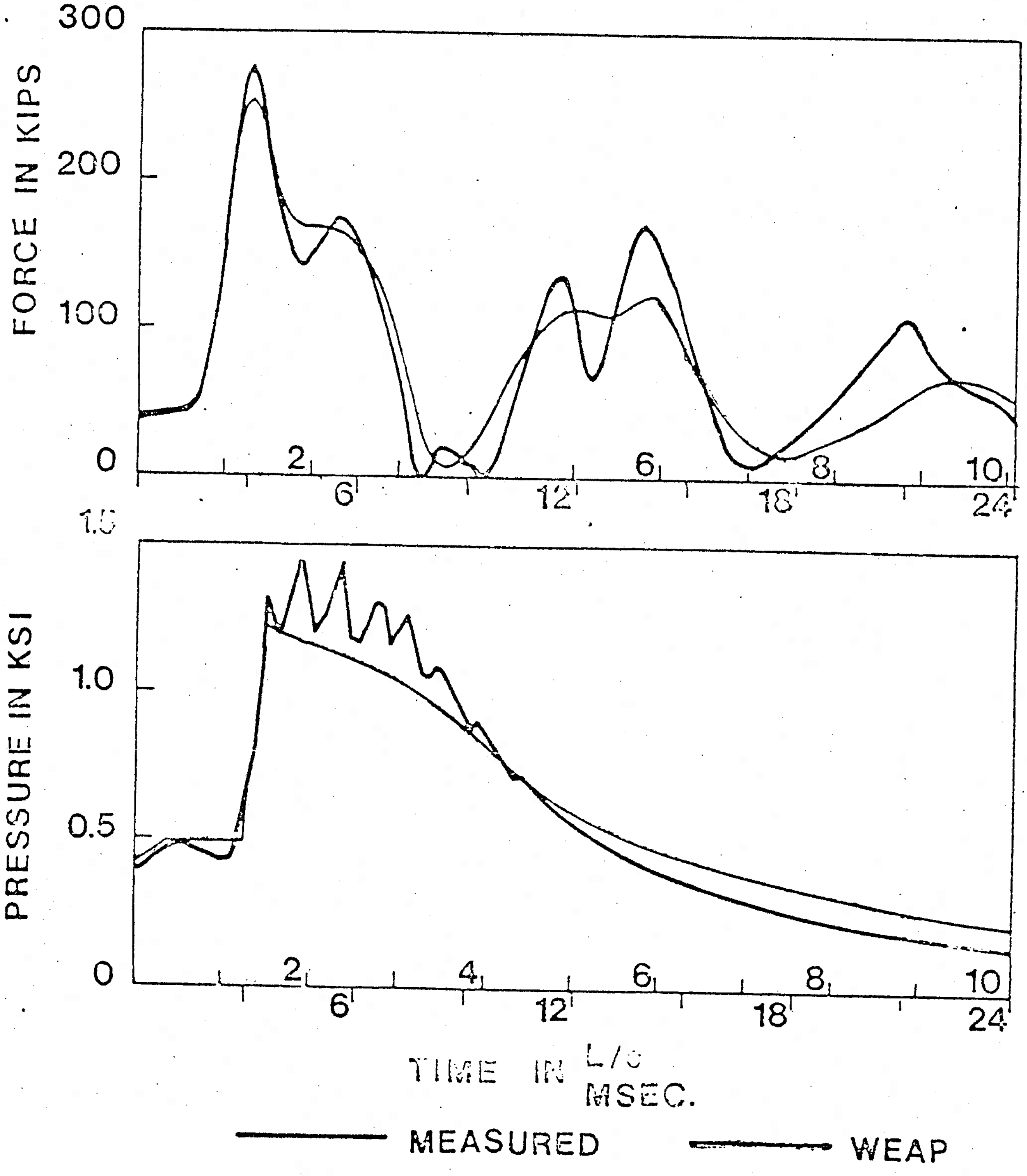
FIGURE 13

from Davisson (1975)



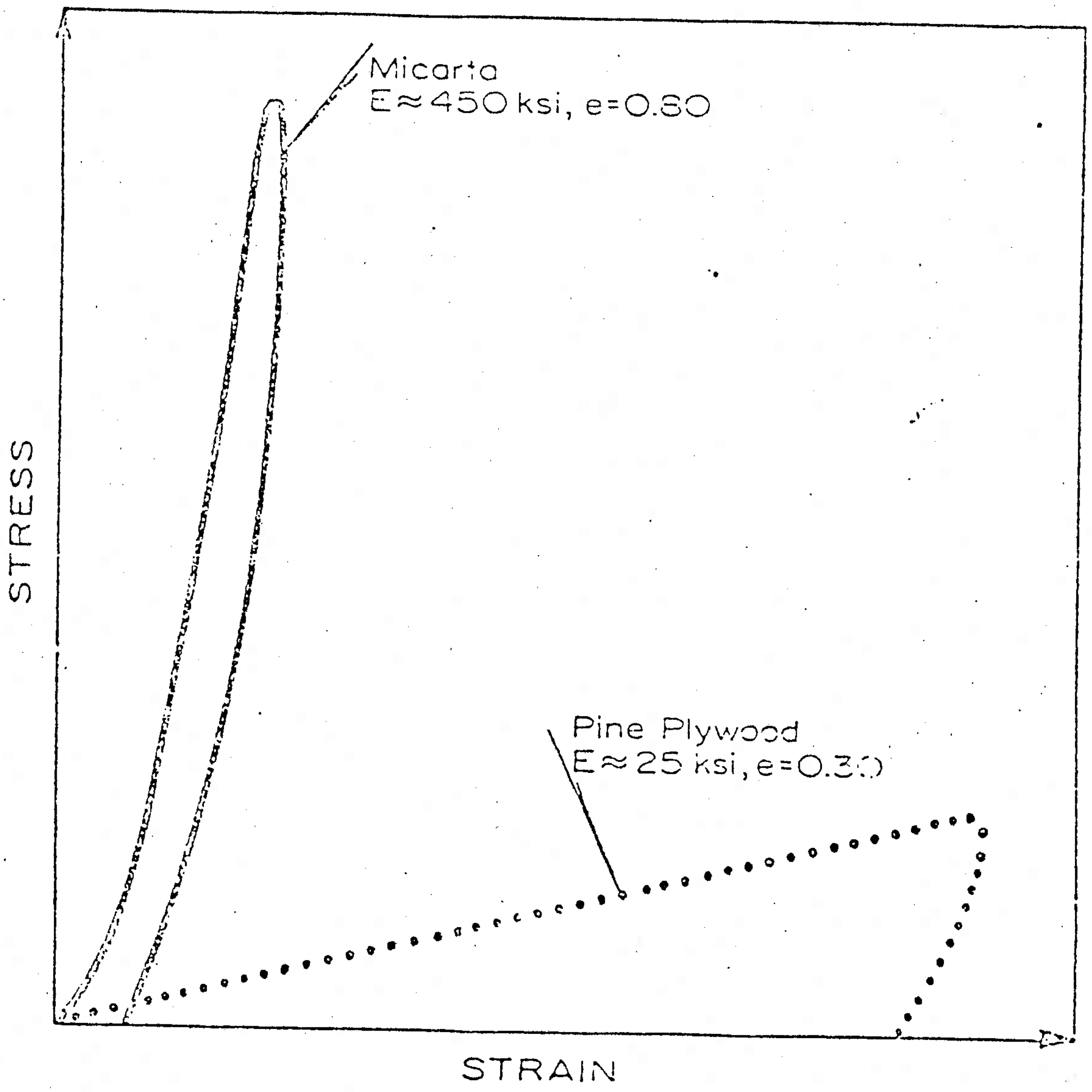
From Davisson (1975)

FIGURE 12

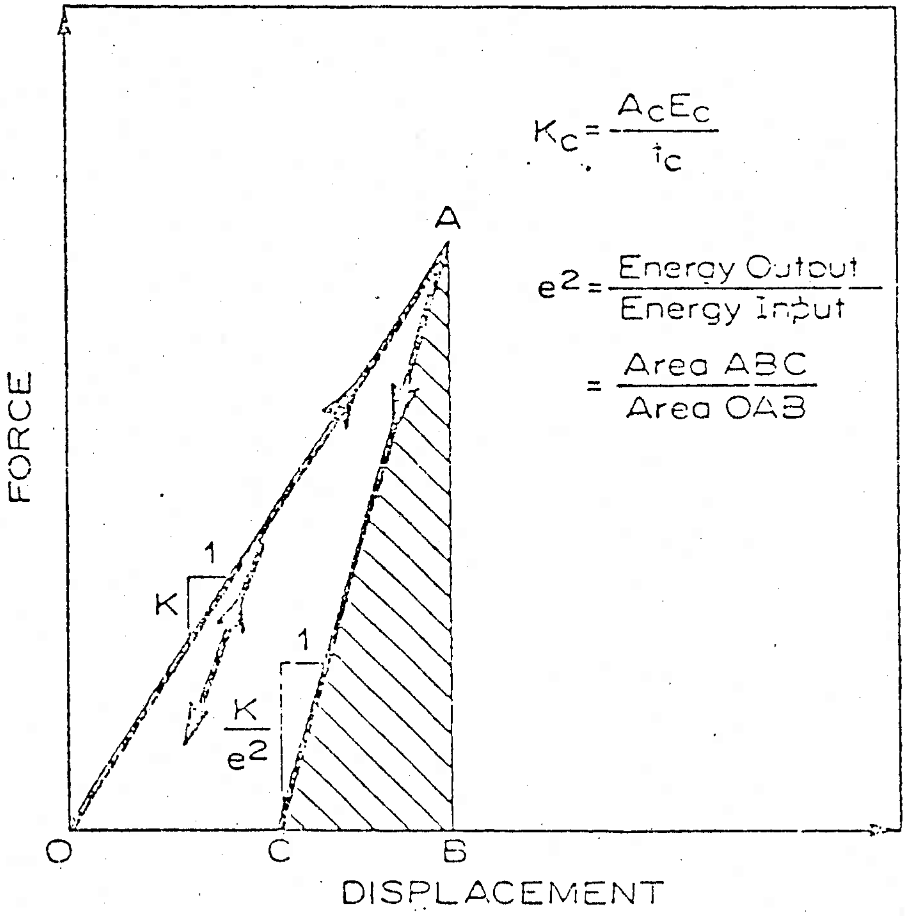


from "WEAP PROGRAM, Volume I – BACKGROUND"

FIGURE 6-1: COMPARISON OF PREDICTED WITH MEASURED PILE TOP FORCES AND COMBUSTION PRESSURES FOR PILE NO.1.



Stress-Strain Behavior of Cushion Materials:
Micarta and Pine Plywood.[20] (Lowery et al, 1967)



Bilinear Cushion Spring Model. (Smith, 1960)

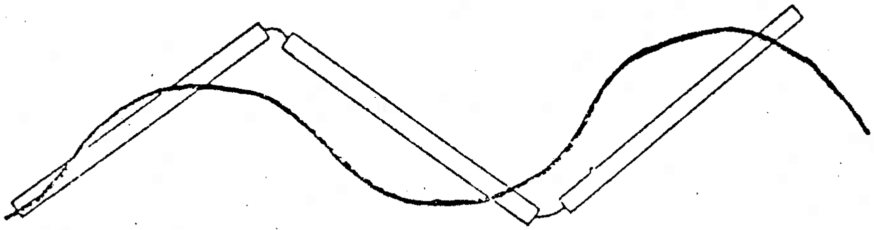


FIG. 3.—LONG FLOATS

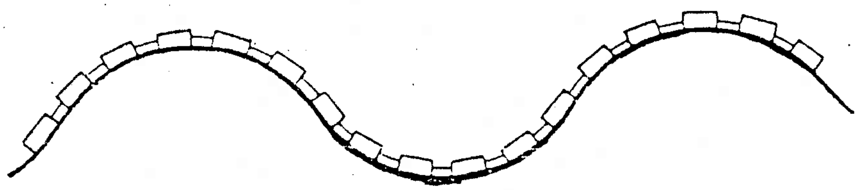
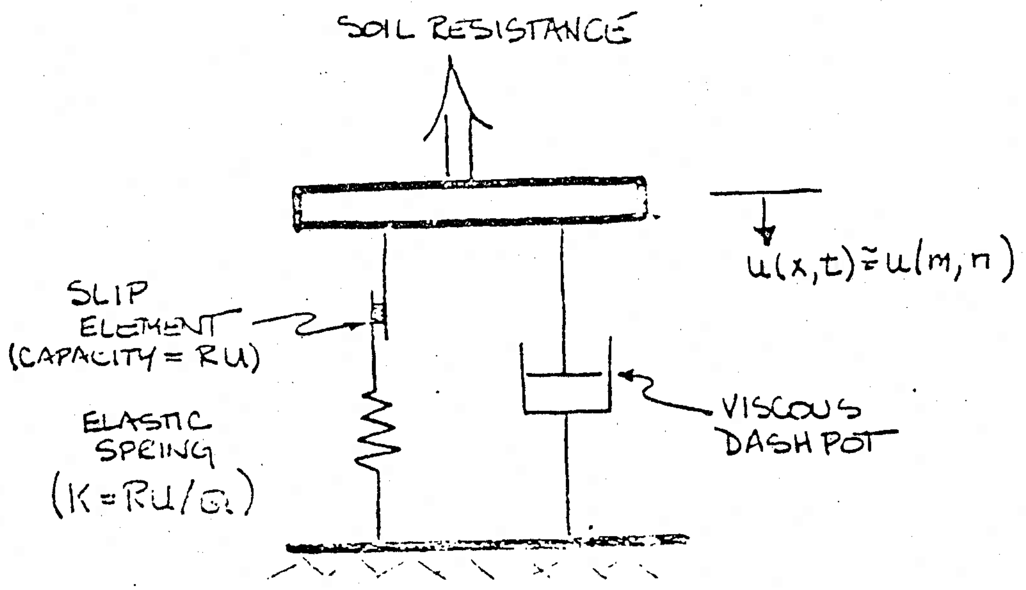
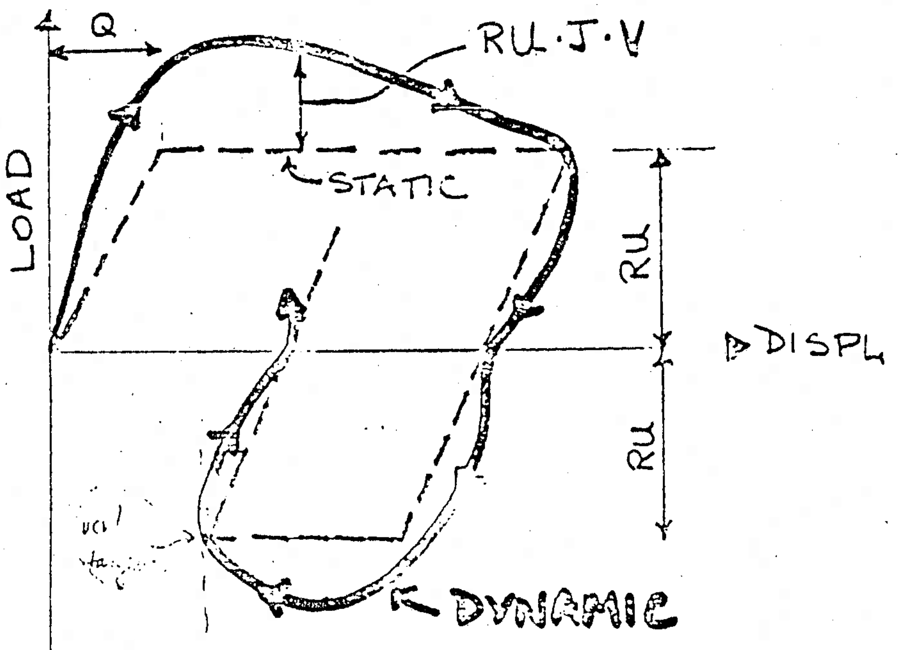


FIG. 2.—SHORT FLOATS

SMITH'S DISCRETIZATION
ANALOGY

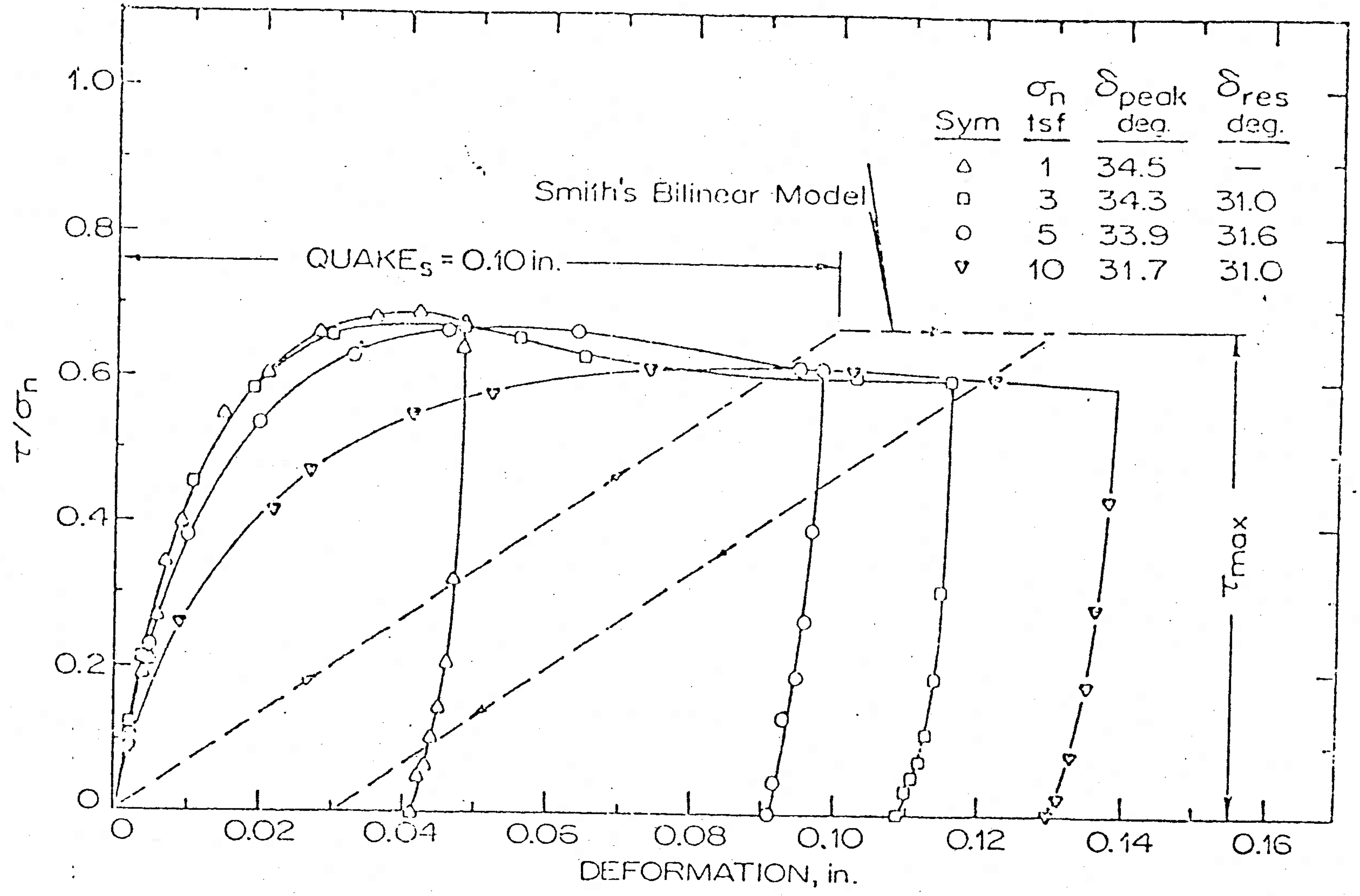


a) RHEOLOGY

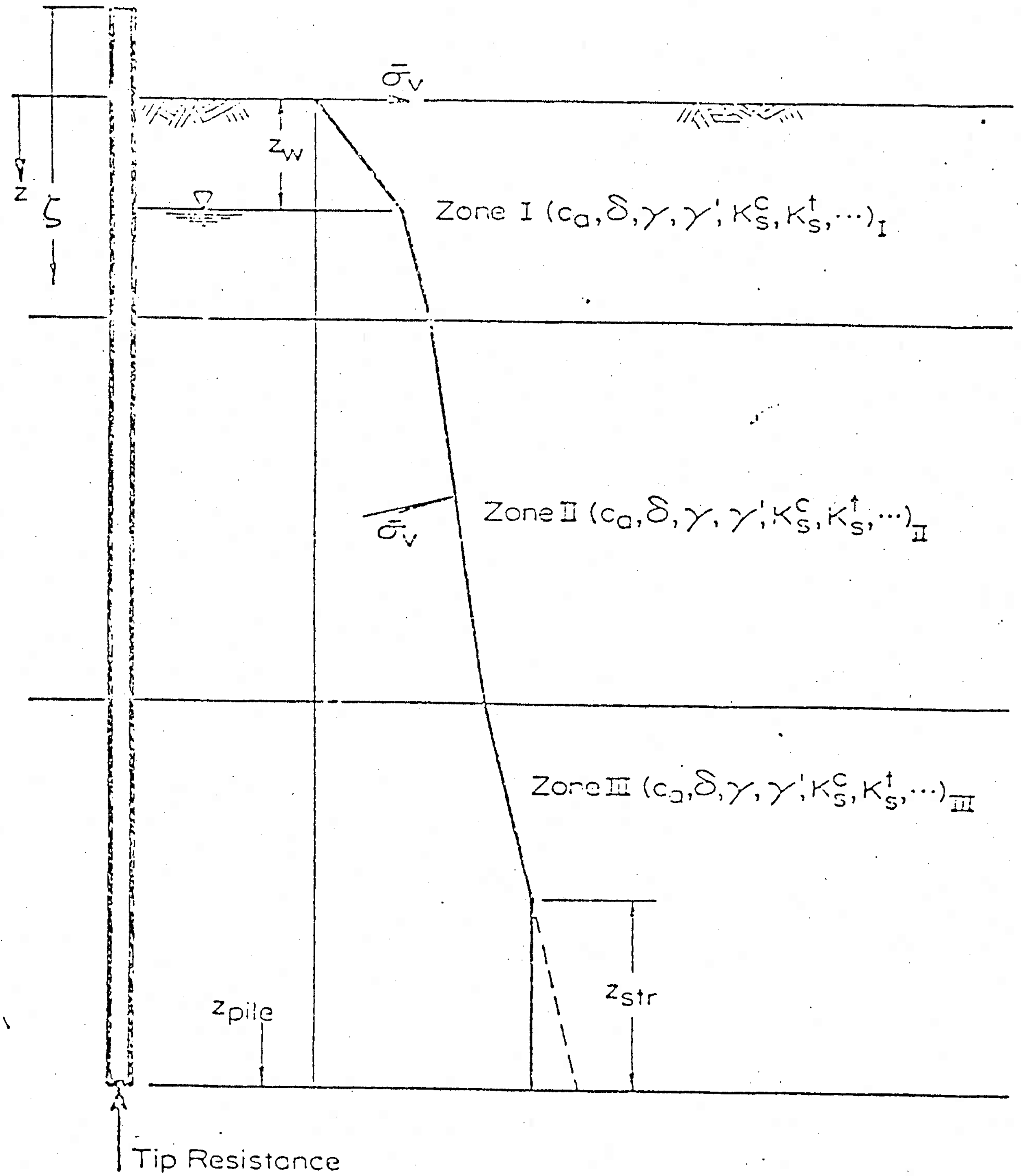


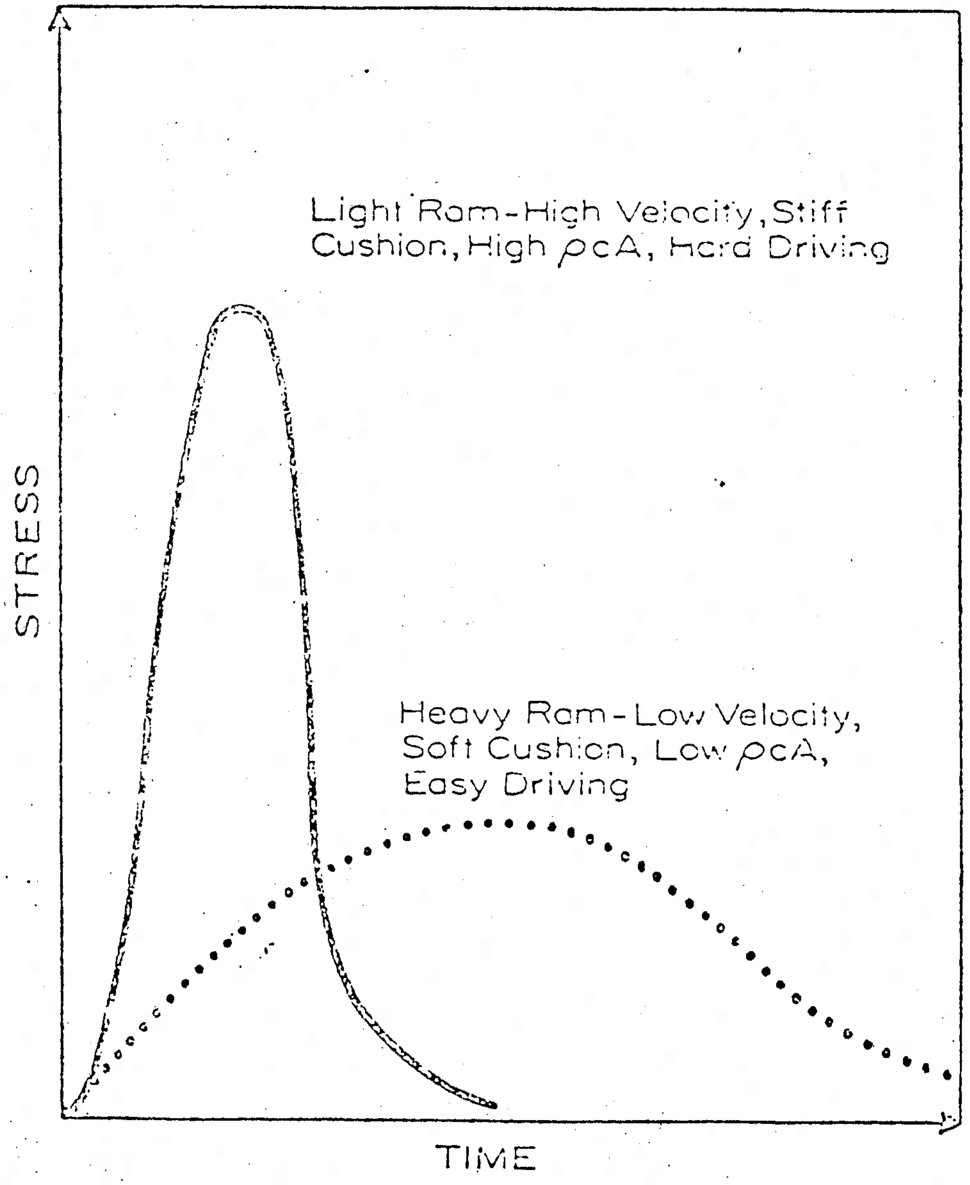
$$R_{DYN} = R_{STATIC}(1 + JV)$$

b) LOAD-DEFORMATION BEHAVIOR



Typical Interface Shear Test Results: Chattahooche River Sand-on-Mortar.


$\bar{\sigma}_v$
z_w
z
ζ
Zone I $(c_a, \delta, \gamma, \gamma', K_s^c, K_s^t, \cdots)_I$
Zone II $(c_a, \delta, \gamma, \gamma', K_s^c, K_s^t, \cdots)_{II}$
$\bar{\sigma}_v$
Zone III $(c_a, \delta, \gamma, \gamma', K_s^c, K_s^t, \cdots)_{III}$
z_{str}
z_{pile}
Tip Resistance



Factors Affecting Impact Stress Transmission and Penetration. (Parola, 1970)

WAVE EQUATION SOLUTION USAGE

PILE BEARING CAPACITY

BLOW COUNT CORRELATIONS

PARAMETER EVALUATIONS

REDRIVING ANALYSES

PILE DRIVEABILITY

WAVE EQUATION SOLUTION USAGE

DYNAMIC FIELD MEASUREMENTS / PREDICTIONS

ENERGY / PEAK FORCE TRANSMITTED

RESISTANCE TO PENETRATION ESTIMATES

RESISTANCE DISTRIBUTION ESTIMATES

PILE DRIVEABILITY

WAVE EQUATION SOLUTION USAGE

COMPLETE / MULTIPLE BLOW ANALYSES

- HARD DRIVING PREDICTIONS
- RESIDUAL LOAD DISTRIBUTION
- AXIAL LOAD / DISPLACEMENT PREDICTIONS
- PILE DRIVEABILITY

TAMU* PROGRAMS

PROGRAM	ADVANTAGES	LIMITATIONS
TTI	CONSIDERABLE EXPERIENCE (SMITH'S BASIC ALGORITHMS)	SINGLE BLOW ONLY (NO MULTIPLE BLOW) POOR DIESEL SIMULATOR
PILEWAVE, TAMFØR (WCC) (WES)	TIMESHARING VERSIONS OF TTI	
ØCEANWAVE	IMPROVED VERSION OF TTI I/O FLEXIBILITY HYDRAULIC HAMMER SIMULATOR	MULTIPLE BLOW (?) POOR DIESEL SIMULATOR
TIDYWAVE	"RESEARCH" VERSION OF ØCEANWAVE	AS ABOVE MORE EXPENSIVE

* LEE LOWERY, TEDDY HIRSCH

CWRU* PROGRAMS

PROGRAM	ADVANTAGES	LIMITATIONS
WEAP	IMPROVED HAMMER SIMULATORS DIESEL HAMMER SIMULATOR I/O FLEXIBILITY	SINGLE BLOW ONLY (NO MULTIPLE BLOW) NO HYDRAULIC HAMMER MODEL MORE EXPENSIVE EQUATIO SOLVER
CAPWAP	INPUT $F(t)$, $a(t)$ AT PILE BUTT OUTPUT RESISTANCE DISTRIBUTION INTERACTIVE PROGRAM	PROPRIETARY (GOBLE & ASSOCIATES) SOLUTIONS SENSITIVE TC HARD DRIVING CONDITI REQUIRES MEASURED $F(t)$ & $a(t)$

* GEORGE GOBLE & FRANK RAUSCHE

DUKE* PROGRAMS

PROGRAM	ADVANTAGES	LIMITATIONS
DUKFØR, PSI	IMPROVED PILE-SOIL INTERACTION MODEL COMPLETE / MULTIPLE BLOW SOLUTION AXIAL LOAD TEST SIMULATION	AIR / STEAM HAMMERS ONLY (CONVENTIONAL HAMMER SIMULATION)

* MIKE HOLLOWAY

HAMMER SPECIFICATIONS

from Conm[illegible]c. Brochu

AIR OR STEAM HAMMERS

RATED ENERGY	MODEL	MANUFACTURER	TYPE	STYLE	BLOWS PER MIN.	WT. OF STRIKING PARTS	TOTAL WEIGHT LBS.	HAMMER LENGTH	JAW DIMENSIONS	BOILER HP REQUIRED (ASME)	STEAM CONSUMP. (LB/HR)	CFM REQ'D	INLET PRESSURE (PSI)	INLET SIZE	√EW
867,960	MRBS 8000	MENCK	SGL.-ACT.	OPEN	32	176,365	330,695	31'10"	CAGE	1500	41,000	17,500	156	8"	391,251
499,070	MRBS 4600	MENCK	SGL.-ACT.	OPEN	36	101,410	176,371	28'0"	CAGE	850	23,000	9,500	156	6"	224,968
325,480	MRBS 3000	MENCK	SGL.-ACT.	OPEN	40	66,135	108,025	25'0"	CAGE	520	15,000	6,000	156	5"	146,716
300,000	3100	VULCAN	SGL.-ACT.	OPEN	58	100,000	174,500	23'4"	18¾"x88"	1,021	32,225	5,965	130	(2)x5"	173,205
300,000	560	VULCAN	SGL.-ACT.	OPEN	45	62,500	134,060	23'0"	18¾"x88"	875	30,150	5,633	150	(2)x5"	136,930
200,000	540	VULCAN	SGL.-ACT.	OPEN	48	40,900	102,980	21'11"	14"x80"	635	21,900	4,200	130	(2)x5"	89,000
189,850	MRBS 1800	MENCK	SGL.-ACT.	OPEN	40	38,580	64,596	20'2"	CAGE	320	8,600	3,700	156	4"	85,583
180,000	OS-60	MKT	SGL.-ACT.	CLOSED	55	60,000	141,150	25'9"	14¾"x72"(M)	750	——	——	135	(2)x3"	103,923
180,000	360	VULCAN	SGL.-ACT.	OPEN	62	60,000	124,830	19'0"	18¾"x88"	750	25,556	4,626	130	(2)x4"	103,923
180,000	060	VULCAN	SGL.-ACT.	OPEN	62	60,000	128,840	19'0"	18¾"x88"(M)	750	25,556	4,626(A)	130	(2)x4"	103,923
164,507	600C	VULCAN	DIFFER.	OPEN	100	60,000	121,000	17'4"	18¾"x88"	860	29,700	6,745	150	(2)x4"	99,349
150,000	300/5	CONMACO	SGL.-ACT.	OPEN	50	30,000	58,100	20'5"	11¼"x56"	300	10,350	——	150	——	67,082
120,000	OS-40	MKT	SGL.-ACT.	CLOSED	55	40,000	111,000	21'3"	14¾"x72"(M)	530	——	——	135	(2)x3"	69,282
120,000	340	VULCAN	SGL.-ACT.	OPEN	60	40,000	98,180	17'11"	14"x80"	600	18,446	3,400	120	(2)x3"	69,282
120,000	040	VULCAN	SGL.-ACT.	OPEN	60	40,000	88,000	19'3"	14¼"x50"	280	10,250	4,500	——	5"	69,282
113,488	400-C	VULCAN	DIFFER.	OPEN	100	40,000	83,000	16'3"	14¼"x50"	700	24,150	4,659(A)	150	5"	63,378
93,340	MRBS 850	MENCK	SGL.-ACT.	OPEN	40	18,960	27,800	19'8"	CAGE	160	4,400	1,950	156	3"	42,068
90,000	030	VULCAN	SGL.-ACT.	OPEN	55	30,000	54,000	15'0"	11¼"x37"	300	9,000	3,000	150	3"	51,964
90,000	300	CONMACO	SGL.-ACT.	OPEN	55	30,000	55,390	16'5"	11¼"x56"	247	8,550	1,903(A)	150	3"	51,961
81,250	8/0	RAYMOND	SGL.-ACT.	OPEN	35	25,000	34,000	19'4"	10¼"x25"	246	8,500	——	135	3"	45,069
75,000	30X	RAYMOND	SGL.-ACT.	OPEN	52	30,000	52,000	19'1"	——	246	8,500	——	150	3"	47,434
72,000	024	VULCAN	SGL.-ACT.	OPEN	55	24,000	45,800	15'7"	11¼"x37"	275	9,488	1,750(A)	120	3"	41,569
60,000	S-20	MKT	SGL.-ACT.	CLOSED	60	20,000	38,650	15'5"	•x36"	190	——	1,720	150	3"	34,640
60,000	020	VULCAN	SGL.-ACT.	OPEN	60	20,000	41,670	15'7"	11¼"x37"	250	7,500	1,634(A)	120	3"	34,641
60,000	200	CONMACO	SGL.-ACT.	OPEN	60	20,000	44,560	15'0"	11¼"x56"	217	7,486	1,634(A)	120	3"	34,641
56,875	5/0	RAYMOND	SGL.-ACT.	OPEN	44	17,500	26,450	16'9"	10¼"x25"	100	4,250	——	150	3"	31,548
50,200	200-C	VULCAN	DIFFER.	OPEN	98	20,000	39,000	13'11"	11¼"x37"	260	8,970	1,746(A)	142	4"	31,685
48,750	016	VULCAN	SGL.-ACT.	OPEN	60	16,250	30,250	13'11"	11¼"x32"	210	6,950	1,275(A)	120	3"	28,148
48,750	4/0	RAYMOND	SGL.-ACT.	OPEN	46	15,000	23,800	16'1"	——	85	——	——	120	2½"	27,042
48,750	150-C	RAYMOND	DIFFER.	OPEN	95-105	15,000	32,500	15'9"	——	——	——	——	120	3"	27,042
48,750	160	CONMACO	SGL.-ACT.	OPEN	60	16,250	33,200	13'10"	11¼"x42"	198	6,950	1,275(A)	120	3"	28,148
46,350	MRBS 500	MKT/MENCK	SGL.-ACT.	OPEN	40	11,300	15,550	16'8"	—x26"	64	2,200	1,060	115	3"	22,886
42,000	014	VULCAN	SGL.-ACT.	OPEN	60	14,000	27,500	13'11"	11¼"x32"	200	6,920	1,282(A)	110	3"	24,248
42,000	140	CONMACO	SGL.-ACT.	OPEN	60	14,000	30,750	13'10"	11¼"x42"	179	6,185	1,164(A)	110	3"	22,248
41,280	160D	CONMACO	DIFFER.	OPEN	103	16,000	35,400	13'7½"	11¼"x42"	237	8,175	1,560(A)	160	3"	25,700
40,625	125	CONMACO	SGL.-ACT.	OPEN	50	12,500	21,940	14'10"	9¼"x32"	119	4,120	940(A)	125	2½"	22,534
40,600	3/0	RAYMOND	SGL.-ACT.	OPEN	48	12,500	21,225	15'7"	10¼"x25"	——	3,000	——	120	2½"	22,528
39,000	012	VULCAN	SGL.-ACT.	OPEN	55	12,000	20,750	15'9"	9¼"x26"	140	4,750	1,120(A)	105	2½"	21,633
37,500	S-14	MKT	SGL.-ACT.	CLOSED	60	14,000	31,700	13'7"	•x36"	155	——	1,260	100	3"	23,000
37,375	115	CONMACO	SGL.-ACT.	OPEN	50	11,500	20,780	14'2"	9¼"x32(C)	99	3,425	910(A)	120	2½"	20,732
37,375	115	CONMACO	SGL.-ACT.	OPEN	50	11,500	20,250	15'0"	9¼"x26"(K)	116	4,000	1,060(A)	120	2½"	20,732
36,000	140-C	VULCAN	DIFFER.	OPEN	103	14,000	27,984	12'3"	11¼"x32"	211	7,279	1,425(A)	140	3"	22,449
36,000	140D	CONMACO	DIFFER.	OPEN	103	14,000	31,200	12'3"	11¼"x42"	211	7,279	1,425(A)	140	3"	22,449
32,885	100C	VULCAN	DIFFER.	OPEN	103	10,000	22,200	14'0"	9¼"x26"	180	6,210	1,245(A)	140	2½"	18,110
32,500	100	CONMACO	SGL.-ACT.	OPEN	50	10,000	19,280	14'2"	9¼"x32"(C)	85	2,945	820(A)	100	2½"	18,028
32,500	100	CONMACO	SGL.-ACT.	OPEN	50	10,000	18,703	15'0"	9¼"x26"(K)	99	3,425	950(A)	100	2½"	18,028
32,500	125C	VULCAN	DIFFER.	OPEN	102	12,500	20,464	12'3"	11¼"x32"	175	6,102	1,406(A)	128	2½"	20,156

32,500	2/0	RAYMOND	SGL.-ACT.	OPEN	50	10,000	18,550	15'[illegible]	10¼"x25"	——	2,400	——	110	2"	[illegible]8
32,500	010	VULCAN	SGL.-ACT.	OPEN	50	10,000	18,750	[illegible]	9¼"x26"	157	5,440	1,002(A)	105	2½"	[illegible],028
32,500	S-10	MKT	SGL.-ACT.	CLOSED	55	10,000	22,380	14'1"	•x30"	130	5,440	1,000	80	2½"	18,028
32,000	120C	VULCAN	DIFFER.	OPEN	108	12,000	25,984	12'3"	11¼"x32"	190	6,618	1,507(A)	133	3"	19,596
26,000	80	CONMACO	SGL.-ACT.	OPEN	50	8,000	17,280	14'2"	9¼"x32"	75	2,580	730(A)	85	2½"	14,422
26,000	80	CONMACO	SGL.-ACT.	OPEN	50	8,000	16,703	15'0"	9¼"x26"	87	3,000	850(A)	85	2½"	14,422
26,000	85C	VULCAN	DIFFER.	OPEN	111	8,525	19,020	12'7"	9¼"x26"	180	6,210	1,245(A)	128	2½"	14,866
26,000	08	VULCAN	SGL.-ACT.	OPEN	50	8,000	16,750	14'10"	9¼"x26"	127	4,380	880(A)	83	2½"	14,422
26,000	S-8	MKT	SGL.-ACT.	CLOSED	55	8,000	18,300	14'4"	•x26"	120	4,380	850	80	2½"	14,422
24,450	80-C	VULCAN	DIFFER.	OPEN	111	8,000	17,885	12'1"	9¼"x26"	180	6,210	1,245(A)	120	2½"	13,985
24,450	80-CH	RAYMOND	DIFFER.	OPEN	110-120	8,000	17,782	11'10"	——	N/A	N/A	——	——	——	13,985
24,450	80-C	RAYMOND	DIFFER.	OPEN	95-105	8,000	17,885	12'2"	——	——	——	——	135	2½"	13,985
24,375	0	RAYMOND	SGL.-ACT.	OPEN	52	7,500	16,000	15'0"	10¼"x25"	——	——	750	110	2"	13,485
24,375	0	VULCAN	SGL.-ACT.	OPEN	50	7,500	16,250	15'0"	9¼"x26"	155	4,380	841(A)	80	2½"	13,485
24,000	C-826	MKT	COMPOUND	CLOSED	85-95	8,000	17,750	12'2"	•x26"	120	——	875	125	2½"	13,856
19,500	65-C	RAYMOND	DIFFER.	OPEN	110	6,500	14,675	11'8"	9¼"x19"	——	3,100	——	120	2"	11,201
19,500	1-S	RAYMOND	SGL.-ACT.	OPEN	58	6,500	12,500	12'9"	7½"x28¼"	——	1,500	——	104	1½"	11,258
19,500	06 (106)	VULCAN	SGL.-ACT.	OPEN	60	6,500	11,200	13'0"	8¼"x20"	94	3,230	625(A)	100	2"	11,258
19,500	65	CONMACO	SGL.-ACT.	OPEN	60	6,500	12,100	13'0"	9¼"x26"(C)	67	2,300	650(A)	100	2"	11,258
19,500	65	CONMACO	SGL.-ACT.	OPEN	60	6,500	11,200	13'0"	8¼"x20"(K)	67	2,300	650(A)	100	2"	11,258
19,500	65-CH	RAYMOND	DIFFER.	OPEN	130	6,500	14,615	12'1"	——	N/A	N/A	——	——	——	11,258
19,200	65-C	VULCAN	DIFFER.	OPEN	117	6,500	14,886	12'1"	8¼"x20"	152	5,244	991(A)	150	2"	11,171
19,150	11B3	MKT	DBL.-ACT.	CLOSED	95	5,000	14,000	11'2"	•x26"	126	——	900	100	2½"	9,785
19,150	1100	BSP	DBL.-ACT.	CLOSED	95	5,000	14,000	11'2"	•x26"	126	——	900	90	2½"	9,785
16,250	S-5	MKT	SGL.-ACT.	CLOSED	60	5,000	12,460	13'3"	•x24"	85	——	600	80	2"	9,000
16,000	C-5	MKT	DBL.-ACT.	CLOSED	100-110	5,000	11,880	8'9"	•x26"	80		585	100	2½"	8,944
15,100	50-C	VULCAN	DIFFER.	OPEN	120	5,000	11,782	11'0"	8¼"x20"	125	4,312	880(A)	120	2"	8,689
15,000	1 (106)	VULCAN	SGL.-ACT.	OPEN	60	5,000	9,700	12'9"	8¼"x20"	81	2,794	565(A)	80	2"	8,660
15,000	1	RAYMOND	SGL.-ACT.	OPEN	60	5,000	11,000	12'9"	7½"x28¼"	——	1,400	500	80	1½"	8,660
15,000	50	CONMACO	SGL.-ACT.	OPEN	60	5,000	10,600	13'0"	9¼"x26"(C)	56	1,925	565(A)	80	2"	8,660
15,000	50	CONMACO	SGL.-ACT.	OPEN	60	5,000	9,700	13'0"	8¼"x20"(K)	56	1,925	565(A)	80	2"	8,660
13,100	10B3	MKT	DBL.-ACT.	CLOSED	105	3,000	10,850	9'2"	••x24"	104	——	750	100	2½"	6,269
13,100	1000	BSP	DBL.-ACT.	CLOSED	105	3,000	10,850	9'2"	•x24"	104	——	750	90	2½"	6,269
10,400	2S	VULCAN	SGL.-ACT.	OPEN	70	4,150	7,850	11'6"	7¼"x19"	50	1,690	336(A)	95	1½"	6,570
8,750	900	BSP	DBL.-ACT.	CLOSED	145	1,600	7,100	8'2"	•x20"	85	——	600	90	2"	3,742
8,750	9B3	MKT	DBL.-ACT.	CLOSED	145	1,600	7,000	8'4"	8½"x20"	85	——	600	100	2"	3,742
7,260	30-C	VULCAN	DIFFER.	OPEN	133	3,000	7,036	8'11"	7¼"x19"	70	2,412	488	120	1½"	4,666
7,260	2	VULCAN	SGL.-ACT.	OPEN	70	3,000	6,700	11'7"	7¼"x19"	49	1,690	336(A)	80	1½"	4,666
4,700	700N	BSP	DBL.-ACT.	CLOSED	225	850	6,500	5'5"	•x15"	——	——	600	90	2"	1,999
4,150	7	MKT	DBL.-ACT.	CLOSED	225	800	5,000	6'1"	•x21"	65	——	450	100	1½"	1,697
4,000	DGH-900	VULCAN	DIFFER.	CLOSED	328	900	5,000	6'9"	VARIES	40	——	580(A)	75	1½"	1,897
3,000	600N	BSP	DBL.-ACT.	CLOSED	250	500	3,800	5'0"	•x15"	——	——	365	90	1½"	1,225
2,500	6	MKT	DBL.-ACT.	CLOSED	275	400	2,900	5'3-1/8"	•x15"	45	——	400	100	1¼"	1,000
1,200	500N	BSP	DBL.-ACT.	CLOSED	330	200	2,000	3'11"	•x12"	——	——	250	90	1¼"	490
1,000	5	MKT	DBL.-ACT.	CLOSED	300	200	1,500	4'7"	6"x11"	35	——	250	100	1¼"	447
386	DGH-100D	VULCAN	DIFFER.	CLOSED	303	100	788	4'2"	4¼"x8¾"	5	——	74	60	1"	196
356	3	MKT	DBL.-ACT.	CLOSED	400	68	675	4'10"	NONE	25	——	110	100	1"	155
——	2	MKT	DBL.-ACT.	CLOSED	500	48	343	2'9"	NONE	15	——	70	125	¾"	——
——	1	MKT	DBL.-ACT.	CLOSED	500	21	145	3'7"	NONE	15	——	70	125	¾"	——

) ADIABATIC COMPRESSION (C) CONMACO CABLE HAMMER (K) CONMACO KEY HAMMER

2/3/76

DIESEL HA[illegible]MERS

(FT	MODEL	MANUFACTURER	ACTING	MIN	LBS.	LBS					
280,000-	K150	KOBE	SGL-ACT.	45-60	33,100	80,500	8'6"	29'8"	CAGE	[illegible]	92,67
141,000-63,360	MB70	MITSUBISHI	SGL-ACT.	38-60	15,840	46,000	8'6"	19'6"	——	7-10	46,58
117,175-62,566	D55	DELMAG	SGL-ACT.	36-47	11,860	26,300	9'10"	17'9"	32	5.54	37,27
105,600-	K60	KOBE	SGL-ACT.	42-60	13,200	37,500	8'0"	24'3"	42	6.5-8.0	37,33
105,000-48,400	D46-02	DELMAG	SGL-ACT.	37-53	10,100	19,900	10'8"	17'3"	32	3.3	32,56
91,100-	K45	KOBE	SGL-ACT.	39-60	9,900	25,600	9'2"	18'6"	36	4.5-5.5	30,03
87,000-43,500	D44	DELMAG	SGL-ACT.	37-56	9,460	22,440	9'2"	15'10"	32	4.5	28,74
84,000-37,840	M43	MITSUBISHI	SGL-ACT.	40-60	9,460	22,660	8'10"	16'3"	37	4.0-5.8	28,18
83,100-38,000	D36-02	DELMAG	SGL-ACT.	37-53	7,900	17,700	10'8"	17'3"	32	3.0	25,62
79,500-	J44	IHI	SGL-ACT.	42-70	9,720	21,500	8'2"	14'10"	37	6.86	27,79
79,000-	K42	KOBE	SGL-ACT.	40-60	9,260	24,000	8'6"	17'8"	36	4.5-5.5	27,04
78,800-	B45	BSP	DBL-ACT.	80-100	10,000	27,500	——	19'3"	36	5.5	28,07
73,780-30,380	D36	DELMAG	SGL-ACT.	37-53	7,940	17,780	9'3"	14'11"	32	3.7	24,20
70,800-	K35	KOBE	SGL-ACT.	39-60	7,700	18,700	9'2"	17'8"	30	3.0-4.0	23,34
64,000-29,040	M33	MITSUBISHI	SGL-ACT.	40-60	7,260	16,940	8'0"	13'2"	32	3.4-5.3	21,55
63,900-	B35	BSP	DBL-ACT.	80-100	7,700	21,200	——	18'5"	36	4.5	22,18
63,500-	J35	IHI	SGL-ACT.	42-70	7,730	16,900	8'3"	14'6"	32	4.76	22,15
63,000-42,000	DE70B	MKT	SGL-ACT.	40-50	7,000	15,460	10'6"	15'10"	26	3.3	21,00
62,900-31,800	D30-02	DELMAG	SGL-ACT.	38-52	6,600	13,150	10'7"	17'2"	26	1.7	20,37
60,100-	K32	KOBE	SGL-ACT.	40-60	7,050	17,750	8'6"	17'8"	30	2.75-3.5	20,58
54,200-23,870	D30	DELMAG	SGL-ACT.	39-60	6,600	12,346	8'3"	14'2"	26	2.9	18,92
50,700-	K25	KOBE	SGL-ACT.	39-60	5,510	13,100	9'3"	17'6"	26	2.5-3.0	16,71
48,400-24,600	D22-02	DELMAG	SGL-ACT.	38-52	4,850	11,400	10'7"	17'2"	26	1.6	15,32
45,700-	B25	BSP	DBL-ACT.	80-100	5,510	15,200	——	17'9"	30	3.5	15,86
45,000-30,000	DE50B	MKT	SGL-ACT.	40-50	5,000	12,050	10'6"	14'9"	26	3.0	15,00
45,000-30,000	DA55B	MKT	SGL-ACT.	40-50	5,000	17,000	10'9"	17'4"	26	4	15,00
45,000-20,240	M23	MITSUBISHI	SGL-ACT.	42-60	5,060	11,220	8'10"	14'1"	26	2.4-3.7	15,09
43,400-	N60	VULCAN	SGL-ACT.	50-60	5,280	12,760	8'2"	15'1"	26	1.85	15,13
41,300-	K22	KOBE	SGL-ACT.	40-60	4,850	12,350	9'2"	17'6"	26	2.0-2.75	14,15
39,780-	D22	DELMAG	SGL-ACT.	42-60	4,850	11,150	8'2"	14'2"	26	3.44	13,87
39,100	J22	IHI	SGL-ACT.	42-70	4,850	10,800	10'0"	14'0"	26	3.2	13,77
38,200-31,200	DA55B	MKT	DBL-ACT.	78-82	5,000	17,000	——	17'4"	26	4.0	13,78
36,000-24,000	DE40	MKT	SGL-ACT.	40-50	4,000	11,275	10'6"	15'0"	26	3.0	11,31
32,549-	N46	VULCAN	SGL-ACT.	50-60	3,960	9,845	8'2"	15'1"	26	1.59	11,35
31,000-17,700	520	LINK-BELT	DBL-ACT.	80-84	5,070	12,545	——	13'6"	28	1.35	12,33
27,100-	D15	DELMAG	SGL-ACT.	40-60	3,300	6,615	8'3"	13'11"	20	1.75	9,45
26,200-	B15	BSP	DBL-ACT.	80-100	3,300	9,000	——	17'0"	26	2.5	9,29
26,000-11,880	M14S	MITSUBISHI	SGL-ACT.	42-60	2,970	7,260	8'9"	13'7"	26	1.3-2.1	8,78
25,200-16,800	DE30B	MKT	SGL-ACT.	40-50	2,800	7,500	10'0"	15'4"	20	2.0	8,40
25,200-16,800	DA35B	MKT	SGL-ACT.	40-50	2,800	10,000	10'9"	17'0"	20	1.7	8,40
25,200-	DE30	MKT	SGL-ACT.	40-50	2,800	8,125	10'9"	15'0"	20	2.0	8,40
24,600-	N33	VULCAN	SGL.-ACT.	50-60	3,000	7,645	8'2"	15'8"	26	1.32	8,59
24,400-	K13	KOBE	SGL.-ACT.	40-60	2,860	7,300	8'6"	16'8"	26	.75-2.0	8,35
22,500-	D12	DELMAG	SGL.-ACT.	40-60	2,750	6,050	8'2"	13'11"	20	2.11	7,86
21,000-16,000	DA35B	MKT	DBL.-ACT.	78-82	2,800	10,000	——	17'0"	20	2.0	7,66
19,840- 7,700	440	LINK BELT	DBL.-ACT.	86-90	4,000	10,300	——	14'6"	20	1.6	8,53
18,000-12,000	DE20	MKT	SGL.-ACT.	40-50	2,000	6,325	9'5"	13'3"	20	1.6	6,00
18,000-	312	LINK BELT	DBL.-ACT.	100-105	3,857	10,375	——	10'9"	26	1.1	8,33
9,050-	D5	DELMAG	SGL.-ACT.	40-60	1,100	2,730	8'3"	12'2".	19	1.32	3,16
8,800-	DE10	MKT	SGL.-ACT.	40-50	1,100	3,100	8'0"	12'2"	10" BP	0.9	3,11
8,100-	180	LINK BELT	DBL.-ACT.	90-95	1,725	4,550	——	11'3"	18	0.65	3,73
3,630-	D4	DELMAG	SGL.-ACT.	50-60	836	1,360	4'4"	7'9"	BEAM	0.21	1,74
1,815-	D2	DELMAG	SGL.-ACT.	60-70	484	792	4'1"	6'9"	BEAM	0.075	93

THE ABOVE INFORMATION HAS BEEN TAKEN FROM MANUFACTURERS' PUBLISHED DATA.

IMPACT EXTRACTOR SPECIFICATIONS

RATED ENERGY FT. LBS.	MODEL	MANUFACTURER	CRANE PULL-TONS MIN/MAX	BLOWS PER MIN.	RAM WEIGHT LBS.	TOTAL WEIGHT LBS.	LENGTH FT.-IN.	BOILER HP. REQ'D. ASME	AIR REQ'D. CFM	INLET PRESSURE (PSI)	INLET SIZE IN.	√EW RATING
12,000	HD-15	BSP	18/45	120	3,850	10,435	19'0"	70	450	100	2"	6,797
9,525	A-4	NILENS	/50	150	5,654	10,910	15'5"	86	640	100	2½"	7,338
6,350	A-3	NILENS	/30	160	3,102	7,340	14'4"	64	470	100	1½"	4,438
5,600	HD-7	BSP	8/20	150	1,155	3,750	16'4"	——	250	100	1½"	2,543
3,615	P-14	DELMAG	10/25	135	1,630	5,450	10'4"	DIESEL	——	——	——	2,427
3,175	A-2	NILENS	/25	160	1,617	4,175	13'6"	37	240	100	1½"	2,259
3,000	600N	BSP	10/13	250	400	6,280	9'6"	——	365	90	1½"	1,095
2,000	HD2000	BSP	3/20	200	500	1,680	8'5"	——	125	100	1½"	
1,640	1200-A	VULCAN	10.5/150	530	1,200	9,200	12'7"	140	1,020	100	2"	1,400
1,200	500N	BSP	5/7	330	200	2,856	7'2"	——	250	90	1¼"	490
1,000	800-A	VULCAN	7/100	550	800	5,640	10'8"	100	740	100	1½"	894
1,000	E-4	MKT	/100	400	400	4,400	10'5"	30	550	100	1½"	632
700	E-2	MKT	/50	450	200	3,600	8'4"	30	400	100	1¼"	374
500	400-A	VULCAN	3.5/50	550	400	2,850	9'4"	50	342	100	1¼"	447
250	200-A	VULCAN	.75/25	550	200	1,500	7'10"	18	173	100	1"	223

THE ABOVE INFORMATION HAS BEEN TAKEN FROM MANUFACTURERS' PUBLISHED DATA.

VIBRATORY DRIVER/EXTRACTOR

CENTRIC OMENT IN.-LB.	MODEL	MANUFACTURER	TYPE DRIVE	FREQUENCY VPM	AMPLITUDE IN.	H.P.	MAX. PULL EXTRACTION TONS	PILE CLAMP FORCE TONS	SUSPENDED WEIGHT LB.	SHIPPING WEIGHT LB.	LENGTH FT.-IN.	WIDTH FT.-IN.	THROAT WIDTH IN.	HAMMER HEIGHT FT.-IN.	HEAD HEIGHT IN.
6940	40E-3VT	FOSTER	ELECTRIC	700-1120	5/16-2	300	60	160/200	40000	42300	10-8	4-6	——	11-0	50
6940	40E-1HT	FOSTER	ELECTRIC	700-1120	5/16-2	300	60	160/200	40000	42300	10-8	9-0	——	7-11	50
3600	ICE812	ICE	HYDRAULIC	480-1200	¼-1	350	40	100	14700	30200	8-0	1-10	12	8-0	29
3500	40H-4	FOSTER	HYDRAULIC	0-1600	5/16-1	460	30/45	100/200	18000	——	8-2	0-12	12	6-7	26
3470	40E-3	FOSTER	ELECTRIC	700-1120	5/16-1	150	40	80/100	20300	32600	10-8	4-6	12	8-3	26
3470	40E-1	FOSTER	ELECTRIC	700-1300	5/16-1	150	50	80/100	16500	28500	9-2	3-6	12	8-3	26
2500	V-18	MKT	HYDRAULIC	0-1600	½	224	40	75	14000	31500	5-3	1-2	14	11-0	38
1800	ICE416	ICE	HYDRAULIC	480-1600	¼-1	220	40	100	12200	26200	8-0	1-10	12	8-9	29
1740	20H-4	FOSTER	HYDRAULIC	0-1500	¼-¾	190	30	80/100	12900	26900	7-0	1-10	12	6-3	26
1740	20SP-1	FOSTER	ELECTRIC	890-1500	5/16-1	100	20	80/100	9100	18800	7-1	2-10	12	6-10	26
1462	V-14	MKT	HYDRAULIC	1500-1850	¼-½	140	40	75	10000	29500	5-3	1-2	14	8-0	38
1000	V-5	MKT	HYDRAULIC	1350	½	55	15	31	8500	11600	5-4	1-2	14	5-10	30
870	10E-1	FOSTER	ELECTRIC	955-1100	3/16-¾	40	16	80	7400	17700	7-4	2-5	12	6-6	26
650	2-17	FOSTER	ELECTRIC	1090-1290	¼-¾	34	13	40	5500	11000	5-9	2-3	14	7-4	24
610	7H-2	FOSTER	HYDRAULIC	0-1800	¼-¾	125	10	60	4680	13000	5-10	1-8	11	6-4	——
260	3H-3	FOSTER	HYDRAULIC	0-2000	1/16-1/5	25	6	40	1590	6000	4-3	1-1	9	4-2	——
174	2-3	FOSTER	ELECTRIC	1800	¼-½	8	5½	12½	1500	5000	3-0	1-7	14	3-0	6

UBC – DETAILED REGULATIONS – CHAPTER 29
Excavations, Foundations, and Retaining Walls

Sec. 2905 – Foundation Investigation - as required

Sec. 2908 – Piles - General Requirements

- Recommended pile type and installed capacities
- Installation criteria and inspection procedures
- Pile load test requirements
- Determination of allowable loads
- Static load test interpretation
- Column action
- Group action
- Downdrag
- Jetting
- Corrosion protection

UBC – DETAILED REGULATIONS – CHAPTER 29
Excavations, Foundations, and Retaining Walls

Sec. 2909 Specific Pile Requirements

Types: Timber, Uncased Cased-in-Place Concrete, Metal Cased Concrete, Precast Concrete, PCPS Concrete, Steel, Concrete-filled Steel Pipe

Subjects: Material, Allowable Stresses, Installation, Reinforcement, Minimum Dimensions, etc.