# APPENDIX A

## Estimating Soil Values

The following are various ways to estimate soil properties needed in the program. These are **estimates only** and do not replace **good engineering judgement** based on experience and the soils data.

## Sands

The Table 2 can help you estimate the angle of internal friction "$\phi$" (Phi) and the effective unit weight "$\gamma$" (Gammad) for sands.

## Shear Modulus G

The "G" estimated from PL-AID is recommended because its more realistic values are based on the University of Florida's research results. The other estimates are typically more conservative and maybe used for initial calculation. PL-AID bases it's estimates of G in sand on the following:

for $N < 40$    0.5 N (ksi)
for $N > 40$    20 (ksi)

or shear modulus "G" can be estimated from:

$$G = \frac{E}{2\ (1\ +\ \nu)}$$

where:

E = Young's Modulus and can be estimated from:

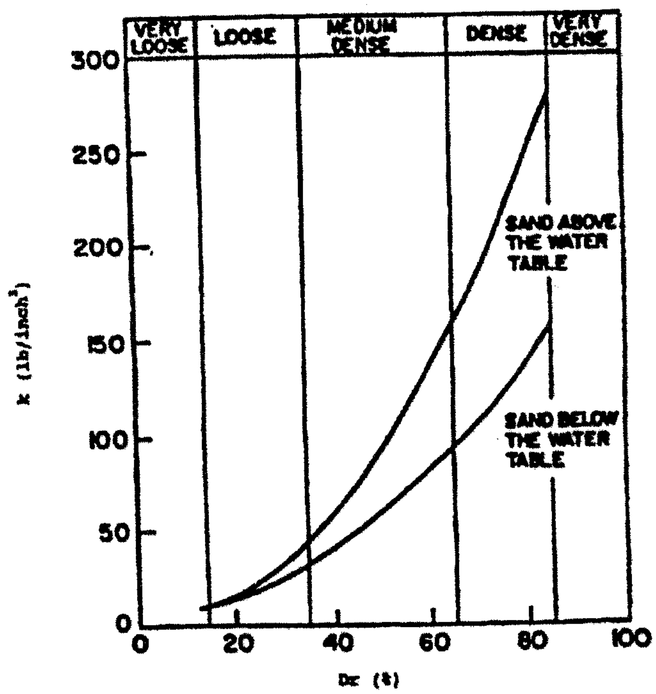


**Figure 126,** K vs Relative Density

**Young's Modulus E**

Normally Consolidated Clean Sands:

$$E\ (ksi) = 0.139\ N_{60}$$

Over Consolidated Clean Sands:

$$E\ (ksi) = 0.208\ N_{60}$$

Sand with fines:

$$E\ (ksi) = 0.069\ N_{60}$$

where:

$N_{60}$ = corrected SPT blow count

In cases of no insitu data, the following can be used for initial estimates until insitu data can be obtained.

$$G = \frac{(0.5)(k)(z)}{(1+\nu)}$$

where:

k = soil modulus
z = depth below ground surface
ν = Poisson's Ratio

**Poisson's Ratio ν**

Poisson's ratio "ν" (RNU) for sand:

| | |
|---|---|
| Loose sand | 0.10 - 0.30 |
| Dense sand | 0.30 - 0.40 |

**Table 2,** Sand estimated soil parameters

Empirical Values for φ and dry unit weight γ for granular soils based on corrected N'

| Description | | Very Loose | Loose | Medium | Dense | Very Dense |
|---|---|---|---|---|---|---|
| Corrected SPT - N' | | 0 to 4 | 4 - 10 | 10 - 30 | 30 - 50 | 50+ |
| Approx. φ* | | 25 | 25 - 30 | 30 - 35 | 35 - 40 | 38 - 43 |
| Soil Modulus **k** | Submerged metric x$10^{-6}$ | 0.010 kip/in³<br>2.71 kN/mm³ | 0.020 kip/in³<br>5.43 kN/mm³ | 0.060 kip/in³<br>16.29 kN/mm³ | 0.125 kip/in³<br>33.93 kN/mm³ | |
| | Above WT metric x$10^{-6}$ | 0.015 kip/in³<br>4.07 kN/mm³ | 0.025 kip/in³<br>6.79 kN/mm³ | 0.090 kip/in³<br>24.43 kN/mm³ | 0.225 kip/in³<br>61.08 kN/mm³ | |
| γ (kip/in³) x $10^{-5}$<br>(kN/mm³) x $10^{-8}$ | | 4.051 - 5.787<br>1.100 - 1.571 | 5.208 - 6.655<br>1.414 - 1.807 | 6.366 - 7.523<br>1.728 - 2.042 | 6.366 - 8.102<br>1.728 - 2.199 | 6.366 - 8.681<br>1.728 - 2.356 |
| **E** | kip/in²<br>kN/mm² | 0.694 - 1.389<br>0.0048 -0.0096 | 1.389 - 3.472<br>0.0096 - 0.0239 | 2.778 - 8.333<br>0.0192 - 0.0575 | 6.944 - 13.889<br>0.0479 - 0.0958 | 13.889 +<br>0.0958 + |

* Use larger value for granular material with 5% or less fine sand and silt.

**Clay**

The Table 3 can help you estimate the undrained shear strength "c" and the effective unit weight "γ" (Gammad), soils modulus "k" and "$\varepsilon_{50}$" for clays.

**Table 3,** Clay Estimated Soil Parameters

| Consistency | Average Undrained Shear Strength "c" (ksi x $10^{-3}$) (kN/mm$^2$ x $10^{-6}$) | Soil Modulus "k" Static (kci) (kN/mm$^3$ x $10^{-6}$) | Soil Modulus "k" Cyclic (kci) (kN/mm$^3$ x $10^{-6}$) | $\varepsilon_{50}$ | Effective Unit Weight γ (kci x $10^{-5}$) (kN/mm$^3$ x $10^{-7}$) | SPT - N |
|---|---|---|---|---|---|---|
| Very Soft Clay | < 1.74<br>< 12 | 0.01<br>2.71 | -<br>- | | 5.8 - 6.9<br>1.574 - 1.873 | 0 - 2 |
| Soft Clay | 1.74 to 3.48<br>12 to 24 | 0.03<br>8.14 | -<br>- | 0.020 | 5.8 - 6.9<br>1.574 - 1.873 | 2 - 4 |
| Medium Clay | 3.48 to 6.94<br>24 to 48 | 0.10<br>27.15 | -<br>- | 0.010 | 6.4 - 7.5<br>1.737 - 2.036 | 4 - 8 |
| Stiff Clay | 6.94 to 13.9<br>48 to 96 | 0.50<br>135.72 | 0.20<br>54.29 | 0.007 | 6.9 - 8.1<br>1.873 - 2.199 | 8 - 16 |
| Very Stiff Clay | 13.9 to 27.8<br>96 to 192 | 1.00<br>271.45 | 0.40<br>108.58 | 0.005 | 6.9 - 8.1<br>1.873 - 2.199 | 16 - 32 |
| Hard Clay | 27.8 to 55.6<br>192 to 383 | 2.00<br>542.89 | 0.80<br>217.16 | 0.004 | 6.9 - 8.1<br>1.873 - 2.199 | 32+ |

## Shear Modulus G

The shear modulus "**G**" can be estimated from:

PL-AID bases it's estimates of G in silts and clays on the following:

### Silts

| | |
|---|---|
| N < 10 | 0.5 N (ksi) |
| N > 10 | 5.0 + 0.175(N - 10) (ksi) |

### Clays

| | |
|---|---|
| N < 10 | 0.5 N (ksi) |
| N > 10 | 5.0 + 0.1(N - 10) (ksi) |

In cases of no insitu data, the following can be used for initial estimates until insitu data can be obtained.

$$G = \frac{(50)(Cu)}{(1+\nu)}$$

where:

Cu = undrained shear strength
ν = Poisson's Ratio

## Poisson's Ratio ν

Poisson's ratio "ν" (RNU) for clay:

| | |
|---|---|
| Saturated soil, undrained condition | 0.50 |
| Partially saturated clay | 0.30 - 0.40 |

## $\tau_F$ (TAUF)

The value of $\tau_F$ (in TSF) can be estimated by the formulas shown in the following Tables.

$\xi_{100}$

Where the program requires $\xi_{100}$, one should not use $2(\xi_{50})$ because $\xi_{100}$ is related to the ultimate shear strength and $\xi_{50}$ is related to (0.5)(ultimate shear strength). But, $\xi_{100} \neq 2\xi_{50}$, actually $\xi_{100} \geq 3$ to 4 times $\xi_{50}$.

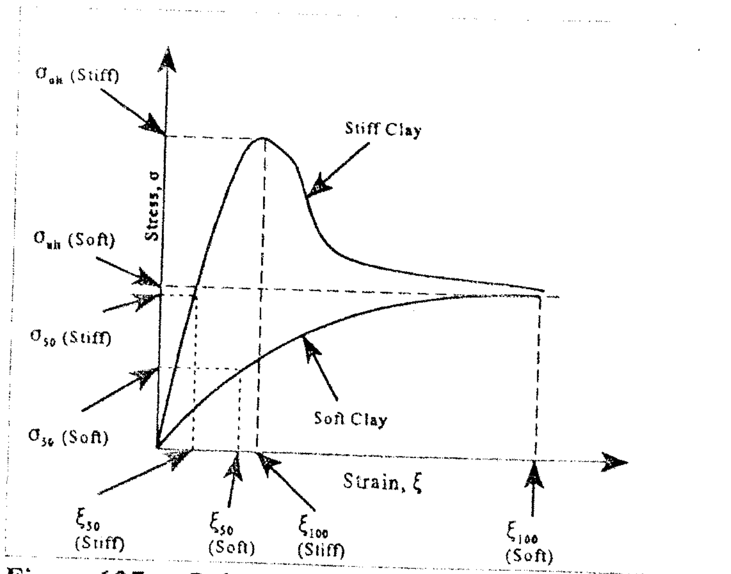


**Figure 127,** Relationship of $\xi$ and $\sigma$

__Shear Modulus G__

The shear modulus "**G**" can be estimated from:

PL-AID bases it's estimates of G in silts and clays on the following:

__Silts__

| | |
|---|---|
| N < 10 | 0.5 N (ksi) |
| N > 10 | 5.0 + 0.175(N - 10) (ksi) |

__Clays__

| | |
|---|---|
| N < 10 | 0.5 N (ksi) |
| N > 10 | 5.0 + 0.1(N - 10) (ksi) |

In cases of no insitu data, the following can be used for initial estimates until insitu data can be obtained.

$$G = \frac{(50)(Cu)}{(1+\nu)}$$

where:

Cu = undrained shear strength
ν = Poisson's Ratio

__Poisson's Ratio ν__

Poisson's ratio "ν" (RNU) for clay:

| | |
|---|---|
| Saturated soil, undrained condition | 0.50 |
| Partially saturated clay | 0.30 - 0.40 |

**Table 4,** $\tau_F$ - Steel H-Piles

| Soil Type | |
|---|---|
| Plastic clay | $\frac{N(110 - N)}{192{,}094}\ (ksi)$ <br> $\frac{N(110 - N)}{2.79 \times 10^{7}}\ (kN/mm^{2})$ |
| Clay-silt-sand mixtures, very silty sand, silts and marls | $-(3.153x10^{-4})+(4.58x10^{-4})N-(6.36x10^{-6})N^{2}+(3.42x10^{-8})N^{3}\ (ksi)$ <br> $-(2.17x10^{-6})+(3.16x10^{-6})N-(4.38x10^{-8})N^{2}+(2.36x10^{-10})N^{3}\ (kN/mm^{2})$ |
| Clean sands | $(1.611x10^{-5})N\ (ksi)$ <br> $(1.111x10^{-7})N\ (kN/mm^{2})$ |
| Soft limestone, very shelly sand | $(1.056x10^{-4})N\ (ksi)$ <br> $(7.278x10^{-7})N\ (kN/mm^{2})$ |

**Table 5,** $\tau_F$ - Steel Pipe Piles

| Soil Type | |
|---|---|
| Plastic clay | $(1.318x10^{-2})+(3.306x10^{-3})\ln(N)$ (*ksi*)<br><br>$(9.088x10^{-5})+(2.279x10^{-5})\ln(N)$ (*kN/mm*$^2$) |
| Clay-silt-sand mixtures, very silty sand, silts and marls | $(3.375x10^{-3})+(2.042x10^{-3})\ln(N)$ (*ksi*)<br><br>$(2.327x10^{-5})+(1.408x10^{-4})\ln(N)$ (*kN/mm*$^2$) |
| Clean sands | $(8.056x10^{-4})+(2.111x10^{-3})\ln(N)$ (*ksi*)<br><br>$(5.55x10^{-6})+(1.456x10^{-5})\ln(N)$ (*kN/mm*$^2$) |
| Soft limestone, very shelly sand | $(2.500x10^{-4})+(1.861x10^{-3})\ln(N)$ (*ksi*)<br><br>$(1.724x10^{-6})+(1.283x10^{-5})\ln(N)$ (*kN/mm*$^2$) |

**Table 6,** $\tau_F$ - Concrete Piles

| Soil Type | |
|---|---|
| Plastic clay | $\frac{(110-N)}{144{,}238}$ $(ksi)$ <br> $\frac{N(110-N)}{20{,}919{,}159}$ $(kN/mm^2)$ |
| Clay-silt-sand mixtures, very silty sand, silts and marls | $\frac{N(110-N)}{164{,}999}$ $(ksi)$ <br> $\frac{N(110-N)}{23{,}930{,}210}$ $(kN/mm^2)$ |
| Clean sands | $(2.639x10^{-4})N$ $(ksi)$ <br> $(1.820x10^{-6})N$ $(kN/mm^2)$ |
| Soft limestone, very shelly sand | $(1.389x10^{-4})N$ $(ksi)$ <br> $(9.576x10^{-7})N$ $(kN/mm^2)$ |

**Ultimate End Bearing [QZ(3)]**

The value of the ultimate end bearing failure can be estimated by the following formulas:

**Table 7,** Ultimate Pile Tip Resistance

| Pile Type | | Soil Type | | | |
|---|---|---|---|---|---|
| | | Plastic clay | Clay-silt-sand mixtures, very silty sand, silts and marls | Clean sands | Soft limestone, very shelly sand |
| Steel H-Piles | (ksi)<br>kN/mm$^2$ | (9.722x$10^{-3}$)N<br>(6.703x$10^{-5}$)N | (2.222x$10^{-2}$)N<br>(1.532x$10^{-4}$)N | (4.444x$10^{-2}$)N<br>(3.064x$10^{-4}$)N | (5.000x$10^{-2}$)N<br>(3.448x$10^{-4}$)N |
| Steel Pipe Piles | (ksi)<br>kN/mm$^2$ | (3.333x$10^{-6}$)N<br>(2.298x$10^{-8}$)N | (6.667x$10^{-6}$)N<br>(4.597x$10^{-8}$)N | (9.167x$10^{-6}$)N<br>(6.320x$10^{-8}$)N | (1.333x$10^{-5}$)N<br>(9.193x$10^{-8}$)N |
| Concrete Piles | (ksi)<br>kN/mm$^2$ | (9.722x$10^{-3}$)N<br>(6.703x$10^{-5}$)N | (2.222x$10^{-2}$)N<br>(1.532x$10^{-4}$)N | (4.444x$10^{-2}$)N<br>(3.064x$10^{-4}$)N | (5.000x$10^{-2}$)N<br>(3.448x$10^{-4}$)N |