E. T-WALL DESIGN EXAMPLES

The following three design examples illustrate the application of the T-Wall Design Procedure outlined in Section 3.4.3 of the Design Guidelines. These examples are provided to help users understand the step-by-step procedure. Nothing presented here shall supersede sound engineering design and judgment.

Design Example #1

A cross section of the wall section used for Example 1 is in Figure 1, based on a wall constructed in New Orleans. The water level used in this example is elevation 10.0. The soil information for this example is shown in Figure 2.

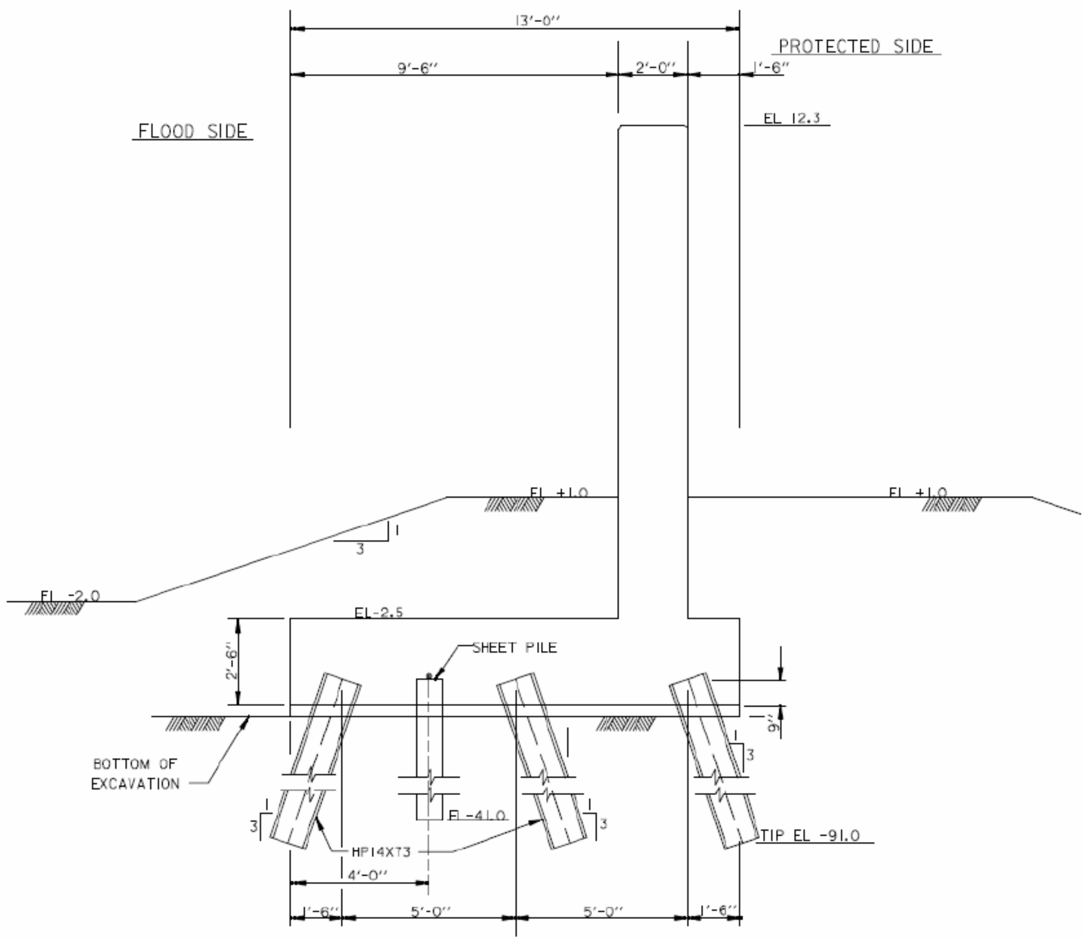


Figure 1. Wall Geometry.

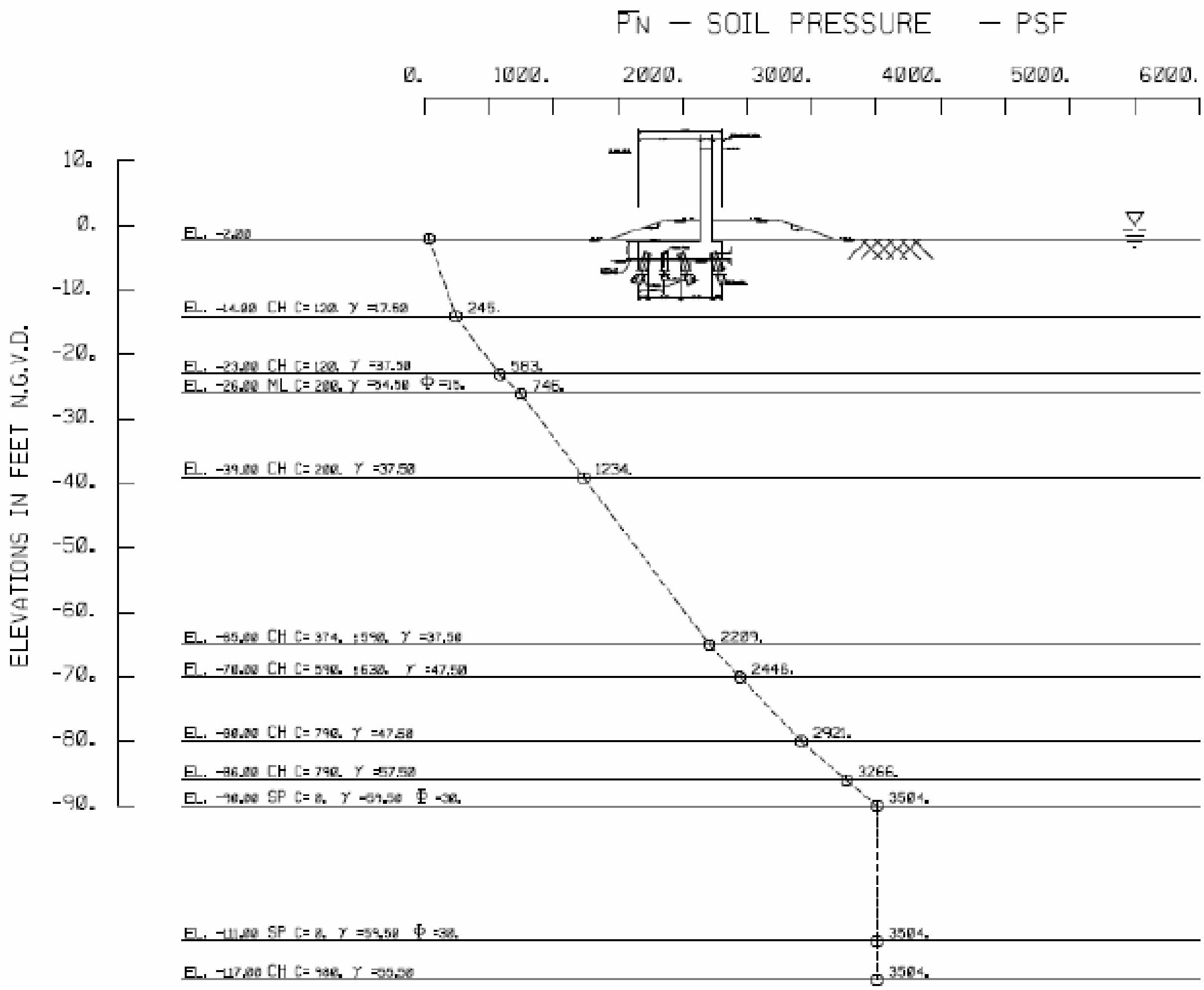


Figure 2. Soil Profile.

Step 1 Initial Slope Stability Analysis

Perform a Spencer's method slope stability analysis to determine the critical slip surface with the water load only on the ground surface and no piles. UTexas4 was used in this example for all of the slope stability analysis. For the design example, the critical failure surface is shown in Figure 3 where the factor of safety is 1.02. Because this value is less than the required value of 1.5, the T-Wall will need to carry an unbalanced load in addition to any loads on the structure.

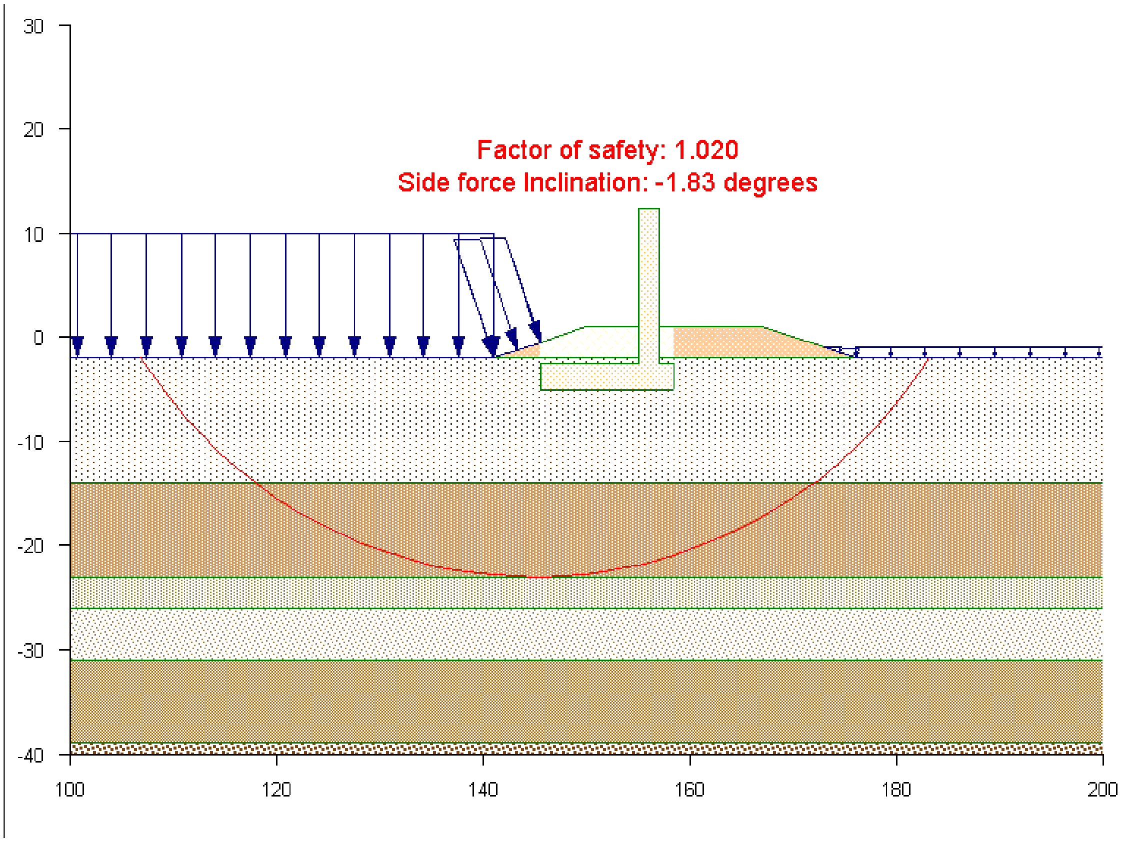


Figure 3. Spencer's analysis of the T-Wall without piles.

Step 2 Unbalanced Force Computations

Determine (unbalanced) forces required to provide the required global stability factor of safety. The critical failure surface extends down to elevation -23' in this example. The top of the soil near the heel is elevation -0.5'. It is assumed that the unbalanced load is halfway between these two elevations. Apply a line load at elevation -11.75, at the x-coordinate of the critical failure surface in Figure 3. After several iterations, a line load of 4,575 lb/ft was found that results in FS = 1.50, as shown in Figure 4.

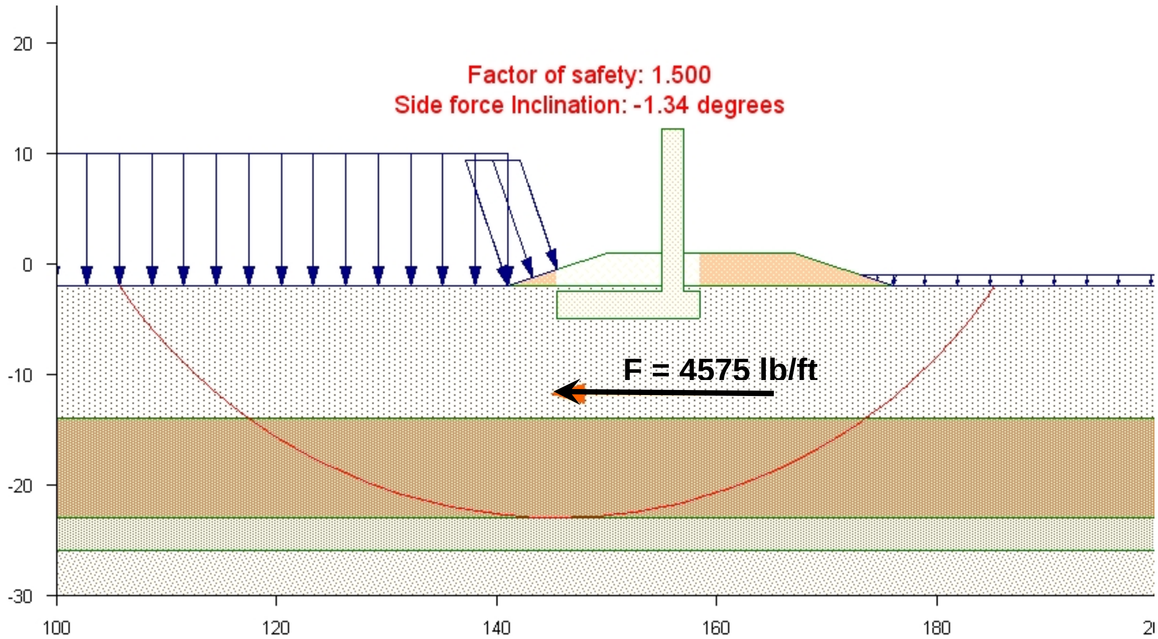


Figure 4. Spencer's analysis of the T-Wall with an unbalanced load to increase global stability.

It should be noted that a search for the critical failure surface was performed with the unbalanced load shown in Figure 4. The search ensures that if the pile foundation of the T-Wall can safely carry the unbalanced load in addition to any other loads on the structure, the global stability will meet the required factor of safety. The UTexas4 input files for Figures 3 and 4 are attached at the end of this example.

Step 3 Allowable Pile Capacity Analysis

3.1 For the preliminary analysis, allowable pile capacities determined by engineers in New Orleans District for the original design of this project are used.

Allowable Compression Load = 74 kips
Allowable Tensile Load = 49 kips

See Figure 5 for ultimate loads vs. depth from a compression pile load test. The compression load above was computed using a factor of safety of 2.0 at a depth of 92 feet. For this test, a casing used precludes skin friction above the critical failure surface.

The tension load is taken from calculated values shown in Figure 6. At elevation -92 feet the ultimate load is calculated to be about 81 tons. The capacity above elevation -23 is about 7 tons. Therefore, the tension capacity can be estimated as 81-7 = 74 tons. Using a safety factor of 3 (no load test), the allowable capacity is 74(2)/3) = 49 kips.

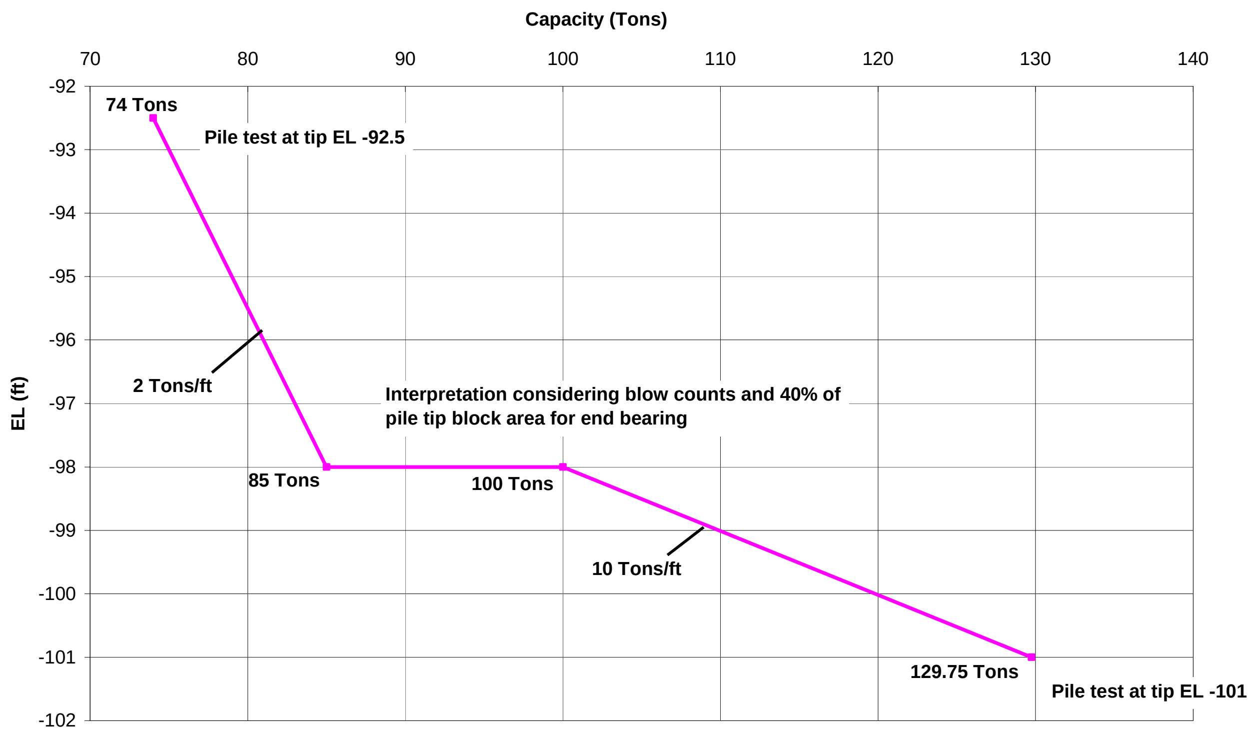


Figure 5. Pile Load Test Data

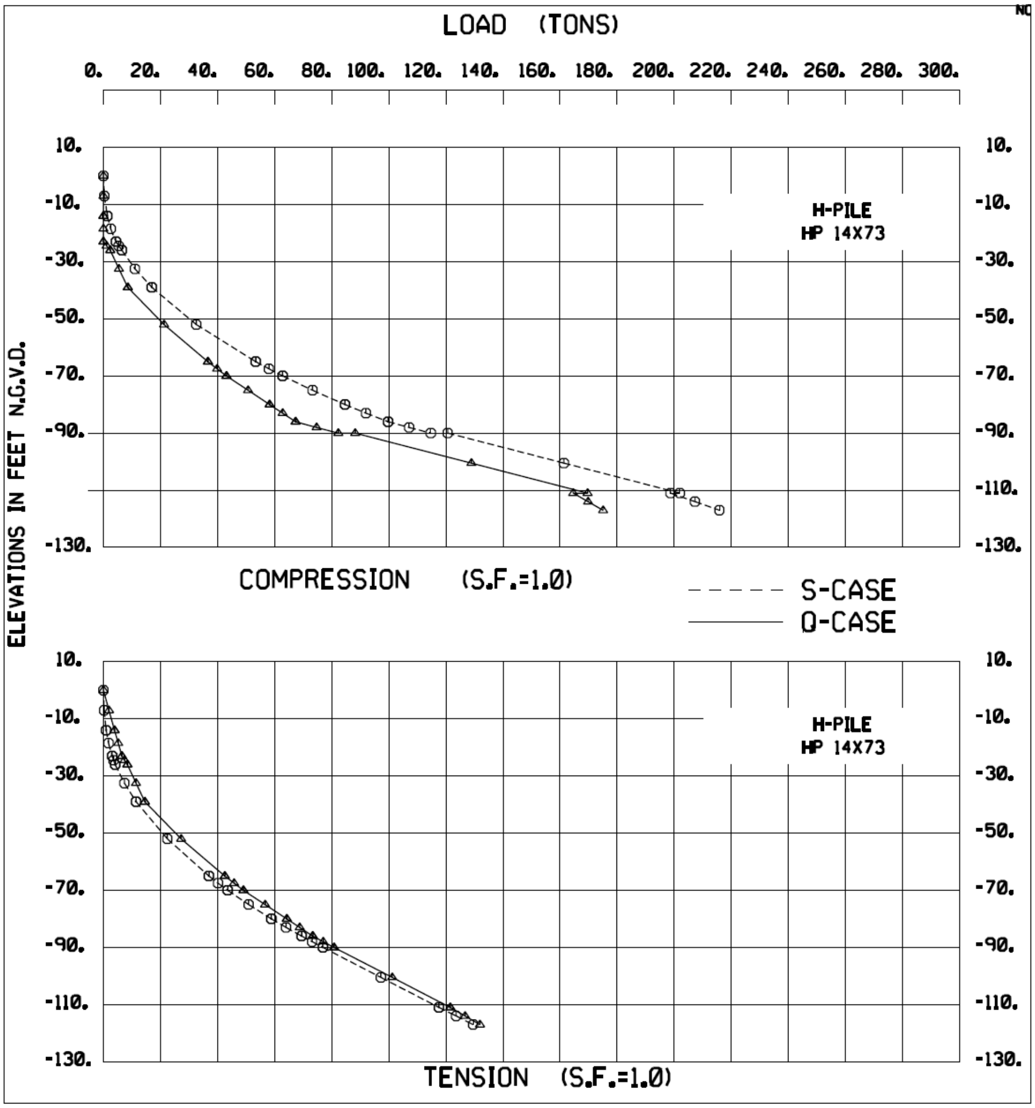


Figure 6. Ultimate Axial Capacity with Depth, Calculated

3.1 Alternate Method. If load tests are not performed, or allowable capacities computed from an ultimate strength method like APile or CAXPile, the axial pile capacities can be determined using TZPILE analyses that simulate lateral and axial pile load tests. The soil profiles used in these analyses are presented in Figure 7. The depth scale is in inches. The simulated load tests (after stripping off the top two layers) were performed at Elevation -23 which is the lowest elevation of the critical circle from Step 1.

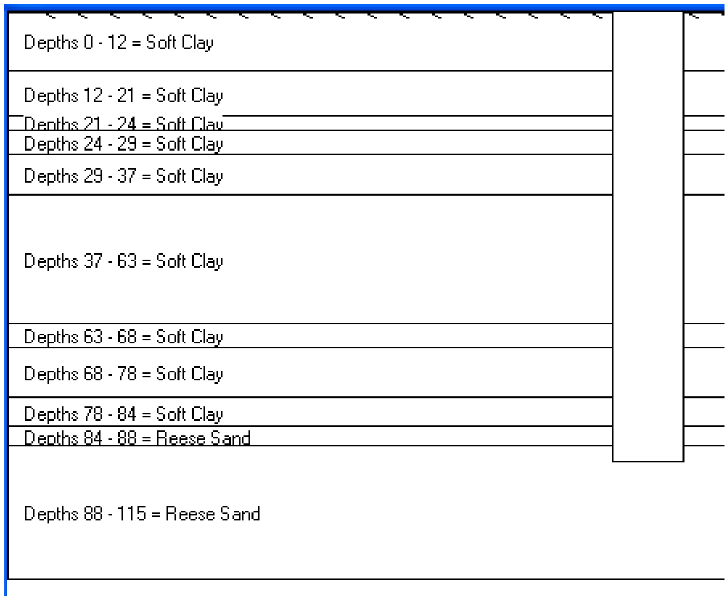


Figure 7. Soil Profiles - Stripped to critical surface of minus 23 for TZPILE and LPILE analysis

A plot of the TZPILE compression load versus settlement (at the pile head) is presented in Figure 8. The allowable compressive load is 58 kips based on and ultimate load of 174 kips and a factor of safety equal to 3.0 (assuming no pile load tests will be performed and no load case related reductions are applicable). Note that the ultimate of 174 kips (87 tons) is approximately equal to the pile capacity curves in Figure 5.

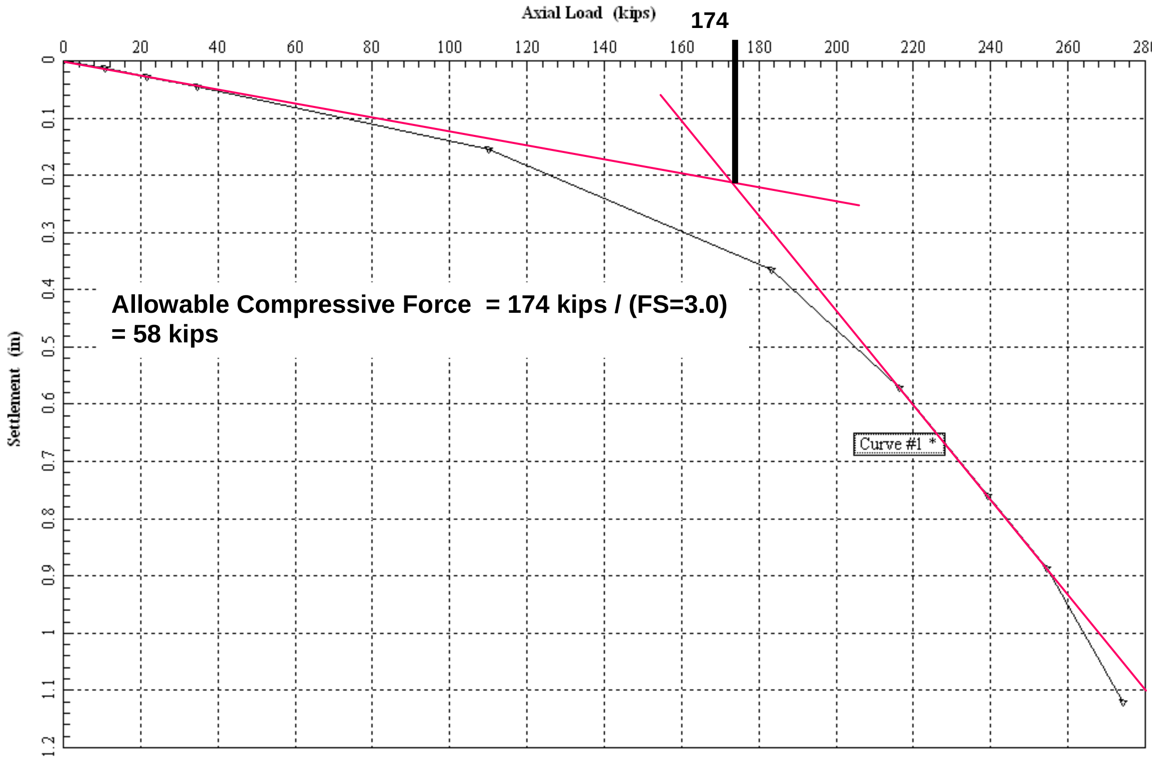


Figure 8. TZPILE Axial Pile Analysis Compression Settlement vs Axial Load Plot for determination of allowable compressive loads in piles by load simulation method.

Similarly, the allowable tensile capacity for a pile can be determined from analysis using the load simulation method. As shown in Figure 9, the ultimate tensile capacity is computed to be 84 kips. The allowable tensile capacity is determined by dividing the ultimate load by the factor of safety of 3.0 (assuming no pile load tests were performed and no load case related reductions are applicable). Thus, the allowable tensile load is 28 kips. This is less than the tension load computed above, but is presented as an example only and is not used in later design. Most likely there is a discrepancy in assumptions in stratigraphy or ultimate strength.

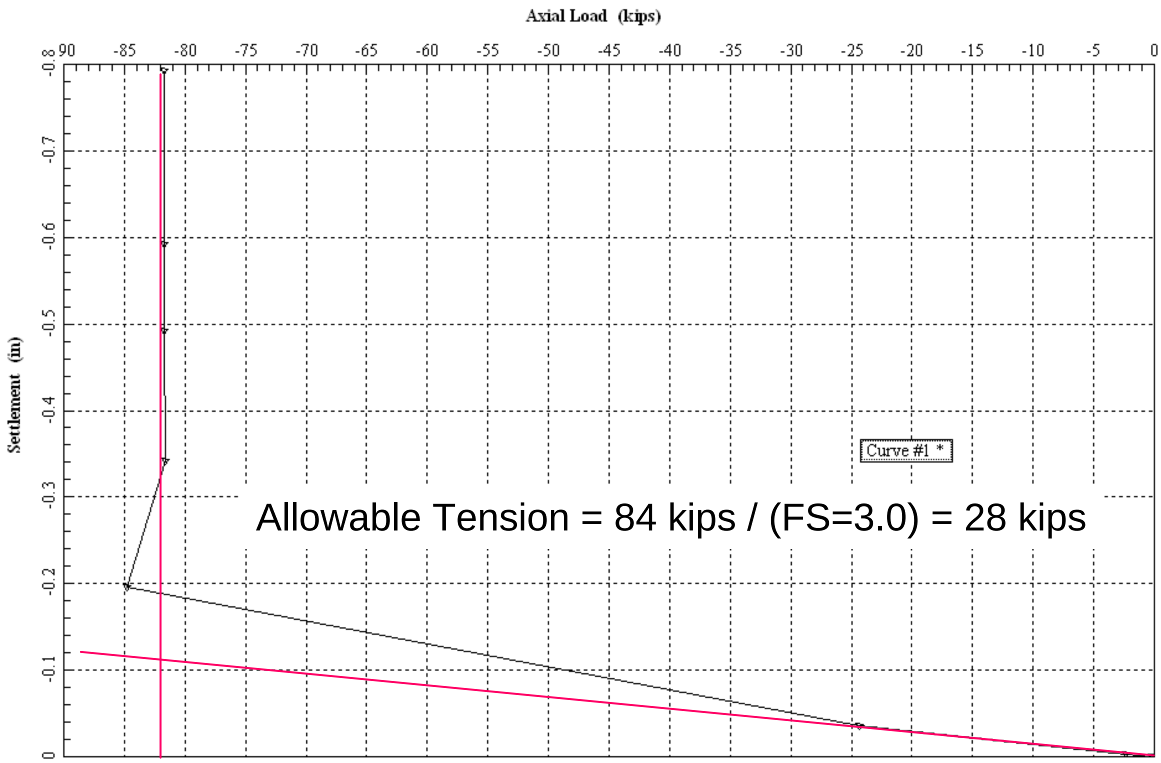


Figure 9. TZPILE Axial Pile Analysis TENSION Settlement vs Load Plot for allowable tensile loads in Piles

3.2 The allowable shear load (from LPILE) is determined from pile head deflection versus lateral load plot on Figure 10. The ultimate load was determined to be 24.5 kips. The allowable load is determined to be 8.2 kips after dividing by the factor of safety of 3.0.

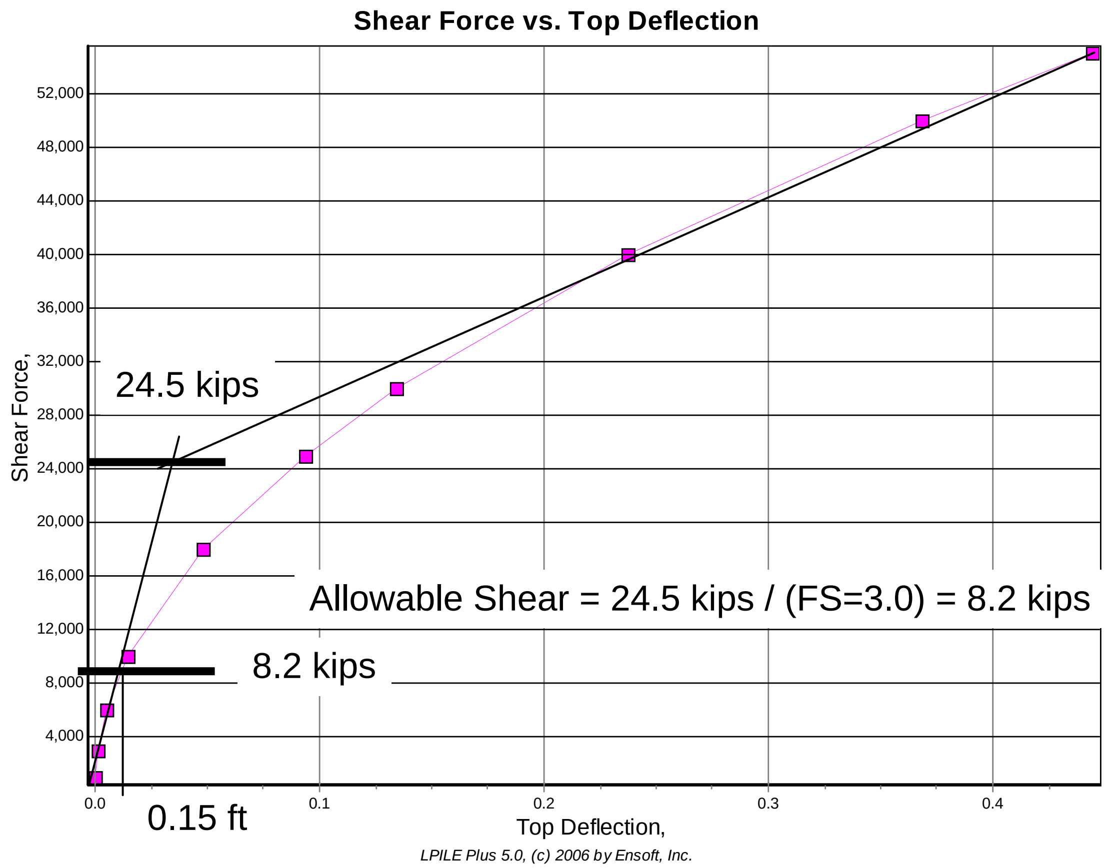


Figure 10. LPILE analysis of Pile head deflection vs shear force at critical surface to determine allowable shear force in piles.

Table 1 tabulates the allowable loads for axially loaded compressive and tensile piles,

Table 1. Allowable Axial and shear loads	
Type	Force (kips)
Axial Compressive	74
Axial Tensile	54
Shear	8.2

Step 4 Initial T-wall and Pile Design

4.1 Use CPGA to analyze all load cases and perform a preliminary pile and T-wall design. The unbalanced force is converted to an "equivalent" force applied to the bottom of the T-wall, $F_{cap,}$ as calculated as shown below (See Figure 11):

$$F_{cap} = F_{ub}\left[\frac{\left(\frac{L_u}{2}+R\right)}{\left(L_p+R\right)}\right]$$

Where:

F_{ub} = unbalanced force computed in step 2.
L_u = distance from top of ground to lowest el. of critical failure surface (in)
L_p = distance from bottom of footing to lowest el. of crit. failure surface (in)

$$R = \sqrt[4]{\frac{EI}{Es}}$$

E = Modulus of Elasticity of Pile (lb/in^2)
I = Moment of Inertia of Pile (in^4)
Es = Modulus of Subgrade Reaction (lb/in^2) below critical failure surface. In New Orleans District this equates to the values listed as K_HB.

For the solution:
Piles = HP 14x73. I = 729 in^4, E = 29,000,000 psi

Soils – Importance of lateral resistance decreases rapidly with depth, therefore only first three layers are input – with the third assumed to continue to the bottom of the pile. The parameters were developed from soil borings from the New Orleans District shown in Figure 12.

Silt, ϕ = 15, C = 200 psf, γ_{sat} = 117 pcf, K_HB ave. = k =167 psi
Clay 1, ϕ = 0 , C = 200 psf, γ_{sat} = 100 pcf, K_HB = k = 88.8 psi
Clay 2, ϕ = 0 , C = 374 psf, γ_{sat} = 100 pcf, K_HB = k = 165.06 psi

The top layer of silt under the critical failure surface is stiffer but only three feet thick. Will use a k = 100 psi.

R therefore is equal to 121 in = 10.08 feet

P_{cap} = 4,575 * (22.5/2 + 10.08) / (18 + 10.08) = 3,475 lb/ft

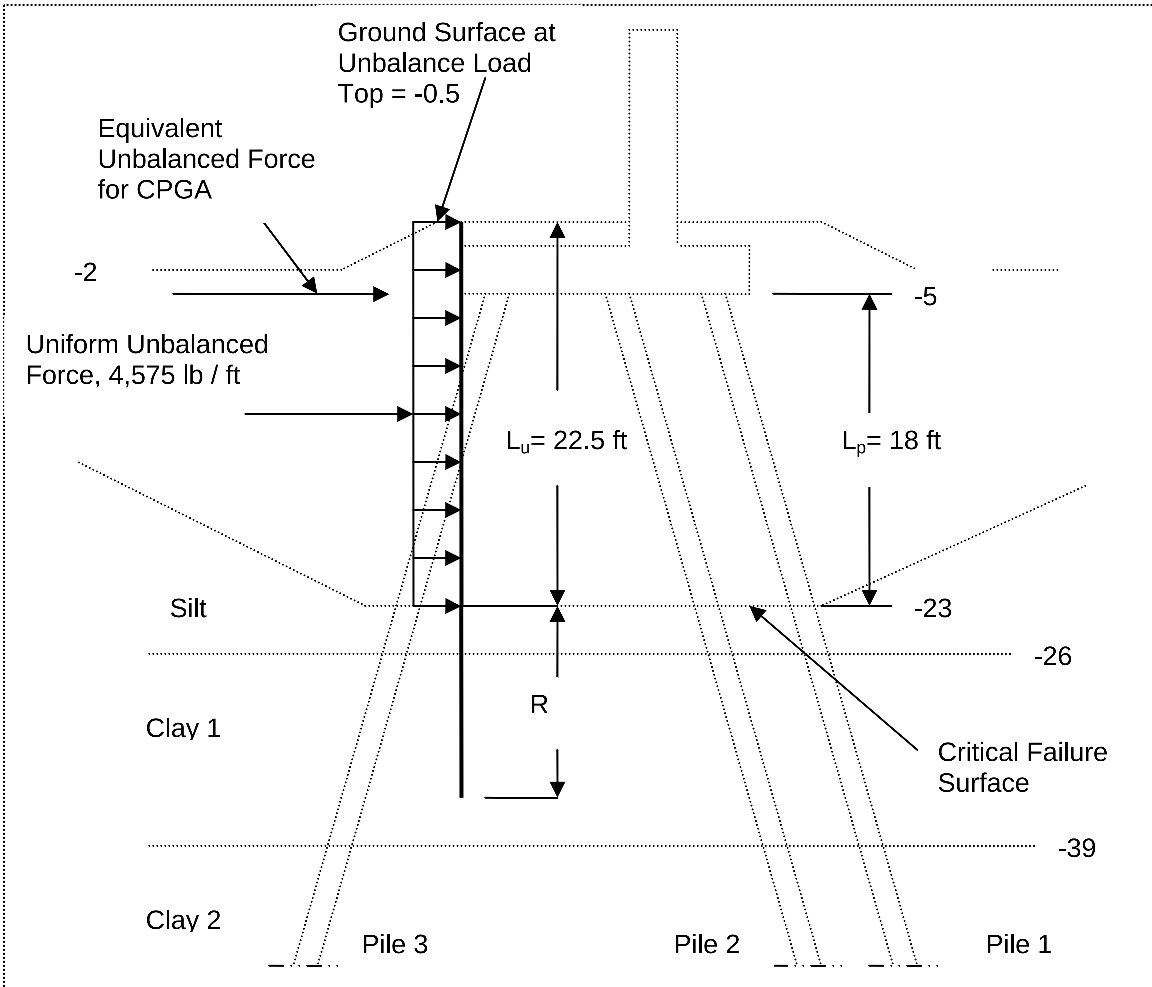


Figure 11. Equivalent Force Computation for Preliminary Design With CPGA

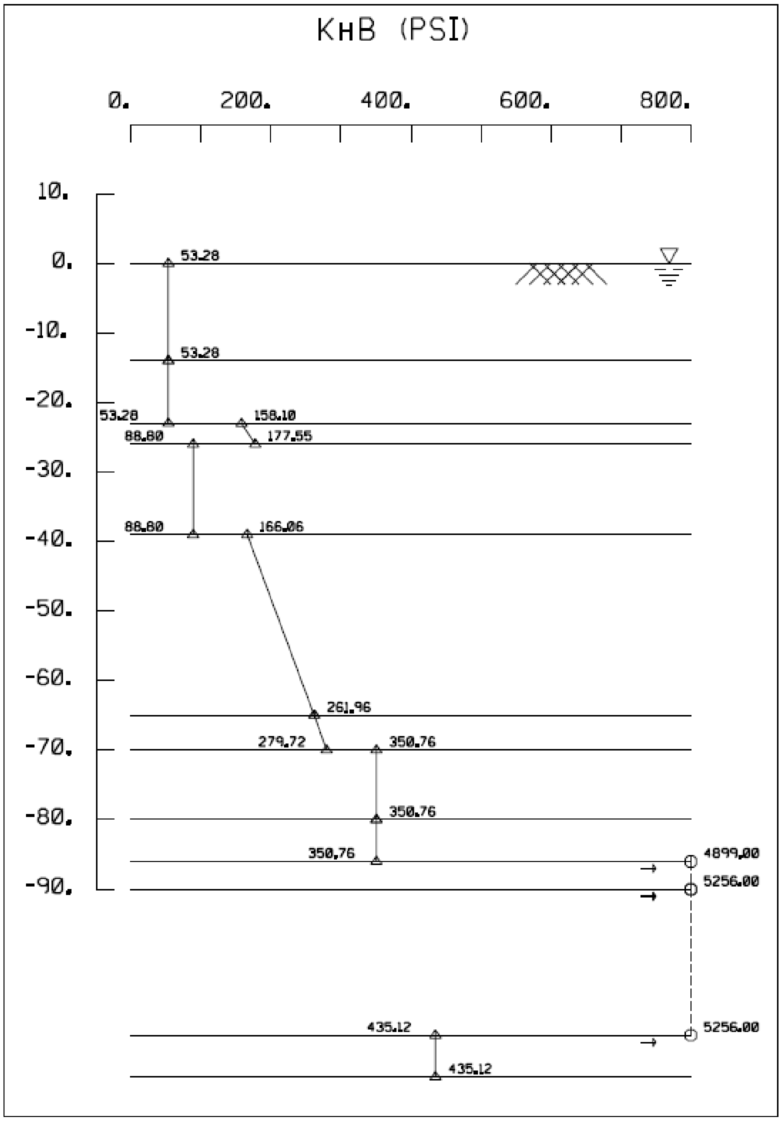


Figure 12. Soil Stiffness with Depth

4.2 This unbalanced force, P_{cap}, is then analyzed with appropriate load cases in CPGA. Generally 8 to 20 load cases may be analyzed depending on expected load conditions. For this example, only the still water case is analyzed but both pervious and impervious foundation conditions are evaluated. See the spreadsheet calculations in Attachment 3 for the computation of the input for CPGA. The model is a 5 foot strip of the pile foundation.

For the CPGA analysis, the soil modulus, Es is adjusted based on the global stability factor of safety. For this example case, the factor of safety is 1.02. Es for CPGA is compute from the ratio of the computed factor of safety to the target factor of safety. From Figure 12, Es at the bottom of the wall footing is about 53.3 psi.

CPGA Es. = (1.02-1.0) / (1.5 – 1.0) * 53.3 = 2.1 psi

4.3 This is already a low value, but group factors from EM 1110-2-2906 can also be added. From page 4-35 of the EM with a spacing to pile diameter ratio of 5 ft / (14/12) = 4B, the reduction is 2.6. Es is therefore 2.1/2.6 = 0.8 psi

The CPGA output is shown in Attachment 4. A summary of results for the two load conditions analyzed are shown below:

LOAD CASE - 1 Pervious Condition

PILE	F1 K	F2 K	F3 K	M1 IN-K	M2 IN-K	M3 IN-K	ALF	CBF	
1	.2	.0	1.5	.0	-31.9	.0	.02	.03	
2	.2	.0	104.6	.0	-29.4	.0	1.41	.35	*
3	-.2	.0	-50.5	.0	30.7	.0	1.03	.18	*

LOAD CASE - 2 Impervious Condition

PILE	F1 K	F2 K	F3 K	M1 IN-K	M2 IN-K	M3 IN-K	ALF	CBF	
1	.2	.0	8.9	.0	-29.6	.0	.12	.05	
2	.1	.0	101.9	.0	-27.3	.0	1.38	.34	*
3	-.2	.0	-46.1	.0	28.7	.0	.94	.16	

Where:
F1 = Shear in pile at pile cap perpendicular to wall
F2 = Shear in Pile at Pile Cap parallel to wall
F3 = Axial Load in Pile
M1 = Maximum moment in pile perpendicular to wall
M2 = Maximum moment in pile parallel to wall
M3 = Torsion in pile
ALF= Axial load factor – computed axial load divided by allowable load
CBF= Combined Bending factor – combined computed axial and bending forces relative to allowable forces

Allowable axial pile capacities used for this analysis, 74 kips compressive and 49 kips tensile, were shown in step 3. The maximum pile forces computed in the middle piles exceed these values. This would require deeper piles or perhaps a revision of the pile layout. From Figure 4, and a factor of safety of 2 for an allowable pile capacity from pile load test data, to reach an allowable of 105 kips (ultimate of 210 kips or 105 tons), the piles only need to be increase to about 99 feet in length. This is not much difference, and the next steps will continue with the layout as shown. The tension piles have slightly exceeded the allowable capacity and could be made a few feet deeper to achieve required loads as well.

Computed deflections from the CPGA analysis are shown below:

PILE CAP DISPLACEMENTS

LOAD CASE	DX IN	DZ IN	R RAD
1	-.7241E+00	-.2963E+00	-.3212E-02
2	-.6757E+00	-.2609E+00	-.2899E-02

These deflections are less than the allowable vertical deflection (DZ) of 0.5 inches and allowable horizontal deflection (DX) of 0.75 inches from the Hurricane and Storm Damage Reduction Design Guidelines.

4.4 Sheet pile design. Seepage design of the sheet pile is not performed for this example.

4.5 Check for resistance against flow through. Since the pile spacing is uniform, we will analyze one row of piles parallel with the loading rather than the entire monolith.

a. Compute the resistance of the flood side row of piles.

$$\sum P_{all} = \frac{n\sum P_{ult}}{1.5}$$

Where:

n = number of piles in the row within a monolith. Or, for monoliths with uniformly spaced pile rows, n = 1. Use 1 for this example

$P_{ult} = \beta(9S_u b)$

S_u = soil shear strength

b = pile width = 14”

β = group reduction factor pile spacing parallel to the load - since the piles batter opposite to each other, there group affects are not computed.

For the soils under the slab, S_u = 120 psf

Therefore: P_{ult} = 9(120 psf)(14 in/12 in/ft) = 1,260 lb/ft

ΣP_{ult} = summation of P_{ult} over the height L_p, as defined in paragraph 4.1

For single layer soil is P_{ult} multiplied by L_p (18 ft) - That is the condition here since the shear strength is constant from the base to the critical failure surface.

ΣP_{ult} = 1,260 lb/ft (18 ft) = 22,680 lb

ΣP_{all} = 1(22,680 lb)/1.5 = 15,120 lb

b. Compute the load acting on the piles below the pile cap.

$$F_{up} = wf_{ub}L_p$$

Where:

w = Monolith width. Since we are looking at one row of piles in this example, w = the pile spacing perpendicular to the unbalanced force (s_t) = 5 ft.

$$f_{ub} = \frac{F_{ub}}{L_u}$$

F_{ub} = Total unbalanced force per foot from Step 2 = 4,575 lb/ft
L_u = 22.5 ft
L_p = 18 ft

f_{ub} = 4,575 lb/ft / 22.5 ft = 203 lb/ft/ft

F_p = 5 ft(203lb/ft/ft)(18ft) = 18,270 lb

c. Check the capacity of the piles 50% of F_p = 18,270 lb(0.50) = 9,135 lb

The capacity ΣP_{all} = 15,120 lb > 9,135 lb so OK for flow-through with this check.

4.6 Second flow through check. Compute the ability of the soil to resist shear failure between the pile rows from the unbalanced force below the base of the T-wall, $f_{ub}L_p$, using the following equation:

$$f_{ub} L_p \leq \frac{A_p S_u}{FS}\left[\frac{2}{(s_t - b)}\right]$$

Where:
A_pS_u = The area bounded by the bottom of the T-wall base, the critical failure surface, the upstream pile row and the downstream pile row multiplied by the shear strength of the soil within that area. – See Figure 13. S_u =120 psf
A_pS_u = (18(10+22)/2)(120 psf) = 34,560 lb
FS = Target factor of safety used in Steps 1 and 2. – 1.5
s_t= the spacing of the piles transverse (perpendicular) to the unbalanced force 5 ft
b = pile width – 14 inches

$f_{pb}L_p$ = (203 lb/ft)(18 ft) = 3,654 lb

$$\frac{A_p S_u}{FS}\left[\frac{2}{(s_t - b)}\right] = \frac{34{,}560}{1.5}\left[\frac{2}{5-\left(\frac{14}{12}\right)}\right] = 12{,}021 \text{ lb}$$

Therefore, capacity against flow through is OK

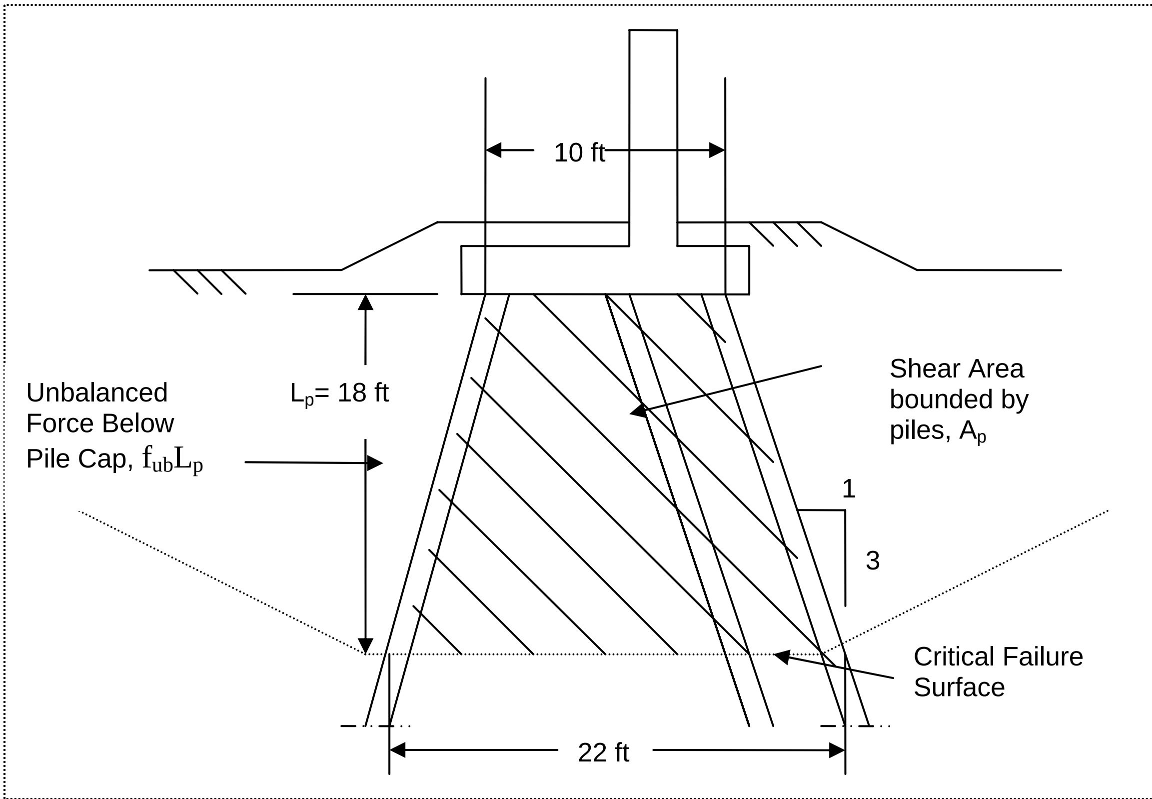


Figure 13. Shear Area for Flow Through Check

Step 5 <u>Pile Group Analysis</u>

5.1 A Group 7 analysis is performed using all loads applied to the T-wall structure. Critical load cases from step 4 would be used. In this example, only one load case with two foundation conditions is shown.

5.2 The loads applied in the Group 7 model include the distributed loads representing the unbalanced force that acts directly on the piles and also the water loads and self-weight of the wall that acts directly on the structure. In Group 7 these loads are resultant horizontal and vertical forces and the moments per width of spacing that act on the T-wall base (pile cap). They also include the unbalance force from the base of the cap to the top of soil, converted to a force and moment at the base of the structure. These forces are calculated using a worksheet or Excel spreadsheet and are shown at then end of the spreadsheets shown in Attachment 3. For this analysis the resultant forces per 5-ft of pile spacing were:

Impervious Foundation Condition

Vertical force	=	61,325 lb
Horizontal force	=	37,231 lb
Moment	=	1,540,666 in-lbs

Pervious Foundation Condition

Vertical force	=	52,731 lb
Horizontal force	=	37,231 lb
Moment	=	1,031,916 in-lbs

5.3 The unbalanced load below the bottom of the footing is applied directly as distributed loads on the pile. Check if ($n\Sigma P_{ult}$) of the flood side pile row is greater than 50% F_p, (from 4.5)

.

$(n\Sigma P_{ult})$ = 1 (22,680) = 22,680 lb

50% F_p = 9,135 lb

Therefore distribute 50% of F_p onto the flood side (left) row of piles.

$0.5 f_{ub} s_t$ = 0.5 (203 lb/ft/ft)(5 ft) = 507.5 lb/ft = 42 lb/in

The remainder is divided among the remaining piles.

Middle pile = 21 lb/in
Right pile = 21 lb/in

5.4 The group 7 model is illustrated in Figure 14.

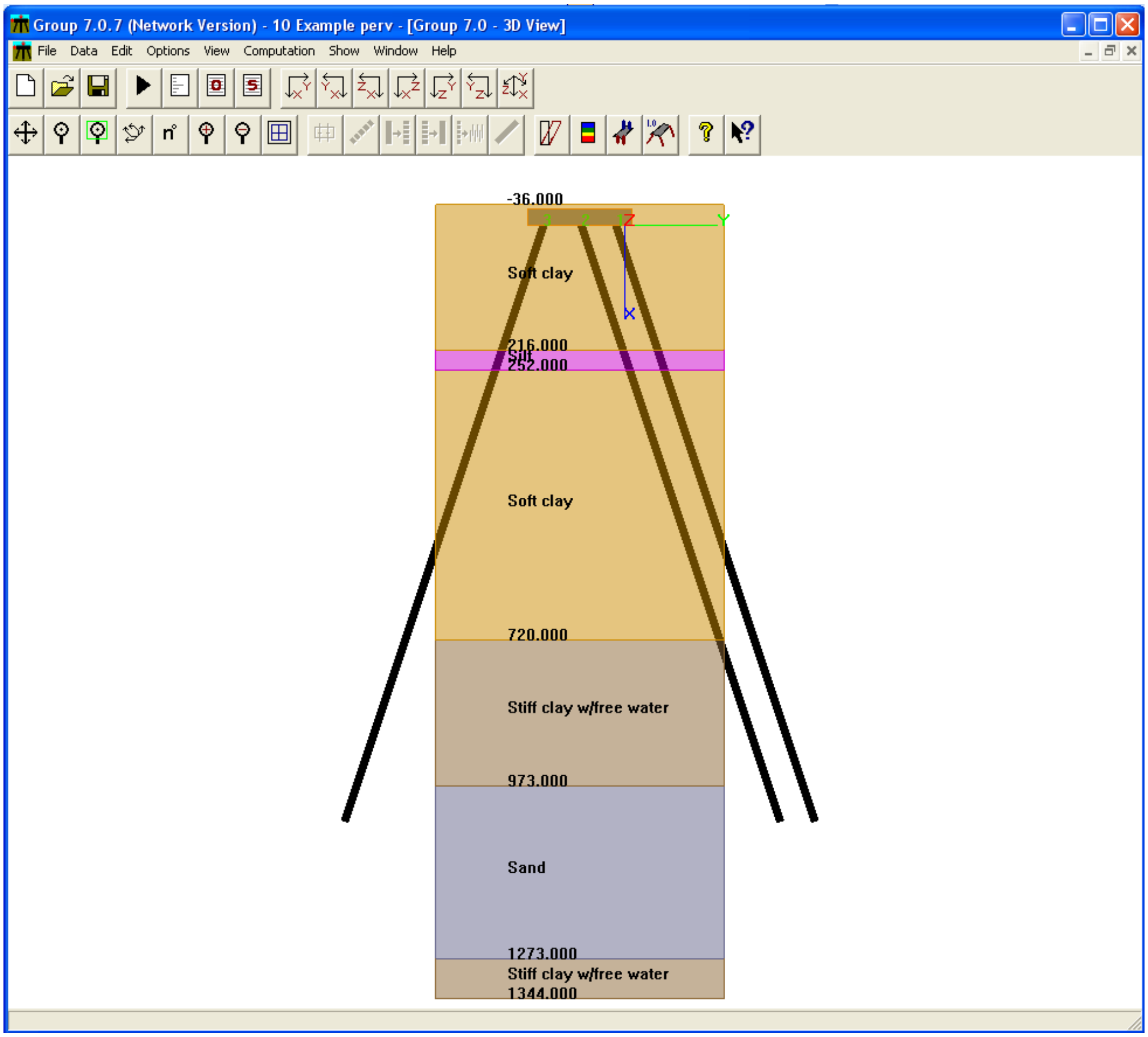


Figure 14. Group 7 Model with Soil Stratigraphy.

5.5 Additionally, in this analysis partial p-y springs can be used be cause the unreinforced factor of safety of 1.020 is between 1.0 and 1.5. The percentage of the full springs is determined as follows:

Partial spring percentage = (1.020 – 1.000)/ (1.5- 1.0) x 100% = 4%

Thus the strengths of in the top two layers, extending to Elevation -23 ft, were reduced to 4% of the undrained shear strength of 120 psf or 4.8 psf (0.0333 psi). The reduced undrained shear strength was used to scale the p-y curves above elevation -23 ft only. The results of the Group 7 analysis are listed in Table 1 where the pile responses for the full loading conditions on T-wall systems are listed. An example of the Group 7 output for the pervious condition are shown in Attachment 5

Table 2. Axial and shear Pile loads per 5-ft of width computed by Group 7 for full loading conditions that include distributed load in 50-25-25 split applied directly to piles and resultant horizontal, vertical and moments due to water loads and self weight applied directly to the structure

Impervious Case	Left Pile	Center Pile	Right Pile
Axial Force (kips)	-35.3 (T)	88.5 (C)	11.6 (C)
Shear Force (kips)	4.49	2.4	2.7
Max. Moment (k-in)	-227	-199	-225
Pervious Case	Left Pile	Center Pile	Right Pile
Axial Force (kips)	-41.3 (T)	93.3 (C)	4.0 (C)
Shear Force (kips)	4.58	2. 5	2.7
Max. Moment (k-in)	-243	-219	-249

Figure 15 shows moment in the piles vs. depth and Figure 16 shows shear vs depth. There is no lateral soil stiffness from 0 to 216 inches.

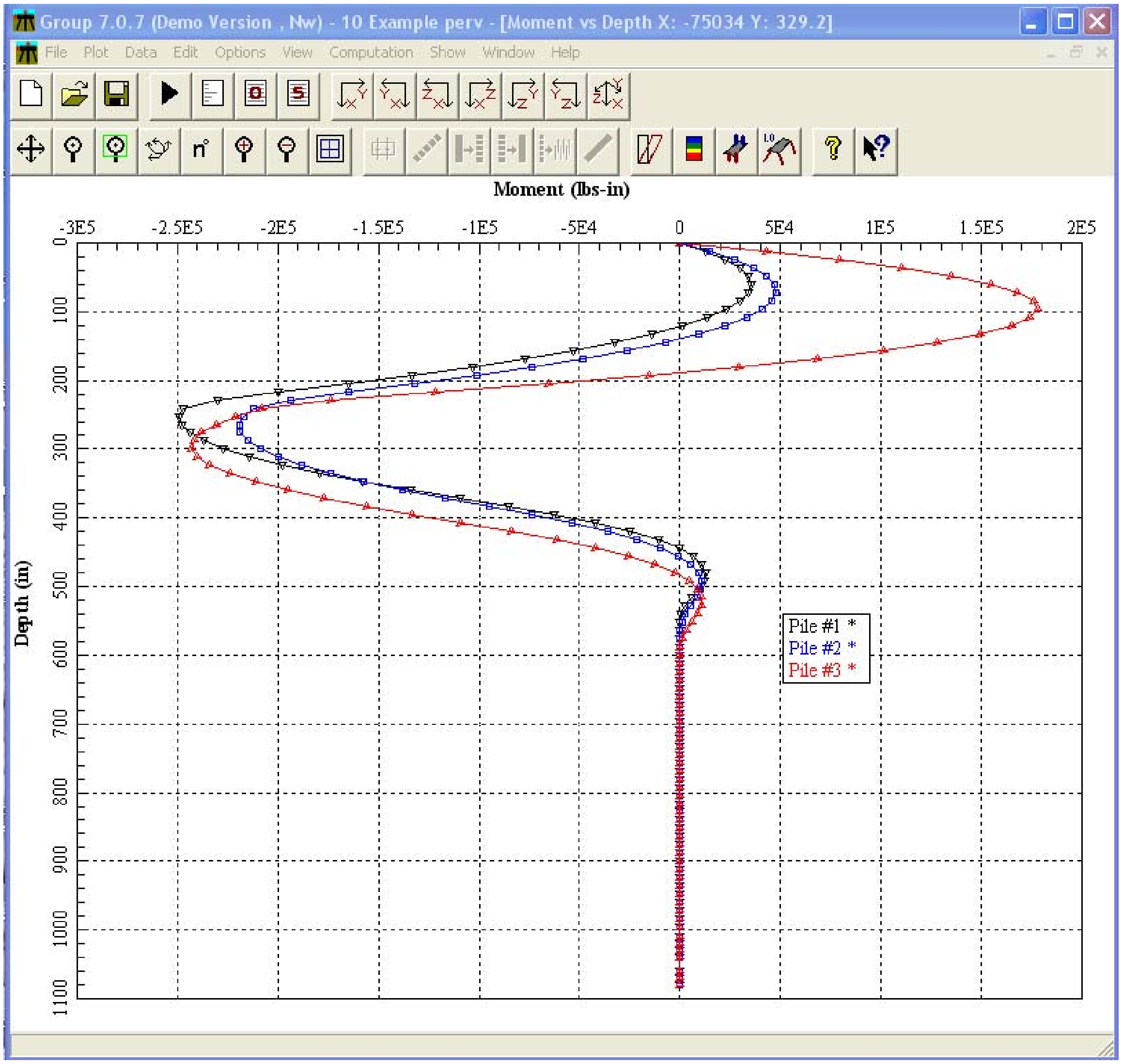


Figure 15. Moment vs depth.

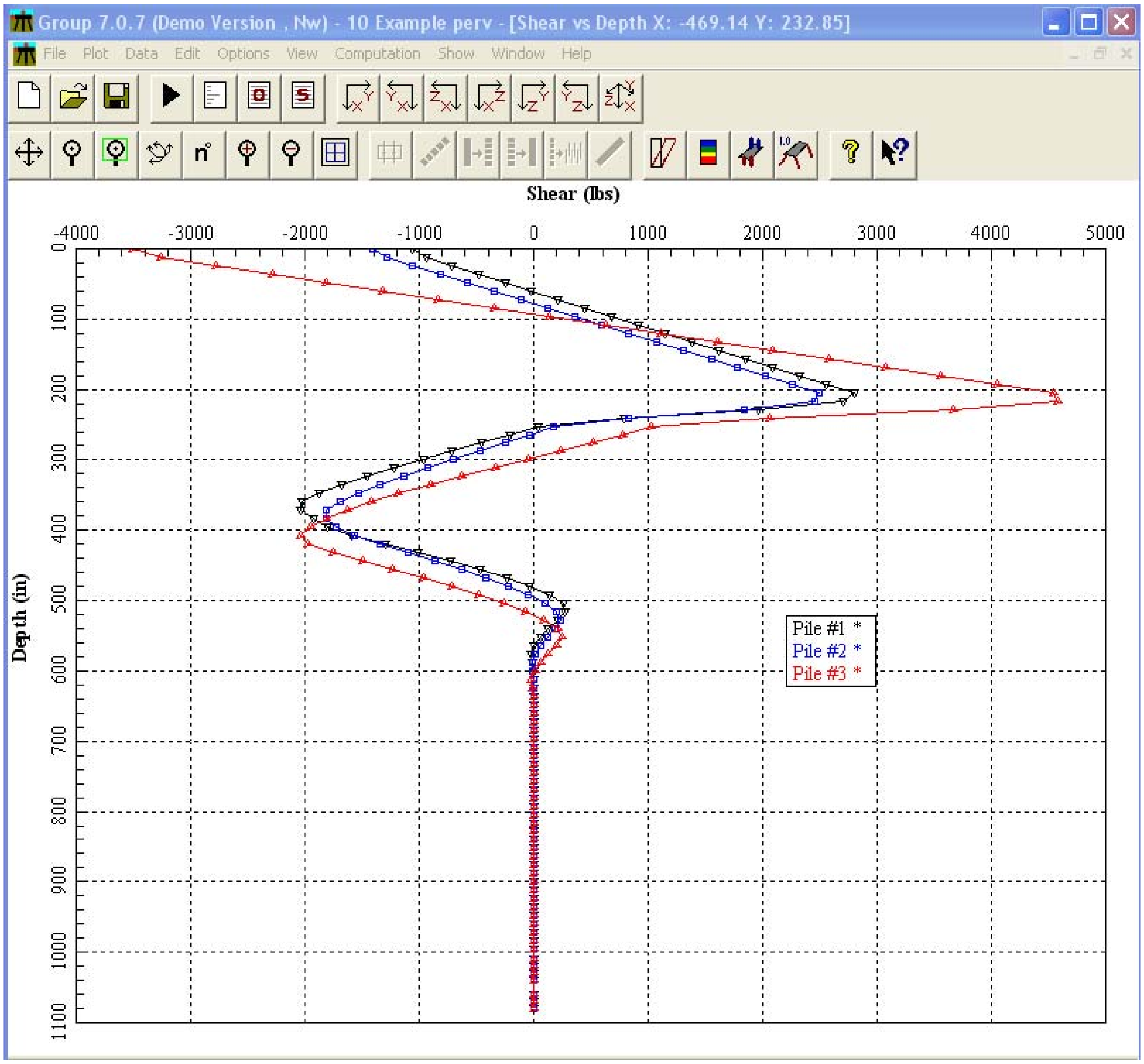


Figure 16. Shear vs depth

5.7 The axial forces and shear in Table 2 are then compared with allowable loads listed in Table 1. The results of the comparison show that:

a. the axial compressive forces in the center pile, 92.5 kips, exceeds the allowable compressive load of 74 kips.
b. the axial tensile force from the left (flood side) pile of -41.0 kips is less than the allowable tensile load of 54 kips.
c. The shear forces in each of the three piles are lower than the allowable shear of 8.2 kips.

Because the axial capacities of the center pile is exceeded, the pile layout must be repeated using a different pile layout. Axial forces and moment in the pile would be compared to allowable values computed according to EM 1110-2-2906. Moment and axial forces in the piles would also be checked for structural strength according to criteria in the Hurricane and Storm Damage Reduction System Design Guidelines and EM1110-2-2906.

Displacements from the Group 7 analysis are as follows:
Deflections

LOAD CASE	DX IN	DZ IN
Pervious	0.520	-0.20
Impervious	0.485	-0.18

These deflections are less than the allowable vertical deflection (DZ) of 0.5 inches and allowable horizontal deflection (DX) of 0.75 inches from the Hurricane and Storm Damage Reduction Design Guidelines.

Deflection of the piles vs. depth is shown in Figure 17.

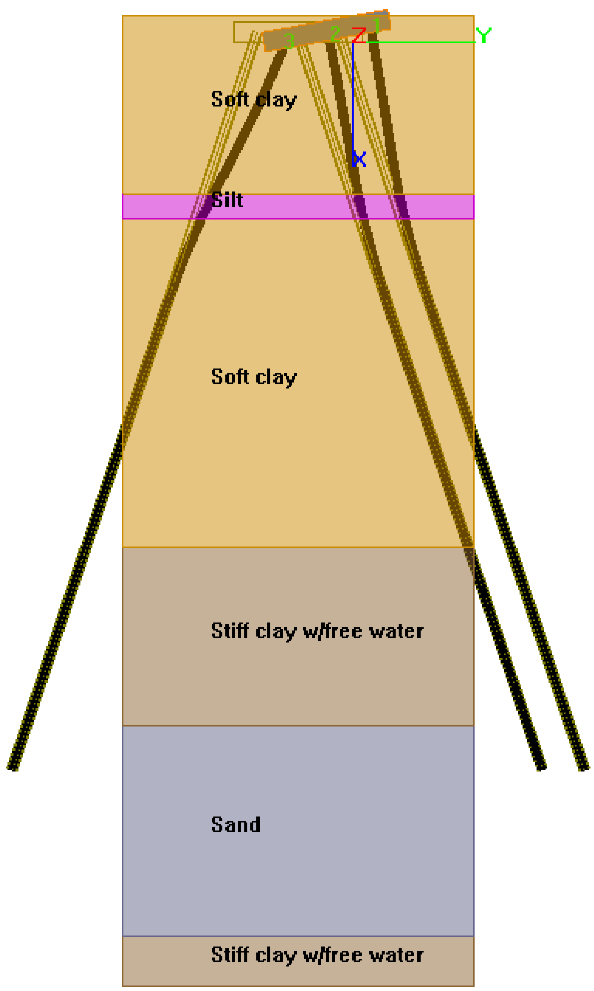


Figure 17 Deformed shape of pile cap

Deflection of the piles vs. depth is shown in Figure 18.

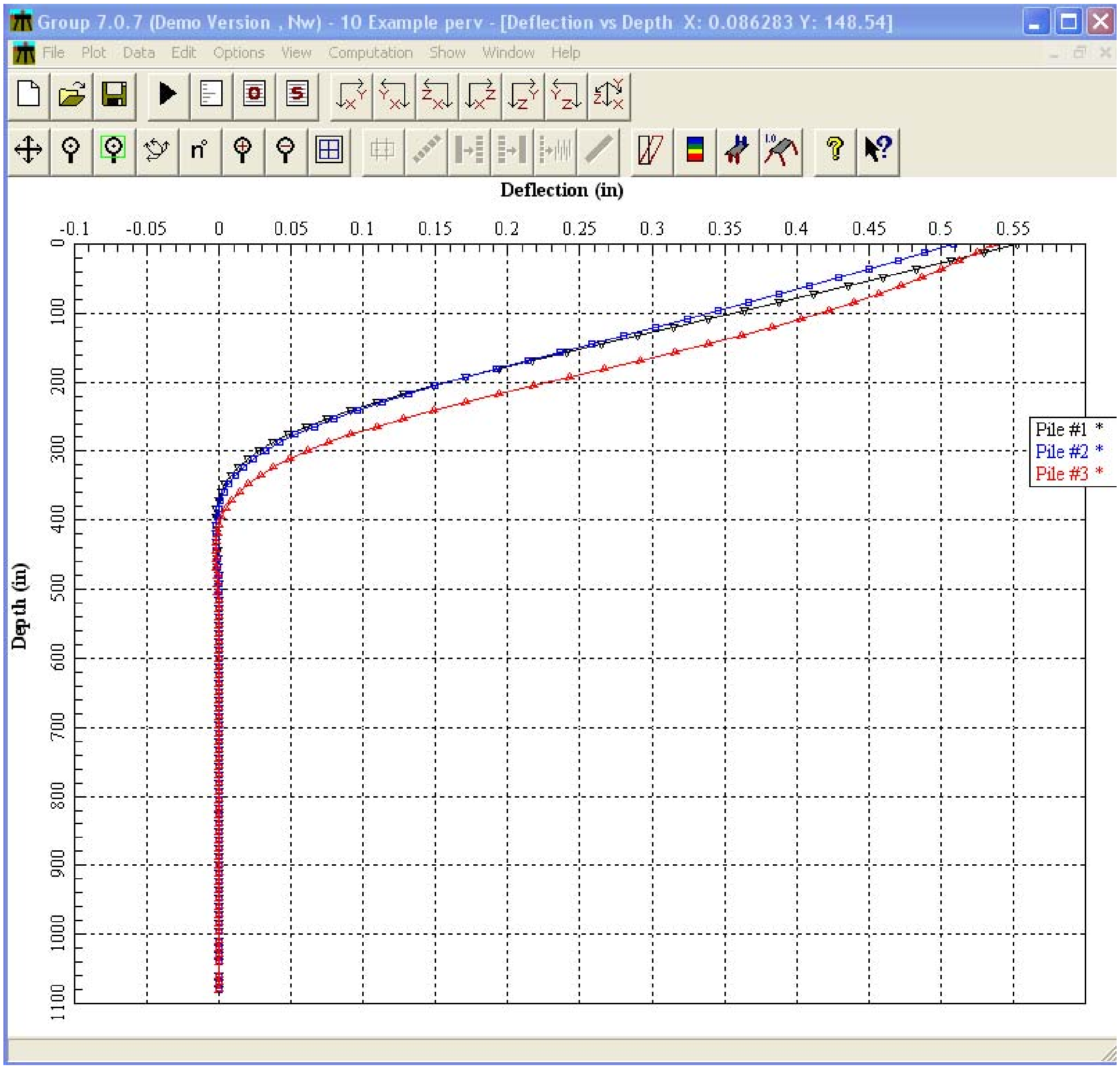


Figure 18 Deflection vs Depth

Step 6 Pile Group Analysis (unbalanced force)

6.1 Perform a Group 7 analysis with the distributed loads applied directly to the piles. The distributed loads are statically equivalent to the unbalanced force of 4,575 lb/ft. No loads are applied to the cap except unbalance forces. The p-y springs are set to 0 to the lowest critical failure surface elevation by setting the ultimate shear stress of these soils at a very low value. The distributed loads were computed in the previous step and are shown in the Excel spreadsheet computations shown in Attachment 3. Results of the Group analysis are shown below:

Table 3. Axial and shear Pile loads per 5-ft of width computed by Group 7			
	Left Pile	Center Pile	Right Pile
Axial Force (kips)	-21.9 (T)	46.5 (C)	-24.5 (T)
Shear Force (kips)	4.24	2.32	2.48

Step 7 Pile Reinforced Slope Stability Analysis

7.1 The UT4 pile reinforcement analysis using the circle from Step 2 is performed to determine if the target Factor of Safety of 1.5 is achieved. The piles are treated as reinforcements in the UT4 and the shear and axial forces from Step 6 are used to determine these forces. The forces in Table 3 must be converted to unit width conditions by dividing by the 5-ft pile spacing to be used as the axial and shear forces in the pile reinforcements in UT4. The results of the analysis are shown in Figure 18. The factor of safety is 1.521 which exceeds that target factor of safety of 1.5. Therefore, the global stability of the foundation is verified in this Step. The input file is listed in Attachment 6.

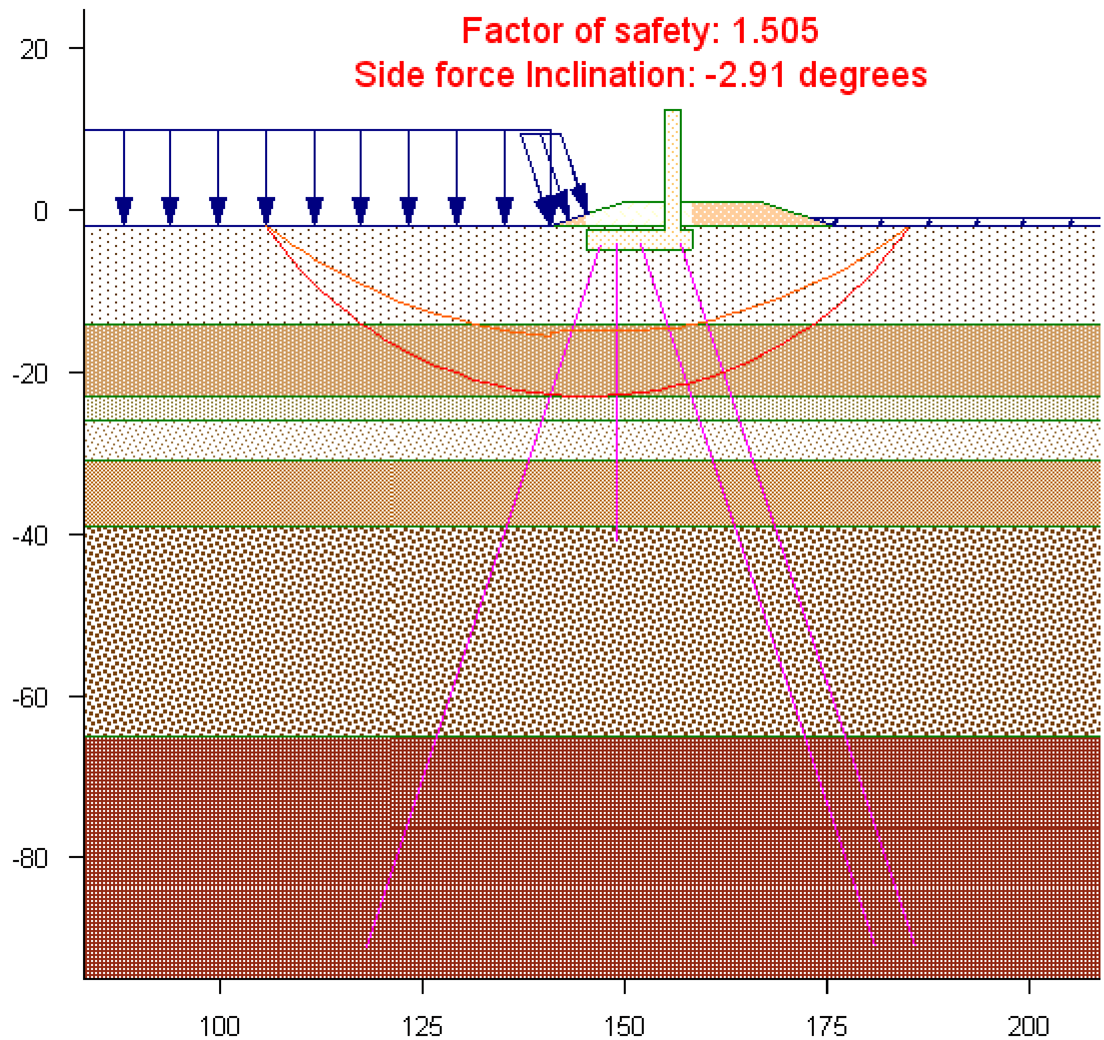


Figure 19. Factor of safety computed using pile forces from Group 7 analysis And critical circle from fixed grid analysis

7.2 Pile axial and shear forces determined in the pile group analysis are input in the slope stability analysis as longitudinal and transverse reinforcement forces. Sign convention for longitudinal forces in UTexas4 is that tensile forces are positive and compressive forces are negative. Sign convention for pile founded T-Walls with piles that extend below the critical failure surface and resist sliding of the soil mass is that transverse forces in UTexas4 are positive in the clockwise direction and negative in the counter-clockwise direction. This results in positive transverse forces in cases where the left side of the T-Wall is the flood side and negative transverse forces in cases where the right side of the T-Wall is the flood side. Positive longitudinal and transverse reinforcement forces for pile founded T-Walls are shown in Figure 20.

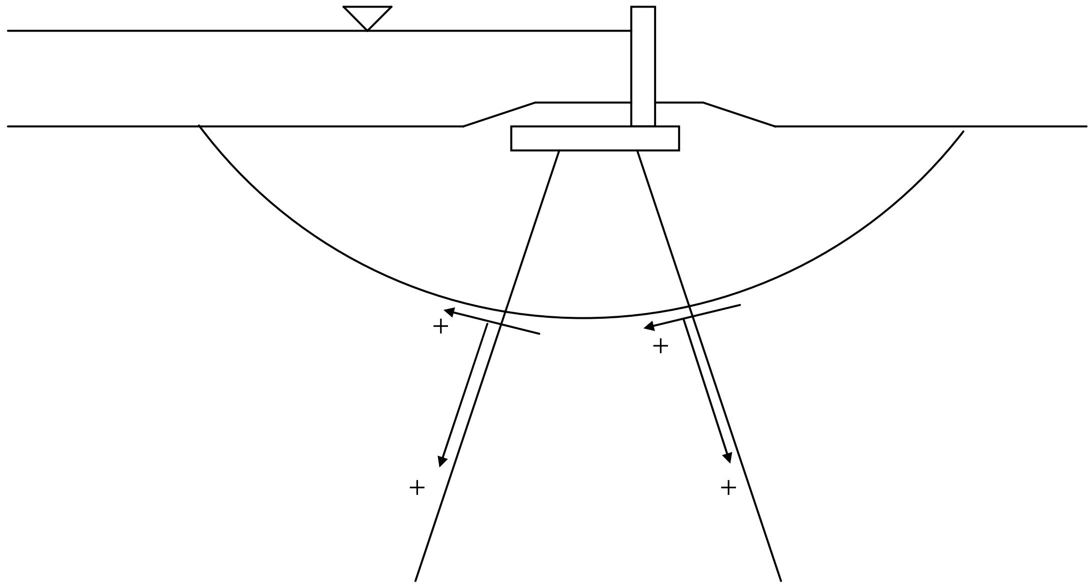


Figure 20. Positive directions for longitudinal and transverse reinforcement loads in pile.

Attachment 1 – Spencer's method analysis without piles that results in Figure 3.

```
HEADING
    T-Wall Deep Seated Analysis
    Analysis without piles

PROFILE LINES
         1     1 Layer 3 (CH) - Floodside
                  .00     -2.00
               141.00     -2.00
               155.00     -2.00

         2     1 Layer 3 (CH) - Landside
               157.00     -2.00
               375.00     -2.00

         3     2 Compacted Fill - FS
               141.00     -2.00
               145.50      -.50

         4     2 Compacted Fill - LS
               158.50      1.00
               167.00      1.00
               176.00     -2.00

         5     3 T-Wall
               145.50     -5.00
               145.50     -2.50
               155.00     -2.50
               155.00     -2.00
               155.00     12.30
               157.00     12.30
               157.00      1.00
               157.00     -2.00
               157.00     -2.50
               158.50     -2.50
               158.50     -5.00

         6     1 Layer 3 (CH) - Under Wall
               145.50     -5.00
               158.50     -5.00

         7     4 Layer 4 (CH)
                  .00    -14.00
               375.00    -14.00

         8     5 Layer 5 (ML)
                  .00    -23.00
               375.00    -23.00

         9     6 Layer 6 (CH)
                  .00    -26.00
               375.00    -26.00

        10     7 Layer 7 (CH)
```

```
                .00     -31.00
             375.00     -31.00

       11     8 Layer 8 (CH)
                .00     -39.00
             375.00     -39.00

       12     9 Layer 9 (CH)
                .00     -65.00
             375.00     -65.00

       13    10 Compacted Fill - Above T Wall Base  FS
             145.50       -.50
             150.00       1.00
             155.00       1.00

       14    10 Compacted Fill - Above T Wall Base  LS
             157.00       1.00
             158.50       1.00


MATERIAL PROPERTIES
     1 Layer 3 (CH)
          80.00 Unit Weight
          Conventional Shear
              120.00        .00
          No Pore Pressure
     2 Compacted Fill
          110.00 Unit Weight
          Conventional Shear
              500.00        .00
          No Pore Pressure
     3 T Wall
          .00 Unit Weight
          Very Strong
     4 Layer 4 (CH)
          100.00 Unit Weight
          Conventional Shear
              120.00        .00
          No Pore Pressure
     5 Layer 5 (ML)
          117.00 Unit Weight
          Conventional Shear
              200.00      15.00
          Piezometric Line
          1
     6 Layer 6 (CH)
          100.00 Unit Weight
          Conventional Shear
              200.00        .00
          No Pore Pressure
     7 Layer 7 (CH)
          100.00 Unit Weight
          Linear Increase
              217.00       8.10
          No Pore Pressure
     8 Layer 8 (CH)
```

```
          100.00 Unit Weight
          Linear Increase
              374.00      8.30
          No Pore Pressure
     9 Layer 9 (CH)
          100.00 Unit Weight
          Linear Increase
              590.00      8.00
          No Pore Pressure
     10 Compacted Fill - Above T-Wall Base
          .00 Unit Weight
          Conventional Shear
                 .00        .00
          No Pore Pressure

PIEZOMETRIC LINES
         1     62.40 Water Level
                 .00     10.00
              145.50     10.00
              145.51     -1.00
              157.00     -1.00
              375.00     -1.00

         2     62.40 Piezometeric levels in ML
                 .00     10.00
              149.50     10.00
              156.00     10.00
              158.50      1.00
              167.00      1.00
              173.00     -1.00
              375.00     -1.00


DISTRIBUTED LOADS
      1
ANALYSIS/COMPUTATION
     Circular Search 1
         146     22      1.00    -100.00       .00
     Tangent
          -23
SINgle-stage Computations
RIGht Face of Slope
LONg-form output
SORt radii
CRItical
PROcedure for computation of Factor of Safety
SPENCER

GRAPH
COMPUTE
```

Attachment 2 – Spencer's method analysis with unbalanced load that results in Figure 4.

```
HEADING
    T-Wall Deep Seated Analysis
    Analysis without piles

PROFILE LINES
         1     1 Layer 3 (CH) - Floodside
                  .00      -2.00
               141.00      -2.00
               155.00      -2.00

         2     1 Layer 3 (CH) - Landside
               157.00      -2.00
               375.00      -2.00

         3     2 Compacted Fill - FS
               141.00      -2.00
               145.50       -.50

         4     2 Compacted Fill - LS
               158.50       1.00
               167.00       1.00
               176.00      -2.00

         5     3 T-Wall
               145.50      -5.00
               145.50      -2.50
               155.00      -2.50
               155.00      -2.00
               155.00      12.30
               157.00      12.30
               157.00       1.00
               157.00      -2.00
               157.00      -2.50
               158.50      -2.50
               158.50      -5.00

         6     1 Layer 3 (CH) - Under Wall
               145.50      -5.00
               158.50      -5.00

         7     4 Layer 4 (CH)
                  .00     -14.00
               375.00     -14.00

         8     5 Layer 5 (ML)
                  .00     -23.00
               375.00     -23.00

         9     6 Layer 6 (CH)
                  .00     -26.00
               375.00     -26.00

        10     7 Layer 7 (CH)
```

```
             .00     -31.00
          375.00     -31.00

    11     8 Layer 8 (CH)
             .00     -39.00
          375.00     -39.00

    12     9 Layer 9 (CH)
             .00     -65.00
          375.00     -65.00

    13    10 Compacted Fill - Above T Wall Base   FS
          145.50       -.50
          150.00       1.00
          155.00       1.00

    14    10 Compacted Fill - Above T Wall Base   LS
          157.00       1.00
          158.50       1.00


MATERIAL PROPERTIES
     1 Layer 3 (CH)
          80.00 Unit Weight
          Conventional Shear
              120.00        .00
          No Pore Pressure
     2 Compacted Fill
          110.00 Unit Weight
          Conventional Shear
              500.00        .00
          No Pore Pressure
     3 T Wall
          .00 Unit Weight
          Very Strong
     4 Layer 4 (CH)
          100.00 Unit Weight
          Conventional Shear
              120.00        .00
          No Pore Pressure
     5 Layer 5 (ML)
          117.00 Unit Weight
          Conventional Shear
              200.00      15.00
          Piezometric Line
          1
     6 Layer 6 (CH)
          100.00 Unit Weight
          Conventional Shear
              200.00        .00
          No Pore Pressure
     7 Layer 7 (CH)
          100.00 Unit Weight
          Linear Increase
              217.00       8.10
          No Pore Pressure
     8 Layer 8 (CH)
```

```
          100.00 Unit Weight
          Linear Increase
              374.00      8.30
          No Pore Pressure
     9 Layer 9 (CH)
          100.00 Unit Weight
          Linear Increase
              590.00      8.00
          No Pore Pressure
     10 Compacted Fill - Above T-Wall Base
          .00 Unit Weight
          Conventional Shear
                 .00       .00
          No Pore Pressure

PIEZOMETRIC LINES
         1     62.40 Water Level
                 .00     10.00
              145.50     10.00
              145.51     -1.00
              157.00     -1.00
              375.00     -1.00

         2     62.40 Piezometeric levels in ML
                 .00     10.00
              149.50     10.00
              156.00     10.00
              158.50      1.00
              167.00      1.00
              173.00     -1.00
              375.00     -1.00


DISTRIBUTED LOADS
      1
LINE LOADS
              1    145      -11.75 -4575.00       .00 1

ANALYSIS/COMPUTATION
     Circular Search 1
         145      22       0.50   -100.00       .00
     Tangent
          -23
SINgle-stage Computations
RIGht Face of Slope
LONg-form output
SORt radii
CRItical
PROcedure for computation of Factor of Safety
SPENCER

GRAPH
COMPUTE
```

UPDATED 23 OCT 07

Attachment 3 Structural Loads for CPGA and Group Analyses

US Army Corps of Engineers Saint Paul Distict	PROJECT TITLE: T-Wall Design Example	COMPUTED BY: KDH	DATE: 07/27/07	SHEET:
	SUBJECT TITLE: Water at El. 10', Pervious	CHECKED BY:	DATE:	

Input for CPGA pile analysis **Pervious Foundation Assumption**

Upstream Water Elevation	*10* ft		Back Fill Soil Elevation	*1*	ft
Downstream Water Elevation	*-1* ft		Front Fill Soil Elevation	*1*	ft
Wall Top Elevation	*12.5* ft		Gamma Water	*0.0625*	kcf
Structure Bottom Elevation	*-5* ft		Gamma Concrete	*0.15*	kcf
Base Width	*13* ft		Gamma Sat. Backfill	*0.110*	kcf
Toe Width	*1.5* ft		Distance to Backfill Break	*5.0*	ft
Wall Thickness	*1.5* ft		Slope of Back Fill	*0.30*	
Base Thickness	*2.5* ft		Soil Elevation at Heel	-0.50	ft

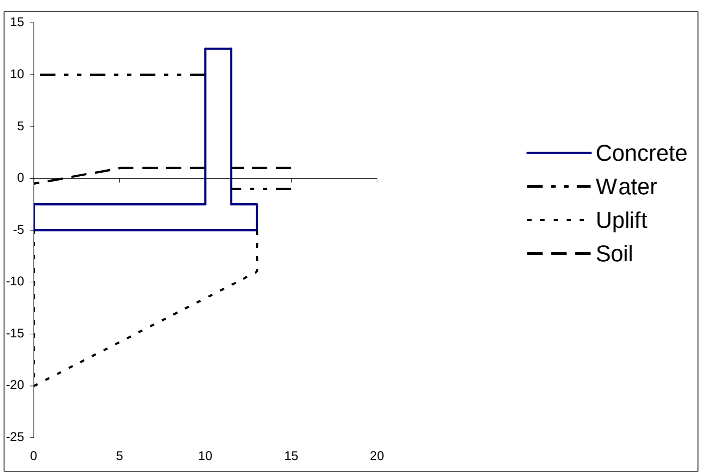
Vertical Forces

Component	Height	x1	x2	Gamma	Force	Arm	Moment	
Stem Concrete	15	10	11.5	0.15	3.38	10.75	36.3	
Heel Concrete	2.5	0	11.5	0.15	4.31	5.75	24.8	
Toe Concrete	2.5	11.5	13	0.15	0.56	12.25	6.9	
Heel Water	9	0	10	0.0625	5.63	5	28.1	
Toe Water	1.5	11.5	13	0.0625	0.14	12.25	1.7	
Heel Soil	3.5	0	10	0.110	3.85	5	19.3	
-Triangle	1.50	0	5.0	-0.048	-0.18	1.67	-0.3	
Toe Soil	3.5	11.5	13	0.110	0.58	12.25	7.1	
Rect Uplift	-4	0	13	0.0625	-3.25	6.5	-21.1	
Tri Uplift	-11	0	13	0.0625	-4.47	4.3	-19.4	
Sum Vertical Forces					10.5		83.4	ft-k

Horizontal Forces

Component	H1	H2	Gamma	Lat. Coeff.	Force	Arm	Moment	
Driving Water	10	-5	0.0625	1	7.03	5.00	35.16	
Resisting Water	-1	-5	0.0625	1	-0.50	1.33	-0.67	
Lateraral soil forces assumed equal and negligible								
Sum Horizontal Forces					6.53	5.28	34.49	ft-k

Total Structural Forces	Net Vert. Force	Arm	Moment	
About Heel	10.55	11.17	117.84	ft-k



Net Vertical Arm		
From Toe	1.83	ft

Moment About Toe
-19.3 ft-k

Model Width
5 ft

UPDATED 23 OCT 07

US Army Corps of Engineers	PROJECT TITLE: T-Wall Design Example	COMPUTED BY: KDH	DATE: 07/27/07	SHEET:
Saint Paul Distict	SUBJECT TITLE: Water at El. 10', Pervious	CHECKED BY:	DATE:	

Calculation of Unbalanced Force

Unbalanced Force. F_{ub}	*4,575*	lb/ft	From UTexas Analysis
Elevation of Critical Surface	*-23*	ft	From UTexas Analysis
Length - Ground to Crit. Surface, Lu	22.5	ft	(assume failure surface is normal to pile)
Length - Base to Crit. Surface, Lp	18	ft	
Pile Moment of Inertia. I	*729*	in^4	HP14x73
Pile Modulus of Elasticity E	*29,000,000*	lb/in^2	
Soil Modulus of Subgrade Reaction, k	*100*	lb/in^2	
Soil Stiffness Parameter, R	121	in	$(EI / k)^{1/4}$
Equivalent Unbalanced Force, Pcap	3,474	lb/ft	$F_{ub} * (L_u/2 +R) / (L_p +R)$

CPGA Input

PX	-50.03	kips
PY		
PZ	52.73	kips
MX	0	
MY	-96.29	kip-ft
MZ	0	

Group Input

3 Pile Rows Parallel to Wall Face

Unbalanced Loading on Piles for Group Analysis

Total	85	lb/in	F_{ub} * Model Width /L_u
50%	42	lb/in	For Pile on Protected Sied
25%	21	lb/in	

Note: Applied to length of pile from bottom of cap to top of critical surface. 18

Unbalanced Loads on Wall for Group Analysis of Just Unbalanced Forces

Distance From Base to Ground Surface, Ds 4.50 ft

PX	0	lb	
PY	4,575	lb	F_{ub} * Model Width / L_u * Ds
PZ	0	lb	
MX	0		
MY	0		
MZ	-123,525	lb-in	-PZ * Ds/2

Total Loads for Group Analysis

PX	52,731	lb	
PY	37,231	lb	PYub + Sum Horizontal * Model Width
PZ	0	lb	
MX	0		
MY	0		
MZ	1,031,916	lb-in	

UPDATED 23 OCT 07

US Army Corps of Engineers Saint Paul Distict	PROJECT TITLE: T-Wall Design Example	COMPUTED BY: KDH	DATE: 07/27/07	SHEET:
	SUBJECT TITLE: Water at El. 10', Impervious	CHECKED BY:	DATE:	

Input for CPGA pile analysis **Impervious Foundation Assumption**

Upstream Water Elevation	*10* ft		Back Fill Soil Elevation	*1*	ft
Downstream Water Elevation	*-1* ft		Front Fill Soil Elevation	*1*	ft
Wall Top Elevation	*12.5* ft		Gamma Water	*0.0625*	kcf
Structure Bottom Elevation	*-5* ft		Gamma Concrete	*0.15*	kcf
Base Width	*13* ft		Gamma Soil	*0.110*	kcf
Toe Width	*1.5* ft		Distance to Backfill Break	*5.0*	ft
Wall Thickness	*1.5* ft		Slope of Back Fill	*0.30*	
Base Thickness	*2.5* ft		Soil Elevation at Heel	-0.50	ft

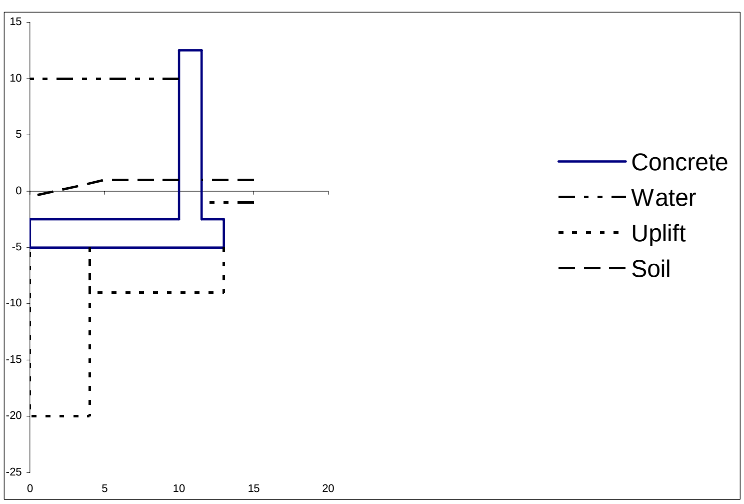
Vertical Forces

Component	Height	x1	x2	Gamma	Force	Arm	Moment	
Stem Concrete	15	10	11.5	0.15	3.38	10.75	36.3	
Heel Concrete	2.5	0	11.5	0.15	4.31	5.75	24.8	
Toe Concrete	2.5	11.5	13	0.15	0.56	12.25	6.9	
Heel Water	9	0	10	0.0625	5.63	5	28.1	
Toe Water	1.5	11.5	13	0.0625	0.14	12.25	1.7	
Heel Soil	3.5	0	10	0.110	3.85	5	19.3	
-Triangle	1.50	0	5.0	-0.048	-0.18	1.67	-0.3	
Toe Soil	3.5	11.5	13	0.110	0.58	12.25	7.1	
Prot. Side Uplift	-4	*4*	13	0.0625	-2.25	8.5	-19.1	
Flood Side Uplift	-15	0	4	0.0625	-3.75	2	-7.5	
Sum Vertical Forces					12.3	kip	97.2	ft-k

Horizontal Forces

Component	H1	H2	Gamma	Lat. Coeff.	Force	Arm	Moment	
Driving Water	10	-5	0.0625	1	7.03	5.00	35.16	
Resisting Water	-1	-5	0.0625	1	-0.50	1.33	-0.67	
Lateraral soil forces assumed equal and negligible								
Sum Horizontal Forces					6.53	kip	34.49	ft-k

Total Structural Forces	Net Vert. Force	Arm	Moment	
About Heel	12.27	10.74	131.71	ft-k



Net Vertical Arm		
From Toe	2.26	ft

Moment About Toe
-27.7 ft-k

Model Width
5 ft

UPDATED 23 OCT 07

US Army Corps of Engineers Saint Paul Distict	PROJECT TITLE: T-Wall Design Example	COMPUTED BY: KDH	DATE: 07/27/07	SHEET:	
	SUBJECT TITLE: Water at El. 10', Impervious	CHECKED BY:	DATE:		

Calculation of Unbalanced Force

Unbalanced Force. F_{ub}	*4,575*	lb/ft	From UTexas Analysis
Elevation of Critical Surface	*-23*	ft	From UTexas Analysis
Length - Ground to Crit. Surface, Lu	23	ft	(assume failure surface is normal to pile)
Length - Base to Crit. Surface, Lp	18	ft	
Pile Moment of Inertia. I	*729*	in^4	HP14x73
Pile Modulus of Elasticity E	*29,000,000*	lb/in^2	
Soil Modulus of Subgrade Reaction, k	*100*	lb/in^2	
Soil Stiffness Parameter, R	121	in	$(EI / k)^{1/4}$
Equivalent Unbalanced Force, Pcap	3,474	lb/ft	F_{ub} * (L_u/2 +R) / (L_p +R)

CPGA Input

PX	-50.03	kips
PY		
PZ	61.33	kips
MX	0	
MY	-138.68	kip-ft
MZ	0	

Group Input

3 Pile Rows Parallel to Wall Face

Unbalanced Loading on Piles for Group Analysis

Total	85	lb/in	F_{ub} * Model Width /L_u
50%	42	lb/in	For Pile on Protected Sied
25%	21	lb/in	

Note: Applied to length of pile from bottom of cap to top of critical surface. 18 ft

Unbalanced Loads on Wall for Group Analysis of Just Unbalanced Forces

Distance From Base to Ground Surface, Ds 4.50 ft

PX	0	lb	
PY	4,575	lb	F_{ub} * Model Width / L_u * Ds
PZ	0	lb	
MX	0		
MY	0		
MZ	-123,525	lb-in	-PZ * Ds/2

Total Loads for Group Analysis

PX	61,325	lb	
PY	37,231	lb	PYub + Sum Horizontal * Model Width
PZ	0	lb	
MX	0		
MY	0		
MZ	1,540,666	lb-in	

Attachment 4 - Preliminary Analysis with CPGA

```
10 Geomatrix T-wall, Example
15 2.5 ft slab, hp 14 x 73 piles, pinned head, 3:1 batter
20 PROP 29000 261 729 21.4 1.0 0 all
30 SOIL ES 0.0008 "TIP" 87 0 all
40 PIN all
50 ALLOW H 74.0 49.0 315.8  315.8  520.6  1573.1 all
70 BATTER 3.0 1 2 3
80 ANGLE 180 1 2
180 PILE 1  1.500 0.00 0.00
201 PILE 2  6.500 0.00 0.00
202 PILE 3  11.50 0.00 0.00
230 LOAD 1 -50.03  0.0  52.73  0.00  -96.29
240 LOAD 2 -50.03  0.0  61.33  0.00  -138.68
334 FOUT 1 2 3 4 5 6 7 MVN10EXT.OUT
335 PFO ALL
```

```
*********************************
 * CASE PROGRAM   #  X0080       *  CPGA - CASE PILE GROUP ANALYSIS PROGRAM
 * VERSION NUMBER # 1993/03/29   *  RUN DATE 27-JUL-2007   RUN TIME 16.23.07
 *********************************


 GEOMATRIX T-WALL, EXAMPLE


 THERE ARE    3 PILES AND
              2 LOAD CASES IN THIS RUN.

 ALL PILE COORDINATES ARE CONTAINED WITHIN A BOX
                                    X          Y          Z
                                  -----      -----      -----
 WITH DIAGONAL COORDINATES = (      1.50 ,      .00 ,      .00 )
                             (     11.50 ,      .00 ,      .00 )


 ******************************************************************************

          PILE PROPERTIES AS INPUT


      E            I1            I2             A            C33           B66
     KSI         IN**4         IN**4         IN**2
  .29000E+05   .26100E+03   .72900E+03   .21400E+02   .10000E+01   .00000E+00

 THESE PILE PROPERTIES APPLY TO THE FOLLOWING PILES -

     ALL


 ******************************************************************************

          SOIL DESCRIPTIONS AS INPUT
```

```
   ES      ESOIL       LENGTH        L            LU
          K/IN**2                    FT           FT
          .80000E-03    T       .87000E+02    .00000E+00

THIS SOIL DESCRIPTION APPLIES TO THE FOLLOWING PILES -

    ALL


********************************************************************************

         PILE GEOMETRY AS INPUT AND/OR GENERATED

NUM         X          Y          Z      BATTER   ANGLE   LENGTH  FIXITY
           FT         FT         FT                        FT

   1      1.50        .00        .00      3.00   180.00   91.71    P
   2      6.50        .00        .00      3.00   180.00   91.71    P
   3     11.50        .00        .00      3.00      .00   91.71    P
                                                          ------
                                                          275.12


********************************************************************************

                        APPLIED LOADS

LOAD      PX         PY         PZ          MX          MY          MZ
CASE       K          K          K         FT-K        FT-K        FT-K

  1     -50.0         .0       52.7          .0       -96.3          .0
  2     -50.0         .0       61.3          .0      -138.7          .0


********************************************************************************

         ORIGINAL PILE GROUP STIFFNESS MATRIX

  .16980E+03   .98653E-05  -.16911E+03   .00000E+00  -.71028E+04   .47353E-03
  .98653E-05   .52928E+00  -.29569E-04   .00000E+00   .14193E-02   .41284E+02
 -.16911E+03  -.29569E-04   .15227E+04   .00000E+00  -.11877E+06  -.14193E-02
  .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00   .00000E+00
 -.71028E+04   .14193E-02  -.11877E+06   .00000E+00   .12919E+08   .94738E-01
  .47353E-03   .41284E+02  -.14193E-02   .00000E+00   .94738E-01   .44904E+04


S(4,4)=0.  PROBLEM WILL BE TREATED AS TWO DIMENSIONAL IN THE X-Z PLANE.

LOAD CASE    1.  NUMBER OF FAILURES =    2.  NUMBER OF PILES IN TENSION =    1.

LOAD CASE    2.  NUMBER OF FAILURES =    1.  NUMBER OF PILES IN TENSION =    1.


********************************************************************************
```

PILE CAP DISPLACEMENTS

LOAD CASE	DX IN	DZ IN	R RAD
1	-.7241E+00	-.2963E+00	-.3212E-02
2	-.6757E+00	-.2609E+00	-.2899E-02

****

ELASTIC CENTER INFORMATION

ELASTIC CENTER IN PLANE X-Z	X FT	Z FT
	7.74	-11.20

LOAD CASE	MOMENT IN X-Z PLANE
1	.21918E+06
2	.44689E+06

****

PILE FORCES IN LOCAL GEOMETRY

M1 & M2 NOT AT PILE HEAD FOR PINNED PILES
* INDICATES PILE FAILURE
# INDICATES CBF BASED ON MOMENTS DUE TO
(F3*EMIN) FOR CONCRETE PILES
B INDICATES BUCKLING CONTROLS

LOAD CASE - 1

PILE	F1 K	F2 K	F3 K	M1 IN-K	M2 IN-K	M3 IN-K	ALF	CBF	
1	.2	.0	1.5	.0	-31.9	.0	.02	.03	
2	.2	.0	104.6	.0	-29.4	.0	1.41	.35	*
3	-.2	.0	-50.5	.0	30.7	.0	1.03	.18	*

LOAD CASE - 2

PILE	F1 K	F2 K	F3 K	M1 IN-K	M2 IN-K	M3 IN-K	ALF	CBF	
1	.2	.0	8.9	.0	-29.6	.0	.12	.05	
2	.1	.0	101.9	.0	-27.3	.0	1.38	.34	*
3	-.2	.0	-46.1	.0	28.7	.0	.94	.16	

****

PILE FORCES IN GLOBAL GEOMETRY

LOAD CASE - 1

PILE	PX	PY	PZ	MX	MY	MZ
	K	K	K	IN-K	IN-K	IN-K
1	-.7	.0	1.4	.0	.0	.0
2	-33.2	.0	99.2	.0	.0	.0
3	-16.1	.0	-47.9	.0	.0	.0

LOAD CASE - 2

PILE	PX	PY	PZ	MX	MY	MZ
	K	K	K	IN-K	IN-K	IN-K
1	-3.0	.0	8.4	.0	.0	.0
2	-32.4	.0	96.6	.0	.0	.0
3	-14.7	.0	-43.6	.0	.0	.0

Attachment 5. Group 7 Output for the Pervious Condition.

```
==============================================================================

                GROUP for Windows, Version 7.0.7

                 Analysis of A Group of Piles
              Subjected to Axial and Lateral Loading

               (c) Copyright ENSOFT, Inc., 1987-2006
                     All Rights Reserved

==============================================================================


This program is licensed to:

k
c

Path to file locations:      C:\KDH\New Orleans\T-walls\Group\
Name of input data file:     10 Example perv.gpd
Name of output file:         10 Example perv.gpo
Name of plot output file:    10 Example perv.gpp
Name of runtime file:        10 Example perv.gpr
Name of output summary file: 10 Example perv.gpt


-----------------------------------------------------------------------------
-
                          Time and Date of Analysis
-----------------------------------------------------------------------------
-

               Date:  July 27, 2007     Time:  17:44: 4
 PILE GROUP ANALYSIS PROGRAM-GROUP
 PC VERSION 6.0 (C) COPYRIGHT ENSOFT,INC. 2000

 THE PROGRAM WAS COMPILED USING MICROSOFT FORTRAN
 POWERSTATION 4.0 (C) COPYRIGHT MICROSOFT CORPORATION, 1996.



      T-wall Example:  F.S. 10.0, P.S. -1.0, Pervious 50% Unbal. Force on
left pile



                *****     INPUT INFORMATION     *****




     * TABLE C *  LOAD AND CONTROL PARAMETERS


     UNITS--
```

```
     V LOAD,LBS      H LOAD,LBS    MOMENT,LBS-IN

     0.5273E+05      0.3723E+05     0.1032E+07

  GROUP NO. 1


               DISTRIBUTED LOAD CURVE          2 POINTS

                          X,IN       LOAD,LBS/IN
                          0.00        0.210E+02
                        216.00        0.210E+02

  GROUP NO. 2


               DISTRIBUTED LOAD CURVE          2 POINTS

                          X,IN       LOAD,LBS/IN
                          0.00        0.210E+02
                        216.00        0.210E+02

  GROUP NO. 3


               DISTRIBUTED LOAD CURVE          2 POINTS

                          X,IN       LOAD,LBS/IN
                          0.00        0.420E+02
                        216.00        0.420E+02


* THE LOADING IS STATIC *


    KPYOP =  0      (CODE TO GENERATE P-Y CURVES)

    ( KPYOP = 1 IF P-Y YES; = 0 IF P-Y NO; = -1 IF P-Y ONLY )


* CONTROL PARAMETERS *
    TOLERANCE ON CONVERGENCE OF FOUNDATION REACTION      =  0.100E-04 IN
    TOLERANCE ON DETERMINATION OF DEFLECTIONS            =  0.100E-04 IN
    MAX NO OF ITERATIONS ALLOWED FOR FOUNDATION ANALYSIS =     100
    MAXIMUM NO. OF ITERATIONS ALLOWED FOR PILE ANALYSIS  =     100



* TABLE D *    ARRANGEMENT OF PILE GROUPS
```

GROUP	CONNECT	NO OF PILE	PILE NO	L-S CURVE	P-Y CURVE
1	PIN	1	1	1	0
2	PIN	1	1	1	0
3	PIN	1	1	1	0

GROUP	VERT,IN	HOR,IN	SLOPE,IN/IN	GROUND,IN	SPRING,LBS-IN
1	0.0000E+00	-0.1500E+02	0.3218E+00	-0.3600E+02	0.0000E+00
2	0.0000E+00	-0.7500E+02	0.3218E+00	-0.3600E+02	0.0000E+00
3	0.0000E+00	-0.1410E+03	-0.3218E+00	-0.3600E+02	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00

* TABLE E *   PILE GEOMETRY AND PROPERTIES
PILE TYPE = 1 - DRIVEN PILE
= 2 - DRILLED SHAFT

PILE	SEC	INC	LENGTH, IN	E ,LBS/IN**2	PILE TYPE
1	1	91	0.1092E+04	0.2900E+08	1

PILE	FROM,IN	TO,IN	DIAM,IN	AREA,IN**2	I,IN**4
1	0.0000E+00	0.1092E+04	0.1400E+02	0.2140E+02	0.7290E+03

* THE PILE ABOVE IS OF LINEARLY ELASTIC MATERIAL *

* TABLE F *   AXIAL LOAD VS SETTLEMENT

(THE LOAD-SETTLEMENT CURVE OF SINGLE PILE IS GENERATED INTERNALLY)

NUM OF CURVES 1

CURVE 1   NUM OF POINTS = 19

POINT	AXIAL LOAD,LBS	SETTLEMENT, IN
1	-0.1727E+06	-0.2221E+01
2	-0.1647E+06	-0.1208E+01
3	-0.1607E+06	-0.7010E+00
4	-0.1369E+06	-0.2609E+00
5	-0.1280E+06	-0.1948E+00
6	-0.4099E+05	-0.5077E-01
7	-0.1984E+05	-0.2476E-01
8	-0.3931E+04	-0.4928E-02
9	-0.3931E+03	-0.4928E-03
10	0.0000E+00	0.0000E+00
11	0.7478E+03	0.9072E-03
12	0.4682E+04	0.5805E-02
13	0.2246E+05	0.2777E-01
14	0.4482E+05	0.5521E-01
15	0.1311E+06	0.2001E+00
16	0.1406E+06	0.2675E+00
17	0.1691E+06	0.7159E+00
18	0.1763E+06	0.1228E+01
19	0.1881E+06	0.2248E+01

* TABLE H *   SOIL DATA FOR AUTO P-Y CURVES

```
SOILS INFORMATION

     AT THE GROUND SURFACE          =     -36.00 IN

    6 LAYER(S) OF SOIL

    LAYER  1
    THE SOIL IS A SOFT CLAY
    X AT THE TOP OF THE LAYER         =     -36.00 IN
    X AT THE BOTTOM OF THE LAYER      =     216.00 IN
    MODULUS OF SUBGRADE REACTION      =  0.100E+00 LBS/IN**3

    LAYER  2
    THE SOIL IS A SILT
    X AT THE TOP OF THE LAYER         =     216.00 IN
    X AT THE BOTTOM OF THE LAYER      =     252.00 IN
    MODULUS OF SUBGRADE REACTION      =  0.300E+02 LBS/IN**3

    LAYER  3
    THE SOIL IS A SOFT CLAY
    X AT THE TOP OF THE LAYER         =     252.00 IN
    X AT THE BOTTOM OF THE LAYER      =     720.00 IN
    MODULUS OF SUBGRADE REACTION      =  0.300E+02 LBS/IN**3

    LAYER  4
    THE SOIL IS A STIFF CLAY BELOW THE WATER TABLE
    X AT THE TOP OF THE LAYER         =     720.00 IN
    X AT THE BOTTOM OF THE LAYER      =     973.00 IN
    MODULUS OF SUBGRADE REACTION      =  0.100E+03 LBS/IN**3

    LAYER  5
    THE SOIL IS A SAND
    X AT THE TOP OF THE LAYER         =     973.00 IN
    X AT THE BOTTOM OF THE LAYER      =    1273.00 IN
    MODULUS OF SUBGRADE REACTION      =  0.600E+02 LBS/IN**3

    LAYER  6
    THE SOIL IS A STIFF CLAY BELOW THE WATER TABLE
    X AT THE TOP OF THE LAYER         =    1273.00 IN
    X AT THE BOTTOM OF THE LAYER      =    1344.00 IN
    MODULUS OF SUBGRADE REACTION      =  0.100E+03 LBS/IN**3


    DISTRIBUTION OF EFFECTIVE UNIT WEIGHT WITH DEPTH
                      16 POINTS

             X,IN    WEIGHT,LBS/IN**3
         -36.0000      0.1010E-01
         108.0000      0.1010E-01
         108.0000      0.2170E-01
         216.0000      0.2170E-01
         216.0000      0.3150E-01
         252.0000      0.3150E-01
         252.0000      0.2170E-01
         720.0000      0.2170E-01
         720.0000      0.2750E-01
```

900.0000	0.2750E-01
900.0000	0.3330E-01
972.0000	0.3330E-01
972.0000	0.3440E-01
1273.0000	0.3440E-01
1273.0000	0.3210E-01
1344.0000	0.3210E-01

DISTRIBUTION OF STRENGTH PARAMETERS WITH DEPTH
16 POINTS

X IN	C LBS/IN**2	PHI,DEGREES	E50	FMAX LBS/IN**2	TIPMAX LBS/IN**2
-36.00	0.3333E-01	0.000	0.2500E-01	0.1000E+00	0.0000E+00
216.00	0.3333E-01	0.000	0.2500E-01	0.1000E+00	0.0000E+00
216.00	0.1390E+01	15.000	0.2500E-01	0.2400E+01	0.0000E+00
252.00	0.1390E+01	15.000	0.2500E-01	0.2700E+01	0.0000E+00
252.00	0.1390E+01	0.000	0.2500E-01	0.1390E+01	0.0000E+00
408.00	0.1390E+01	0.000	0.2500E-01	0.1390E+01	0.0000E+00
408.00	0.2590E+01	0.000	0.2000E-01	0.2590E+01	0.0000E+00
720.00	0.4100E+01	0.000	0.1000E-01	0.4100E+01	0.0000E+00
720.00	0.4100E+01	0.000	0.1000E-01	0.4100E+01	0.0000E+00
780.00	0.4300E+01	0.000	0.1000E-01	0.4300E+01	0.0000E+00
780.00	0.5500E+01	0.000	0.1000E-01	0.5500E+01	0.0000E+00
973.00	0.5500E+01	0.000	0.1000E-01	0.5500E+01	0.0000E+00
973.00	0.0000E+00	30.000	0.0000E+00	0.1300E+02	0.0000E+00
1273.00	0.0000E+00	30.000	0.0000E+00	0.1400E+02	0.0000E+00
1273.00	0.6800E+01	0.000	0.1000E-01	0.6800E+01	0.0000E+00
1344.00	0.6800E+01	0.000	0.1000E-01	0.6800E+01	0.0000E+00

REDUCTION FACTORS FOR CLOSELY-SPACED PILE GROUPS

GROUP NO	P-FACTOR	Y-FACTOR
1	1.00	1.00
2	0.83	1.00
3	0.87	1.00

T-wall Example: F.S. 10.0, P.S. -1.0, Pervious 50% Unbal. Force on left pile

***** COMPUTATION RESULTS *****

VERT. LOAD, LBS	HORI. LOAD, LBS	MOMENT,IN-LBS
0.5273E+05	0.3723E+05	0.1032E+07

DISPLACEMENT OF GROUPED PILE FOUNDATION

```
          VERTICAL,IN    HORIZONTAL,IN    ROTATION,RAD

         -0.2048E+00      0.5260E+00       0.2313E-02


     NUMBER OF ITERATIONS =   4


  * TABLE I *   COMPUTATION ON INDIVIDUAL PILE


    * PILE GROUP *  1


 PILE TOP DISPLACEMENTS AND REACTIONS


       THE GLOBAL STRUCTURE COORDINATE SYSTEM
       --------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN
STRESS,LBS/IN**2

-0.170E+00  0.526E+00 -.192E-02 0.421E+04 0.307E+02 0.000E+00   0.187E+03


       THE LOCAL MEMBER COORDINATE SYSTEM
       ------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN
STRESS,LBS/IN**2

 0.496E-02  0.553E+00 -.192E-02 0.400E+04-0.130E+04 0.000E+00   0.187E+03


          LATERALLY LOADED PILE
```

X IN	DEFLECTION IN	MOMENT LBS-IN	SHEAR LBS	SOIL REACTION LBS/IN	TOTAL STRESS LBS/IN**2	FLEXURAL RIGIDITY LBS-IN**2
*****	**********	**********	**********	**********	**********	**********
0.00	0.553E+00	0.000E+00	-0.106E+04	0.180E+01	0.187E+03	0.211E+11
12.00	0.530E+00	0.126E+05	-0.944E+03	0.178E+01	0.308E+03	0.211E+11
24.00	0.507E+00	0.225E+05	-0.714E+03	0.175E+01	0.403E+03	0.211E+11
36.00	0.483E+00	0.296E+05	-0.482E+03	0.172E+01	0.471E+03	0.211E+11
48.00	0.460E+00	0.339E+05	-0.251E+03	0.169E+01	0.512E+03	0.211E+11
60.00	0.436E+00	0.354E+05	-0.191E+02	0.166E+01	0.527E+03	0.211E+11
72.00	0.412E+00	0.341E+05	0.213E+03	0.163E+01	0.515E+03	0.211E+11
84.00	0.388E+00	0.301E+05	0.446E+03	0.160E+01	0.476E+03	0.211E+11
96.00	0.364E+00	0.233E+05	0.679E+03	0.157E+01	0.410E+03	0.211E+11

108.00	0.339E+00	0.136E+05	0.912E+03	0.153E+01	0.318E+03	0.211E+11
120.00	0.315E+00	0.116E+04	0.115E+04	0.149E+01	0.198E+03	0.211E+11
132.00	0.290E+00	-0.141E+05	0.138E+04	0.145E+01	0.322E+03	0.211E+11
144.00	0.265E+00	-0.322E+05	0.162E+04	0.141E+01	0.496E+03	0.211E+11
156.00	0.241E+00	-0.530E+05	0.185E+04	0.137E+01	0.696E+03	0.211E+11
168.00	0.217E+00	-0.768E+05	0.209E+04	0.132E+01	0.924E+03	0.211E+11
180.00	0.194E+00	-0.103E+06	0.232E+04	0.127E+01	0.118E+04	0.211E+11
192.00	0.171E+00	-0.133E+06	0.256E+04	0.122E+01	0.146E+04	0.211E+11
204.00	0.149E+00	-0.165E+06	0.280E+04	0.116E+01	0.177E+04	0.211E+11
216.00	0.128E+00	-0.200E+06	0.270E+04	0.572E+02	0.211E+04	0.211E+11
228.00	0.109E+00	-0.230E+06	0.196E+04	0.878E+02	0.239E+04	0.211E+11
240.00	0.912E-01	-0.247E+06	0.791E+03	0.106E+03	0.256E+04	0.211E+11
252.00	0.751E-01	-0.249E+06	0.356E+02	0.196E+02	0.258E+04	0.211E+11
264.00	0.607E-01	-0.248E+06	-0.205E+03	0.206E+02	0.257E+04	0.211E+11
276.00	0.479E-01	-0.244E+06	-0.456E+03	0.212E+02	0.253E+04	0.211E+11
288.00	0.369E-01	-0.237E+06	-0.712E+03	0.214E+02	0.246E+04	0.211E+11
300.00	0.275E-01	-0.227E+06	-0.967E+03	0.212E+02	0.237E+04	0.211E+11
312.00	0.196E-01	-0.214E+06	-0.122E+04	0.206E+02	0.224E+04	0.211E+11
324.00	0.131E-01	-0.198E+06	-0.146E+04	0.194E+02	0.209E+04	0.211E+11
336.00	0.805E-02	-0.179E+06	-0.168E+04	0.177E+02	0.191E+04	0.211E+11
348.00	0.418E-02	-0.158E+06	-0.188E+04	0.147E+02	0.170E+04	0.211E+11
360.00	0.139E-02	-0.134E+06	-0.202E+04	0.102E+02	0.148E+04	0.211E+11
372.00	-0.487E-03	-0.109E+06	-0.204E+04	-0.728E+01	0.123E+04	0.211E+11
384.00	-0.162E-02	-0.852E+05	-0.193E+04	-0.108E+02	0.100E+04	0.211E+11
396.00	-0.217E-02	-0.627E+05	-0.180E+04	-0.119E+02	0.789E+03	0.211E+11
408.00	-0.230E-02	-0.420E+05	-0.159E+04	-0.234E+02	0.590E+03	0.211E+11
420.00	-0.214E-02	-0.247E+05	-0.130E+04	-0.244E+02	0.424E+03	0.211E+11
432.00	-0.181E-02	-0.108E+05	-0.101E+04	-0.238E+02	0.291E+03	0.211E+11
444.00	-0.141E-02	-0.421E+03	-0.733E+03	-0.225E+02	0.191E+03	0.211E+11
456.00	-0.101E-02	0.676E+04	-0.474E+03	-0.207E+02	0.252E+03	0.211E+11
468.00	-0.647E-03	0.110E+05	-0.240E+03	-0.183E+02	0.292E+03	0.211E+11
480.00	-0.363E-03	0.125E+05	-0.368E+02	-0.155E+02	0.307E+03	0.211E+11
492.00	-0.165E-03	0.118E+05	0.130E+03	-0.123E+02	0.301E+03	0.211E+11
504.00	-0.465E-04	0.940E+04	0.254E+03	-0.832E+01	0.277E+03	0.211E+11
516.00	0.748E-05	0.575E+04	0.277E+03	0.452E+01	0.242E+03	0.211E+11
528.00	0.223E-04	0.276E+04	0.209E+03	0.681E+01	0.213E+03	0.211E+11
540.00	0.184E-04	0.743E+03	0.128E+03	0.658E+01	0.194E+03	0.211E+11
552.00	0.943E-05	-0.323E+03	0.563E+02	0.543E+01	0.190E+03	0.211E+11
564.00	0.264E-05	-0.608E+03	0.160E+01	0.368E+01	0.193E+03	0.211E+11
576.00	0.200E-08	-0.362E+03	-0.232E+02	0.448E+00	0.190E+03	0.211E+11
588.00	-0.177E-06	-0.514E+02	-0.161E+02	-0.163E+01	0.187E+03	0.211E+11
600.00	-0.493E-08	0.245E+02	-0.217E+01	-0.692E+00	0.187E+03	0.211E+11
612.00	0.875E-10	0.750E+00	0.102E+01	0.159E+00	0.187E+03	0.211E+11
624.00	0.841E-14	-0.128E-01	0.312E-01	0.538E-02	0.187E+03	0.211E+11
636.00	-0.136E-15	-0.127E-05	-0.535E-03	-0.891E-04	0.187E+03	0.211E+11
648.00	-0.135E-19	0.199E-07	-0.531E-07	-0.913E-08	0.187E+03	0.211E+11
660.00	0.200E-21	0.205E-11	0.830E-09	0.138E-09	0.187E+03	0.211E+11
672.00	0.206E-25	-0.293E-13	0.853E-13	0.146E-13	0.187E+03	0.211E+11
684.00	-0.279E-27	-0.310E-17	-0.122E-14	-0.204E-15	0.187E+03	0.211E+11
696.00	-0.296E-31	0.410E-19	-0.129E-18	-0.221E-19	0.187E+03	0.211E+11
708.00	0.370E-33	0.233E-23	0.171E-20	0.285E-21	0.187E+03	0.211E+11
720.00	0.144E-31	0.149E-23	0.632E-25	0.109E-26	0.187E+03	0.211E+11
732.00	0.183E-31	0.815E-24	0.482E-25	0.140E-26	0.187E+03	0.211E+11
744.00	0.166E-31	0.338E-24	0.320E-25	0.130E-26	0.187E+03	0.211E+11
756.00	0.126E-31	0.470E-25	0.182E-25	0.100E-26	0.187E+03	0.211E+11
768.00	0.833E-32	-0.995E-25	0.819E-26	0.670E-27	0.187E+03	0.211E+11
780.00	0.471E-32	-0.150E-24	0.186E-26	0.385E-27	0.187E+03	0.211E+11

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     792.00  0.211E-32 -0.144E-24 -0.150E-26  0.175E-27  0.187E+03  0.211E+11
     804.00  0.493E-33 -0.114E-24 -0.279E-26  0.414E-28  0.187E+03  0.211E+11
     816.00 -0.351E-33 -0.772E-25 -0.286E-26 -0.299E-28  0.187E+03  0.211E+11
     828.00 -0.670E-33 -0.450E-25 -0.234E-26 -0.579E-28  0.187E+03  0.211E+11
     840.00 -0.682E-33 -0.211E-25 -0.163E-26 -0.597E-28  0.187E+03  0.211E+11
     852.00 -0.551E-33 -0.584E-26 -0.979E-27 -0.489E-28  0.187E+03  0.211E+11
     864.00 -0.379E-33  0.239E-26 -0.481E-27 -0.341E-28  0.187E+03  0.211E+11
     876.00 -0.224E-33  0.570E-26 -0.154E-27 -0.204E-28  0.187E+03  0.211E+11
     888.00 -0.108E-33  0.608E-26  0.290E-28 -0.998E-29  0.187E+03  0.211E+11
     900.00 -0.332E-34  0.501E-26  0.107E-27 -0.311E-29  0.187E+03  0.211E+11
     912.00  0.749E-35  0.350E-26  0.122E-27  0.710E-30  0.187E+03  0.211E+11
     924.00  0.244E-34  0.208E-26  0.104E-27  0.234E-29  0.187E+03  0.211E+11
     936.00  0.270E-34  0.101E-26  0.738E-28  0.263E-29  0.187E+03  0.211E+11
     948.00  0.228E-34  0.314E-27  0.446E-28  0.224E-29  0.187E+03  0.211E+11
     960.00  0.164E-34 -0.599E-28  0.213E-28  0.164E-29  0.187E+03  0.211E+11
     972.00  0.105E-34 -0.197E-27  0.512E-29  0.106E-29  0.187E+03  0.211E+11
     984.00  0.590E-35 -0.183E-27 -0.169E-29  0.753E-31  0.187E+03  0.211E+11
     996.00  0.255E-35 -0.157E-27 -0.234E-29  0.343E-31  0.187E+03  0.211E+11
    1008.00  0.260E-36 -0.126E-27 -0.257E-29  0.368E-32  0.187E+03  0.211E+11
    1020.00 -0.117E-35 -0.953E-28 -0.249E-29 -0.174E-31  0.187E+03  0.211E+11
    1032.00 -0.194E-35 -0.666E-28 -0.220E-29 -0.304E-31  0.187E+03  0.211E+11
    1044.00 -0.226E-35 -0.424E-28 -0.180E-29 -0.370E-31  0.187E+03  0.211E+11
    1056.00 -0.230E-35 -0.234E-28 -0.134E-29 -0.392E-31  0.187E+03  0.211E+11
    1068.00 -0.217E-35 -0.102E-28 -0.875E-30 -0.387E-31  0.187E+03  0.211E+11
    1080.00 -0.198E-35 -0.245E-29 -0.423E-30 -0.366E-31  0.187E+03  0.211E+11
    1092.00 -0.177E-35  0.000E+00 -0.155E-44 -0.340E-31  0.187E+03  0.211E+11

     NUMBER OF ITERATIONS IN LLP =    14


       * PILE GROUP *   2


 PILE TOP DISPLACEMENTS AND REACTIONS


       THE GLOBAL STRUCTURE COORDINATE SYSTEM
       --------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN
STRESS,LBS/IN**2

-0.314E-01  0.526E+00 -.164E-02 0.890E+05 0.279E+05 0.000E+00   0.436E+04


       THE LOCAL MEMBER COORDINATE SYSTEM
       ------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN
STRESS,LBS/IN**2

 0.137E+00  0.509E+00 -.164E-02 0.933E+05-0.165E+04 0.000E+00   0.436E+04


          LATERALLY LOADED PILE
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X IN	DEFLECTION IN	MOMENT LBS-IN	SHEAR LBS	SOIL REACTION LBS/IN	TOTAL STRESS LBS/IN**2	FLEXURAL RIGIDITY LBS-IN**2
*****	**********	**********	**********	**********	**********	**********
0.00	0.509E+00	0.000E+00	-0.141E+04	0.146E+01	0.436E+04	0.211E+11
12.00	0.489E+00	0.151E+05	-0.129E+04	0.144E+01	0.450E+04	0.211E+11
24.00	0.470E+00	0.273E+05	-0.106E+04	0.142E+01	0.462E+04	0.211E+11
36.00	0.450E+00	0.367E+05	-0.820E+03	0.140E+01	0.471E+04	0.211E+11
48.00	0.429E+00	0.432E+05	-0.585E+03	0.138E+01	0.477E+04	0.211E+11
60.00	0.409E+00	0.469E+05	-0.349E+03	0.136E+01	0.481E+04	0.211E+11
72.00	0.388E+00	0.478E+05	-0.114E+03	0.134E+01	0.482E+04	0.211E+11
84.00	0.367E+00	0.457E+05	0.123E+03	0.131E+01	0.480E+04	0.211E+11
96.00	0.346E+00	0.408E+05	0.359E+03	0.129E+01	0.475E+04	0.211E+11
108.00	0.324E+00	0.331E+05	0.596E+03	0.126E+01	0.468E+04	0.211E+11
120.00	0.302E+00	0.225E+05	0.833E+03	0.123E+01	0.457E+04	0.211E+11
132.00	0.280E+00	0.900E+04	0.107E+04	0.120E+01	0.444E+04	0.211E+11
144.00	0.258E+00	-0.734E+04	0.131E+04	0.117E+01	0.443E+04	0.211E+11
156.00	0.236E+00	-0.265E+05	0.155E+04	0.113E+01	0.461E+04	0.211E+11
168.00	0.214E+00	-0.486E+05	0.178E+04	0.110E+01	0.482E+04	0.211E+11
180.00	0.192E+00	-0.734E+05	0.202E+04	0.106E+01	0.506E+04	0.211E+11
192.00	0.171E+00	-0.101E+06	0.226E+04	0.102E+01	0.533E+04	0.211E+11
204.00	0.150E+00	-0.132E+06	0.250E+04	0.974E+00	0.562E+04	0.211E+11
216.00	0.131E+00	-0.165E+06	0.246E+04	0.487E+02	0.594E+04	0.211E+11
228.00	0.113E+00	-0.194E+06	0.184E+04	0.757E+02	0.622E+04	0.211E+11
240.00	0.955E-01	-0.212E+06	0.826E+03	0.929E+02	0.640E+04	0.211E+11
252.00	0.799E-01	-0.217E+06	0.168E+03	0.167E+02	0.644E+04	0.211E+11
264.00	0.657E-01	-0.219E+06	-0.379E+02	0.176E+02	0.646E+04	0.211E+11
276.00	0.531E-01	-0.219E+06	-0.253E+03	0.183E+02	0.646E+04	0.211E+11
288.00	0.419E-01	-0.215E+06	-0.475E+03	0.186E+02	0.642E+04	0.211E+11
300.00	0.322E-01	-0.209E+06	-0.699E+03	0.187E+02	0.637E+04	0.211E+11
312.00	0.239E-01	-0.200E+06	-0.921E+03	0.184E+02	0.628E+04	0.211E+11
324.00	0.170E-01	-0.188E+06	-0.114E+04	0.177E+02	0.617E+04	0.211E+11
336.00	0.114E-01	-0.174E+06	-0.134E+04	0.166E+02	0.603E+04	0.211E+11
348.00	0.697E-02	-0.157E+06	-0.153E+04	0.146E+02	0.587E+04	0.211E+11
360.00	0.361E-02	-0.138E+06	-0.169E+04	0.117E+02	0.568E+04	0.211E+11
372.00	0.118E-02	-0.117E+06	-0.181E+04	0.803E+01	0.548E+04	0.211E+11
384.00	-0.453E-03	-0.951E+05	-0.182E+04	-0.594E+01	0.527E+04	0.211E+11
396.00	-0.144E-02	-0.738E+05	-0.173E+04	-0.865E+01	0.507E+04	0.211E+11
408.00	-0.192E-02	-0.537E+05	-0.157E+04	-0.184E+02	0.487E+04	0.211E+11
420.00	-0.203E-02	-0.362E+05	-0.134E+04	-0.200E+02	0.471E+04	0.211E+11
432.00	-0.190E-02	-0.216E+05	-0.110E+04	-0.201E+02	0.456E+04	0.211E+11
444.00	-0.162E-02	-0.983E+04	-0.859E+03	-0.196E+02	0.445E+04	0.211E+11
456.00	-0.127E-02	-0.910E+03	-0.629E+03	-0.186E+02	0.437E+04	0.211E+11
468.00	-0.918E-03	0.533E+04	-0.414E+03	-0.172E+02	0.441E+04	0.211E+11
480.00	-0.602E-03	0.909E+04	-0.219E+03	-0.153E+02	0.444E+04	0.211E+11
492.00	-0.347E-03	0.106E+05	-0.480E+02	-0.131E+02	0.446E+04	0.211E+11
504.00	-0.165E-03	0.103E+05	0.941E+02	-0.105E+02	0.446E+04	0.211E+11
516.00	-0.533E-04	0.841E+04	0.202E+03	-0.745E+01	0.444E+04	0.211E+11
528.00	0.143E-05	0.545E+04	0.234E+03	0.208E+01	0.441E+04	0.211E+11
540.00	0.191E-04	0.279E+04	0.189E+03	0.554E+01	0.438E+04	0.211E+11
552.00	0.177E-04	0.924E+03	0.122E+03	0.557E+01	0.437E+04	0.211E+11
564.00	0.100E-04	-0.140E+03	0.601E+02	0.475E+01	0.436E+04	0.211E+11
576.00	0.332E-05	-0.519E+03	0.111E+02	0.341E+01	0.436E+04	0.211E+11

588.00	0.151E-06	-0.408E+03	-0.181E+02	0.145E+01	0.436E+04	0.211E+11
600.00	-0.238E-06	-0.865E+02	-0.180E+02	-0.147E+01	0.436E+04	0.211E+11
612.00	-0.375E-07	0.239E+02	-0.383E+01	-0.893E+00	0.436E+04	0.211E+11
624.00	0.792E-10	0.552E+01	0.995E+00	0.890E-01	0.436E+04	0.211E+11
636.00	0.183E-11	-0.111E-01	0.230E+00	0.385E-01	0.436E+04	0.211E+11
648.00	-0.109E-15	-0.268E-03	-0.462E-03	-0.733E-04	0.436E+04	0.211E+11
660.00	-0.269E-17	0.152E-07	-0.112E-04	-0.186E-05	0.436E+04	0.211E+11
672.00	0.141E-21	0.395E-09	0.632E-09	0.999E-10	0.436E+04	0.211E+11
684.00	0.376E-23	-0.195E-13	0.165E-10	0.274E-11	0.436E+04	0.211E+11
696.00	-0.171E-27	-0.553E-15	-0.814E-15	-0.128E-15	0.436E+04	0.211E+11
708.00	-0.499E-29	0.127E-19	-0.230E-16	-0.384E-17	0.436E+04	0.211E+11
720.00	0.743E-28	0.824E-20	0.342E-21	0.562E-23	0.436E+04	0.211E+11
732.00	0.975E-28	0.455E-20	0.263E-21	0.749E-23	0.436E+04	0.211E+11
744.00	0.898E-28	0.193E-20	0.176E-21	0.700E-23	0.436E+04	0.211E+11
756.00	0.689E-28	0.321E-21	0.101E-21	0.546E-23	0.436E+04	0.211E+11
768.00	0.458E-28	-0.502E-21	0.463E-22	0.368E-23	0.436E+04	0.211E+11
780.00	0.262E-28	-0.794E-21	0.114E-22	0.214E-23	0.436E+04	0.211E+11
792.00	0.119E-28	-0.778E-21	-0.737E-23	0.988E-24	0.436E+04	0.211E+11
804.00	0.300E-29	-0.620E-21	-0.148E-22	0.252E-24	0.436E+04	0.211E+11
816.00	-0.172E-29	-0.424E-21	-0.154E-22	-0.147E-24	0.436E+04	0.211E+11
828.00	-0.355E-29	-0.250E-21	-0.127E-22	-0.307E-24	0.436E+04	0.211E+11
840.00	-0.368E-29	-0.119E-21	-0.895E-23	-0.322E-24	0.436E+04	0.211E+11
852.00	-0.300E-29	-0.347E-22	-0.542E-23	-0.266E-24	0.436E+04	0.211E+11
864.00	-0.208E-29	0.112E-22	-0.270E-23	-0.187E-24	0.436E+04	0.211E+11
876.00	-0.124E-29	0.301E-22	-0.892E-24	-0.113E-24	0.436E+04	0.211E+11
888.00	-0.606E-30	0.328E-22	0.123E-24	-0.560E-25	0.436E+04	0.211E+11
900.00	-0.193E-30	0.273E-22	0.568E-24	-0.181E-25	0.436E+04	0.211E+11
912.00	0.331E-31	0.192E-22	0.657E-24	0.314E-26	0.436E+04	0.211E+11
924.00	0.129E-30	0.115E-22	0.564E-24	0.124E-25	0.436E+04	0.211E+11
936.00	0.146E-30	0.566E-23	0.405E-24	0.142E-25	0.436E+04	0.211E+11
948.00	0.124E-30	0.182E-23	0.247E-24	0.122E-25	0.436E+04	0.211E+11
960.00	0.906E-31	-0.260E-24	0.119E-24	0.902E-26	0.436E+04	0.211E+11
972.00	0.585E-31	-0.104E-23	0.295E-25	0.589E-26	0.436E+04	0.211E+11
984.00	0.335E-31	-0.973E-24	-0.842E-26	0.427E-27	0.436E+04	0.211E+11
996.00	0.151E-31	-0.843E-24	-0.122E-25	0.203E-27	0.436E+04	0.211E+11
1008.00	0.244E-32	-0.683E-24	-0.136E-25	0.346E-28	0.436E+04	0.211E+11
1020.00	-0.554E-32	-0.518E-24	-0.133E-25	-0.826E-28	0.436E+04	0.211E+11
1032.00	-0.999E-32	-0.365E-24	-0.119E-25	-0.156E-27	0.436E+04	0.211E+11
1044.00	-0.120E-31	-0.233E-24	-0.979E-26	-0.195E-27	0.436E+04	0.211E+11
1056.00	-0.123E-31	-0.130E-24	-0.736E-26	-0.210E-27	0.436E+04	0.211E+11
1068.00	-0.118E-31	-0.568E-25	-0.483E-26	-0.210E-27	0.436E+04	0.211E+11
1080.00	-0.109E-31	-0.138E-25	-0.236E-26	-0.202E-27	0.436E+04	0.211E+11
1092.00	-0.993E-32	0.000E+00	-0.143E-40	-0.191E-27	0.436E+04	0.211E+11

NUMBER OF ITERATIONS IN LLP =   13

* PILE GROUP *   3

PILE TOP DISPLACEMENTS AND REACTIONS

THE GLOBAL STRUCTURE COORDINATE SYSTEM

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 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN
STRESS,LBS/IN**2

 0.121E+00  0.526E+00 -.997E-03-0.405E+05 0.927E+04 0.000E+00   0.193E+04


       THE LOCAL MEMBER COORDINATE SYSTEM
       ------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN
STRESS,LBS/IN**2

-0.513E-01  0.537E+00 -.997E-03-0.413E+05-0.400E+04 0.000E+00   0.193E+04


          LATERALLY LOADED PILE
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X	DEFLECTION	MOMENT	SHEAR	SOIL REACTION	TOTAL STRESS	FLEXURAL RIGIDITY
IN	IN	LBS-IN	LBS	LBS/IN	LBS/IN**2	LBS-IN**2
*****	**********	**********	**********	**********	**********	**********
0.00	0.537E+00	0.000E+00	-0.351E+04	0.154E+01	0.193E+04	0.211E+11
12.00	0.525E+00	0.426E+05	-0.326E+04	0.153E+01	0.234E+04	0.211E+11
24.00	0.513E+00	0.793E+05	-0.278E+04	0.152E+01	0.269E+04	0.211E+11
36.00	0.500E+00	0.110E+06	-0.229E+04	0.151E+01	0.299E+04	0.211E+11
48.00	0.487E+00	0.135E+06	-0.181E+04	0.149E+01	0.323E+04	0.211E+11
60.00	0.472E+00	0.155E+06	-0.132E+04	0.148E+01	0.342E+04	0.211E+11
72.00	0.457E+00	0.168E+06	-0.834E+03	0.146E+01	0.355E+04	0.211E+11
84.00	0.440E+00	0.176E+06	-0.347E+03	0.144E+01	0.362E+04	0.211E+11
96.00	0.422E+00	0.178E+06	0.140E+03	0.143E+01	0.364E+04	0.211E+11
108.00	0.403E+00	0.174E+06	0.627E+03	0.140E+01	0.360E+04	0.211E+11
120.00	0.383E+00	0.165E+06	0.111E+04	0.138E+01	0.351E+04	0.211E+11
132.00	0.362E+00	0.149E+06	0.160E+04	0.135E+01	0.336E+04	0.211E+11
144.00	0.339E+00	0.128E+06	0.209E+04	0.132E+01	0.316E+04	0.211E+11
156.00	0.316E+00	0.101E+06	0.258E+04	0.129E+01	0.290E+04	0.211E+11
168.00	0.292E+00	0.681E+05	0.307E+04	0.126E+01	0.258E+04	0.211E+11
180.00	0.267E+00	0.294E+05	0.356E+04	0.122E+01	0.221E+04	0.211E+11
192.00	0.243E+00	-0.152E+05	0.405E+04	0.119E+01	0.208E+04	0.211E+11
204.00	0.218E+00	-0.656E+05	0.454E+04	0.114E+01	0.256E+04	0.211E+11
216.00	0.194E+00	-0.122E+06	0.458E+04	0.749E+02	0.310E+04	0.211E+11
228.00	0.171E+00	-0.174E+06	0.367E+04	0.119E+03	0.360E+04	0.211E+11
240.00	0.149E+00	-0.208E+06	0.206E+04	0.150E+03	0.393E+04	0.211E+11
252.00	0.128E+00	-0.221E+06	0.103E+04	0.203E+02	0.406E+04	0.211E+11
264.00	0.109E+00	-0.231E+06	0.781E+03	0.217E+02	0.415E+04	0.211E+11
276.00	0.915E-01	-0.238E+06	0.515E+03	0.227E+02	0.422E+04	0.211E+11
288.00	0.755E-01	-0.242E+06	0.237E+03	0.235E+02	0.426E+04	0.211E+11
300.00	0.612E-01	-0.243E+06	-0.479E+02	0.240E+02	0.426E+04	0.211E+11
312.00	0.486E-01	-0.240E+06	-0.336E+03	0.241E+02	0.424E+04	0.211E+11
324.00	0.376E-01	-0.234E+06	-0.624E+03	0.239E+02	0.418E+04	0.211E+11
336.00	0.282E-01	-0.224E+06	-0.907E+03	0.233E+02	0.408E+04	0.211E+11
348.00	0.203E-01	-0.211E+06	-0.118E+04	0.216E+02	0.396E+04	0.211E+11
360.00	0.139E-01	-0.195E+06	-0.142E+04	0.190E+02	0.381E+04	0.211E+11

372.00	0.875E-02	-0.177E+06	-0.163E+04	0.163E+02	0.363E+04	0.211E+11
384.00	0.484E-02	-0.156E+06	-0.181E+04	0.134E+02	0.343E+04	0.211E+11
396.00	0.200E-02	-0.133E+06	-0.195E+04	0.995E+01	0.321E+04	0.211E+11
408.00	0.559E-04	-0.109E+06	-0.204E+04	0.539E+01	0.298E+04	0.211E+11
420.00	-0.114E-02	-0.840E+05	-0.197E+04	-0.172E+02	0.274E+04	0.211E+11
432.00	-0.177E-02	-0.615E+05	-0.175E+04	-0.204E+02	0.252E+04	0.211E+11
444.00	-0.198E-02	-0.420E+05	-0.149E+04	-0.218E+02	0.233E+04	0.211E+11
456.00	-0.190E-02	-0.257E+05	-0.123E+04	-0.221E+02	0.218E+04	0.211E+11
468.00	-0.164E-02	-0.125E+05	-0.968E+03	-0.216E+02	0.205E+04	0.211E+11
480.00	-0.130E-02	-0.246E+04	-0.715E+03	-0.206E+02	0.195E+04	0.211E+11
492.00	-0.949E-03	0.462E+04	-0.477E+03	-0.190E+02	0.198E+04	0.211E+11
504.00	-0.625E-03	0.896E+04	-0.261E+03	-0.170E+02	0.202E+04	0.211E+11
516.00	-0.362E-03	0.109E+05	-0.714E+02	-0.146E+02	0.204E+04	0.211E+11
528.00	-0.173E-03	0.107E+05	0.862E+02	-0.117E+02	0.203E+04	0.211E+11
540.00	-0.561E-04	0.877E+04	0.206E+03	-0.829E+01	0.202E+04	0.211E+11
552.00	0.741E-06	0.570E+04	0.246E+03	0.168E+01	0.199E+04	0.211E+11
564.00	0.187E-04	0.287E+04	0.200E+03	0.602E+01	0.196E+04	0.211E+11
576.00	0.172E-04	0.910E+03	0.127E+03	0.603E+01	0.194E+04	0.211E+11
588.00	0.941E-05	-0.181E+03	0.604E+02	0.510E+01	0.193E+04	0.211E+11
600.00	0.288E-05	-0.539E+03	0.847E+01	0.357E+01	0.194E+04	0.211E+11
612.00	0.284E-07	-0.384E+03	-0.198E+02	0.115E+01	0.193E+04	0.211E+11
624.00	-0.207E-06	-0.632E+02	-0.171E+02	-0.160E+01	0.193E+04	0.211E+11
636.00	-0.122E-07	0.268E+02	-0.271E+01	-0.799E+00	0.193E+04	0.211E+11
648.00	0.123E-09	0.183E+01	0.112E+01	0.161E+00	0.193E+04	0.211E+11
660.00	0.251E-13	-0.180E-01	0.763E-01	0.130E-01	0.193E+04	0.211E+11
672.00	-0.176E-15	-0.374E-05	-0.750E-03	-0.125E-03	0.193E+04	0.211E+11
684.00	-0.361E-19	0.258E-07	-0.156E-06	-0.264E-07	0.193E+04	0.211E+11
696.00	0.239E-21	0.538E-11	0.108E-08	0.179E-09	0.193E+04	0.211E+11
708.00	0.488E-25	-0.186E-13	0.225E-12	0.375E-13	0.193E+04	0.211E+11
720.00	-0.113E-21	-0.119E-13	-0.501E-15	-0.853E-17	0.193E+04	0.211E+11
732.00	-0.145E-21	-0.652E-14	-0.383E-15	-0.111E-16	0.193E+04	0.211E+11
744.00	-0.132E-21	-0.272E-14	-0.255E-15	-0.103E-16	0.193E+04	0.211E+11
756.00	-0.100E-21	-0.400E-15	-0.146E-15	-0.796E-17	0.193E+04	0.211E+11
768.00	-0.664E-22	0.774E-15	-0.660E-16	-0.534E-17	0.193E+04	0.211E+11
780.00	-0.377E-22	0.118E-14	-0.154E-16	-0.308E-17	0.193E+04	0.211E+11
792.00	-0.170E-22	0.114E-14	0.115E-16	-0.141E-17	0.193E+04	0.211E+11
804.00	-0.408E-23	0.903E-15	0.220E-16	-0.343E-18	0.193E+04	0.211E+11
816.00	0.269E-23	0.615E-15	0.226E-16	0.229E-18	0.193E+04	0.211E+11
828.00	0.526E-23	0.359E-15	0.185E-16	0.455E-18	0.193E+04	0.211E+11
840.00	0.539E-23	0.170E-15	0.130E-16	0.473E-18	0.193E+04	0.211E+11
852.00	0.437E-23	0.478E-16	0.782E-17	0.388E-18	0.193E+04	0.211E+11
864.00	0.302E-23	-0.180E-16	0.386E-17	0.272E-18	0.193E+04	0.211E+11
876.00	0.179E-23	-0.448E-16	0.125E-17	0.163E-18	0.193E+04	0.211E+11
888.00	0.867E-24	-0.480E-16	-0.207E-18	0.801E-19	0.193E+04	0.211E+11
900.00	0.271E-24	-0.397E-16	-0.840E-18	0.254E-19	0.193E+04	0.211E+11
912.00	-0.544E-25	-0.278E-16	-0.961E-18	-0.516E-20	0.193E+04	0.211E+11
924.00	-0.190E-24	-0.166E-16	-0.821E-18	-0.183E-19	0.193E+04	0.211E+11
936.00	-0.213E-24	-0.810E-17	-0.587E-18	-0.207E-19	0.193E+04	0.211E+11
948.00	-0.181E-24	-0.255E-17	-0.356E-18	-0.178E-19	0.193E+04	0.211E+11
960.00	-0.131E-24	0.433E-18	-0.171E-18	-0.130E-19	0.193E+04	0.211E+11
972.00	-0.840E-25	0.154E-17	-0.417E-19	-0.847E-20	0.193E+04	0.211E+11
984.00	-0.477E-25	0.143E-17	0.127E-19	-0.608E-21	0.193E+04	0.211E+11
996.00	-0.211E-25	0.123E-17	0.181E-19	-0.284E-21	0.193E+04	0.211E+11
1008.00	-0.284E-26	0.996E-18	0.200E-19	-0.403E-22	0.193E+04	0.211E+11
1020.00	0.859E-26	0.753E-18	0.195E-19	0.128E-21	0.193E+04	0.211E+11
1032.00	0.149E-25	0.528E-18	0.173E-19	0.233E-21	0.193E+04	0.211E+11
1044.00	0.176E-25	0.336E-18	0.142E-19	0.288E-21	0.193E+04	0.211E+11

1056.00	0.180E-25	0.187E-18	0.106E-19	0.307E-21	0.193E+04	0.211E+11
1068.00	0.171E-25	0.811E-19	0.696E-20	0.305E-21	0.193E+04	0.211E+11
1080.00	0.157E-25	0.196E-19	0.339E-20	0.291E-21	0.193E+04	0.211E+11
1092.00	0.142E-25	0.211E-33	-0.227E-34	0.273E-21	0.193E+04	0.211E+11

NUMBER OF ITERATIONS IN LLP = 14

Attachment 6 – Spencer's method analysis with piles as reinforcement (Figure 20).

```
HEADING
    T-Wall Deep Seated Analysis
    Analysis without piles

PROFILE LINES
         1     1 Layer 3 (CH) - Floodside
                  .00      -2.00
               141.00      -2.00
               155.00      -2.00

         2     1 Layer 3 (CH) - Landside
               157.00      -2.00
               375.00      -2.00

         3     2 Compacted Fill - FS
               141.00      -2.00
               145.50       -.50

         4     2 Compacted Fill - LS
               158.50       1.00
               167.00       1.00
               176.00      -2.00

         5     3 T-Wall
               145.50      -5.00
               145.50      -2.50
               155.00      -2.50
               155.00      -2.00
               155.00      12.30
               157.00      12.30
               157.00       1.00
               157.00      -2.00
               157.00      -2.50
               158.50      -2.50
               158.50      -5.00

         6     1 Layer 3 (CH) - Under Wall
               145.50      -5.00
               158.50      -5.00

         7     4 Layer 4 (CH)
                  .00     -14.00
               375.00     -14.00

         8     5 Layer 5 (ML)
                  .00     -23.00
               375.00     -23.00

         9     6 Layer 6 (CH)
                  .00     -26.00
               375.00     -26.00

        10     7 Layer 7 (CH)
                  .00     -31.00
```

```
            375.00    -31.00

      11     8 Layer 8 (CH)
               .00    -39.00
            375.00    -39.00

      12     9 Layer 9 (CH)
               .00    -65.00
            375.00    -65.00

      13    10 Compacted Fill - Above T Wall Base   FS
            145.50      -.50
            150.00      1.00
            155.00      1.00

      14    10 Compacted Fill - Above T Wall Base   LS
            157.00      1.00
            158.50      1.00


MATERIAL PROPERTIES
     1 Layer 3 (CH)
          80.00 Unit Weight
          Conventional Shear
              120.00       .00
          No Pore Pressure
     2 Compacted Fill
          110.00 Unit Weight
          Conventional Shear
              500.00       .00
          No Pore Pressure
     3 T Wall
          .00 Unit Weight
          Very Strong
     4 Layer 4 (CH)
          100.00 Unit Weight
          Conventional Shear
              120.00       .00
          No Pore Pressure
     5 Layer 5 (ML)
          117.00 Unit Weight
          Conventional Shear
              200.00     15.00
          Piezometric Line
          1
     6 Layer 6 (CH)
          100.00 Unit Weight
          Conventional Shear
              200.00       .00
          No Pore Pressure
     7 Layer 7 (CH)
          100.00 Unit Weight
          Linear Increase
              217.00      8.10
          No Pore Pressure
     8 Layer 8 (CH)
          100.00 Unit Weight
```

```
          Linear Increase
              374.00      8.30
          No Pore Pressure
     9 Layer 9 (CH)
          100.00 Unit Weight
          Linear Increase
              590.00      8.00
          No Pore Pressure
     10 Compacted Fill - Above T-Wall Base
          .00 Unit Weight
          Conventional Shear
                 .00       .00
          No Pore Pressure

PIEZOMETRIC LINES
         1      62.40 Water Level
                 .00     10.00
              145.50     10.00
              145.51     -1.00
              157.00     -1.00
              375.00     -1.00

         2      62.40 Piezometeric levels in ML
                 .00     10.00
              149.50     10.00
              156.00     10.00
              158.50      1.00
              167.00      1.00
              173.00     -1.00
              375.00     -1.00


DISTRIBUTED LOADS
      1
REINFORCEMENT LINES
              1        .00          2
118.083     -91.0 4380  848.
147.000     -4.25   4380        848

              2        .00          2
152.000     -4.25 -9300   464
180.917     -91.0 -9300   464

              3        .00          2
157.000     -4.25  4900   496
185.917     -91.0  4900   496

              4        .00          1
149.000     -4.25     0.    0.
149.000     -41.0     0.    0.

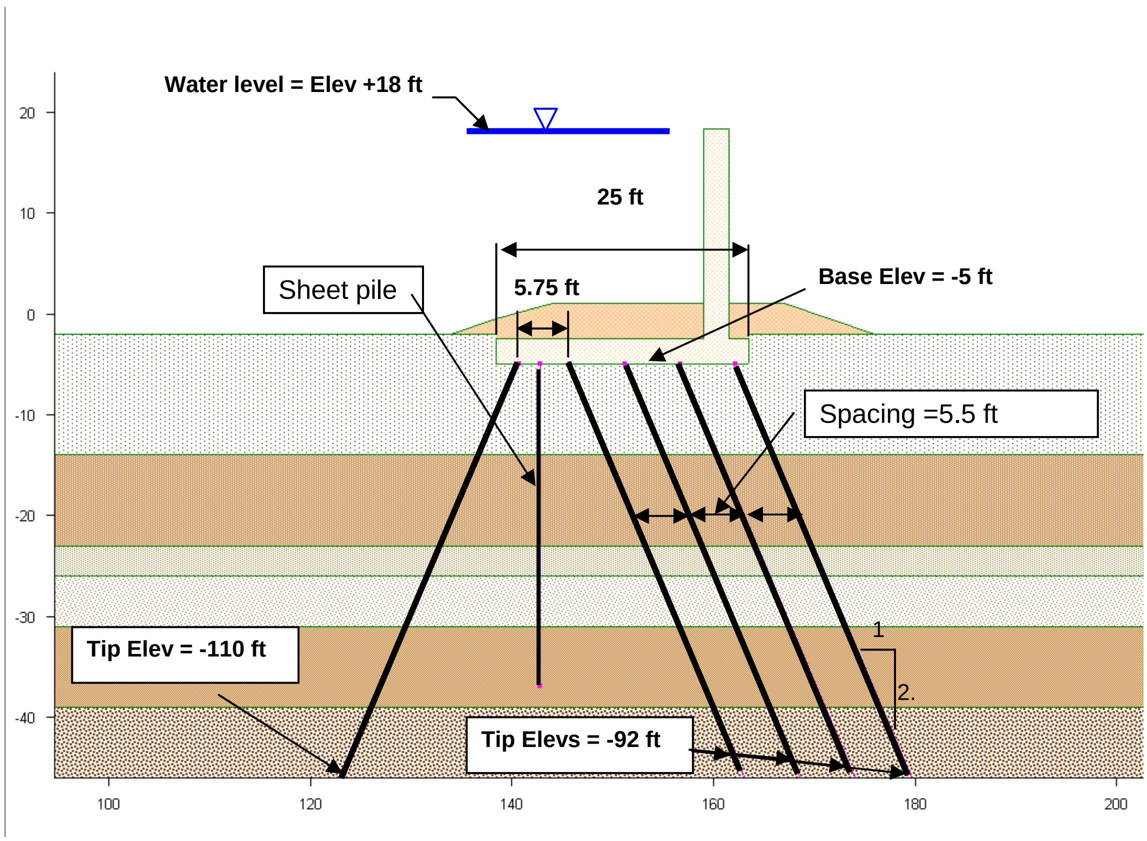

ANALYSIS/COMPUTATION
     Circular
         145.5     25        48
SINgle-stage Computations
RIGht Face of Slope
```

```
LONg-form output
SORt radii
CRItical
PROcedure for computation of Factor of Safety
SPENCER

GRAPH
COMPUTE
```

Design Example #2

A cross section of the wall section used for Example 2 is shown below. The water level used in this example is elevation 18.0 and the design situation is assumed to be a top of wall load case. The wall geometry including the wall dimensions and the pile layout is presented in Figure 1. The spacing of the piles in the out of plane direction is 5-ft. The piles tips extend to Elevation -110 ft. The soil profile and shear strengths for the foundation are shown in Figure 2.



Cross-sectional view of pile layout

Figure 1. Wall Geometry.

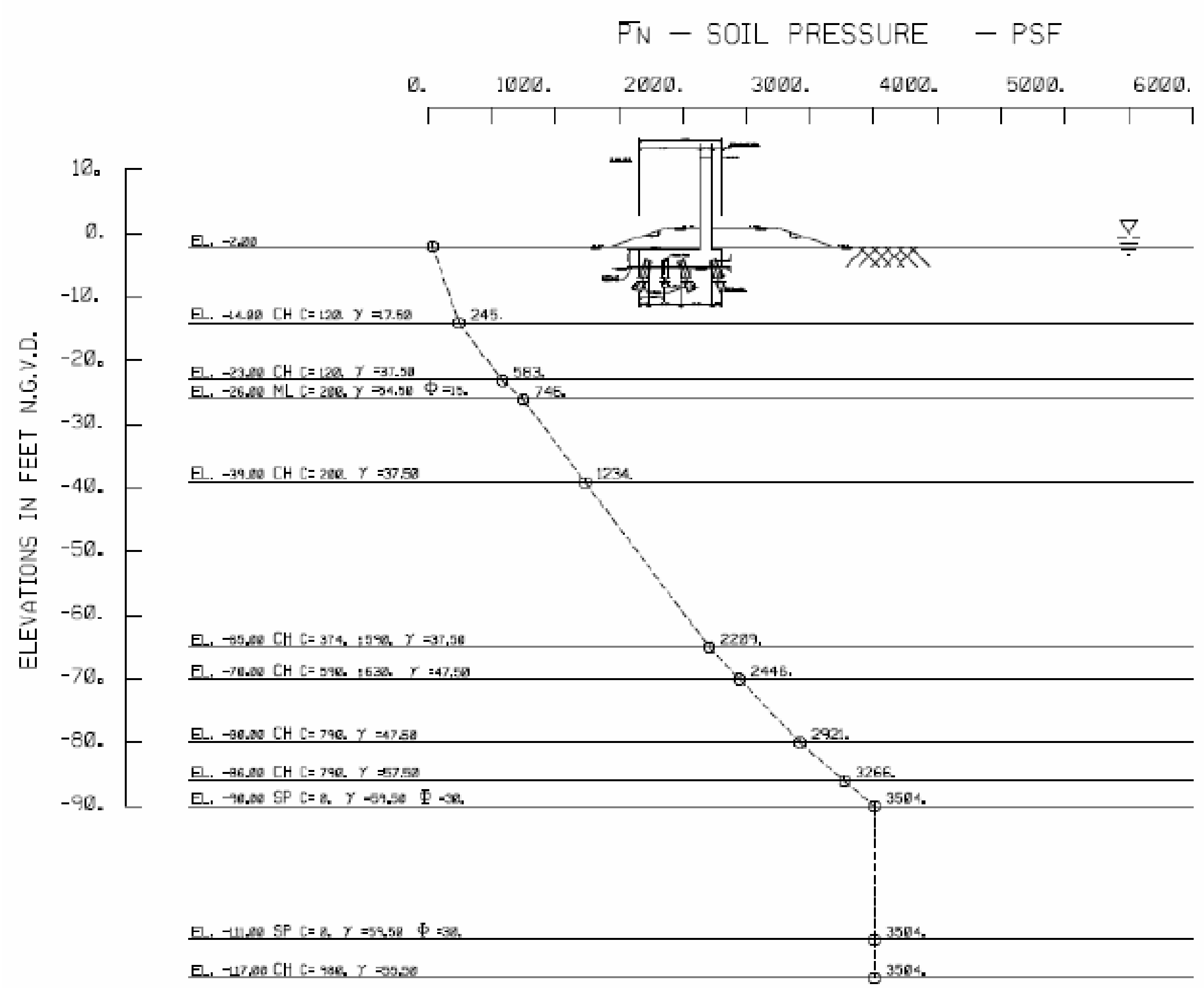


Figure 2. Soil Profile.

Step 1 <u>Initial Slope Stability Analysis</u>

Perform a Spencer's method slope stability analysis to determine the critical slip surface with the water load only on the ground surface and no piles. The required factor of safety according to the Hurricane and Storm Damage Reduction System Design Guidelines for the top of wall load condition is 1.4. For the design example, the critical failure surface is shown in Figure 1 where the factor of safety is 0.529. Because this value is less than the required value of 1.4, the T-Wall will need to carry an unbalanced load in addition to any loads on the structure.

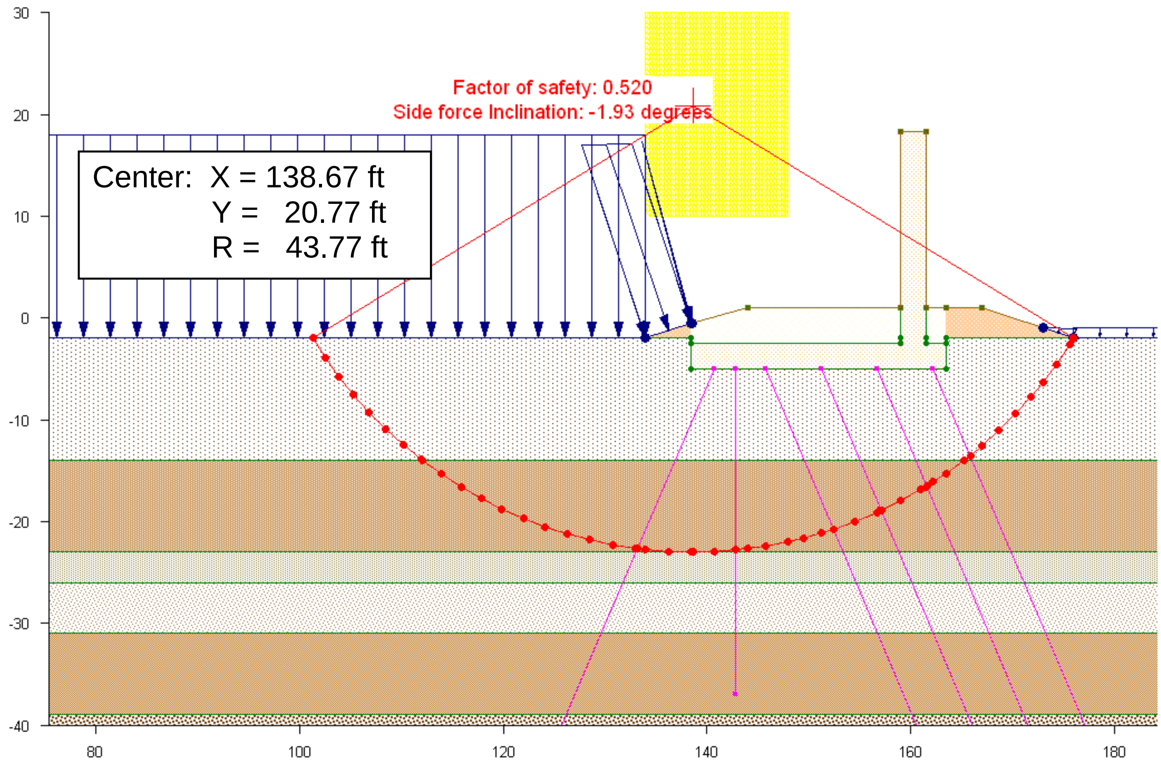


Figure 3. Spencer's analysis of the T-Wall without piles.

Step 2 Unbalanced Force Computations

Step 2 involves the determination of the (unbalanced) forces needed to provide the required global stability factor of safety. The base of the T-Wall is at elevation -5 ft. The critical failure surface extends down to elevation -23' in this example. The ground surface above the heel of the T-wall is at Elevation – 0.5 ft. In the design procedure, the unbalanced load is assumed to act halfway between these two elevations and at the x-coordinate of the heel of the T-wall. Thus, a horizontal line load is applied at elevation -11.75 ft at the x-coordinate along a vertical line passing through the heel of the T-wall. A trial and error process showed that an unbalanced force of 17480 lb/ft would result in a factor of safety of 1.4 as shown in Figure 2.

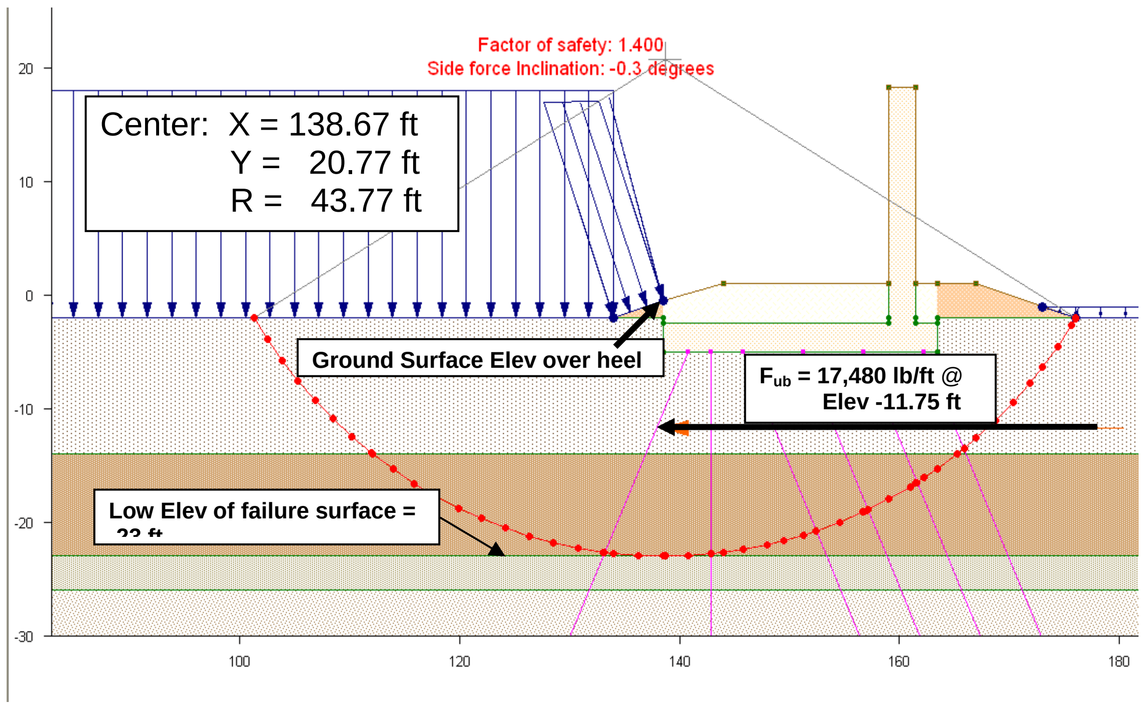


Figure 4. Spencer's analysis of the T-Wall with an unbalanced load to increase global stability.

It should be noted that unbalanced load was determined from a fixed grid search.for the critical as shown in Figure 2. Step 2 provides that if the pile foundation of the T-Wall can safely carry the unbalanced load on the structure, the global stability will meet the required factor of safety. The UTexas4 input files for Figures 1 and 2 are attached at the end of this example.

Step 3 Allowable Pile Capacity Analysis

3.1 For the preliminary analysis, allowable pile capacities determined by engineers in New Orleans District for the original design of this project are shown in Figure 3 for ultimate loads vs. depth. Since this is a top of wall load case, a 50% over stress is allowed according to the Hurricane and Storm Protection System Design Guidelines. For the case with load test data, the net factor would be 2.0/1.5 = 1.333. For the case with calculated capacities, the allowable load factor would be 3.0/1.5 = 2.0.

The allowable loads for compression pile can be determined using the chart on Figure 5 which plots pile load test results. This test was performed with casing above the critical failure surface to preclude contribution of skin friction above that point. The tip elevation of the piles is equal to Elevation -92.5 ft. where the ultimate load is 74 tons.

Allowable Compressive load = (74 tons x 2 kips/ton/ 2) x 1.5

= 111 kips

In the preceding calculation and in accordance with the Hurricane and Storm Protection Guidelines, the factor of safety was equal to 2 because the allowable capacity was determined from load tests and the 50% overstress is permitted as well.

The allowable tension load was determined from prior calculations provided by MVN that are shown in the lower panel of Figure 6. For a tip Elevation of -110-ft, the ultimate capacity is 120 tons. The capacity at elevation -23 is about 7 tons. Therefore, the tension capacity can be estimated as 120-7 = 113 tons. From this, the allowable capacity is determined as follows:

Allowable Tensile Load = (113 tons x 2 kips/ton/3) x 1.5

= 113 kips

In this calculation and in accordance with the Hurricane and Storm Protection Guidelines, the factor of safety was equal to 3 because the allowable capacity was determined by calculations based on the skin friction between the soil and the pile and the pile length.. The 50 % overstress factor was set to 1.5.

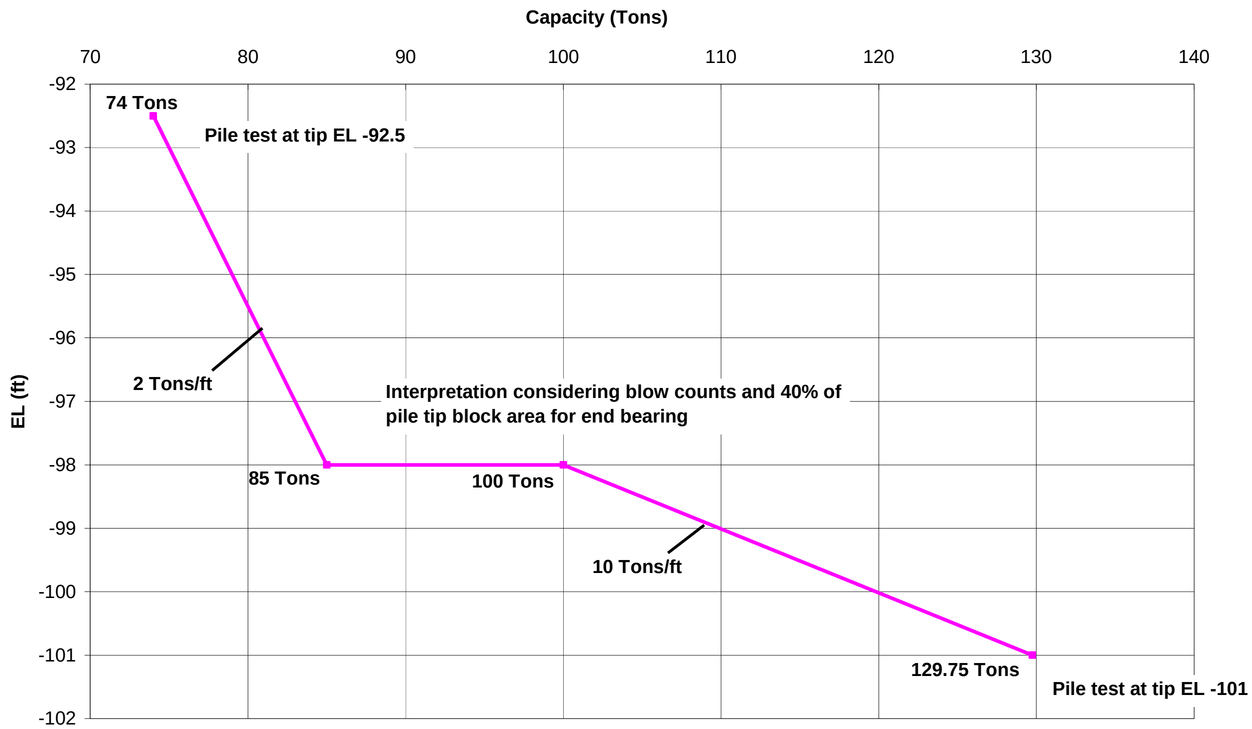


Figure 5. Pile Load Test Data

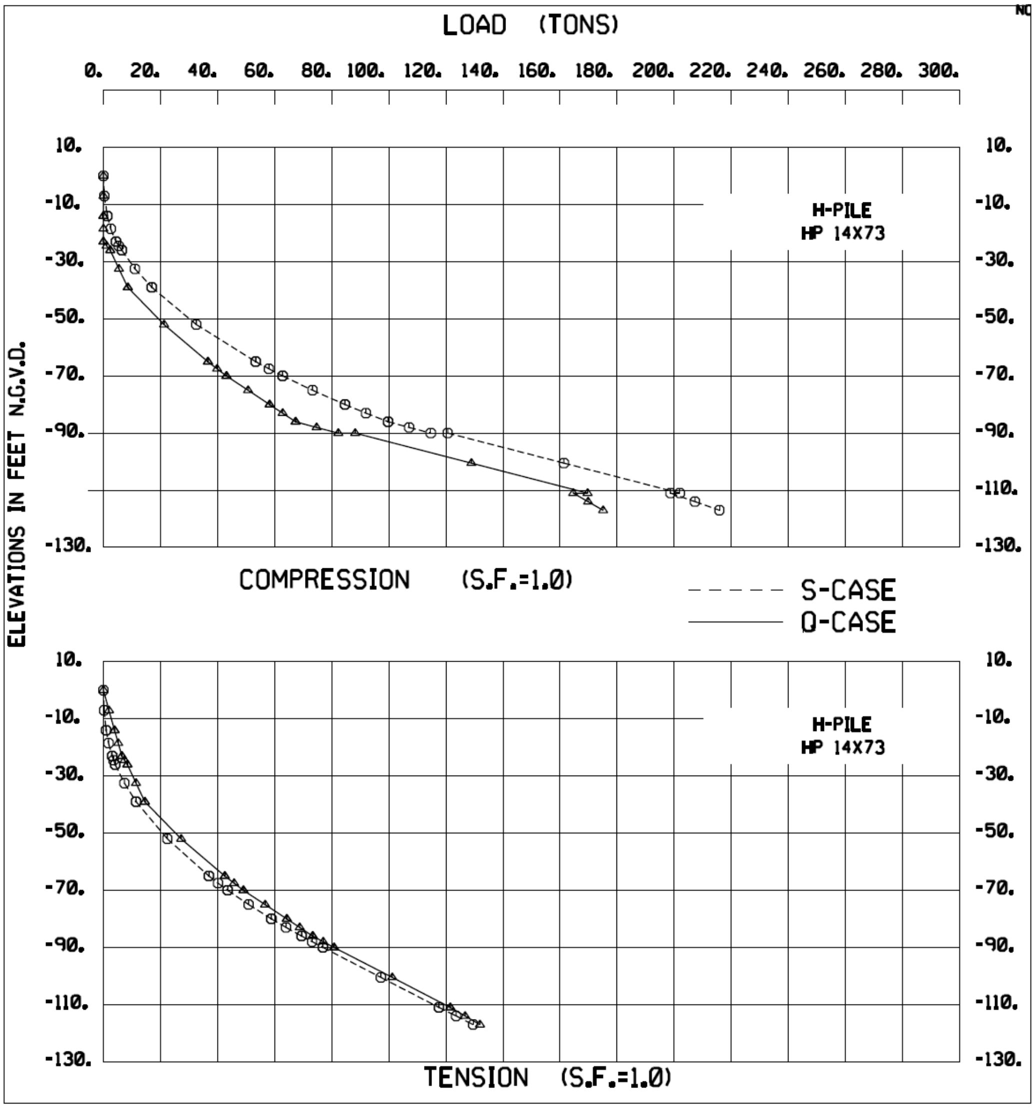


Figure 6. Ultimate Axial Capacity with Depth, Calculated

3.2 The allowable shear load is determined from pile head deflection versus lateral load plot on Figure 7 computed using the ENSOFT program LPILE. The ultimate load was determined to be 24.5 kips. The allowable load is determined to be 8.2 kips after dividing by the factor of safety of 3.0. However, the allowable load can be increased by 50% due to the 50% overstress allowed for the top of wall condition provided by the Hurricane and Storm Protection Guidelines. Thus, the allowable shear computed as follows:

Allowable pile shear = (24.5 kips / 3) x 1.5 = 12.25 kips

A summary of the allowable loads for the piles extending to Elevation -110 ft is presented in Table 1 below.

Table 1. Allowable Pile Capacities for Design Example 2 for Piles Extending to Elevation -110 ft	
Load Type	Allowable Load (kips)
Axial Compressive Load	194.6
Axial Tensile Load	120
Shear	12.25

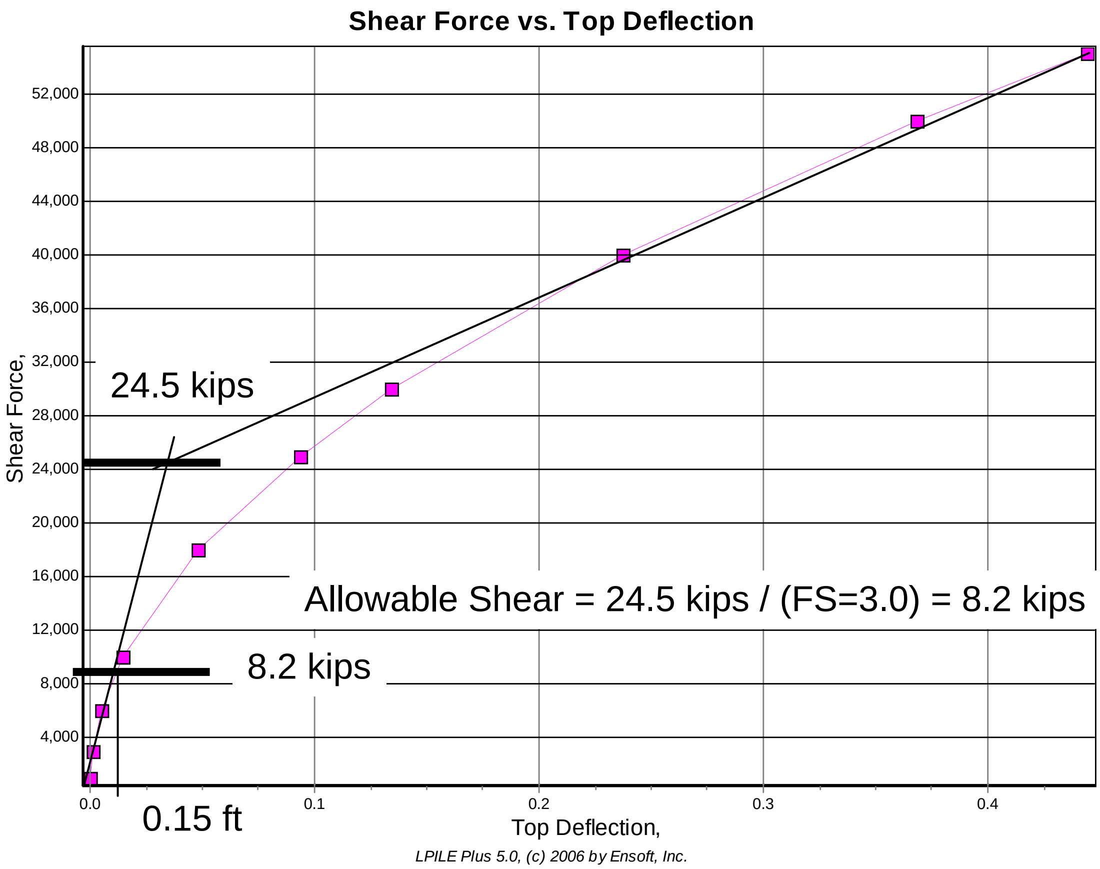


Figure 7. LPILE analysis of Pile head deflection vs shear force at critical surface to determine allowable shear force in piles.

Step 4 Initial T-wall and Pile Design

4.1 Use CPGA to analyze all load cases and perform a preliminary pile and T-wall design. The unbalanced force is converted to an "equivalent" force applied to the bottom of the T-wall, $F_{cap,}$ as calculated as shown below (See Figure 8):

$$F_{cap} = F_{ub}\left[\frac{\left(\frac{L_u}{2}+R\right)}{\left(L_p+R\right)}\right]$$

Where:

F_{ub} = unbalanced force computed in step 2.

L_u = distance from top of ground to lowest el. of critical failure surface (in)

L_p = distance from bottom of footing to lowest el. of crit. failure surface (in)

$$R = \sqrt[4]{\frac{EI}{Es}}$$

E = Modulus of Elasticity of Pile (lb/in^2)

I = Moment of Inertia of Pile (in^4)

Es = Modulus of Subgrade Reaction (lb/in^2) below critical failure surface. In New Orleans District this equates to the values listed as K_HB.

For the solution:

Piles = HP 14x73. I = 729 in^4, E = 29,000,000 psi

Soils – Importance of lateral resistance decreases rapidly with depth, therefore only first three layers are input – with the third assumed to continue to the bottom of the pile. The parameters were developed from soil borings from the New Orleans District and are as shown in Figure 9.

Silt, ϕ = 15, C = 200 psf, γ_{sat} = 117 pcf, K_HB ave. = k =167 psi
Clay 1, ϕ = 0 , C = 200 psf, γ_{sat} = 100 pcf, K_HB = k = 88.8 psi
Clay 2, ϕ = 0 , C = 374 psf, γ_{sat} = 100 pcf, K_HB = k = 165.06 psi

The top layer of silt under the critical failure surface is stiffer but only three feet thick. Will use a k = 100 psi.

R therefore is equal to 120 in = 10 feet

P_{cap} = 17,480 * (22.5/2 + 10) / (18 + 10) = 13,266 lb/ft

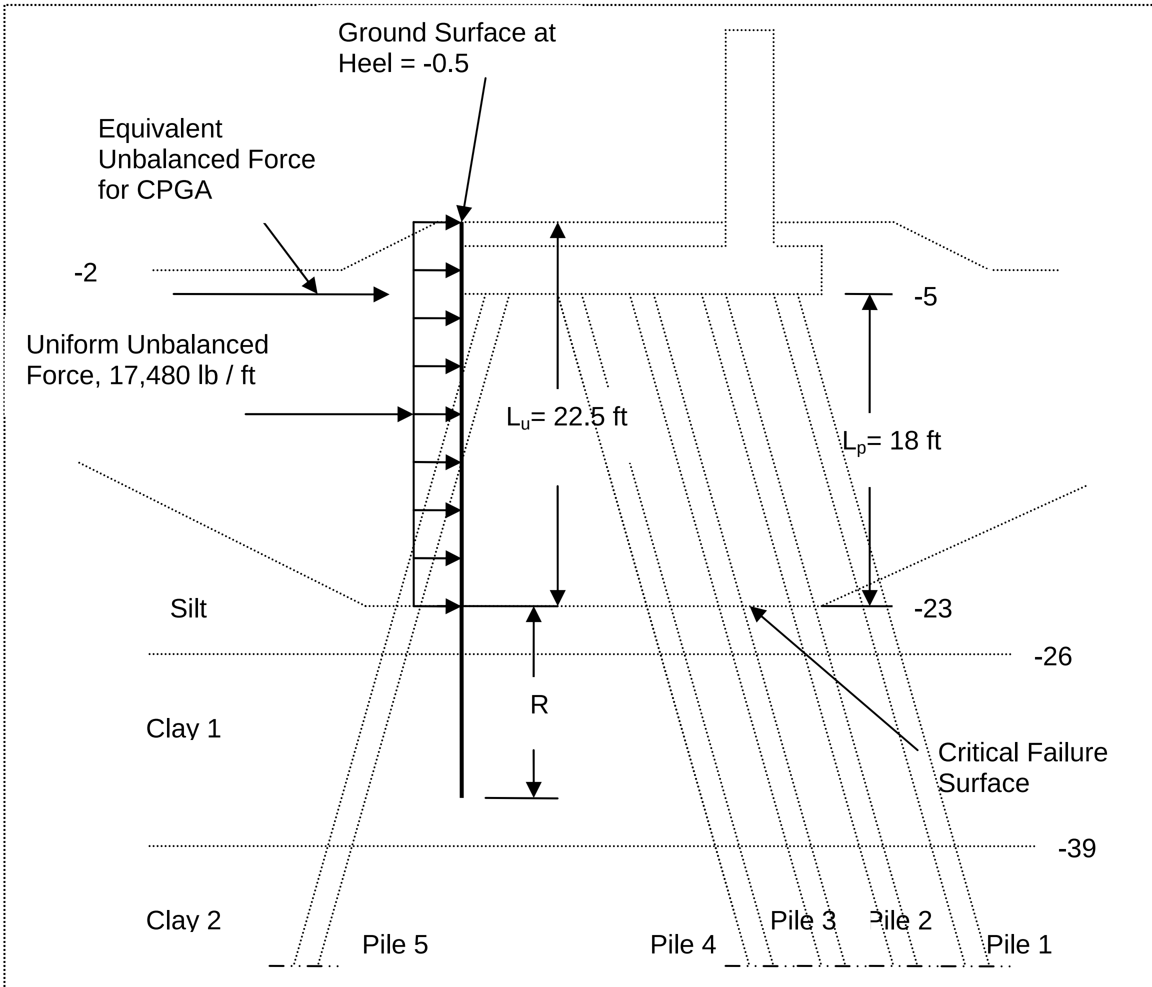


Figure 8. Equivalent Force Computation for Preliminary Design With CPGA

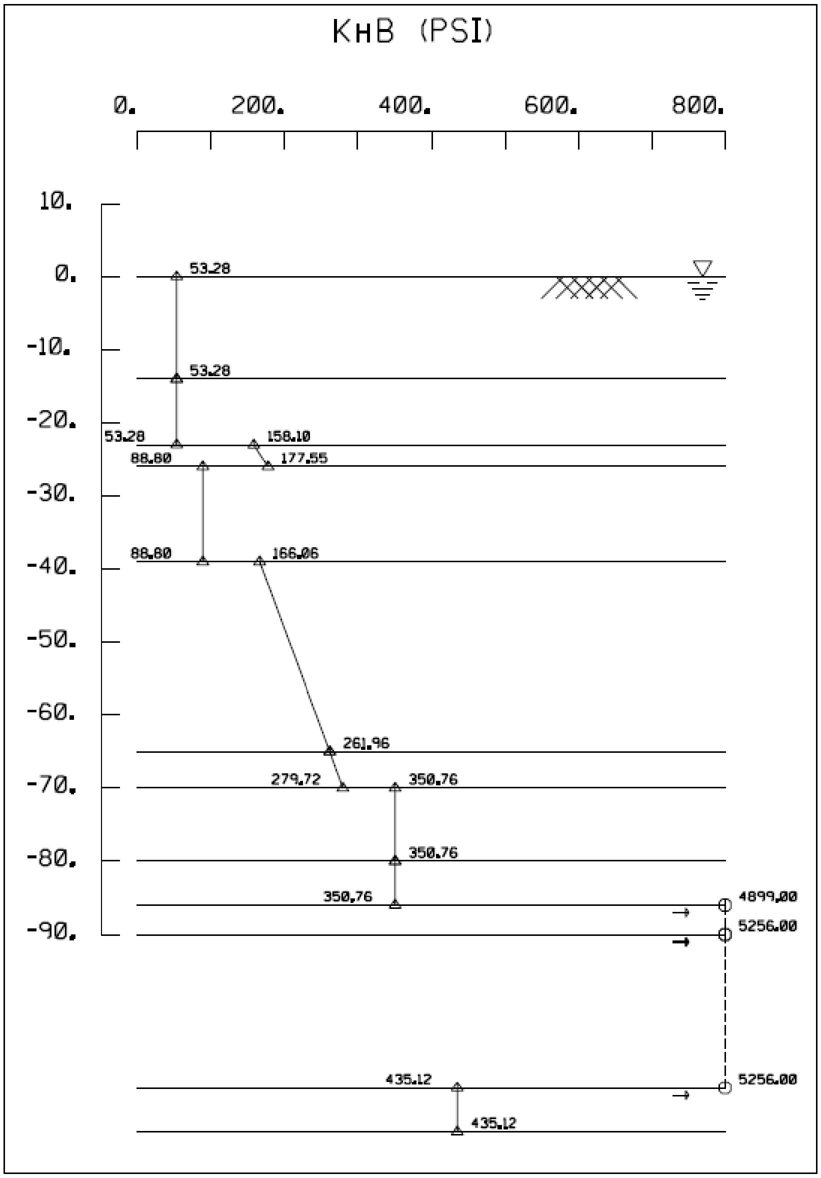


Figure 9. Soil Stiffness with Depth

4.2 This unbalanced force is then analyzed with appropriate load cases in CPGA. Generally 8 to 20 load cases may be analyzed depending on expected load conditions. For this example, only the water at top of wall case is analyzed but both pervious and impervious foundation conditions are evaluated. See the spreadsheet calculations in Attachment 3 for the computation of the input for CPGA. The model is a 5 foot strip of the pile foundation.

For the CPGA analysis, the soil modulus, Es is input at a very low value, 0.00001 psi, because the factor of safety is less than 1.0.

The CPGA output is shown in Attachment 4. A summary of results for the two load conditions analyzed are shown below:

LOAD CASE - 1

PILE	F1 K	F2 K	F3 K	M1 IN-K	M2 IN-K	M3 IN-K	ALF	CBF
1	.0	.0	6.8	.0	-4.0	.0	.06	.02
2	.0	.0	47.2	.0	-3.8	.0	.42	.15
3	.0	.0	87.6	.0	-3.7	.0	.79	.28
4	.0	.0	127.9	.0	-3.5	.0	1.15	.41
5	.0	.0	-125.0	.0	3.5	.0	1.11	.40

LOAD CASE - 2

PILE	F1 K	F2 K	F3 K	M1 IN-K	M2 IN-K	M3 IN-K	ALF	CBF
1	.0	.0	22.3	.0	-3.4	.0	.20	.07
2	.0	.0	56.9	.0	-3.3	.0	.51	.18
3	.0	.0	91.4	.0	-3.2	.0	.82	.29
4	.0	.0	126.0	.0	-3.0	.0	1.14	.40
5	.0	.0	-97.8	.0	3.1	.0	.87	.31

Where:
F1 = Shear in pile at pile cap perpendicular to wall
F2 = Shear in Pile at Pile Cap parallel to wall
F3 = Axial Load in Pile
M1 = Maximum moment in pile perpendicular to wall
M2 = Maximum moment in pile parallel to wall
M3 = Torsion in pile
ALF= Axial load factor – computed axial load divided by allowable load
CBF= Combined Bending factor – combined computed axial and bending forces relative to allowable forces

From the CPGA analysis, axial loads in the piles are somewhat over the allowable values. Still they are close to being OK, and knowing that the initial design using CPGA is conservative compared to the more exact Group 7 analysis, this configuration will be carried forward into the Group 7 analysis.

Computed deflections from the CPGA analysis are shown below:

PILE CAP DISPLACEMENTS

LOAD CASE	DX IN	DZ IN	R RAD
1	-.7899E+00	-.3207E+00	-.1201E-02
2	-.6897E+00	-.2476E+00	-.1028E-02

These deflections are less than the allowable vertical deflection (DZ) of 0.5 inches X an overstress factor of 1.5 = 0.75" and the allowable horizontal deflection (DX) of 0.75 inches X an allowable overstress factor of 1.5 = 1.125 inches from the Hurricane and Storm Damage Reduction Design Guidelines.

4.4 Sheet pile design. Seepage design of the sheet pile is not performed for this example.

4.5 Check for resistance against flow through. Since the pile spacing is uniform, we will analyze one row of piles parallel with the loading rather than the entire monolith.

a. Compute the resistance of the flood side row of piles.

$$\sum P_{all} = \frac{n \sum P_{ult}}{1.5}$$

Where:

n = number of piles in the row within a monolith. Or, for monoliths with uniformly spaced pile rows, n = 1. Use 1 for this example

$P_{ult} = \beta(9S_u b)$

S_u = soil shear strength

b = pile width = 14"

β = group reduction factor pile spacing parallel to the load - since the piles batter opposite to each other, there group affects are not computed.

For the soils under the slab, S_u = 120 psf

Therefore: P_{ult} = 9(120 psf)(14 in/12 in/ft) = 1,260 lb/ft

ΣP_{ult} = summation of P_{ult} over the height L_p, as defined in paragraph 4.1

For single layer soil is P_{ult} multiplied by L_p (18 ft) - That is the condition here since the shear strength is constant from the base to the critical failure surface.

ΣP_{ult} = 1,260 lb/ft (18 ft) = 22,680 lb

ΣP_{all} = 1(22,680 lb)/1.5 = 15,120 lb

b. Compute the load acting on the piles below the pile cap.

$$F_{up} = w f_{ub} L_p$$

Where:

w = Monolith width. Since we are looking at one row of piles in this example, w = the pile spacing perpendicular to the unbalanced force (s_t) = 5 ft.

$$f_{ub} = \frac{F_{ub}}{L_u}$$

F_{ub} = Total unbalanced force per foot from Step 2 = 17,480 lb/ft
L_u = 22.5 ft
L_p = 18 ft

f_{ub} = 17,480 lb/ft / 22.5 ft = 777 lb/ft/ft

F_p = 5 ft(777lb/ft/ft)(18ft) = 69,930lb

c. Check the capacity of the piles 50% of F_p = 69,930 lb(0.50) = 34,965 lb

The capacity ΣP_{all} = 15,120 lb < 34,965 lb so the flood side row of piles is not adequate and the capacity of the rest of the pile rows must be added. The capacity ΣP_{all} is the same as computed for the flood side row of piles except as modified by the group reduction factor. Since the batter of the flood side and next row of piles is opposite, the flood side pile can be considered as single pile and the next row of piles as a lead row of piles. The next rows of piles would be trailing piles. The row spacing is 5'6".

Using a row spacing of 5'6", the group reduction factor (β) for the lead piles is

$$\beta = 0.7(s/b)^{0.26} \quad ; or = 1.0 \text{ for } s/b > 4.0 \qquad (5)$$

Where:
s = spacing between piles parallel to loading

For s = 5'6" and b=14" for HP14x73 piles, s/b = 4.71
Since s/b = 4.71 < 4.0, β = 1.0 for the lead pile

For trailing piles, the reduction factor, β, is:

$$\beta = 0.48(s/b)^{0.38} \quad ; or = 1.0 \text{ for } s/b > 7.0 \qquad (6)$$

$$\beta = 0.48(4.71)^{0.38} = 0.87$$

Shortcutting the math in the equations presented in the previous page, for the trailing piles, ΣP_{all} = β ΣP_{all} = 0.87 * 15,120 = 13,154 lb

Summing ΣP_{all} for all 5 pile rows , the total allowable unbalanced force is:

15,120 + 15,120 + 13,154 + 13,154 + 13,154 = 69,702 lb

Since F_p = 69,930 lb, the difference is 228 lb, or about 0.3%. For the purposes of this example, this is considered close enough.

4.6 Second flow through check. Compute the ability of the soil to resist shear failure between the pile rows from the unbalanced force below the base of the T-wall, $f_{ub}L_p$, using the following equation:

$$f_{ub}L_p \leq \frac{A_p S_u}{FS}\left[\frac{2}{(s_t - b)}\right]$$

Where:

A_pS_u = The area bounded by the bottom of the T-wall base, the critical failure surface, the upstream pile row and the downstream pile row multiplied by the shear strength of the soil within that area. – See Figure 10. S_u =120 psf

A_pS_u = (18(22.5+36.5)/2)(120 psf) = 64,152 lb

FS = Target factor of safety used in Steps 1 and 2. – 1.5

s_t= the spacing of the piles transverse (perpendicular) to the unbalanced force 5 ft

b = pile width – 14 inches

$f_{pb}L_p$ = (777 lb/ft)(18 ft) = 13,986 lb

$$\frac{A_p S_u}{FS}\left[\frac{2}{(s_t - b)}\right] = \frac{64{,}152}{1.5}\left[\frac{2}{5 - \left(\frac{14}{12}\right)}\right] = 22{,}314 \text{ lb}$$

Therefore, capacity against flow through is OK

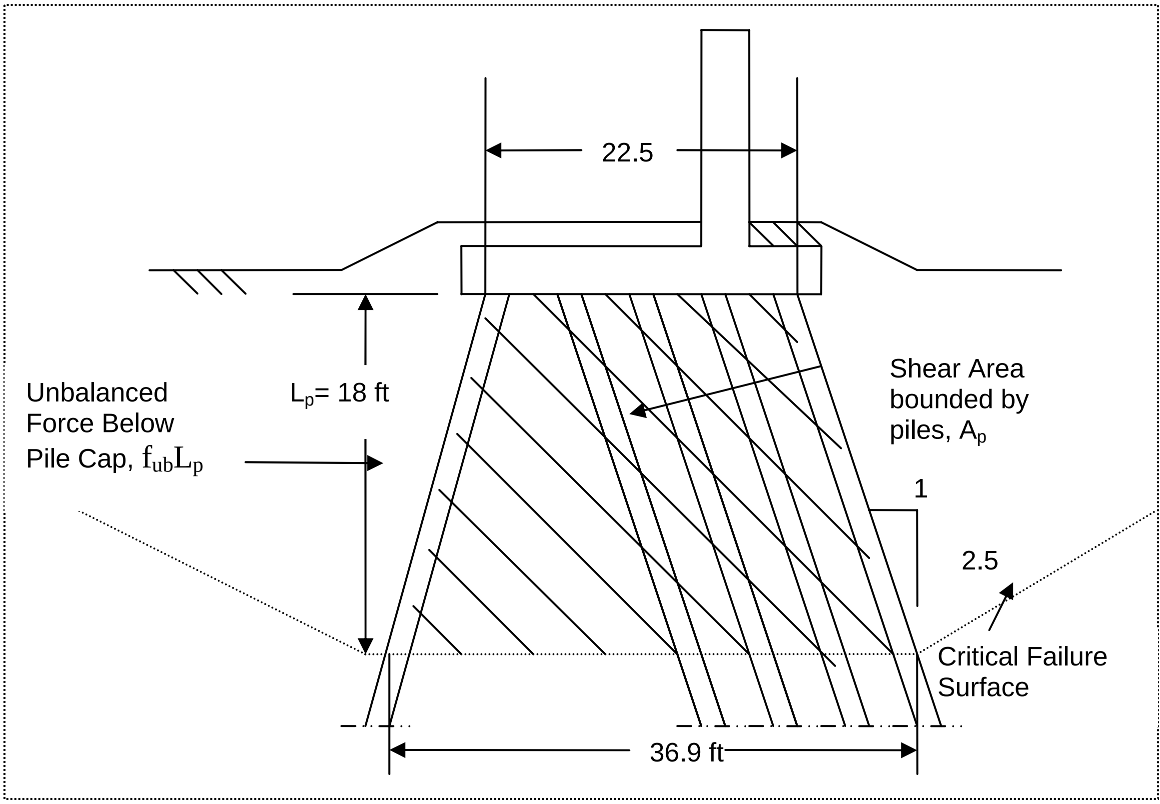


Figure 10. Shear Area for Flow-through Check

Step 5 <u>Pile Group Analysis</u>

5.1 A Group 7 analysis is performed using all loads applied to the T-wall structure. Critical load cases from step 4 would be used. In this example, only one load case with two foundation conditions is shown.

5.2 The loads applied in the Group 7 model include the distributed loads representing the unbalanced force that acts directly on the piles and also the water loads and self-weight of the wall that acts directly on the structure. In Group 7 these loads are resultant horizontal and vertical forces and the moments per width of spacing that act on the T-wall base (pile cap). They also include the unbalance force from the base of the cap to the top of soil, converted to a force and moment at the base of the structure. These forces are calculated using a worksheet or Excel spreadsheet and are shown at then end of the spreadsheets shown in Attachment 3. For this analysis the resultant forces per 5-ft of pile spacing were:

Pervious Foundation Condition

Vertical force	=	134,114 lb
Horizontal force	=	97,636 lb
Moment	=	7,347,343 in-lbs

Impervious Foundation Condition

Vertical force	=	184,583 lb
Horizontal force	=	97,636 lb
Moment	=	15,636,093 in-lbs

5.3 The unbalanced load below the bottom of the footing is applied directly as distributed loads on the pile. Check if ($n\Sigma P_{ult}$) of the flood side pile row is greater than 50% F_p, (from 4.5)

.

$(n\Sigma P_{ult}) = 1\ (22{,}680) = 22{,}680$ lb

50% F_p = 34,965 lb

Since $n\Sigma P_{ult}$ < 50% F_p ,distribute P_{ult} onto the flood side (left) row of piles.

P_{ult} = 1,260 p/ft = 105 lb/in

The remainder of F_p is divided among the remaining piles = 69,930 – 22,680 = 47,250 lb

This is distributed onto each pile according to a ratio of the group factors shown in table 2 (pile numbers as shown in figure 6) as computed in step 4.5. Since the load will be applied to the piles in Group 7 as a distributed load in lb/in, First, the total load will be divided into the load applied to one vertical inch

= 47,250 lb / (18ft /12in/ft) = 218.8 lb/in.

The sum of the distribution factors is 0.87+0.87+0.87+1.0 = 3.61.

The force on the trailing piles is 218.8 lb/in * 0.87/3.61 = 52.7 lb/in
The force on the leading pile is 218.8 lb/in * 1.0/3.61 = 60.6 lb/in

Table 2. Pile Reduction Factors and Ultimate Distributed Loads for each Pile				
Pile	(s/b)	Pile type	β	Load, lb/in
1	4.71	Trailing	0.87	52.7
2	4.71	Trailing	0.87	52.7
3	4.71	Trailing	0.87	52.7
4	4.71	Lead	1.0	60.6
5	4.71	Single	1.0	105

5.4 Thus, all the loads including the pile cap loads and the distributed loads are identified and and a Group 7 analysis is performed using all the loads applied to the T-wall system. The group 7 model is shown in Figure 11.

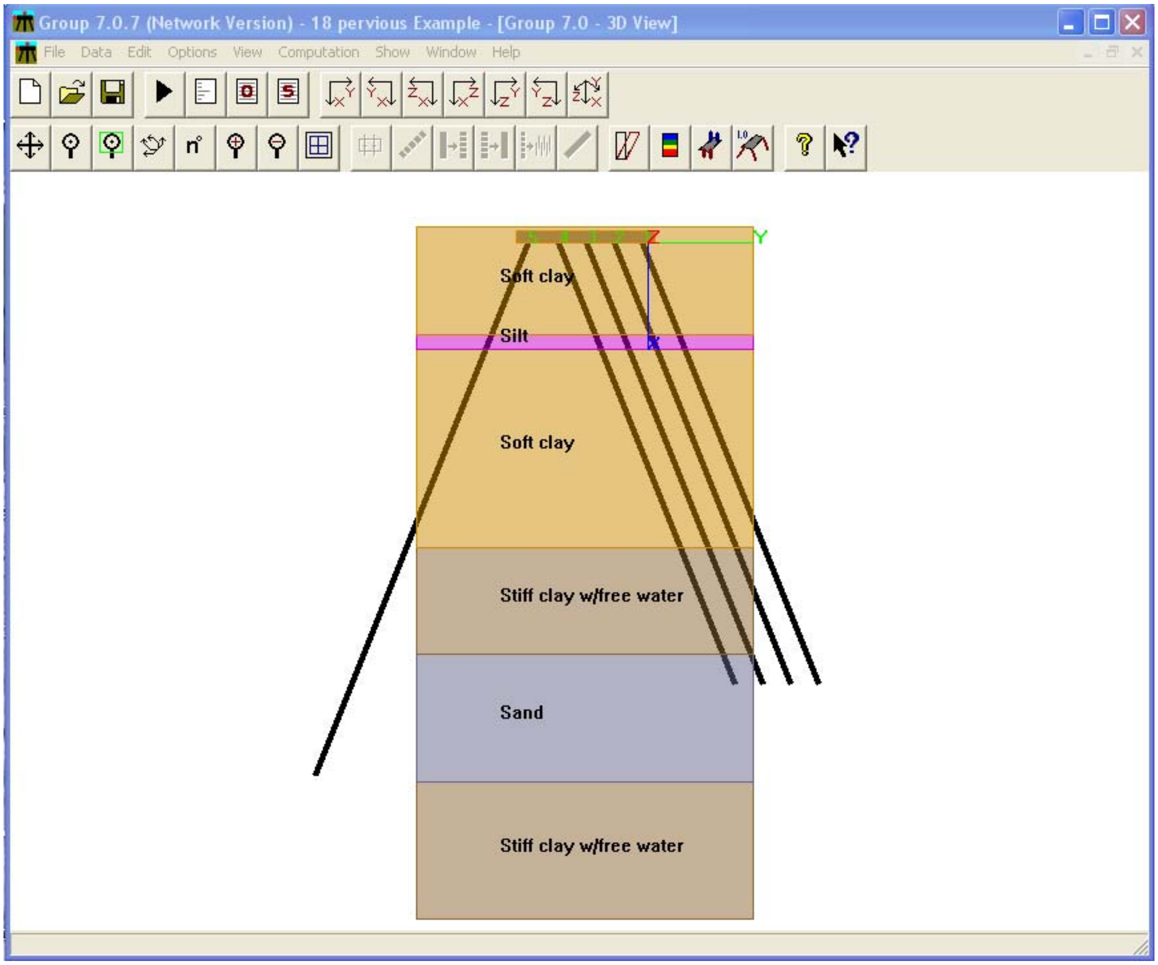


Figure 11. Group 7 Model

5.2 Since the factor of safety without piles was less than one, the lateral stiffness of the soil from the bottom of the pile cap to the top of the critical failure surface at -23 feet will be set to zero by using very small numbers for the ultimate shear strength of the soil. The lateral soil reaction against the pile (not including the applied soil loads) is shown in Figure 12

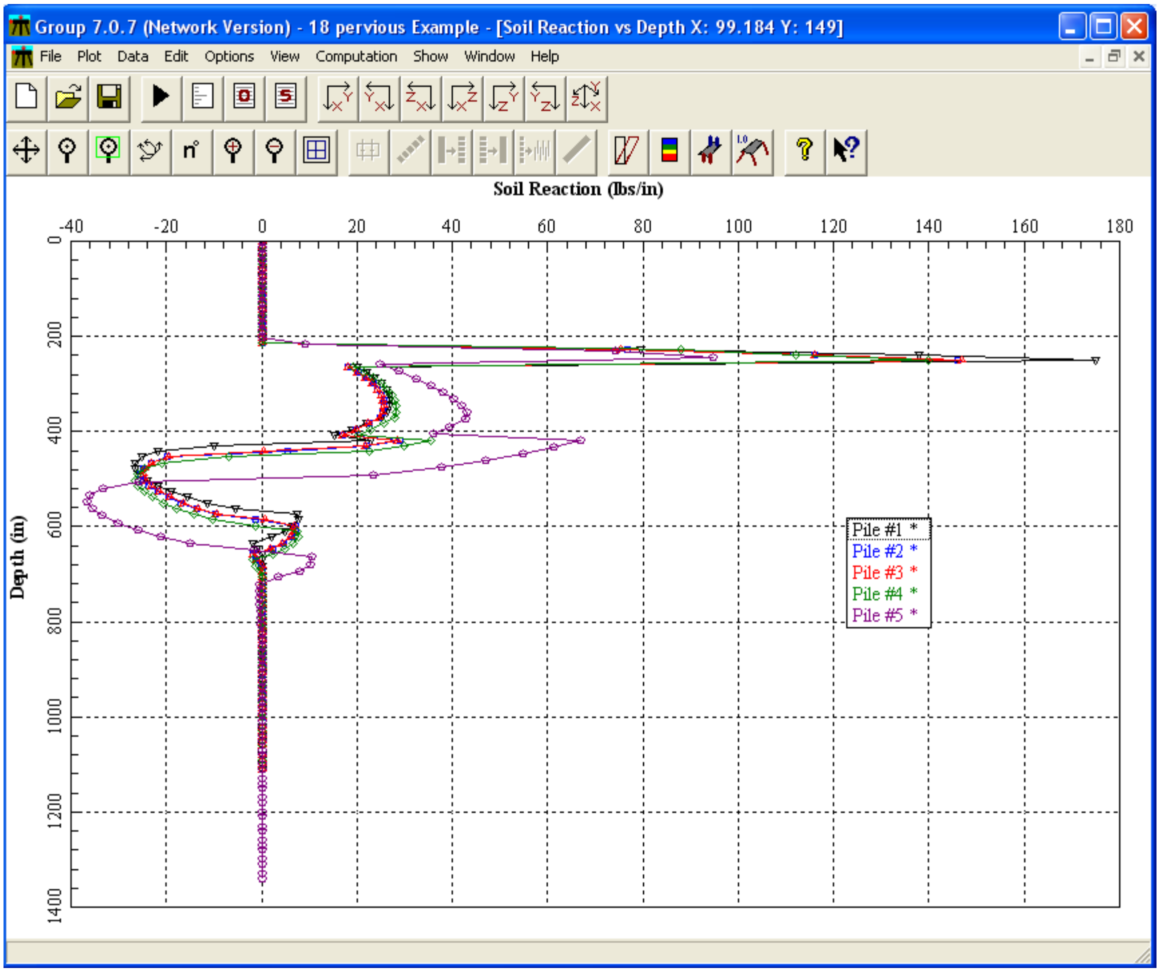


Figure 12 Soil Reaction on Piles with Depth

The pile responses to the applied loads are the sought after information from the Group 7 analysis to determine if the design requirements are achieved for a given pile layout. An illustration of the moment in the piles versus depth for this iteration shown in Figure 13 for the pervious sheet pile condition. An illustration of the shear is shown in Figure 14.

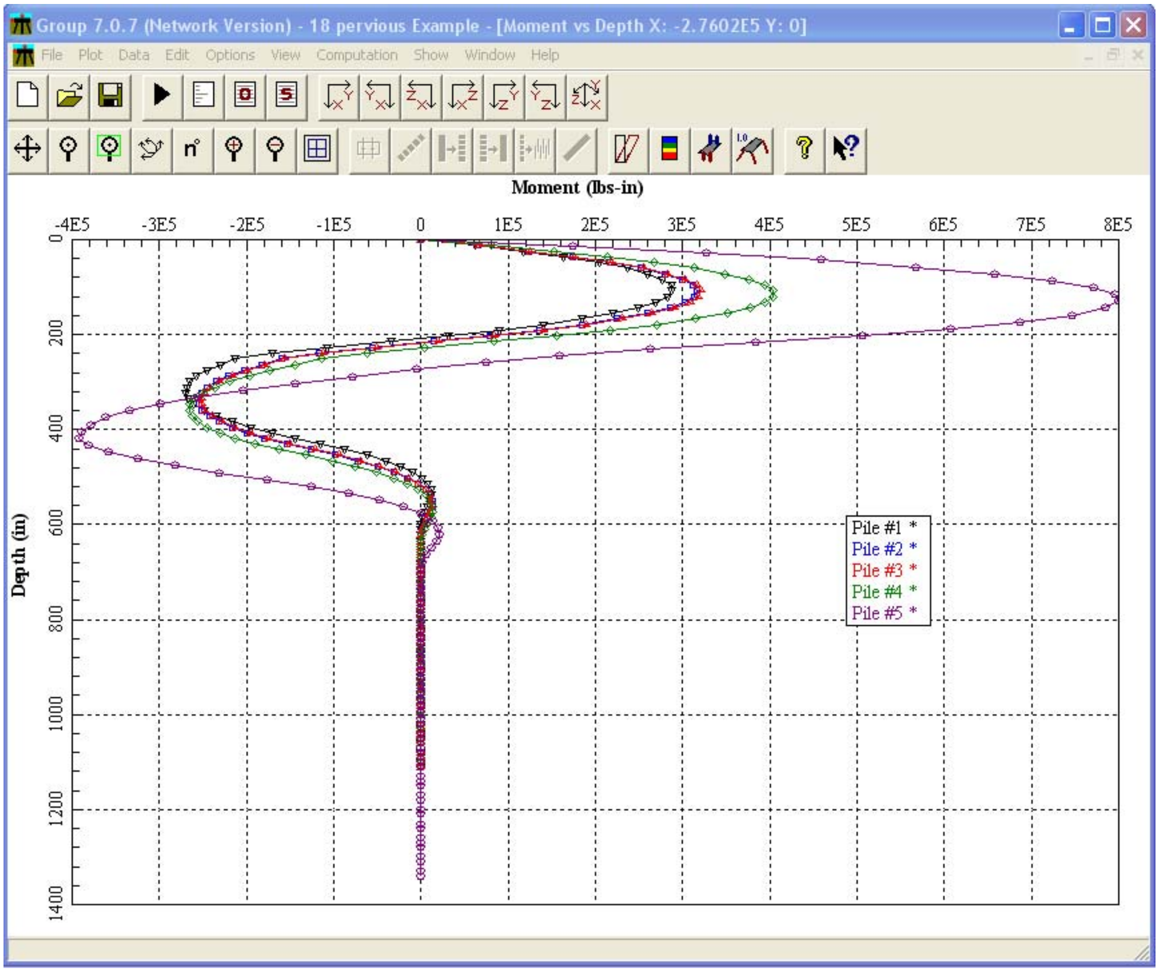


Figure 13 Moment in Piles With Depth

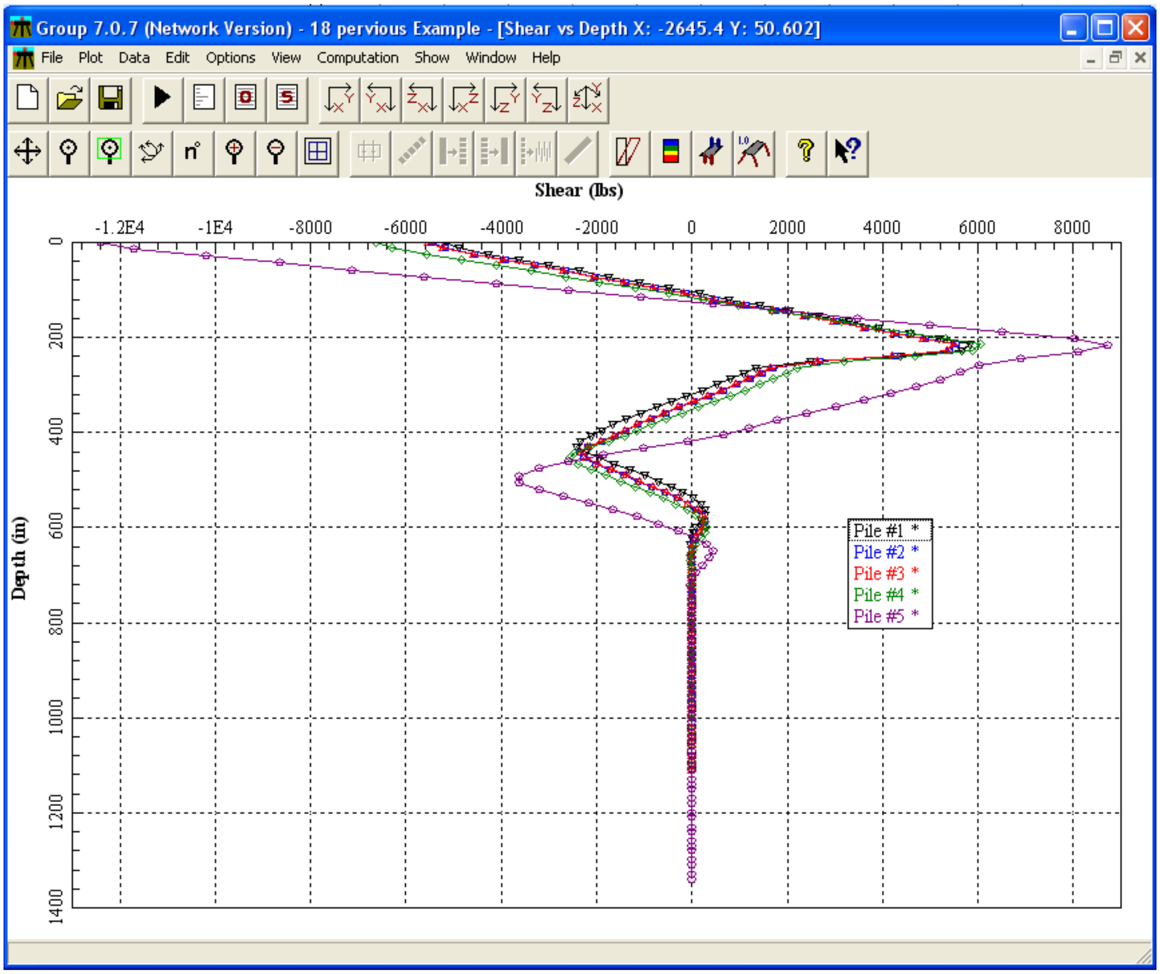


Figure 14. Shear diagrams for each of the four piles.

Grouped displacements of the pile cap from the Group 7 analysis are listed in Table 4.

Table 4. Grouped Pile Foundation displacements from Group 7 analysis

	Vert. Displacement, Inches	Hor. Displacement, Inches	Rotation Radians
Pervious	-0.2120	0.5254	0.0008644
Impervious	-0.1549	0.4424	0.0007479

These deflections are less than the allowable vertical deflection (DZ) of 0.5 inches and only slightly greater than the allowable horizontal deflection (DX) of 0.75 inches from the Hurricane and Storm Damage Reduction Design Guidelines, even with out increases allowed for the top of wall load case. Figure 13 below shows displacement with depth.

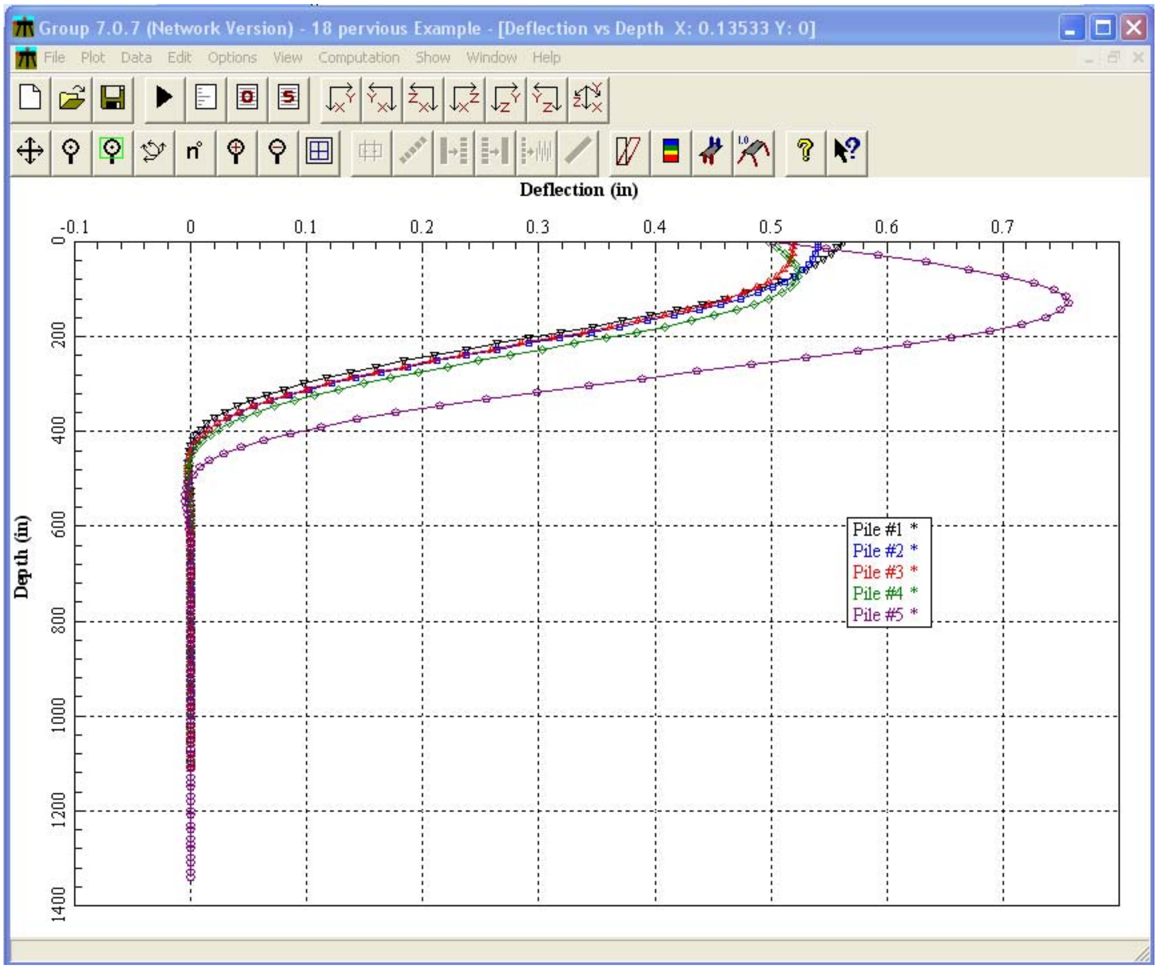


Figure 15. Deflection with Depth for the Pervious Foundation Condition.

5.3 Specifically, the deflections, axial loads and shear and bending moments in the piles are what must be evaluated to determine if the design requirements are met. The results of the Group 7 analysis are reported where the pile responses for the full loading conditions on T-wall systems are listed are listed in Table 5.

Table 5. Axial, shear and moments in piles computed by Group 7 for full loading conditions that include distributed loads applied directly to piles and resultant horizontal, vertical and moments due to water loads.

Pervious Case				
Pile Number	Pile Location	Axial (kips)	Shear (kips)	Maximum Moment In-kips
1	Right	8.21 (C)	5.82	288
2	Right-center	49.7 (C)	5.54	321
3	Center	80.8 (C)	5.49	473
4	Left-center	112 (C)	6.04	404
5	Left	-111 (T)	8.71	800
Impervious Case				
1	Right	24.7 (C)	5.68	303
2	Right-center	57.5 (C)	5.47	326
3	Center	84.5 (C)	5.43	331
4	Left-center	111 (C)	6.0	414
5	Left	-84.2 (T)	8.65	808

The axial forces and shear in Table 5 are then compared with allowable pile capacities summarized in Table 1 as determined in Step 3. The results of the comparison show that:

a. The axial compressive forces in the Piles 1, 2 and 3 are both less than the axial compressive pile capacity of 111 kips for both the pervious and impervious conditions. The axial force in pile 4 is slightly over for the pervious case and could be regarded as OK or the piles could be driven slightly deeper.
b. The axial tensile forces from the left (flood side) Pile 5 are less than the allowable tensile force of 113 kips..
c. The shear forces in each of the three piles are lower than the allowable shear of 12.2 kips for both foundation conditions.
d. Moment and axial forces in the piles would also be checked for structural strength according to criteria in the Hurricane and Storm Damage Reduction System Design Guidelines and EM1110-2-2906.

Step 6 Pile Group Analysis (unbalanced force)

6.1 A Group 7 analysis was performed with the unbalance force applied directly to the piles. The uniform unbalanced force above the base of the wall is added as a force and moment at the base of the wall. The distributed loads are statically equivalent to the unbalanced force of 17,480 lb/ft. No loads are applied to the cap except unbalance forces. The p-y springs are set to 0 to the critical failure surface by setting the ultimate shear stress of these soils at a very low value. The distributed loads were computed in the previous step and shown in Table 6. The pile cap forces were computed in the Excel spreadsheet of Attachement 3::

Py = 17,480 lb
Mz = -471,960 in-lb

The pile responses from the Group 7 analysis are shown in Table 10 below:

Table 6. Axial and shear Pile loads per 5-ft of width computed by Group 7 for static equivalent to unbalanced load only.

Pile	Axial (lb)	Shear (lb)
1	-44,800 (T)	5,650
2	-1,780 (T)	5,460
3	42,100 (C)	5,400
4	75,500 (C)	5,980
5	-75,800 (T)	8,590

Step 7 Pile Reinforced Slope Stability Analysis

7.1 The UT4 pile reinforcement analysis using the circle from Step 5 is performed to determine if the target Factor of Safety of 1.4 is achieved. The piles are treated as reinforcements in the UT4 and the shear and axial forces from Step 6 are used to determine these forces. The forces in Table 6 must be converted to unit width conditions by divided by the 5-ft pile spacing to be used as the axial and shear forces in the pile reinforcements in UT4. Additionally, the sign must be changed because compressive forces are negative in UT4. The UT4 forces used for pile reinforceement are shown in the Table 6. The results of the analysis are shown in Figure 16. The factor of safety is 1.526 which is greater than the target factor of safety of 1.4 for global stability. Since the compute factor of safety is slightly below the required value an additional iteration is required. The unbalanced force will be adjusted slightly to improve the global factor of safety.

Table 11. Axial and shear Pile reinforcement forces per unit width for input into UTEXAS4.		
Pile	Axial (lb)	Shear (lb)
1	8,960 (T)	1,130
2	356 (T)	1,092
3	-8,420 (C)	1,080
4	-15,100 (C)	1,196
5	15,160 (T)	1,718

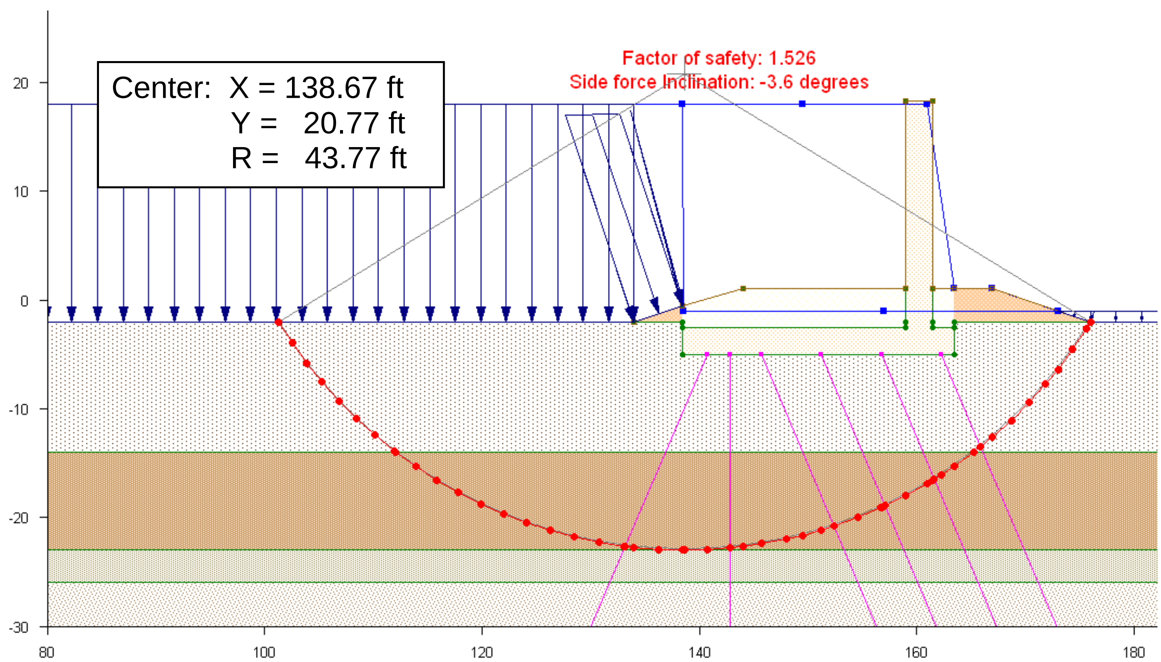


Figure 16. Factor of safety computed using pile forces from Group 7 analysis And critical circle from fixed grid analysis

Attachment 1 – UTexas analysis without piles that results in Figure 1.
Search for Critical Circle

```
EADING
    T-Wall Deep Seated Analysis
    Step 2 Search for unbalanced load

PROFILE LINES
         1     1 Layer 3 (CH) - Floodside
                  .00      -2.00
               134.00      -2.00
               138.50      -2.00

         2     1 Layer 3 (CH) - Landside
               163.50      -2.00
               375.00      -2.00

         3     2 Compacted Fill - FS
               134.00      -2.00
               138.50       -.50

         4     2 Compacted Fill - LS
               163.50       1.00
               167.00       1.00
               176.00      -2.00

         5     3 T-Wall
               138.50      -5.00
               138.50      -2.50
               159.00      -2.50
               159.00      -2.00
               159.00      18.30
               161.50      18.30
               161.50      1.00
               161.50      -2.00
               161.50      -2.50
               163.50      -2.50
               163.50      -5.00

         6     1 Layer 3 (CH) - Under Wall
               138.50      -5.00
               163.50      -5.00

         7     4 Layer 4 (CH)
                  .00     -14.00
               375.00     -14.00

         8     5 Layer 5 (ML)
                  .00     -23.00
               375.00     -23.00

         9     6 Layer 6 (CH)
                  .00     -26.00
               375.00     -26.00

        10     7 Layer 7 (CH)
```

```
              .00     -31.00
           375.00     -31.00

     11     8 Layer 8 (CH)
              .00     -39.00
           375.00     -39.00

     12     9 Layer 9 (CH)
              .00     -65.00
           375.00     -65.00

     13    10 Compacted Fill - Above T Wall Base  FS
           138.50       -.50
           144.00       1.00
           159.00       1.00

     14    10 Compacted Fill - Above T Wall Base  LS
           161.50       1.00
           163.50       1.00


MATERIAL PROPERTIES
     1 Layer 3 (CH)
          80.00 Unit Weight
          Conventional Shear
              120.00        .00
          No Pore Pressure
     2 Compacted Fill
          110.00 Unit Weight
          Conventional Shear
              500.00        .00
          No Pore Pressure
     3 T Wall
          .00 Unit Weight
          Very Strong
     4 Layer 4 (CH)
          100.00 Unit Weight
          Conventional Shear
              120.00        .00
          No Pore Pressure
     5 Layer 5 (ML)
          117.00 Unit Weight
          Conventional Shear
              200.00      15.00
          Piezometric Line
          1
     6 Layer 6 (CH)
          100.00 Unit Weight
          Conventional Shear
              200.00        .00
          No Pore Pressure
     7 Layer 7 (CH)
          100.00 Unit Weight
          Linear Increase
              217.00       8.10
          No Pore Pressure
     8 Layer 8 (CH)
```

```
          100.00 Unit Weight
          Linear Increase
              374.00      8.30
          No Pore Pressure
     9 Layer 9 (CH)
          100.00 Unit Weight
          Linear Increase
              590.00      8.00
          No Pore Pressure
     10 Compacted Fill - Above T-Wall Base
          .00 Unit Weight
          Conventional Shear
                 .00       .00
          No Pore Pressure

PIEZOMETRIC LINES
         1      62.40 Water Level
                 .00     18.00
              138.50     18.00
              138.51     -1.00
              157.00     -1.00
              375.00     -1.00

         2      62.40 Piezometeric levels in ML
                 .00     18.00
              149.50     18.00
              161.00     18.00
              163.50      1.00
              167.00      1.00
              173.00     -1.00
              375.00     -1.00


DISTRIBUTED LOADS
      1
REINFORCEMENT LINES
              1        .00         2
100.00      -100.0      0      0.
140.75      -5.000  0   0

              2         .00        2
145.75      -5.000         0     0.
182.55      -92.00         0.    0.

              3         .00        2
151.25      -5.000       0.     0.
188.05      -92.00       0.     0.

              4         .00        2
156.75      -5.000           0.   0.
193.55      -92.0       0.   0.

              5         .00        2
162.25  -5.000       0.   0.
199.30  -92.00       0.   0.

              6         .00        1
```

```
142.875     -5.00 0.0   0.0
142.875     -37.00      0.0   0.0


ANALYSIS/COMPUTATION
       Circular Search 2
          40.00     40.00
         134.00     10.00
         148.00     10.00
         148.00     30.00
         134.00     30.00
           2.00       .01
     Tangent
         -23.00

SINgle-stage Computations
RIGht Face of Slope
LONg-form output
SORt radii
CRItical
PROcedure for computation of Factor of Safety
SPENCER

GRAPH
COMPUTE
```

Attachment 2 – UTexas analysis with unbalanced load that results in Figure 2. Search for the unbalanced Load

```
HEADING
    T-Wall Deep Seated Analysis
    Step 2 Search for unbalanced load

PROFILE LINES
         1    1 Layer 3 (CH) - Floodside
                 .00      -2.00
              134.00      -2.00
              138.50      -2.00

         2    1 Layer 3 (CH) - Landside
              163.50      -2.00
              375.00      -2.00

         3    2 Compacted Fill - FS
              134.00      -2.00
              138.50       -.50

         4    2 Compacted Fill - LS
              163.50       1.00
              167.00       1.00
              176.00      -2.00

         5    3 T-Wall
              138.50      -5.00
              138.50      -2.50
              159.00      -2.50
              159.00      -2.00
              159.00      18.30
              161.50      18.30
              161.50      1.00
              161.50      -2.00
              161.50      -2.50
              163.50      -2.50
              163.50      -5.00

         6    1 Layer 3 (CH) - Under Wall
              138.50      -5.00
              163.50      -5.00

         7    4 Layer 4 (CH)
                 .00     -14.00
              375.00     -14.00

         8    5 Layer 5 (ML)
                 .00     -23.00
              375.00     -23.00

         9    6 Layer 6 (CH)
                 .00     -26.00
              375.00     -26.00
```

```
     10     7 Layer 7 (CH)
               .00     -31.00
            375.00     -31.00

     11     8 Layer 8 (CH)
               .00     -39.00
            375.00     -39.00

     12     9 Layer 9 (CH)
               .00     -65.00
            375.00     -65.00

     13    10 Compacted Fill - Above T Wall Base  FS
            138.50       -.50
            144.00       1.00
            159.00       1.00

     14    10 Compacted Fill - Above T Wall Base  LS
            161.50       1.00
            163.50       1.00


MATERIAL PROPERTIES
     1 Layer 3 (CH)
          80.00 Unit Weight
          Conventional Shear
              120.00        .00
          No Pore Pressure
     2 Compacted Fill
          110.00 Unit Weight
          Conventional Shear
              500.00        .00
          No Pore Pressure
     3 T Wall
          .00 Unit Weight
          Very Strong
     4 Layer 4 (CH)
          100.00 Unit Weight
          Conventional Shear
              120.00        .00
          No Pore Pressure
     5 Layer 5 (ML)
          117.00 Unit Weight
          Conventional Shear
              200.00      15.00
          Piezometric Line
          1
     6 Layer 6 (CH)
          100.00 Unit Weight
          Conventional Shear
              200.00        .00
          No Pore Pressure
     7 Layer 7 (CH)
          100.00 Unit Weight
          Linear Increase
              217.00       8.10
          No Pore Pressure
```

```
     8 Layer 8 (CH)
          100.00 Unit Weight
          Linear Increase
              374.00      8.30
          No Pore Pressure
     9 Layer 9 (CH)
          100.00 Unit Weight
          Linear Increase
              590.00      8.00
          No Pore Pressure
     10 Compacted Fill - Above T-Wall Base
          .00 Unit Weight
          Conventional Shear
                 .00       .00
          No Pore Pressure

PIEZOMETRIC LINES
         1      62.40 Water Level
                 .00     18.00
              138.50     18.00
              138.51     -1.00
              157.00     -1.00
              375.00     -1.00

         2      62.40 Piezometeric levels in ML
                 .00     18.00
              149.50     18.00
              161.00     18.00
              163.50      1.00
              167.00      1.00
              173.00     -1.00
              375.00     -1.00


DISTRIBUTED LOADS
      1
LINE LOAD
  1 138.5 -11.75 -17480. 0 1

REINFORCEMENT LINES
              1       .00         2
100.00      -100.0      0     0.
140.75      -5.000  0   0

              2        .00        2
145.75      -5.000         0     0.
182.55      -92.00         0.    0.

              3        .00        2
151.25      -5.000       0.     0.
188.05      -92.00       0.     0.

              4        .00        2
156.75      -5.000           0.   0.
193.55      -92.0      0.   0.

              5        .00        2
```

```
162.25  -5.000       0.   0.
199.30  -92.00       0.   0.

              6        .00        1
142.875     -5.00 0.0   0.0
142.875     -37.00      0.0   0.0


ANALYSIS/COMPUTATION
       Circular
      138.67   20.77  43.77
SINgle-stage Computations
RIGht Face of Slope
LONg-form output
SORt radii
CRItical
PROcedure for computation of Factor of Safety
SPENCER

GRAPH
COMPUTE
```

Attachment 3 Structural Loads for CPGA and Group Analyses

US Army Corps of Engineers Saint Paul Distict	PROJECT TITLE: T-Wall Design Example	COMPUTED BY: KDH	DATE: 07/31/07	SHEET:	
	SUBJECT TITLE: Water at El. 18', Pervious	CHECKED BY:	DATE:		

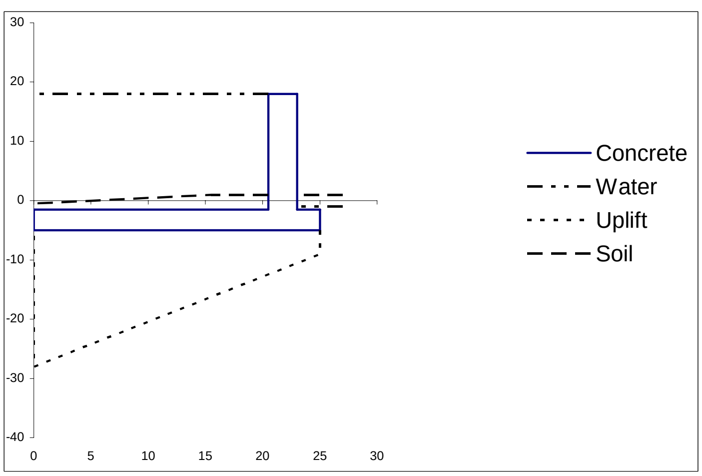
Input for CPGA pile analysis **Pervious Foundation Assumption**

Upstream Water Elevation	*18*	ft	Back Fill Soil Elevation	*1*	ft
Downstream Water Elevation	*-1*	ft	Front Fill Soil Elevation	*1*	ft
Wall Top Elevation	*18*	ft	Gamma Water	*0.0625*	kcf
Structure Bottom Elevation	*-5*	ft	Gamma Concrete	*0.15*	kcf
Base Width	*25*	ft	Gamma Sat. Backfill	*0.110*	kcf
Toe Width	*2*	ft	Distance to Backfill Break	*5.0*	ft
Wall Thickness	*2.5*	ft	Slope of Back Fill	*0.18*	
Base Thickness	*3.5*	ft	Soil Elevation at Heel	-0.50	ft

Vertical Forces								
Component	Height	x1	x2	Gamma	Force	Arm	Moment	
Stem Concrete	19.5	20.5	23	0.15	7.31	21.75	159.0	
Heel Concrete	3.5	0	23	0.15	12.08	11.5	138.9	
Toe Concrete	3.5	23	25	0.15	1.05	24	25.2	
Heel Water	17	0	20.5	0.0625	21.78	10.25	223.3	
Toe Water	0.5	23	25	0.0625	0.06	24	1.5	
Heel Soil	2.5	0	20.5	0.110	5.64	10.25	57.8	
-Triangle	1.50	0	15.5	-0.048	-0.55	5.17	-2.9	
Toe Soil	2.5	23	25	0.110	0.55	24	13.2	
Rect Uplift	-4	0	25	0.0625	-6.25	12.5	-78.1	
Tri Uplift	-19	0	25	0.0625	-14.84	8.3	-123.7	
Sum Vertical Forces					26.8		414.2	ft-k

Horizontal Forces								
Component	H1	H2	Gamma	Lat. Coeff.	Force	Arm	Moment	
Driving Water	18	-5	0.0625	1	16.53	7.67	126.74	
Resisting Water	-1	-5	0.0625	1	-0.50	1.33	-0.67	
Lateraral soil forces assumed equal and negligible								
Sum Horizontal Forces					16.03	7.86	126.07	ft-k

Total Structural Forces	Net Vert. Force	Arm	Moment	
About Heel	26.82	20.14	540.25	ft-k



Net Vertical Arm		
From Toe	4.86	ft

Moment About Toe
-130.3 ft-k

Model Width
5 ft

UPDATED 23 OCT 07

US Army Corps of Engineers Saint Paul Distict	PROJECT TITLE: T-Wall Design Example	COMPUTED BY: KDH	DATE: 07/31/07	SHEET:
	SUBJECT TITLE: Water at El. 18', Pervious	CHECKED BY:	DATE:	

Calculation of Unbalanced Force

Unbalanced Force. F_{ub}	*17,480*	lb/ft	From UTexas Analysis
Elevation of Critical Surface	*-23.0*	ft	From UTexas Analysis
Length - Ground to Crit. Surface, Lu	22.5	ft	(assume failure surface is normal to pile)
Length - Base to Crit. Surface, Lp	18	ft	
Pile Moment of Inertia. I	*729*	in^4	HP14x73
Pile Modulus of Elasticity E	*29,000,000*	lb/in^2	
Soil Modulus of Subgrade Reaction, k	*100*	lb/in^2	
Soil Stiffness Parameter, R	121	in	$(EI / k)^{1/4}$
Equivalent Unbalanced Force	13,273	lb/ft	$F_{ub} * (L_u/2 + R) / (L_p + R)$

CPGA Input

PX	-146.52	kips
PY		
PZ	134.11	kips
MX	0	
MY	-651.61	kip-ft
MZ	0	

Group Input

4 Pile Rows Parallel to Wall Face

Unbalanced Loading on Piles for Group Analysis

Total	324	lb/in	F_{ub} * Model Width /L_u
50%	162	lb/in	For Pile Row on Flood Side
17%	54	lb/in	

Note: Applied to length of pile from bottom of cap to top of critical surface. 18

Unbalanced Loads on Wall for Group Analysis of Just Unbalanced Forces

Distance From Base to Ground Surface, Ds 4.50 ft

PX	0	lb	
PY	17,480	lb	F_{ub} * Model Width / L_u * Ds
PZ	0	lb	
MX	0		
MY	0		
MZ	-471,960	lb-in	-PZ * Ds/2

Total Loads for Group Analysis

PX	134,114	lb	
PY	97,636	lb	PYub + Sum Horizontal * Model Width
PZ	0	lb	
MX	0		
MY	0		
MZ	7,347,343	lb-in	

UPDATED 23 OCT 07

US Army Corps of Engineers Saint Paul Distict	PROJECT TITLE: T-Wall Design Example	COMPUTED BY: KDH	DATE: 07/31/07	SHEET:
	SUBJECT TITLE: Water at El. 18', Impervious	CHECKED BY:	DATE:	

Input for CPGA pile analysis **Impervious Foundation Assumption**

Upstream Water Elevation	*18* ft		Back Fill Soil Elevation	*1*	ft
Downstream Water Elevation	*-1* ft		Front Fill Soil Elevation	*1*	ft
Wall Top Elevation	*18* ft		Gamma Water	*0.0625*	kcf
Structure Bottom Elevation	*-5* ft		Gamma Concrete	*0.15*	kcf
Base Width	*25* ft		Gamma Sat. Backfill	*0.110*	kcf
Toe Width	*2* ft		Distance to Backfill Break	*5.0*	ft
Wall Thickness	*2.5* ft		Slope of Back Fill	*0.18*	
Base Thickness	*3.5* ft		Soil Elevation at Heel	-0.50	ft

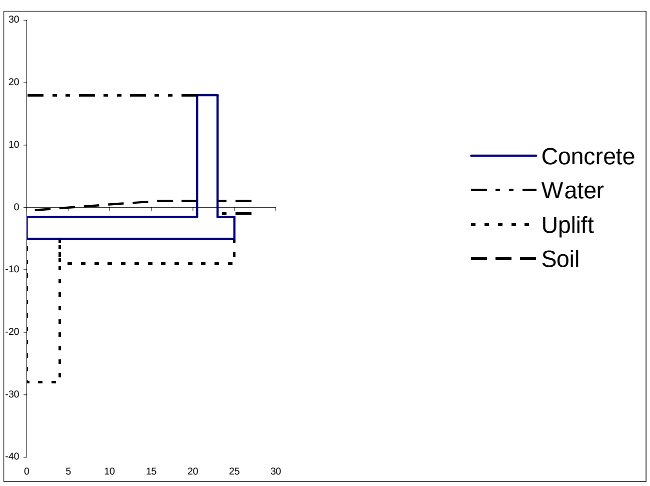
Vertical Forces

Component	Height	x1	x2	Gamma	Force	Arm	Moment	
Stem Concrete	19.5	20.5	23	0.15	7.31	21.75	159.0	
Heel Concrete	3.5	0	23	0.15	12.08	11.5	138.9	
Toe Concrete	3.5	23	25	0.15	1.05	24	25.2	
Heel Water	17	0	20.5	0.0625	21.78	10.25	223.3	
Toe Water	0.5	23	25	0.0625	0.06	24	1.5	
Heel Soil	2.5	0	20.5	0.110	5.64	10.25	57.8	
-Triangle	1.50	0	15.5	-0.048	-0.55	5.17	-2.9	
Toe Soil	2.5	23	25	0.110	0.55	24	13.2	
Prot. Side Uplift	-4	*4*	25	0.0625	-5.25	14.5	-76.1	
Flood Side Uplift	-23	0	4	0.0625	-5.75	2	-11.5	
Sum Vertical Forces					36.9	kip	528.4	ft-k

Horizontal Forces

Component	H1	H2	Gamma	Lat. Coeff.	Force	Arm	Moment	
Driving Water	18	-5	0.0625	1	16.53	7.67	126.74	
Resisting Water	-1	-5	0.0625	1	-0.50	1.33	-0.67	
Lateraral soil forces assumed equal and negligible								
Sum Horizontal Forces					16.03	kip	126.07	ft-k

Total Structural Forces	Net Vert. Force	Arm	Moment	
About Heel	36.92	17.73	654.45	ft-k



Net Vertical Arm		
From Toe	7.27	ft

Moment About Toe
-268.5 ft-k

Model Width
5 ft

UPDATED 23 OCT 07

US Army Corps of Engineers Saint Paul Distict	PROJECT TITLE: T-Wall Design Example	COMPUTED BY: KDH	DATE: 07/31/07	SHEET:	
	SUBJECT TITLE: Water at El. 18', Impervious	CHECKED BY:	DATE:		

Calculation of Unbalanced Force

Unbalanced Force. F_{ub}	*17,480*	lb/ft	From UTexas Analysis
Elevation of Critical Surface	*-23*	ft	From UTexas Analysis
Length - Ground to Crit. Surface, Lu	22.5	ft	(assume failure surface is normal to pile)
Length - Base to Crit. Surface, Lp	18	ft	
Pile Moment of Inertia. I	*729*	in^4	HP14x73
Pile Modulus of Elasticity E	*29,000,000*	lb/in^2	
Soil Modulus of Subgrade Reaction, k	*100*	lb/in^2	
Soil Stiffness Parameter, R	121	in	$(EI / k)^{1/4}$
Equivalent Unbalanced Force	13,273	lb/ft	$F_{ub} * (L_u/2 + R) / (L_p + R)$

CPGA Input

PX	-146.52	kips
PY		
PZ	184.58	kips
MX	0	
MY	-1,342.34	kip-ft
MZ	0	

Group Input

4 Pile Rows Parallel to Wall Face

Unbalanced Loading on Piles for Group Analysis

Total	324	lb/in	F_{ub} * Model Width /L_u
50%	162	lb/in	For Pile on Protected Side
17%	54	lb/in	

Note: Applied to length of pile from bottom of cap to top of critical surface. 18 ft

Unbalanced Loads on Wall for Group Analysis of Just Unbalanced Forces

Distance From Base to Ground Surface, Ds 4.50 ft

PX	0	lb	
PY	17,480	lb	F_{ub} * Model Width / L_u * Ds
PZ	0	lb	
MX	0		
MY	0		
MZ	-471,960	lb-in	-PZ * Ds/2

Total Loads for Group Analysis

PX	184,583	lb	
PY	97,636	lb	PYub + Sum Horizontal * Model Width
PZ	0	lb	
MX	0		
MY	0		
MZ	15,636,093	lb-in	

Attachment 4 - Preliminary Analysis with CPGA

Input File:

```
10 T-wall Example, Water on FS 18, Group Reducton Test - with group
15 3.5 ft slab, hp 14 x 73 piles, pinned head, 2.5:1 batter
20 PROP 29000 261 729 21.4 1.0 0 all
30 SOIL ES 0.00001 "TIP" 87.5 0 1 2 3
32 SOIL ES 0.00001 "TIP" 87.5 0 4
37 SOIL ES 0.00001 "TIP" 105.0 0 5
40 PIN all
50 ALLOW H 111.0 113.0 315.8  315.8  520.6  1573.1 all
70 BATTER 2.5 all
80 ANGLE 180 1 2 3 4
180 PILE 1  1.250 0.00 0.00
201 PILE 2  6.75 0.00 0.00
202 PILE 3  12.25 0.00 0.00
203 PILE 4  17.75 0.00 0.00
205 PILE 5  23.75 0.00 0.00
230 LOAD 1 -146.52  0.0  134.11  0.00  -651.61
255 LOAD 2 -146.52  0.0  184.58  0.00 -1342.34
334 FOUT 1 2 3 4 5 6 7 MVN18G5.out
335 PFO ALL
```

Output:

```
 ********************************
 * CASE PROGRAM   #  X0080      *  CPGA - CASE PILE GROUP ANALYSIS PROGRAM
 * VERSION NUMBER # 1993/03/29  *  RUN DATE 31-JUL-2007   RUN TIME 16.36.10
 ********************************


 T-WALL EXAMPLE, WATER ON FS 18, GROUP REDUCTON TEST - WITH GROUP


 THERE ARE     5 PILES AND
               2 LOAD CASES IN THIS RUN.

 ALL PILE COORDINATES ARE CONTAINED WITHIN A BOX
                                    X          Y          Z
                                  -----      -----      -----
 WITH DIAGONAL COORDINATES = (      1.25 ,      .00 ,      .00 )
                             (     23.75 ,      .00 ,      .00 )


 ******************************************************************************

          PILE PROPERTIES AS INPUT


       E            I1            I2            A            C33           B66
      KSI          IN**4         IN**4         IN**2
   .29000E+05   .26100E+03   .72900E+03   .21400E+02   .10000E+01   .00000E+00

 THESE PILE PROPERTIES APPLY TO THE FOLLOWING PILES -
```

ALL

****

SOIL DESCRIPTIONS AS INPUT

ES	ESOIL	LENGTH	L	LU
	K/IN**2		FT	FT
	.10000E-04	T	.87500E+02	.00000E+00

THIS SOIL DESCRIPTION APPLIES TO THE FOLLOWING PILES -

1 2 3

ES	ESOIL	LENGTH	L	LU
	K/IN**2		FT	FT
	.10000E-04	T	.87500E+02	.00000E+00

THIS SOIL DESCRIPTION APPLIES TO THE FOLLOWING PILES -

4

ES	ESOIL	LENGTH	L	LU
	K/IN**2		FT	FT
	.10000E-04	T	.10500E+03	.00000E+00

THIS SOIL DESCRIPTION APPLIES TO THE FOLLOWING PILES -

5

****

PILE GEOMETRY AS INPUT AND/OR GENERATED

NUM	X	Y	Z	BATTER	ANGLE	LENGTH	FIXITY
	FT	FT	FT			FT	
1	1.25	.00	.00	2.50	180.00	94.24	P
2	6.75	.00	.00	2.50	180.00	94.24	P
3	12.25	.00	.00	2.50	180.00	94.24	P
4	17.75	.00	.00	2.50	180.00	94.24	P
5	23.75	.00	.00	2.50	.00	113.09	P

						490.05	

****

APPLIED LOADS

LOAD	PX	PY	PZ	MX	MY	MZ
CASE	K	K	K	FT-K	FT-K	FT-K

1	-146.5	.0	134.1	.0	-651.6	.0
2	-146.5	.0	184.6	.0	-1342.3	.0

****

ORIGINAL PILE GROUP STIFFNESS MATRIX

.36589E+03	.26469E-04	-.59923E+03	.00000E+00	.41347E+05	.30175E-02
.26469E-04	.32977E-01	-.66172E-04	.00000E+00	.75436E-02	.48872E+01
-.59923E+03	-.66172E-04	.22866E+04	.00000E+00	-.32808E+06	-.75436E-02
.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
.41347E+05	.75436E-02	-.32808E+06	.00000E+00	.66918E+08	.12203E+01
.30175E-02	.48872E+01	-.75436E-02	.00000E+00	.12203E+01	.10222E+04

S(4,4)=0. PROBLEM WILL BE TREATED AS TWO DIMENSIONAL IN THE X-Z PLANE.

LOAD CASE 1. NUMBER OF FAILURES = 2. NUMBER OF PILES IN TENSION = 1.

LOAD CASE 2. NUMBER OF FAILURES = 1. NUMBER OF PILES IN TENSION = 1.

****

PILE CAP DISPLACEMENTS

LOAD CASE	DX IN	DZ IN	R RAD
1	-.7899E+00	-.3207E+00	-.1201E-02
2	-.6897E+00	-.2476E+00	-.1028E-02

****

ELASTIC CENTER INFORMATION

	X FT	Z FT
ELASTIC CENTER IN PLANE X-Z	16.62	-17.81

LOAD CASE	MOMENT IN X-Z PLANE
1	.70738E+07
2	.29723E+08

****

PILE FORCES IN LOCAL GEOMETRY

M1 & M2 NOT AT PILE HEAD FOR PINNED PILES

```
* INDICATES PILE FAILURE
# INDICATES CBF BASED ON MOMENTS DUE TO
          (F3*EMIN) FOR CONCRETE PILES
B INDICATES BUCKLING CONTROLS
```

LOAD CASE - 1

PILE	F1	F2	F3	M1	M2	M3	ALF	CBF	
	K	K	K	IN-K	IN-K	IN-K			
1	.0	.0	6.8	.0	-4.0	.0	.06	.02	
2	.0	.0	47.2	.0	-3.8	.0	.42	.15	
3	.0	.0	87.6	.0	-3.7	.0	.79	.28	
4	.0	.0	127.9	.0	-3.5	.0	1.15	.41	*
5	.0	.0	-125.0	.0	3.5	.0	1.11	.40	*

LOAD CASE - 2

PILE	F1	F2	F3	M1	M2	M3	ALF	CBF	
	K	K	K	IN-K	IN-K	IN-K			
1	.0	.0	22.3	.0	-3.4	.0	.20	.07	
2	.0	.0	56.9	.0	-3.3	.0	.51	.18	
3	.0	.0	91.4	.0	-3.2	.0	.82	.29	
4	.0	.0	126.0	.0	-3.0	.0	1.14	.40	*
5	.0	.0	-97.8	.0	3.1	.0	.87	.31	

****

PILE FORCES IN GLOBAL GEOMETRY

LOAD CASE - 1

PILE	PX	PY	PZ	MX	MY	MZ
	K	K	K	IN-K	IN-K	IN-K
1	-2.5	.0	6.3	.0	.0	.0
2	-17.5	.0	43.8	.0	.0	.0
3	-32.5	.0	81.3	.0	.0	.0
4	-47.5	.0	118.8	.0	.0	.0
5	-46.4	.0	-116.0	.0	.0	.0

LOAD CASE - 2

PILE	PX	PY	PZ	MX	MY	MZ
	K	K	K	IN-K	IN-K	IN-K
1	-8.3	.0	20.7	.0	.0	.0
2	-21.1	.0	52.8	.0	.0	.0
3	-34.0	.0	84.9	.0	.0	.0

4	-46.8	.0	117.0	.0	.0	.0
5	-36.3	.0	-90.8	.0	.0	.0

Attachment 5. Group 7 Output File for Pervious Condition

```
==============================================================================

                GROUP for Windows, Version 7.0.7

                 Analysis of A Group of Piles
              Subjected to Axial and Lateral Loading

               (c) Copyright ENSOFT, Inc., 1987-2006
                     All Rights Reserved

==============================================================================


This program is licensed to:

k
c

Path to file locations:      C:\KDH\New Orleans\T-walls\Group\
Name of input data file:     18 pervious Example.gpd
Name of output file:         18 pervious Example.gpo
Name of plot output file:    18 pervious Example.gpp
Name of runtime file:        18 pervious Example.gpr
Name of output summary file: 18 pervious Example.gpt


------------------------------------------------------------------------------
                          Time and Date of Analysis
------------------------------------------------------------------------------

               Date:  July 31, 2007     Time:  14:43: 5
 PILE GROUP ANALYSIS PROGRAM-GROUP
 PC VERSION 6.0 (C) COPYRIGHT ENSOFT,INC. 2000

 THE PROGRAM WAS COMPILED USING MICROSOFT FORTRAN
 POWERSTATION 4.0 (C) COPYRIGHT MICROSOFT CORPORATION, 1996.


     T-wall Examplel : F.S. 18.0, P.S. -1.0,  Pervious Foundation Condition


                *****     INPUT INFORMATION     *****



     * TABLE C *  LOAD AND CONTROL PARAMETERS


     UNITS--

          V LOAD,LBS      H LOAD,LBS    MOMENT,LBS-IN
```

```
   0.1341E+06     0.9764E+05     0.7347E+07

GROUP NO. 1

             DISTRIBUTED LOAD CURVE          2 POINTS

                       X,IN       LOAD,LBS/IN
                       0.00         0.527E+02
                     216.00         0.527E+02

GROUP NO. 2

             DISTRIBUTED LOAD CURVE          2 POINTS

                       X,IN       LOAD,LBS/IN
                       0.00         0.527E+02
                     216.00         0.527E+02

GROUP NO. 3

             DISTRIBUTED LOAD CURVE          2 POINTS

                       X,IN       LOAD,LBS/IN
                       0.00         0.527E+02
                     216.00         0.527E+02

GROUP NO. 4

             DISTRIBUTED LOAD CURVE          2 POINTS

                       X,IN       LOAD,LBS/IN
                       0.00         0.606E+02
                     216.00         0.606E+02

GROUP NO. 5

             DISTRIBUTED LOAD CURVE          2 POINTS

                       X,IN       LOAD,LBS/IN
                       0.00         0.105E+03
                     216.00         0.105E+03

* THE LOADING IS STATIC *

  KPYOP =  0     (CODE TO GENERATE P-Y CURVES)

  ( KPYOP = 1 IF P-Y YES; = 0 IF P-Y NO; = -1 IF P-Y ONLY )
```

```
* CONTROL PARAMETERS *
    TOLERANCE ON CONVERGENCE OF FOUNDATION REACTION      =  0.100E-04 IN
    TOLERANCE ON DETERMINATION OF DEFLECTIONS            =  0.100E-04 IN
    MAX NO OF ITERATIONS ALLOWED FOR FOUNDATION ANALYSIS =     100
    MAXIMUM NO. OF ITERATIONS ALLOWED FOR PILE ANALYSIS  =     100



* TABLE D *   ARRANGEMENT OF PILE GROUPS

  GROUP  CONNECT  NO OF PILE PILE NO  L-S CURVE  P-Y CURVE
    1      PIN         1        1         1           0
    2      PIN         1        1         1           0
    3      PIN         1        1         1           0
    4      PIN         1        1         1           0
    5      PIN         1        2         2           0

  GROUP          VERT,IN      HOR,IN    SLOPE,IN/IN  GROUND,IN SPRING,LBS-IN
    1          0.0000E+00 -0.1500E+02  0.3805E+00 -0.3600E+02  0.0000E+00
    2          0.0000E+00 -0.8100E+02  0.3805E+00 -0.3600E+02  0.0000E+00
    3          0.0000E+00 -0.1470E+03  0.3805E+00 -0.3600E+02  0.0000E+00
    4          0.0000E+00 -0.2130E+03  0.3805E+00 -0.3600E+02  0.0000E+00
    5          0.0000E+00 -0.2850E+03 -0.3805E+00 -0.3600E+02  0.0000E+00
    6          0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00


* TABLE E *   PILE GEOMETRY AND PROPERTIES
              PILE TYPE = 1 - DRIVEN PILE
                        = 2 - DRILLED SHAFT

  PILE  SEC  INC       LENGTH, IN     E  ,LBS/IN**2 PILE TYPE
    1    1    94       0.1124E+04     0.2900E+08        1
    2    1    94       0.1357E+04     0.2900E+08        1

  PILE   FROM,IN      TO,IN      DIAM,IN   AREA,IN**2    I,IN**4

    1  0.0000E+00  0.1124E+04  0.1400E+02  0.2140E+02  0.7290E+03

      * THE PILE ABOVE IS OF LINEARLY ELASTIC MATERIAL *

    2  0.0000E+00  0.1357E+04  0.1400E+02  0.2140E+02  0.7290E+03

      * THE PILE ABOVE IS OF LINEARLY ELASTIC MATERIAL *


* TABLE F *   AXIAL LOAD VS SETTLEMENT

(THE LOAD-SETTLEMENT CURVE OF SINGLE PILE IS GENERATED INTERNALLY)

  NUM OF CURVES  2

   CURVE  1          NUM OF POINTS = 19

       POINT       AXIAL LOAD,LBS      SETTLEMENT, IN
```

1	-0.1891E+06	-0.2251E+01
2	-0.1787E+06	-0.1234E+01
3	-0.1735E+06	-0.7251E+00
4	-0.1415E+06	-0.2707E+00
5	-0.1307E+06	-0.2010E+00
6	-0.4273E+05	-0.5355E-01
7	-0.2066E+05	-0.2609E-01
8	-0.4091E+04	-0.5188E-02
9	-0.4091E+03	-0.5188E-03
10	0.0000E+00	0.0000E+00
11	0.7980E+03	0.9819E-03
12	0.4913E+04	0.6167E-02
13	0.2352E+05	0.2946E-01
14	0.4697E+05	0.5852E-01
15	0.1339E+06	0.2068E+00
16	0.1454E+06	0.2779E+00
17	0.1824E+06	0.7411E+00
18	0.1908E+06	0.1256E+01
19	0.2052E+06	0.2280E+01

CURVE 2 NUM OF POINTS = 19

POINT	AXIAL LOAD,LBS	SETTLEMENT, IN
1	-0.2895E+06	-0.2450E+01
2	-0.2689E+06	-0.1413E+01
3	-0.2586E+06	-0.8941E+00
4	-0.1956E+06	-0.3808E+00
5	-0.1747E+06	-0.2904E+00
6	-0.7760E+05	-0.9714E-01
7	-0.3898E+05	-0.4799E-01
8	-0.7512E+04	-0.9355E-02
9	-0.7512E+03	-0.9355E-03
10	0.0000E+00	0.0000E+00
11	0.7529E+03	0.9375E-03
12	0.7529E+04	0.9375E-02
13	0.3907E+05	0.4810E-01
14	0.7775E+05	0.9734E-01
15	0.1749E+06	0.2908E+00
16	0.1960E+06	0.3816E+00
17	0.2594E+06	0.8961E+00
18	0.2701E+06	0.1415E+01
19	0.2908E+06	0.2453E+01

* TABLE H * SOIL DATA FOR AUTO P-Y CURVES

SOILS INFORMATION

AT THE GROUND SURFACE = -36.00 IN

6 LAYER(S) OF SOIL

LAYER 1
THE SOIL IS A SOFT CLAY
X AT THE TOP OF THE LAYER = -36.00 IN

```
X AT THE BOTTOM OF THE LAYER      =     216.00 IN
MODULUS OF SUBGRADE REACTION      =  0.100E+00 LBS/IN**3

LAYER   2
THE SOIL IS A SILT
X AT THE TOP OF THE LAYER         =     216.00 IN
X AT THE BOTTOM OF THE LAYER      =     252.00 IN
MODULUS OF SUBGRADE REACTION      =  0.300E+02 LBS/IN**3

LAYER   3
THE SOIL IS A SOFT CLAY
X AT THE TOP OF THE LAYER         =     252.00 IN
X AT THE BOTTOM OF THE LAYER      =     720.00 IN
MODULUS OF SUBGRADE REACTION      =  0.300E+02 LBS/IN**3

LAYER   4
THE SOIL IS A STIFF CLAY BELOW THE WATER TABLE
X AT THE TOP OF THE LAYER         =     720.00 IN
X AT THE BOTTOM OF THE LAYER      =     973.00 IN
MODULUS OF SUBGRADE REACTION      =  0.100E+03 LBS/IN**3

LAYER   5
THE SOIL IS A SAND
X AT THE TOP OF THE LAYER         =     973.00 IN
X AT THE BOTTOM OF THE LAYER      =    1273.00 IN
MODULUS OF SUBGRADE REACTION      =  0.600E+02 LBS/IN**3

LAYER   6
THE SOIL IS A STIFF CLAY BELOW THE WATER TABLE
X AT THE TOP OF THE LAYER         =    1273.00 IN
X AT THE BOTTOM OF THE LAYER      =    1600.00 IN
MODULUS OF SUBGRADE REACTION      =  0.100E+03 LBS/IN**3


DISTRIBUTION OF EFFECTIVE UNIT WEIGHT WITH DEPTH
                  16 POINTS

            X,IN   WEIGHT,LBS/IN**3
        -36.0000     0.1010E-01
        108.0000     0.1010E-01
        108.0000     0.2170E-01
        216.0000     0.2170E-01
        216.0000     0.3150E-01
        252.0000     0.3150E-01
        252.0000     0.2170E-01
        720.0000     0.2170E-01
        720.0000     0.2750E-01
        900.0000     0.2750E-01
        900.0000     0.3330E-01
        972.0000     0.3330E-01
        972.0000     0.3440E-01
       1273.0000     0.3440E-01
       1273.0000     0.3210E-01
       1600.0000     0.3210E-01


DISTRIBUTION OF STRENGTH PARAMETERS WITH DEPTH
```

16 POINTS

X IN	C LBS/IN**2	PHI,DEGREES	E50	FMAX LBS/IN**2	TIPMAX LBS/IN**2
-36.00	0.1000E-04	0.000	0.2500E-01	0.0000E+00	0.0000E+00
216.00	0.1000E-04	0.000	0.2500E-01	0.0000E+00	0.0000E+00
216.00	0.1390E+01	15.000	0.2500E-01	0.2400E+01	0.0000E+00
252.00	0.1390E+01	15.000	0.2500E-01	0.2700E+01	0.0000E+00
252.00	0.1390E+01	0.000	0.2500E-01	0.1390E+01	0.0000E+00
408.00	0.1390E+01	0.000	0.2500E-01	0.1390E+01	0.0000E+00
408.00	0.2590E+01	0.000	0.2000E-01	0.2590E+01	0.0000E+00
720.00	0.4100E+01	0.000	0.1000E-01	0.4100E+01	0.0000E+00
720.00	0.4100E+01	0.000	0.1000E-01	0.4100E+01	0.0000E+00
780.00	0.4300E+01	0.000	0.1000E-01	0.4300E+01	0.0000E+00
780.00	0.5500E+01	0.000	0.1000E-01	0.5500E+01	0.0000E+00
973.00	0.5500E+01	0.000	0.1000E-01	0.5500E+01	0.0000E+00
973.00	0.0000E+00	30.000	0.0000E+00	0.1300E+02	0.0000E+00
1273.00	0.0000E+00	30.000	0.0000E+00	0.1400E+02	0.0000E+00
1273.00	0.6800E+01	0.000	0.1000E-01	0.6800E+01	0.0000E+00
1600.00	0.6800E+01	0.000	0.1000E-01	0.6800E+01	0.0000E+00

REDUCTION FACTORS FOR CLOSELY-SPACED PILE GROUPS

GROUP NO	P-FACTOR	Y-FACTOR
1	1.00	1.00
2	0.87	1.00
3	0.87	1.00
4	0.87	1.00
5	0.89	1.00

T-wall Examplel : F.S. 18.0, P.S. -1.0, Pervious Foundation Condition

***** COMPUTATION RESULTS *****

VERT. LOAD, LBS	HORI. LOAD, LBS	MOMENT,IN-LBS
0.1341E+06	0.9764E+05	0.7347E+07

DISPLACEMENT OF GROUPED PILE FOUNDATION

VERTICAL,IN	HORIZONTAL,IN	ROTATION,RAD
-0.2120E+00	0.5254E+00	0.8644E-03

NUMBER OF ITERATIONS =   4

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 * TABLE I *   COMPUTATION ON INDIVIDUAL PILE

   * PILE GROUP *  1

PILE TOP DISPLACEMENTS AND REACTIONS

      THE GLOBAL STRUCTURE COORDINATE SYSTEM
      --------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN
STRESS,LBS/IN**2

-0.199E+00  0.525E+00 -.408E-03 0.978E+04-0.237E+04 0.000E+00   0.383E+03

      THE LOCAL MEMBER COORDINATE SYSTEM
      ------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN
STRESS,LBS/IN**2

 0.103E-01  0.562E+00 -.408E-03 0.820E+04-0.584E+04 0.000E+00   0.383E+03
```

LATERALLY LOADED PILE

X IN	DEFLECTION IN	MOMENT LBS-IN	SHEAR LBS	SOIL REACTION LBS/IN	TOTAL STRESS LBS/IN**2	FLEXURAL RIGIDITY LBS-IN**2
*****	**********	**********	**********	**********	**********	**********
0.00	0.562E+00	0.000E+00	-0.521E+04	0.543E-03	0.383E+03	0.211E+11
11.96	0.557E+00	0.622E+05	-0.489E+04	0.542E-03	0.981E+03	0.211E+11
23.91	0.552E+00	0.117E+06	-0.426E+04	0.540E-03	0.151E+04	0.211E+11
35.87	0.545E+00	0.164E+06	-0.363E+04	0.538E-03	0.196E+04	0.211E+11
47.83	0.538E+00	0.204E+06	-0.300E+04	0.536E-03	0.234E+04	0.211E+11
59.79	0.530E+00	0.236E+06	-0.237E+04	0.533E-03	0.265E+04	0.211E+11
71.74	0.520E+00	0.260E+06	-0.174E+04	0.530E-03	0.288E+04	0.211E+11
83.70	0.508E+00	0.277E+06	-0.111E+04	0.525E-03	0.304E+04	0.211E+11
95.66	0.494E+00	0.287E+06	-0.481E+03	0.521E-03	0.313E+04	0.211E+11
107.62	0.478E+00	0.288E+06	0.149E+03	0.515E-03	0.315E+04	0.211E+11
119.57	0.460E+00	0.283E+06	0.779E+03	0.509E-03	0.310E+04	0.211E+11
131.53	0.441E+00	0.269E+06	0.141E+04	0.501E-03	0.297E+04	0.211E+11
143.49	0.419E+00	0.249E+06	0.204E+04	0.493E-03	0.277E+04	0.211E+11
155.45	0.396E+00	0.220E+06	0.267E+04	0.484E-03	0.250E+04	0.211E+11
167.40	0.372E+00	0.184E+06	0.330E+04	0.474E-03	0.215E+04	0.211E+11
179.36	0.346E+00	0.141E+06	0.393E+04	0.462E-03	0.174E+04	0.211E+11
191.32	0.319E+00	0.900E+05	0.456E+04	0.450E-03	0.125E+04	0.211E+11
203.28	0.292E+00	0.315E+05	0.519E+04	0.437E-03	0.686E+03	0.211E+11
215.23	0.264E+00	-0.346E+05	0.582E+04	0.423E-03	0.715E+03	0.211E+11
227.19	0.237E+00	-0.108E+06	0.566E+04	0.795E+02	0.142E+04	0.211E+11
239.15	0.210E+00	-0.170E+06	0.436E+04	0.138E+03	0.202E+04	0.211E+11
251.11	0.184E+00	-0.213E+06	0.249E+04	0.175E+03	0.243E+04	0.211E+11
263.06	0.160E+00	-0.230E+06	0.133E+04	0.200E+02	0.260E+04	0.211E+11

275.02	0.138E+00	-0.245E+06	0.108E+04	0.220E+02	0.274E+04	0.211E+11
286.98	0.117E+00	-0.257E+06	0.806E+03	0.238E+02	0.285E+04	0.211E+11
298.94	0.979E-01	-0.265E+06	0.513E+03	0.251E+02	0.292E+04	0.211E+11
310.89	0.806E-01	-0.269E+06	0.207E+03	0.261E+02	0.297E+04	0.211E+11
322.85	0.651E-01	-0.270E+06	-0.109E+03	0.267E+02	0.298E+04	0.211E+11
334.81	0.514E-01	-0.267E+06	-0.430E+03	0.269E+02	0.295E+04	0.211E+11
346.77	0.395E-01	-0.260E+06	-0.751E+03	0.267E+02	0.288E+04	0.211E+11

NUMBER OF ITERATIONS IN LLP =   18

* PILE GROUP * 2

PILE TOP DISPLACEMENTS AND REACTIONS

THE GLOBAL STRUCTURE COORDINATE SYSTEM

XDISPL,IN	YDISPL,IN	SLOPE	AXIAL,LBS	LAT,LBS	BM,LBS-IN	STRESS,LBS/IN**2
-0.142E+00	0.525E+00	-.879E-04	0.485E+05	0.128E+05	0.000E+00	0.232E+04

THE LOCAL MEMBER COORDINATE SYSTEM

XDISPL,IN	YDISPL,IN	SLOPE	AXIAL,LBS	LAT,LBS	BM,LBS-IN	STRESS,LBS/IN**2
0.633E-01	0.541E+00	-.879E-04	0.497E+05	-0.611E+04	0.000E+00	0.232E+04

LATERALLY LOADED PILE

X IN	DEFLECTION IN	MOMENT LBS-IN	SHEAR LBS	SOIL REACTION LBS/IN	TOTAL STRESS LBS/IN**2	FLEXURAL RIGIDITY LBS-IN**2
*****	**********	**********	**********	**********	**********	**********
0.00	0.541E+00	0.000E+00	-0.548E+04	0.464E-03	0.232E+04	0.211E+11
11.96	0.540E+00	0.655E+05	-0.517E+04	0.464E-03	0.295E+04	0.211E+11
23.91	0.538E+00	0.123E+06	-0.454E+04	0.464E-03	0.351E+04	0.211E+11
35.87	0.536E+00	0.174E+06	-0.391E+04	0.463E-03	0.399E+04	0.211E+11
47.83	0.532E+00	0.217E+06	-0.328E+04	0.462E-03	0.440E+04	0.211E+11
59.79	0.527E+00	0.252E+06	-0.265E+04	0.460E-03	0.474E+04	0.211E+11
71.74	0.521E+00	0.279E+06	-0.202E+04	0.458E-03	0.501E+04	0.211E+11
83.70	0.512E+00	0.299E+06	-0.139E+04	0.456E-03	0.520E+04	0.211E+11
95.66	0.501E+00	0.312E+06	-0.758E+03	0.453E-03	0.532E+04	0.211E+11
107.62	0.489E+00	0.316E+06	-0.128E+03	0.449E-03	0.536E+04	0.211E+11
119.57	0.474E+00	0.313E+06	0.502E+03	0.444E-03	0.533E+04	0.211E+11
131.53	0.457E+00	0.303E+06	0.113E+04	0.439E-03	0.523E+04	0.211E+11
143.49	0.438E+00	0.285E+06	0.176E+04	0.433E-03	0.506E+04	0.211E+11
155.45	0.417E+00	0.259E+06	0.239E+04	0.426E-03	0.481E+04	0.211E+11
167.40	0.394E+00	0.225E+06	0.302E+04	0.418E-03	0.449E+04	0.211E+11

179.36	0.370E+00	0.184E+06	0.365E+04	0.409E-03	0.409E+04	0.211E+11
191.32	0.345E+00	0.135E+06	0.428E+04	0.400E-03	0.362E+04	0.211E+11
203.28	0.318E+00	0.790E+05	0.491E+04	0.389E-03	0.308E+04	0.211E+11
215.23	0.291E+00	0.152E+05	0.554E+04	0.378E-03	0.247E+04	0.211E+11
227.19	0.264E+00	-0.562E+05	0.540E+04	0.768E+02	0.286E+04	0.211E+11
239.15	0.238E+00	-0.117E+06	0.425E+04	0.116E+03	0.344E+04	0.211E+11
251.11	0.212E+00	-0.160E+06	0.268E+04	0.146E+03	0.386E+04	0.211E+11
263.06	0.187E+00	-0.183E+06	0.170E+04	0.182E+02	0.408E+04	0.211E+11
275.02	0.164E+00	-0.203E+06	0.147E+04	0.202E+02	0.428E+04	0.211E+11
286.98	0.142E+00	-0.221E+06	0.122E+04	0.219E+02	0.444E+04	0.211E+11
298.94	0.121E+00	-0.235E+06	0.948E+03	0.233E+02	0.458E+04	0.211E+11
310.89	0.102E+00	-0.245E+06	0.662E+03	0.244E+02	0.468E+04	0.211E+11

NUMBER OF ITERATIONS IN LLP = 18

* PILE GROUP * 3

PILE TOP DISPLACEMENTS AND REACTIONS

THE GLOBAL STRUCTURE COORDINATE SYSTEM

XDISPL,IN	YDISPL,IN	SLOPE	AXIAL,LBS	LAT,LBS	BM,LBS-IN	STRESS,LBS/IN**2
-0.850E-01	0.525E+00	-.116E-05	0.773E+05	0.243E+05	0.000E+00	0.378E+04

THE LOCAL MEMBER COORDINATE SYSTEM

XDISPL,IN	YDISPL,IN	SLOPE	AXIAL,LBS	LAT,LBS	BM,LBS-IN	STRESS,LBS/IN**2
0.116E+00	0.519E+00	-.116E-05	0.808E+05	-0.617E+04	0.000E+00	0.378E+04

LATERALLY LOADED PILE

X IN	DEFLECTION IN	MOMENT LBS-IN	SHEAR LBS	SOIL REACTION LBS/IN	TOTAL STRESS LBS/IN**2	FLEXURAL RIGIDITY LBS-IN**2
*****	**********	**********	**********	**********	**********	**********
0.00	0.519E+00	0.000E+00	-0.554E+04	0.458E-03	0.378E+04	0.211E+11
11.96	0.519E+00	0.662E+05	-0.522E+04	0.458E-03	0.441E+04	0.211E+11
23.91	0.519E+00	0.125E+06	-0.459E+04	0.458E-03	0.498E+04	0.211E+11
35.87	0.518E+00	0.176E+06	-0.396E+04	0.458E-03	0.547E+04	0.211E+11
47.83	0.515E+00	0.219E+06	-0.333E+04	0.457E-03	0.588E+04	0.211E+11
59.79	0.511E+00	0.255E+06	-0.270E+04	0.456E-03	0.623E+04	0.211E+11
71.74	0.505E+00	0.283E+06	-0.207E+04	0.454E-03	0.650E+04	0.211E+11
83.70	0.498E+00	0.303E+06	-0.144E+04	0.452E-03	0.669E+04	0.211E+11
95.66	0.488E+00	0.316E+06	-0.811E+03	0.449E-03	0.681E+04	0.211E+11

107.62	0.476E+00	0.321E+06	-0.181E+03	0.445E-03	0.686E+04	0.211E+11
119.57	0.462E+00	0.318E+06	0.449E+03	0.441E-03	0.683E+04	0.211E+11
131.53	0.446E+00	0.308E+06	0.108E+04	0.435E-03	0.673E+04	0.211E+11
143.49	0.428E+00	0.290E+06	0.171E+04	0.429E-03	0.656E+04	0.211E+11
155.45	0.408E+00	0.264E+06	0.234E+04	0.423E-03	0.631E+04	0.211E+11
167.40	0.386E+00	0.230E+06	0.297E+04	0.415E-03	0.599E+04	0.211E+11
179.36	0.362E+00	0.189E+06	0.360E+04	0.406E-03	0.559E+04	0.211E+11
191.32	0.338E+00	0.140E+06	0.423E+04	0.397E-03	0.513E+04	0.211E+11
203.28	0.312E+00	0.840E+05	0.486E+04	0.386E-03	0.458E+04	0.211E+11
215.23	0.285E+00	0.200E+05	0.549E+04	0.375E-03	0.397E+04	0.211E+11
227.19	0.259E+00	-0.516E+05	0.536E+04	0.753E+02	0.427E+04	0.211E+11
239.15	0.233E+00	-0.112E+06	0.421E+04	0.116E+03	0.486E+04	0.211E+11
251.11	0.208E+00	-0.156E+06	0.264E+04	0.147E+03	0.528E+04	0.211E+11
263.06	0.183E+00	-0.179E+06	0.165E+04	0.181E+02	0.550E+04	0.211E+11
275.02	0.160E+00	-0.200E+06	0.142E+04	0.201E+02	0.569E+04	0.211E+11
286.98	0.138E+00	-0.217E+06	0.117E+04	0.217E+02	0.586E+04	0.211E+11
298.94	0.118E+00	-0.231E+06	0.905E+03	0.232E+02	0.600E+04	0.211E+11
310.89	0.995E-01	-0.242E+06	0.621E+03	0.243E+02	0.610E+04	0.211E+11
322.85	0.825E-01	-0.249E+06	0.326E+03	0.250E+02	0.617E+04	0.211E+11
334.81	0.671E-01	-0.252E+06	0.244E+02	0.255E+02	0.620E+04	0.211E+11
346.77	0.534E-01	-0.252E+06	-0.281E+03	0.256E+02	0.619E+04	0.211E+11

NUMBER OF ITERATIONS IN LLP = 16

* PILE GROUP * 4

PILE TOP DISPLACEMENTS AND REACTIONS

THE GLOBAL STRUCTURE COORDINATE SYSTEM

XDISPL,IN	YDISPL,IN	SLOPE	AXIAL,LBS	LAT,LBS	BM,LBS-IN	STRESS,LBS/IN**2
-0.279E-01	0.525E+00	0.585E-03	0.107E+06	0.347E+05	0.000E+00	0.523E+04

THE LOCAL MEMBER COORDINATE SYSTEM

XDISPL,IN	YDISPL,IN	SLOPE	AXIAL,LBS	LAT,LBS	BM,LBS-IN	STRESS,LBS/IN**2
0.169E+00	0.498E+00	0.585E-03	0.112E+06	-0.736E+04	0.000E+00	0.523E+04

LATERALLY LOADED PILE

X IN	DEFLECTION IN	MOMENT LBS-IN	SHEAR LBS	SOIL REACTION LBS/IN	TOTAL STRESS LBS/IN**2	FLEXURAL RIGIDITY LBS-IN**2
*****	**********	**********	**********	**********	**********	**********
0.00	0.498E+00	0.000E+00	-0.664E+04	0.452E-03	0.523E+04	0.211E+11

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     11.96  0.505E+00  0.802E+05 -0.628E+04  0.454E-03  0.600E+04  0.211E+11
     23.91  0.512E+00  0.152E+06 -0.555E+04  0.456E-03  0.668E+04  0.211E+11
     35.87  0.517E+00  0.214E+06 -0.483E+04  0.457E-03  0.729E+04  0.211E+11
     47.83  0.521E+00  0.268E+06 -0.410E+04  0.459E-03  0.780E+04  0.211E+11
     59.79  0.523E+00  0.313E+06 -0.338E+04  0.459E-03  0.823E+04  0.211E+11
     71.74  0.523E+00  0.349E+06 -0.265E+04  0.459E-03  0.858E+04  0.211E+11
     83.70  0.521E+00  0.376E+06 -0.193E+04  0.459E-03  0.884E+04  0.211E+11
     95.66  0.516E+00  0.394E+06 -0.120E+04  0.457E-03  0.902E+04  0.211E+11
    107.62  0.509E+00  0.404E+06 -0.479E+03  0.455E-03  0.910E+04  0.211E+11
    119.57  0.498E+00  0.404E+06  0.246E+03  0.452E-03  0.911E+04  0.211E+11
    131.53  0.485E+00  0.395E+06  0.970E+03  0.448E-03  0.902E+04  0.211E+11
    143.49  0.470E+00  0.377E+06  0.169E+04  0.443E-03  0.885E+04  0.211E+11
    155.45  0.451E+00  0.351E+06  0.242E+04  0.437E-03  0.860E+04  0.211E+11
    167.40  0.431E+00  0.315E+06  0.314E+04  0.430E-03  0.826E+04  0.211E+11
    179.36  0.408E+00  0.271E+06  0.387E+04  0.423E-03  0.783E+04  0.211E+11
    191.32  0.384E+00  0.217E+06  0.459E+04  0.414E-03  0.732E+04  0.211E+11
    203.28  0.358E+00  0.155E+06  0.532E+04  0.404E-03  0.672E+04  0.211E+11
    215.23  0.330E+00  0.843E+05  0.604E+04  0.394E-03  0.604E+04  0.211E+11
    227.19  0.303E+00  0.467E+04  0.588E+04  0.880E+02  0.527E+04  0.211E+11
    239.15  0.275E+00 -0.624E+05  0.469E+04  0.112E+03  0.583E+04  0.211E+11
    251.11  0.248E+00 -0.114E+06  0.318E+04  0.140E+03  0.632E+04  0.211E+11
    263.06  0.221E+00 -0.144E+06  0.222E+04  0.193E+02  0.662E+04  0.211E+11
    275.02  0.196E+00 -0.173E+06  0.198E+04  0.214E+02  0.689E+04  0.211E+11
    286.98  0.172E+00 -0.197E+06  0.171E+04  0.234E+02  0.712E+04  0.211E+11
    298.94  0.149E+00 -0.219E+06  0.142E+04  0.250E+02  0.733E+04  0.211E+11
    310.89  0.127E+00 -0.236E+06  0.112E+04  0.263E+02  0.750E+04  0.211E+11
    322.85  0.107E+00 -0.250E+06  0.796E+03  0.273E+02  0.763E+04  0.211E+11
    334.81  0.889E-01 -0.260E+06  0.466E+03  0.280E+02  0.772E+04  0.211E+11
    346.77  0.724E-01 -0.265E+06  0.129E+03  0.283E+02  0.778E+04  0.211E+11
    358.72  0.577E-01 -0.266E+06 -0.209E+03  0.282E+02  0.779E+04  0.211E+11
    NUMBER OF ITERATIONS IN LLP =    21


      * PILE GROUP *   5


 PILE TOP DISPLACEMENTS AND REACTIONS


      THE GLOBAL STRUCTURE COORDINATE SYSTEM
      --------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN
STRESS,LBS/IN**2

 0.343E-01  0.525E+00 0.321E-02-0.108E+06 0.282E+05 0.000E+00   0.518E+04


      THE LOCAL MEMBER COORDINATE SYSTEM
      ------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN
STRESS,LBS/IN**2

-0.163E+00  0.501E+00 0.321E-02-0.111E+06-0.140E+05 0.000E+00   0.518E+04
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LATERALLY LOADED PILE

X IN	DEFLECTION IN	MOMENT LBS-IN	SHEAR LBS	SOIL REACTION LBS/IN	TOTAL STRESS LBS/IN**2	FLEXURAL RIGIDITY LBS-IN**2
*****	**********	**********	**********	**********	**********	**********
0.00	0.501E+00	0.000E+00	-0.124E+05	0.468E-03	0.518E+04	0.211E+11
14.44	0.547E+00	0.174E+06	-0.117E+05	0.482E-03	0.685E+04	0.211E+11
28.87	0.592E+00	0.327E+06	-0.102E+05	0.495E-03	0.832E+04	0.211E+11
43.31	0.633E+00	0.458E+06	-0.865E+04	0.506E-03	0.958E+04	0.211E+11
57.74	0.670E+00	0.568E+06	-0.714E+04	0.515E-03	0.106E+05	0.211E+11
72.18	0.701E+00	0.657E+06	-0.562E+04	0.523E-03	0.115E+05	0.211E+11
86.62	0.726E+00	0.724E+06	-0.410E+04	0.529E-03	0.121E+05	0.211E+11
101.05	0.744E+00	0.771E+06	-0.259E+04	0.534E-03	0.126E+05	0.211E+11
115.49	0.754E+00	0.796E+06	-0.107E+04	0.536E-03	0.128E+05	0.211E+11
129.93	0.756E+00	0.800E+06	0.443E+03	0.537E-03	0.129E+05	0.211E+11
144.36	0.750E+00	0.784E+06	0.196E+04	0.535E-03	0.127E+05	0.211E+11
158.80	0.737E+00	0.746E+06	0.347E+04	0.532E-03	0.123E+05	0.211E+11
173.23	0.716E+00	0.687E+06	0.499E+04	0.527E-03	0.118E+05	0.211E+11
187.67	0.689E+00	0.607E+06	0.651E+04	0.520E-03	0.110E+05	0.211E+11
202.11	0.655E+00	0.506E+06	0.802E+04	0.512E-03	0.100E+05	0.211E+11
216.54	0.617E+00	0.384E+06	0.871E+04	0.906E+01	0.886E+04	0.211E+11
230.98	0.575E+00	0.263E+06	0.811E+04	0.743E+02	0.771E+04	0.211E+11
245.41	0.530E+00	0.159E+06	0.689E+04	0.948E+02	0.671E+04	0.211E+11
259.85	0.483E+00	0.746E+05	0.603E+04	0.247E+02	0.590E+04	0.211E+11
274.29	0.436E+00	-0.466E+04	0.564E+04	0.287E+02	0.522E+04	0.211E+11
288.72	0.389E+00	-0.779E+05	0.520E+04	0.323E+02	0.593E+04	0.211E+11
303.16	0.343E+00	-0.145E+06	0.471E+04	0.354E+02	0.657E+04	0.211E+11
317.60	0.298E+00	-0.204E+06	0.418E+04	0.381E+02	0.714E+04	0.211E+11
332.03	0.255E+00	-0.256E+06	0.362E+04	0.403E+02	0.763E+04	0.211E+11
346.47	0.215E+00	-0.299E+06	0.302E+04	0.419E+02	0.805E+04	0.211E+11
360.90	0.177E+00	-0.334E+06	0.241E+04	0.430E+02	0.839E+04	0.211E+11
375.34	0.143E+00	-0.361E+06	0.179E+04	0.428E+02	0.864E+04	0.211E+11
389.78	0.112E+00	-0.379E+06	0.120E+04	0.395E+02	0.882E+04	0.211E+11
404.21	0.855E-01	-0.389E+06	0.652E+03	0.361E+02	0.891E+04	0.211E+11
418.65	0.625E-01	-0.392E+06	-0.916E+02	0.669E+02	0.894E+04	0.211E+11
433.09	0.434E-01	-0.382E+06	-0.102E+04	0.613E+02	0.884E+04	0.211E+11
447.52	0.280E-01	-0.359E+06	-0.185E+04	0.548E+02	0.863E+04	0.211E+11
461.96	0.161E-01	-0.325E+06	-0.259E+04	0.471E+02	0.830E+04	0.211E+11
476.39	0.749E-02	-0.282E+06	-0.320E+04	0.377E+02	0.789E+04	0.211E+11
490.83	0.162E-02	-0.231E+06	-0.364E+04	0.234E+02	0.740E+04	0.211E+11
505.27	-0.196E-02	-0.176E+06	-0.362E+04	-0.258E+02	0.687E+04	0.211E+11
519.70	-0.382E-02	-0.126E+06	-0.320E+04	-0.332E+02	0.639E+04	0.211E+11
534.14	-0.444E-02	-0.830E+05	-0.270E+04	-0.360E+02	0.598E+04	0.211E+11
548.57	-0.424E-02	-0.478E+05	-0.218E+04	-0.366E+02	0.564E+04	0.211E+11
563.01	-0.356E-02	-0.203E+05	-0.166E+04	-0.356E+02	0.537E+04	0.211E+11
577.45	-0.269E-02	-0.204E+03	-0.116E+04	-0.335E+02	0.518E+04	0.211E+11
591.88	-0.181E-02	0.129E+05	-0.697E+03	-0.303E+02	0.530E+04	0.211E+11
606.32	-0.107E-02	0.197E+05	-0.289E+03	-0.261E+02	0.537E+04	0.211E+11
620.76	-0.512E-03	0.211E+05	0.518E+02	-0.211E+02	0.538E+04	0.211E+11
635.19	-0.167E-03	0.181E+05	0.313E+03	-0.150E+02	0.535E+04	0.211E+11
649.63	-0.166E-06	0.120E+05	0.431E+03	-0.147E+01	0.529E+04	0.211E+11
664.06	0.478E-04	0.565E+04	0.366E+03	0.105E+02	0.523E+04	0.211E+11
678.50	0.401E-04	0.147E+04	0.216E+03	0.102E+02	0.519E+04	0.211E+11
692.94	0.178E-04	-0.582E+03	0.838E+02	0.808E+01	0.518E+04	0.211E+11
707.37	0.135E-05	-0.947E+03	-0.337E+00	0.357E+01	0.519E+04	0.211E+11
721.81	-0.579E-05	-0.569E+03	-0.233E+02	-0.393E+00	0.518E+04	0.211E+11

736.24	-0.733E-05	-0.274E+03	-0.168E+02	-0.506E+00	0.518E+04	0.211E+11
750.68	-0.616E-05	-0.841E+02	-0.100E+02	-0.433E+00	0.518E+04	0.211E+11
765.12	-0.416E-05	0.154E+02	-0.476E+01	-0.298E+00	0.518E+04	0.211E+11
779.55	-0.231E-05	0.528E+02	-0.139E+01	-0.168E+00	0.518E+04	0.211E+11
793.99	-0.982E-06	0.552E+02	0.352E+00	-0.729E-01	0.518E+04	0.211E+11
808.43	-0.199E-06	0.424E+02	0.987E+00	-0.150E-01	0.518E+04	0.211E+11
822.86	0.167E-06	0.265E+02	0.100E+01	0.128E-01	0.518E+04	0.211E+11
837.30	0.271E-06	0.134E+02	0.758E+00	0.211E-01	0.518E+04	0.211E+11
851.73	0.243E-06	0.465E+01	0.466E+00	0.193E-01	0.518E+04	0.211E+11
866.17	0.169E-06	-0.705E-01	0.229E+00	0.136E-01	0.518E+04	0.211E+11
880.61	0.957E-07	-0.195E+01	0.741E-01	0.785E-02	0.518E+04	0.211E+11
895.04	0.419E-07	-0.220E+01	-0.772E-02	0.349E-02	0.518E+04	0.211E+11
909.48	0.965E-08	-0.172E+01	-0.388E-01	0.816E-03	0.518E+04	0.211E+11
923.91	-0.565E-08	-0.107E+01	-0.412E-01	-0.485E-03	0.518E+04	0.211E+11
938.35	-0.104E-07	-0.526E+00	-0.311E-01	-0.906E-03	0.518E+04	0.211E+11
952.79	-0.995E-08	-0.172E+00	-0.182E-01	-0.879E-03	0.518E+04	0.211E+11
967.22	-0.781E-08	-0.128E-03	-0.683E-02	-0.700E-03	0.518E+04	0.211E+11
981.66	-0.567E-08	0.253E-01	-0.132E-02	-0.638E-04	0.518E+04	0.211E+11
996.10	-0.378E-08	0.374E-01	-0.528E-03	-0.454E-04	0.518E+04	0.211E+11
1010.53	-0.226E-08	0.401E-01	0.878E-05	-0.289E-04	0.518E+04	0.211E+11
1024.97	-0.113E-08	0.369E-01	0.328E-03	-0.154E-04	0.518E+04	0.211E+11
1039.40	-0.371E-09	0.305E-01	0.478E-03	-0.532E-05	0.518E+04	0.211E+11
1053.84	0.905E-10	0.230E-01	0.506E-03	0.137E-05	0.518E+04	0.211E+11
1068.28	0.326E-09	0.158E-01	0.459E-03	0.518E-05	0.518E+04	0.211E+11
1082.71	0.406E-09	0.966E-02	0.373E-03	0.676E-05	0.518E+04	0.211E+11
1097.15	0.390E-09	0.499E-02	0.275E-03	0.681E-05	0.518E+04	0.211E+11
1111.59	0.326E-09	0.173E-02	0.183E-03	0.593E-05	0.518E+04	0.211E+11
1126.02	0.244E-09	-0.279E-03	0.107E-03	0.463E-05	0.518E+04	0.211E+11
1140.46	0.165E-09	-0.133E-02	0.497E-04	0.326E-05	0.518E+04	0.211E+11
1154.89	0.992E-10	-0.170E-02	0.114E-04	0.204E-05	0.518E+04	0.211E+11
1169.33	0.501E-10	-0.164E-02	-0.110E-04	0.107E-05	0.518E+04	0.211E+11
1183.77	0.172E-10	-0.137E-02	-0.214E-04	0.380E-06	0.518E+04	0.211E+11
1198.20	-0.214E-11	-0.102E-02	-0.238E-04	-0.489E-07	0.518E+04	0.211E+11
1212.64	-0.114E-10	-0.680E-03	-0.215E-04	-0.270E-06	0.518E+04	0.211E+11
1227.07	-0.140E-10	-0.397E-03	-0.171E-04	-0.342E-06	0.518E+04	0.211E+11
1241.51	-0.127E-10	-0.186E-03	-0.123E-04	-0.320E-06	0.518E+04	0.211E+11
1255.95	-0.954E-11	-0.416E-04	-0.823E-05	-0.248E-06	0.518E+04	0.211E+11
1270.38	-0.597E-11	0.510E-04	-0.529E-05	-0.160E-06	0.518E+04	0.211E+11
1284.82	-0.291E-11	0.110E-03	-0.165E-05	-0.344E-06	0.518E+04	0.211E+11
1299.26	-0.936E-12	0.982E-04	0.163E-05	-0.112E-06	0.518E+04	0.211E+11
1313.69	0.709E-13	0.629E-04	0.238E-05	0.856E-08	0.518E+04	0.211E+11
1328.13	0.458E-12	0.294E-04	0.191E-05	0.559E-07	0.518E+04	0.211E+11
1342.56	0.556E-12	0.753E-05	0.102E-05	0.686E-07	0.518E+04	0.211E+11
1357.00	0.580E-12	0.000E+00	0.357E-22	0.722E-07	0.518E+04	0.211E+11

NUMBER OF ITERATIONS IN LLP = 16

Design Example #3

A cross section of the wall section used for Example 3 is shown in Figure 1, and is based on a wall constructed in New Orleans at Gainard Woods. The water level used in this example is elevation 17.0' and assumed to be a top of wall load case. The target factor of safety was chosen to be 1.5 in this example rather than the required 1.4 (for demonstration purposes) to provide a greater disparity from the without pile factor of safety. The water level on the protected side is assumed to be at the bottom of footing as the ground slopes toward a canal on the protected side. The soil information for this example is listed in Table 1.

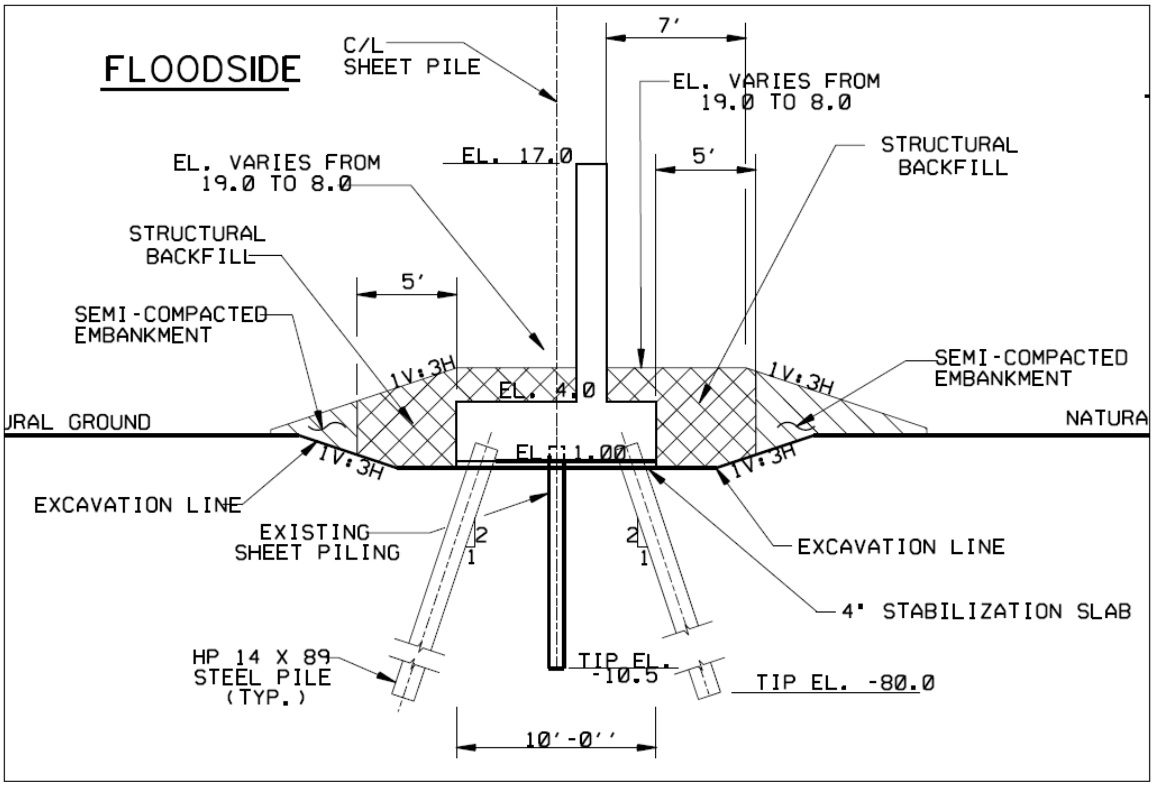


Figure 1. Wall Geometry.

Table 1. Soil Properties

Top of Layer Elevation, ft	Saturated Unit Weight, pcf	Undrained Shear Strength, psf	Friction Angle, Phi
4	108	400	0
2	86	300	0
-7	98	300	0
-10	100	300	0
-22	120	0	30
-27	100	320	0
-40	100	450	0
-45	100	450	0

Step 1 Initial Slope Stability Analysis

Perform a Spencer's method slope stability analysis to determine the critical slip surface with the water load only on the ground surface and no piles. UTexas4 was used in this example for all of the slope stability analysis. For the design example, the critical failure surface is shown in Figure 2 where the factor of safety is 1.34. Because this value is less than the required value of 1.5, the T-Wall will need to carry an unbalanced load in addition to any loads on the structure.

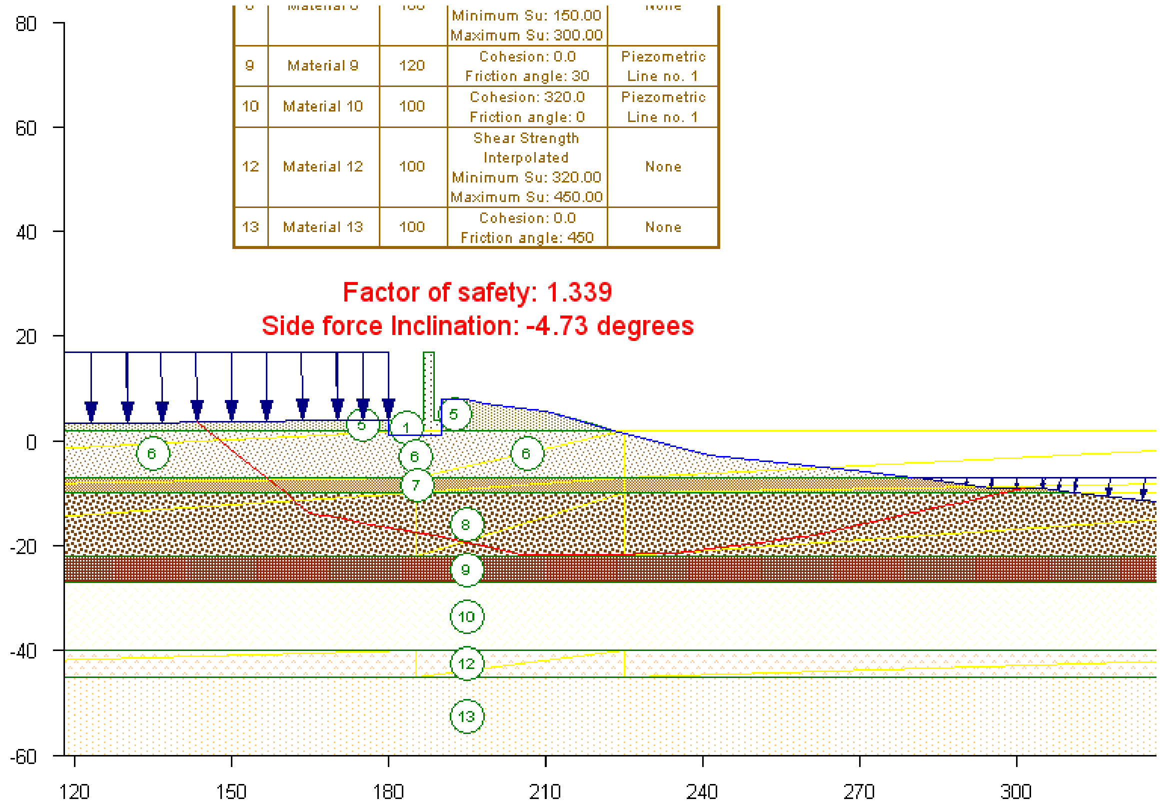


Figure 2. Spencer's analysis of the T-Wall without piles.

Step 2 Unbalanced Force Computations

Determine (unbalanced) forces required to provide the required global stability factor of safety. The critical failure surface extends down to elevation -22' in this example. The elevation of the ground surface at the heel of the T-Wall is at elevation 4'. It is assumed that the unbalanced load is halfway between these two elevations. Apply a line load at elevation -9', at the midpoint of the expected base width (for a non-circular failure surface). A line load of 3800 lb/ft at this location results in F=1.50. The target factor of safety is 1.5 so the computed unbalanced load is slightly too low in this example.

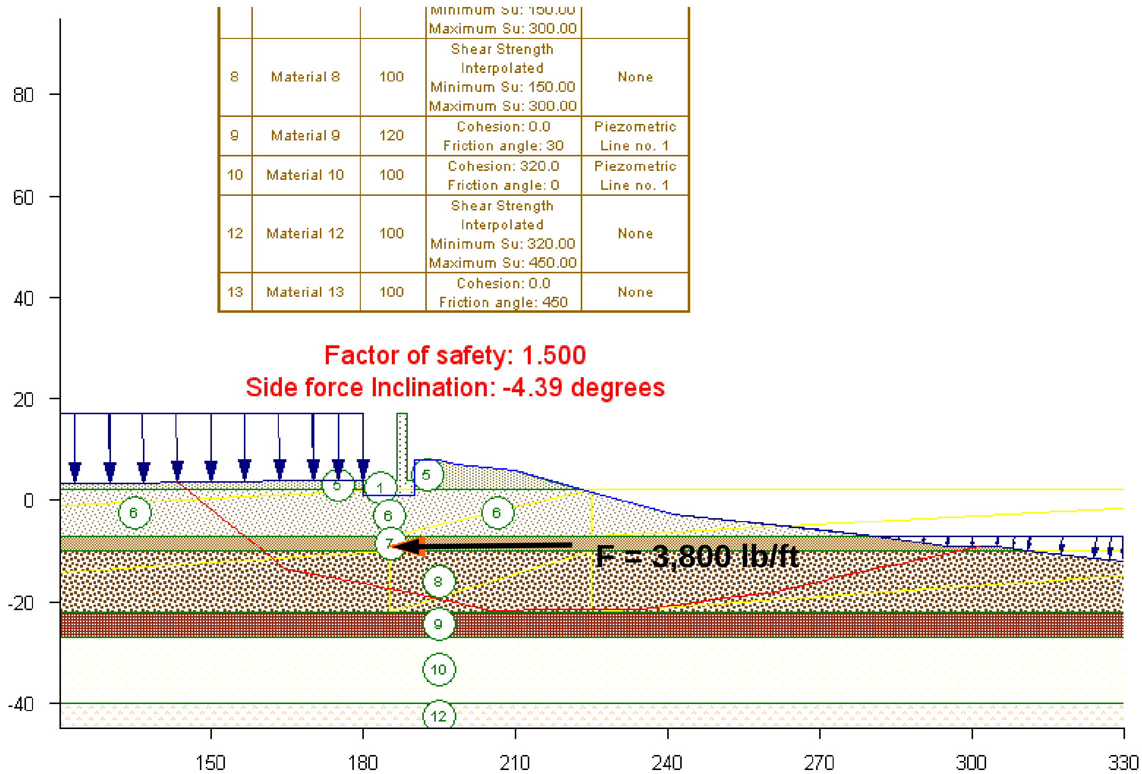


Figure 3. Spencer's analysis of the T-Wall with an unbalanced load to increase global stability (note FS is slightly below target FS=1.5 in this example).

It should be noted that a search for the critical failure surface was performed with the unbalanced load shown in Figure 3. The search ensures that if the pile foundation of the T-Wall can safely carry the unbalanced load in addition to any other loads on the structure, the global stability will meet the required factor of safety. The UTexas4 input files for Figures 2 and 3 are attached at the end of this example.

Step 3 Allowable Pile Capacity Analysis

3.1 For the preliminary analysis, allowable pile capacities determined by engineers in New Orleans District for the original design of this project are shown in Figure 4 for ultimate loads vs. depth. The solid line is for the Q case and the dashed line is for the S case. For water to the top of wall under hurricane surge loadings with fine grained soils, the Q case will be used. No axial capacity is accounted for above the lowest elevation of the critical surface in the graph. Since this is treated as a still water load case, the allowable load factor is 3.0.

From the figures below and knowing that maximum pile loads in compression will be about 65 kips, the required ultimate capacity is 65*3/2kips/ton = 98 tons. This would be a pile driven depth to about 100 feet from Figure 4. The tensile capacity is about the same.

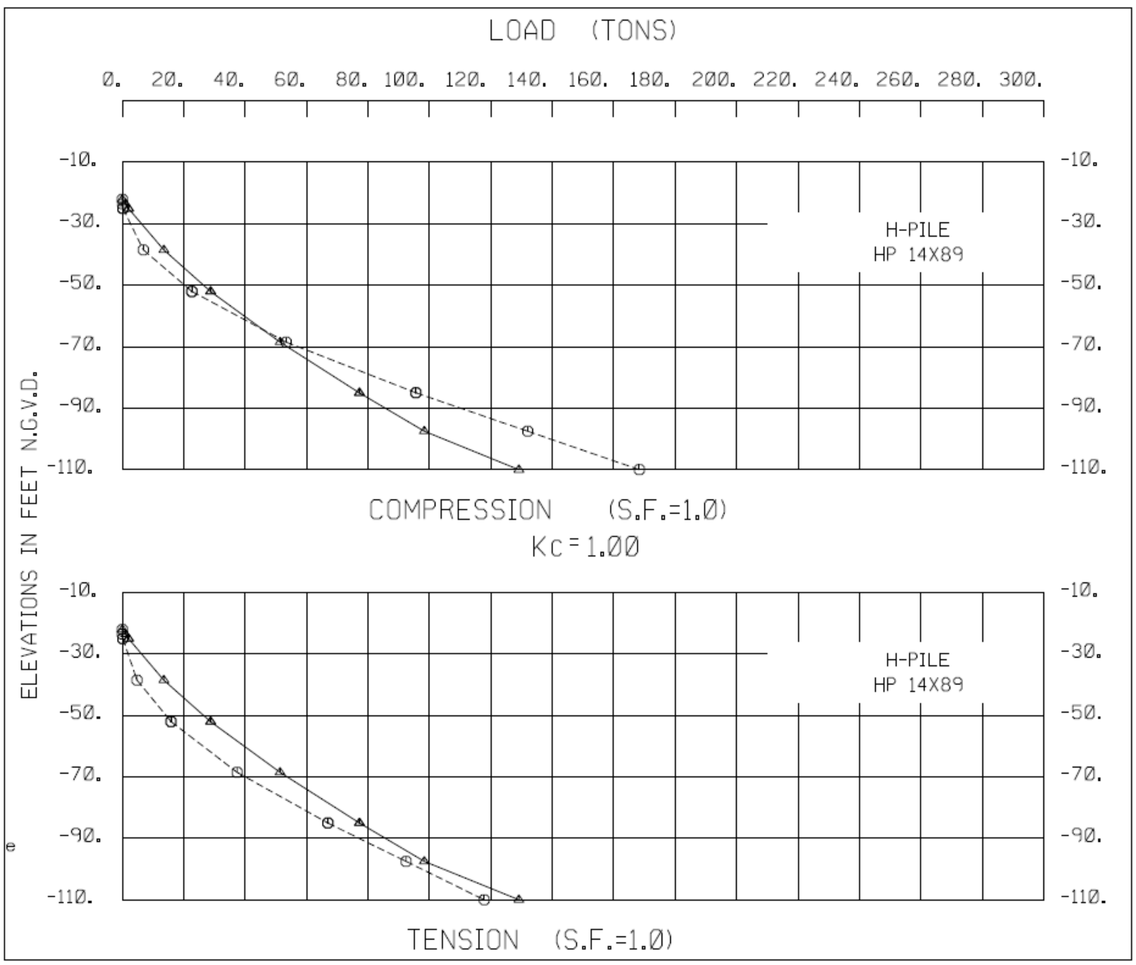


Figure 4. Ultimate Axial Capacity with Depth, Calculated

3.2 The allowable shear load (from LPILE or COM624G) is determined from pile head deflection versus lateral load plot. This was not determined for this problem.

Step 4 Initial T-wall and Pile Design

4.1 Use CPGA to analyze all load cases and perform a preliminary pile and T-wall design. The unbalanced force is converted to an "equivalent" force applied to the bottom of the T-wall, F_{cap}, as calculated as shown below (See Figure 5):

$$F_{cap} = F_{ub}\left[\frac{\left(\frac{L_u}{2}+R\right)}{\left(L_p+R\right)}\right]$$

Where:

F_{ub} = unbalanced force computed in step 2.

L_u = distance from top of ground to lowest el. of critical failure surface (in)

L_p = distance from bottom of footing to lowest el. of crit. failure surface (in)

$$R = \sqrt[4]{\frac{EI}{Es}}$$

E = Modulus of Elasticity of Pile (lb/in^2)

I = Moment of Inertia of Pile (in^4)

Es = Modulus of Subgrade Reaction (lb/in^2) below critical failure surface. In New Orleans District this equates to the values listed as K_HB.

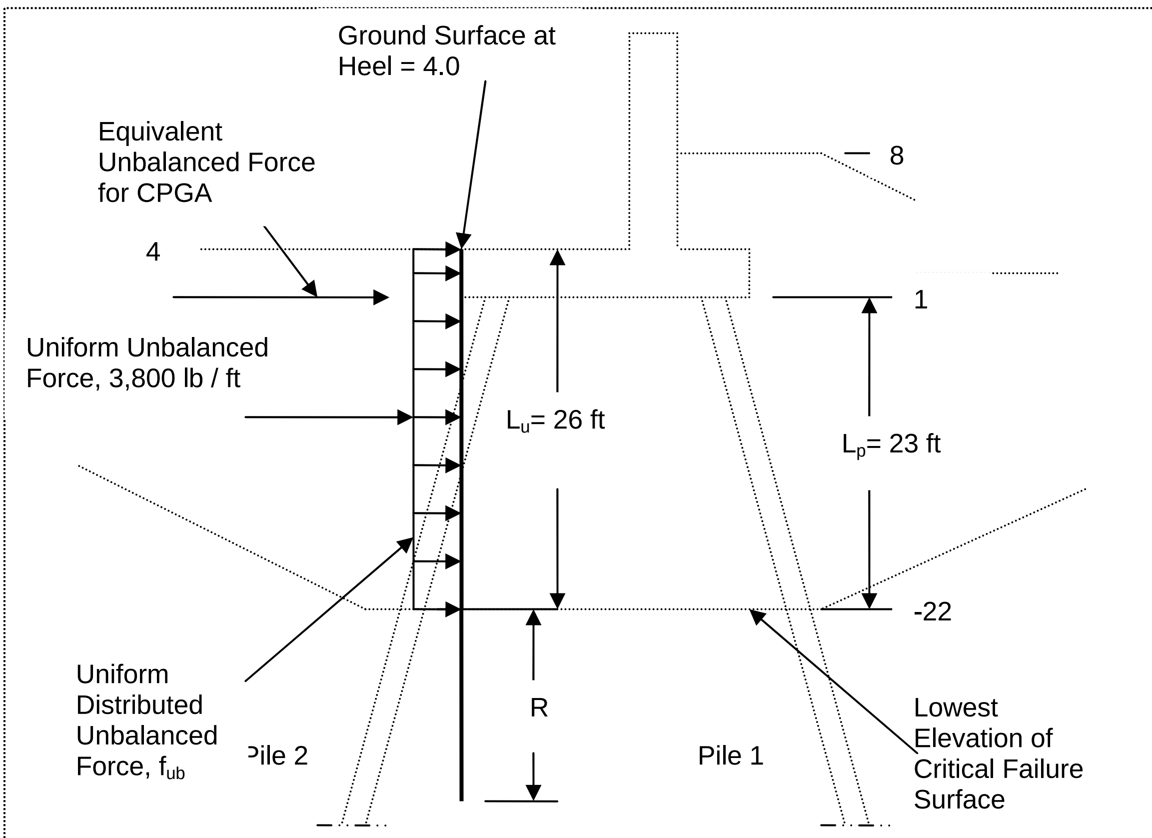


Figure 5. Equivalent Force Computation for Preliminary Design with CPGA

For the solution:
Piles = HP 14x89.   I = 904 in^4, E = 29,000,000 psi

Soils – the stiffness, Es, below the failure surface is shown in Figure 6. Based on this a value of 120 psi is used.

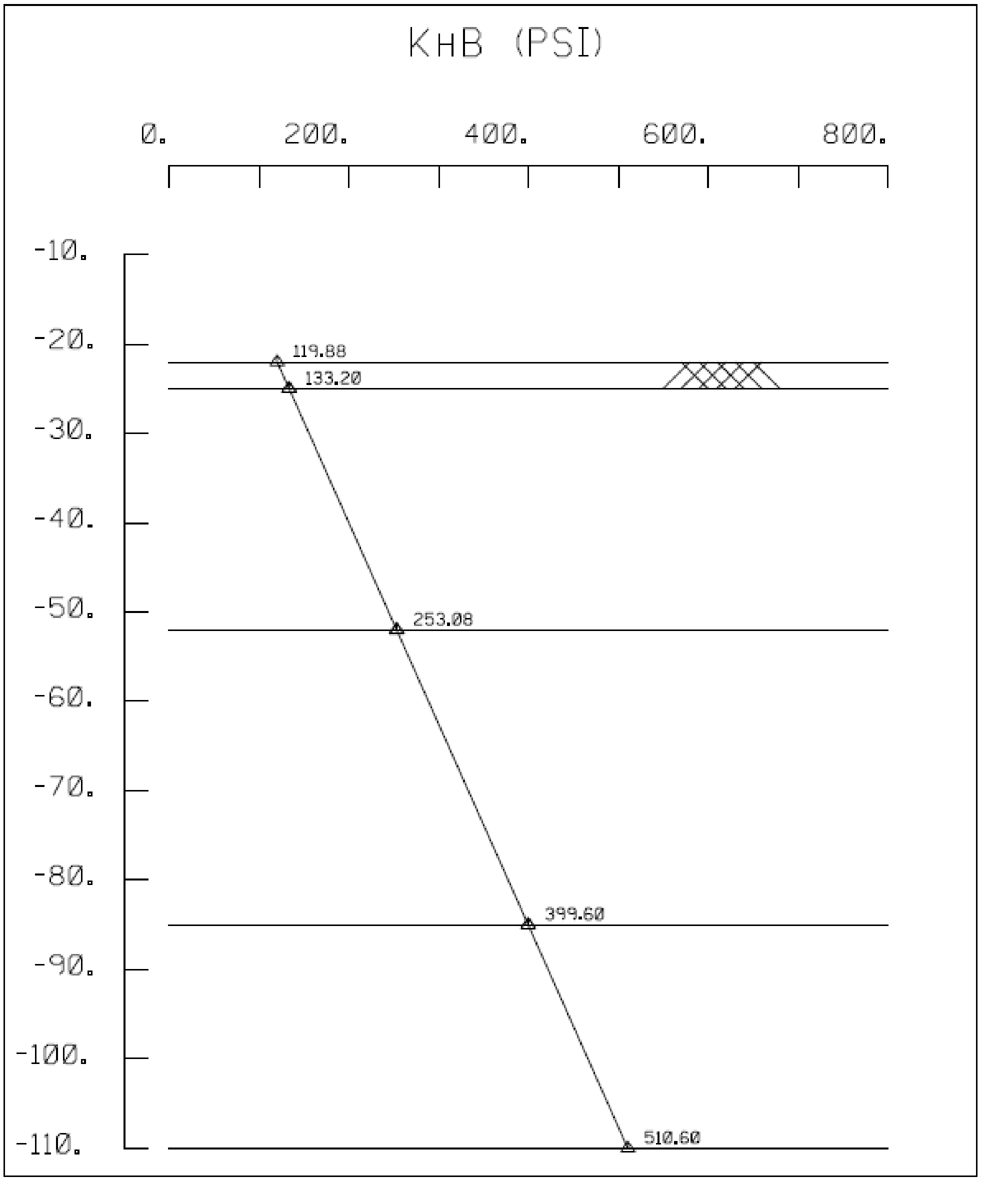


Figure 6. Soil Stiffness with Depth

R therefore is equal to 120 in = 10 feet

P_{cap} = 3800 * (26/2 + 10) / (23 + 10) = 2648 lb/ft

4.2 This unbalanced force is then analyzed with appropriate load cases in CPGA. Generally 8 to 20 load cases may be analyzed depending on expected load conditions. For this example, only the water at top of wall case is analyzed but both pervious and impervious foundation conditions are evaluated. See the spreadsheet calculations in Attachment 3 for the computation of the input for CPGA. The model is a 5 foot strip of the pile foundation.

For the CPGA analysis, the soil modulus, Es is adjusted based on the global stability factor of safety. For this example case, the factor of safety is 1.34. Es for CPGA is computed from the ratio of the computed factor of safety to the target factor of safety. At the bottom of the wall footing, the soil has a shear strength of about 300 psf. Es = 0.2222 Qu B. Therefore, Es = 0.2222(300)(14/12) = 78 psi = at the bottom of the wall footing. Computing Es based on reduction of factor of safety:

CPGA Es = (1.34-1.0) / (1.5 – 1.0) * 78 = 46 psi

4.3. Group reductions are according to EM 1110-2-2906. Since the pile spacing is greater than 8B in the direction of load and 2.5B parallel to the load, no reduction is necessary.

The CPGA output is shown in Attachment 4. A summary of results for the two load conditions analyzed are shown below:

```
          PILE FORCES IN LOCAL GEOMETRY

              M1 & M2 NOT AT PILE HEAD FOR PINNED PILES
              * INDICATES PILE FAILURE
              # INDICATES CBF BASED ON MOMENTS DUE TO
                          (F3*EMIN) FOR CONCRETE PILES
              B INDICATES BUCKLING CONTROLS
```

LOAD CASE - 1 Pervious Condition

PILE	F1 K	F2 K	F3 K	M1 IN-K	M2 IN-K	M3 IN-K	ALF	CBF
1	3.7	.0	62.5	.0	-259.0	.0	.96	.25
2	-4.1	.0	-13.7	.0	289.5	.0	.21	.13

LOAD CASE - 2 Impervious Condition

PILE	F1 K	F2 K	F3 K	M1 IN-K	M2 IN-K	M3 IN-K	ALF	CBF
1	2.4	.0	65.0	.0	-171.6	.0	1.00	.23
2	-2.9	.0	-16.2	.0	202.1	.0	.25	.11

```
Where:
F1 =  Shear in pile at pile cap perpendicular to wall
F2 =  Shear in Pile at Pile Cap parallel to wall
F3 =  Axial Load in Pile
M1 =  Maximum moment in pile perpendicular to wall
M2 =  Maximum moment in pile parallel to wall
M3 =  Torsion in pile
ALF=  Axial load factor – computed axial load divided by allowable load
CBF=  Combined Bending factor – combined computed axial and bending
forces relative to allowable forces
```

The pile layout is adequate according to the CPGA analysis.

Computed deflections from the CPGA analysis are shown below:

PILE CAP DISPLACEMENTS

LOAD CASE	DX IN	DZ IN	R RAD
1	-.7541E+00	-.2047E+00	-.5023E-02
2	-.5370E+00	-.4687E-01	-.2391E-02

These deflections are a bit more than the allowable vertical deflection (DZ) of 0.5 inches and allowable horizontal deflection (DX) of 0.75 inches from the Hurricane and Storm Damage Reduction Design Guidelines.

4.4 Sheet pile design. Seepage design of the sheet pile is not performed for this example.

4.5 Check for resistance against flow through. Since the pile spacing is uniform, we will analyze one row of piles parallel with the loading rather than the entire monolith.

a. Compute the resistance of the flood side row of piles.

$$\sum P_{all} = \frac{n \sum P_{ult}}{1.5}$$

Where:

n = number of piles in the row within a monolith. Or, for monoliths with uniformly spaced pile rows, n = 1. Use 1 for this example

$P_{ult} = \beta(9S_u b)$

S_u = soil shear strength

b = pile width = 14”

β = group reduction factor pile spacing parallel to the load - since the piles batter opposite to each other, there group affects are not computed.

For the soils under the slab, S_u = 300 psf

Therefore: P_{ult} = 9(300)(14/12) = 3,150 lb/ft

ΣP_{ult} = summation of P_{ult} over the height L_p, as defined in paragraph 4.1
For single layer soil is P_{ult} multiplied by L_p (23 ft) - That is the condition here since the shear strength is constant from the base to the critical failure surface.

ΣP_{ult} = 3,150(23) = 72,450 lb
ΣP_{all} = 1(72,450)/1.5 = 48,300 lb

b. Compute the load acting on the piles below the pile cap.

$$F_{up} = wf_{ub}L_p$$

Where:
w = Monolith width. Since we are looking at one row of piles in this example, w = the pile spacing perpendicular to the unbalanced force (s_t) = 5 ft.

$$f_{ub} = \frac{F_{ub}}{L_u}$$

F_{ub} = Total unbalanced force per foot from Step 2 = 3,800 lb/ft
L_u = 26 ft
L_p = 23 ft

f_{ub} = 3,800/ 26 = 146 lb/ft/ft

F_p = 5(146)(23) = 3,358 lb

c. Check the capacity of the piles 50% of F_p = 3,358(0.50) = 1,679 lb

The capacity ΣP_{all} = 48,300 lb > 1,679 lb so OK for flow through with this check.

4.6 Second flow through check. Compute the ability of the soil to resist shear failure between the pile rows from the unbalanced force below the base of the T-wall, $f_{ub}L_p$, using the following equation:

$$f_{ub}L_p \leq \frac{A_p S_u}{FS}\left[\frac{2}{(s_t - b)}\right]$$

Where:
A_pS_u = The area bounded by the bottom of the T-wall base, the critical failure surface, the upstream pile row and the downstream pile row multiplied by the shear strength of the soil within that area. – See Figure 7. S_u =300 psf
A_pS_u = (23(10+25.33)/2)(300 psf) = 122,000 lb
FS = Target factor of safety used in Steps 1 and 2. – 1.5
s_t= the spacing of the piles transverse (perpendicular) to the unbalanced force 5 ft
b = pile width – 14 inches

$f_{pb}L_p =$ (246 lb/ft)(23 ft) = 5,658 lb

$$\frac{A_p S_u}{FS}\left[\frac{2}{(s_t - b)}\right] = \frac{122{,}000}{1.5}\left[\frac{2}{5-\left(\frac{14}{12}\right)}\right] = 42{,}434 \text{ lb}$$

Therefore, capacity against flow through is OK

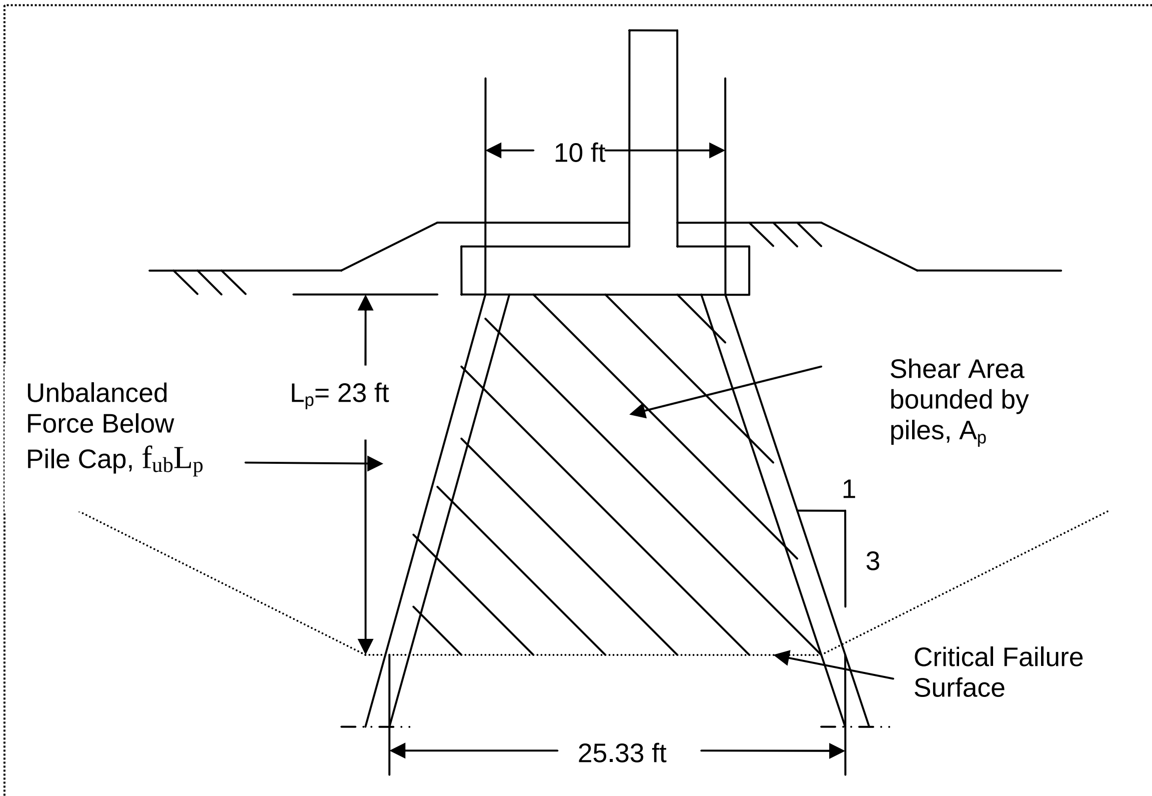


Figure 7. Shear Area for Flow Through Calculation

Step 5 Pile Group Analysis

5.1 A Group 7 analysis is performed using all loads applied to the T-wall structure. Critical load cases from step 4 would be used. In this example, only one load case with two foundation conditions was performed.

5.2 The loads applied in the Group 7 model include the distributed loads representing the unbalanced force that acts directly on the piles and also the water loads and self-weight of the wall that acts directly on the structure. In Group 7 these loads are resultant horizontal and vertical forces and the moments per width of spacing that act on the T-wall base (pile cap). They also include the unbalance force from the base of the cap to the top of soil, converted to a force and moment at the base of the structure. These forces are calculated using a worksheet or Excel spreadsheet and are shown at then end of the spreadsheets shown in Attachment 3. For this analysis the resultant forces per 5-ft of pile spacing were:

Pervious Foundation Condition

Vertical force	=	43,803 lb
Horizontal force	=	29,986 lb
Moment	=	-322,384 in-lbs

Impervious Foundation Condition

Vertical force	=	43,803 lb
Horizontal force	=	29,986 lb
Moment	=	-572,384 in-lbs

5.3 The unbalance load below the bottom of the footing is applied directly as distributed loads on the pile. Check if ($n\Sigma P_{ult}$) of the flood side pile row is greater than 50% F_p, (from 4.5)

.

($n\Sigma P_{ult}$) = 1 (72,450 lb) = 72,450 lb

50% F_p = 1,679 lb

Therefore distribute 50% of F_p onto each row of piles.

$0.5f_{ub}s_t$ = 0.5 (146 lb/ft/ft)(5 ft) = 365 lb/ft = 31 lb/in

5.4 The Group 7 model is shown in Figure 8.

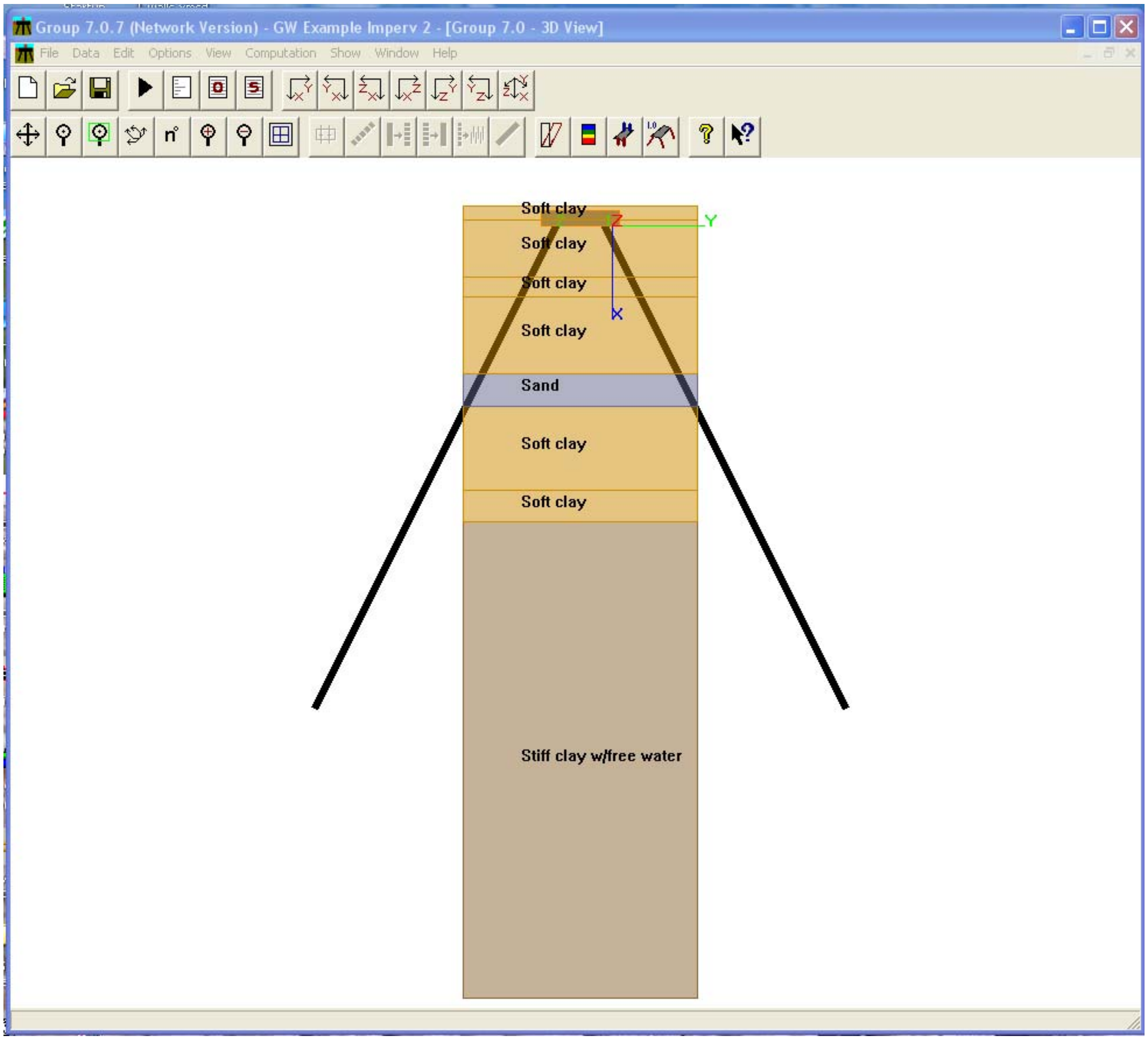


Figure 8. Group 7 Model

5.5 Additionally, in this analysis partial p-y springs can be used because the unreinforced factor of safety of 1.34 is between 1.0 and 1.5. The percentage of the full springs is determined as follows :

Partial spring percentage = (1.339 – 1.000)/ (1.5- 1.0) x 100% = 68%

Thus the strengths of in the top 4 layers, extending to Elevation -22 ft, were reduced to 68% of the undrained shear strength. The reduced undrained shear strength was used to scale the p-y curves above elevation -22 ft only. The results of the Group 7 analysis are listed in Table 1 where the pile responses for the full loading conditions on T-wall systems are listed. The complete Group 7 file for the Pervious Case is shown in Attachment 5.

Impervious Case	Left Pile (Pile #2)	Right Pile (Pile #1)
Axial Force (kips)	-14.5 (T)	62.5 (C)
Shear Force (kips)	1.3	1.5
Max. Moment (k-in)	64.4	118.3
Pervious Case	Left Pile (Pile #2)	Right Pile (Pile #1)
Axial Force (kips)	-14.5(T)	62.5 (C)
Shear Force (kips)	1.3	1.6
Max. Moment (k-in)	64	117.9

Illustration of the moment in the piles with depth is shown in Figure 9. The shear is shown in figure 10.

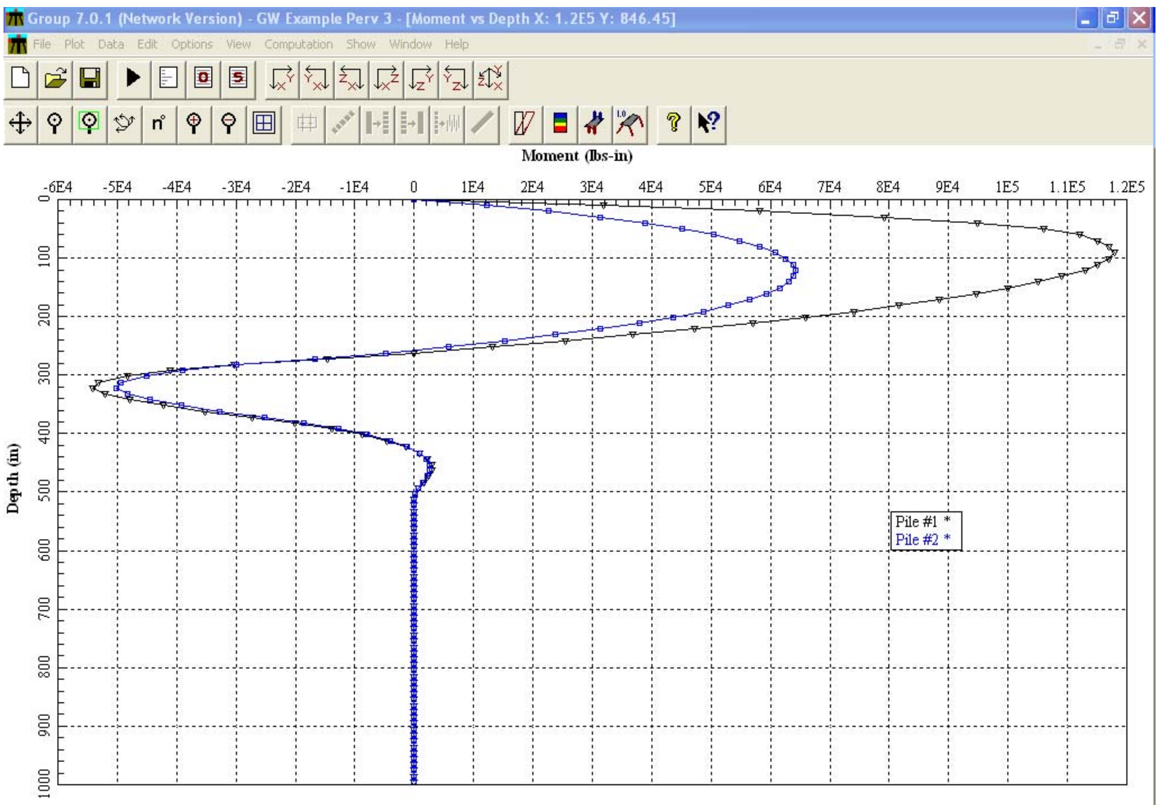


Figure 9. Moment in piles with depth for the pervious case

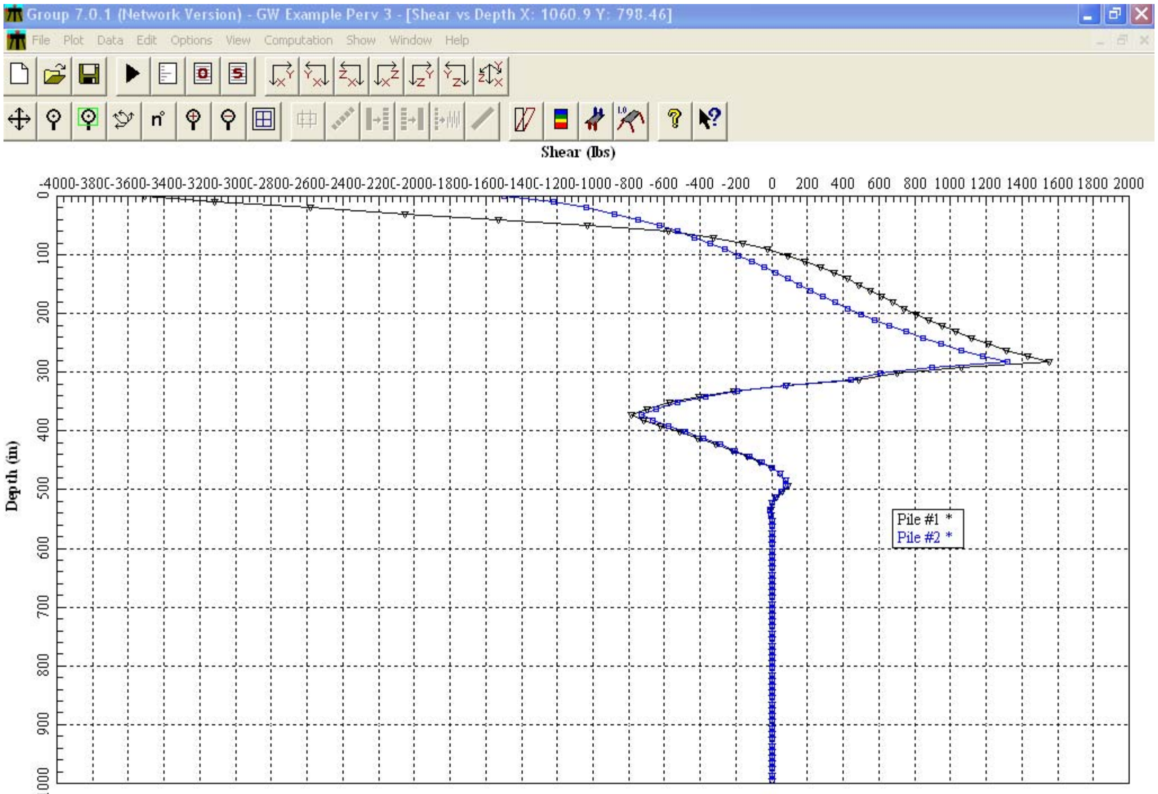


Figure 10. Shear versus depth for the pervious Case.

The axial force is found in the summary text from Group 7.

5.7 The axial forces and shear in Table 1 are then compared with allowable pile capacities determined in Step 3. The results of the comparison show that:

a. the axial compressive forces in the center pile, 62.5 kips, is less than the allowable capacity of 65 kips.
b. the axial tensile force from the left (flood side) pile of -14.5 kips is less than the allowable tensile load of 65 kips.
c. The shear forces in each of the three piles is much lower than the shear computed in examples 1 and 2. LPILE should be used to develop lateral capacity to verify its adequacy.

5.6 Moment and axial forces in the piles would also be checked for structural strength according to criteria in the Hurricane and Storm Damage Reduction System Design Guidelines and EM1110-2-2906.

Displacements from the Group 7 analysis are as follows:

```
PILE CAP DISPLACEMENTS
```

	VERTICAL,IN	HORIZONTAL,IN	ROTATION,RAD
Pervious	0.1129E+00	0.1042E-01	-0.1221E-02
Impervious	0.1129E+00	0.1042E-01	-0.1221E-02

These deflections are much less than the allowable vertical deflection (DZ) of 0.5 inches and allowable horizontal deflection (DX) of 0.75 inches from the Hurricane and Storm Damage Reduction Design Guidelines, even with out increases allowed for the top of wall load case. Figure 11 below shows displacement with depth.

Figure 11. Deflection with Depth for the pervious foundation condition.

Step 6 Pile Group Analysis (unbalanced force)

6.1 Perform a Group 7 analysis with the unbalance force applied directly to the piles. The uniform unbalanced force above the base of the wall is added as a force and moment at the base of the wall. The distributed loads are statically equivalent to the unbalanced force of 3,800 lb/ft. No loads are applied to the cap except unbalance forces above the base of the wall equivalent to 2,192 lb lateral load and -43,803 lb-ft moment. The p-y springs are set to 0 to the critical failure surface by setting the ultimate shear stress of these soils at a very low value. The distributed loads were computed in the previous step and are shown in the Excel spreadsheet computations shown in Attachment 2. Results of the Group analysis are shown below:

Table2. Axial and shear Pile loads per 5-ft of width computed by Group 7 with unbalanced load distributed evenly on two piles

Impervious Case	Left Pile	Right Pile
Axial Force (kips)	-1.0 (T)	0.9 (C)
Shear Force (kips)	-13.2	-13.5

Step 7 Pile Reinforced Slope Stability Analysis

7.1 The UT4 pile reinforcement analysis using the slip surface from Step 5 is performed to determine if the target Factor of Safety of 1.5 is achieved. The piles are treated as reinforcements in the UT4 and the shear and axial forces from Step 6 are used to determine these forces. The forces in Table 2 must be converted to unit width conditions by dividing by the 5-ft pile spacing to be used as the axial and shear forces in the pile reinforcements in UT4. The results of the analysis are shown in Figure 12. The factor of safety is 1.574 which exceeds the target factor of safety of 1.5 . When the computed factor of safety exceeds the target, the global stability of the foundation is verified in this Step. The UTexas file used in this step is shown in attachment 5 of this example.

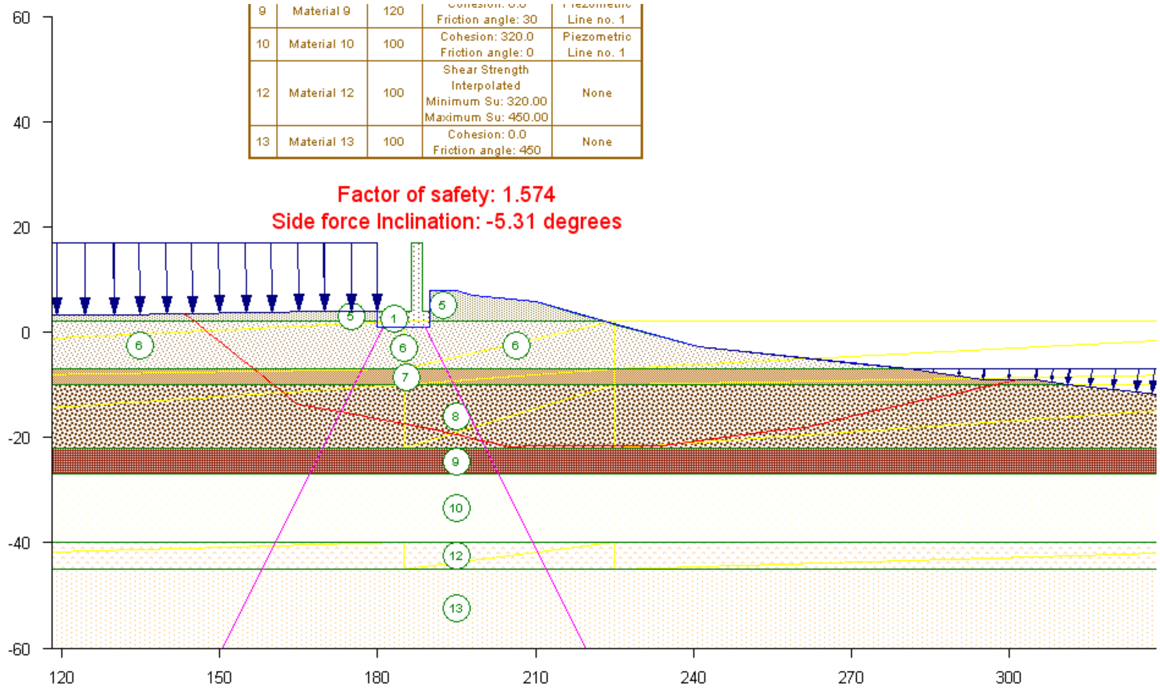


Figure 12. Factor of safety computed using pile forces from Group 7 analysis And critical failure surface from Step 2

Attachment 1 – UTexas analysis without piles that results in Figure 3.

```
HEADING
    T-wall Deep Seated Analysis
    Step 1 Analysis Without Piles

PROFILE LINES
         1    5 Profile 5
                 .00      3.30
              130.00      3.30
              170.00      4.00
              180.00      4.00

         3    1 T-wall
              180.00      4.00
              186.50      4.00
              186.51     17.00
              188.50     17.00
              188.51      4.00
              190.00      4.00

         2    5 Profile 5 PS
              190.00      8.00
              195.00      8.00
              198.00      7.00
              210.00      5.80
              216.20      4.00
              219.50      3.03
              219.60      3.00
              223.00      2.00

         6    6 Profile 6 - FS
                 .00      2.00
              180.00      2.00

         7    6 Profile 6 - Under Wall
              180.00      1.00
              190.00      1.00

         8    6 Profile 6 - PS
              190.00      2.00
              223.00      2.00
              225.00      1.47
              241.00     -2.80
              271.00     -6.00
              280.00     -6.90
              281.00     -7.00

         9    7 Profile 7
                 .00     -7.00
              281.00     -7.00
              295.00     -9.00
              305.00     -9.00
              311.00    -10.00
```

```
    10     8 Profile Line 8
              .00     -10.00
           311.00     -10.00
           324.00     -11.37
           330.00     -12.00
           337.50     -11.50
           345.00     -11.00
           351.00     -10.50
           358.00      -9.30
           400.00      -9.30

    11     9 Profile Line 9
              .00     -22.00
           400.00     -22.00

    12    10 Profile Line 10
              .00     -27.00
           400.00     -27.00

    13    12 Profile Line 12
              .00     -40.00
           400.00     -40.00

    14    13 Profile Line 13
              .00     -45.00
           400.00     -45.00


MATERIAL PROPERTIES
     1 T-wall
          0.00 Unit Weight
          Very Strong
     5 Material 5
          108.00 Unit Weight
          Conventional Shear
              400.00        .00
          No Pore Pressure
     6 Material 6
          86.00 Unit Weight
          Interpolate Strengths
              150.00     300.00
          No Pore Pressure
     7 Material 7
          98.00 Unit Weight
          Interpolate Strengths
              150.00     300.00
          No Pore Pressure
     8 Material 8
          100.00 Unit Weight
          Interpolate Strengths
              150.00     300.00
          No Pore Pressure
     9 Material 9
          120.00 Unit Weight
          Conventional Shear
                 .00      30.00
          Piezometric Line
```

```
          1
     10 Material 10
          100.00 Unit Weight
          Conventional Shear
              320.00       .00
          Piezometric Line
          1
     12 Material 12
          100.00 Unit Weight
          Interpolate Strengths
              320.00    450.00
          No Pore Pressure
     13 Material 13
          100.00 Unit Weight
          Conventional Shear
                 .00    450.00
          No Pore Pressure

PIEZOMETRIC LINES
         1      62.40 Water Level
                 .00     17.00
              180.00     17.00
              180.00      1.00
              190.00      1.00
              190.00      8.00
              195.00      8.00
              198.00      7.00
              210.00      5.80
              223.00      2.00
              241.00     -2.80
              271.00     -6.00
              280.00     -6.90
              400.00     -6.90


DISTRIBUTED LOADS
      1
INTERPOLATION DATA
Su - Undrained Shear Strength
            .00      2.00    300.00         6
            .00     -7.00    300.00         6
         185.00      2.00    300.00         6
         185.00     -7.00    300.00         6
         225.00      2.00    150.00         6
         225.00     -7.00    150.00         6
         400.00      2.00    150.00         6
         400.00     -7.00    150.00         6
            .00      -7.00    300.00         7
            .00     -10.00    300.00         7
         185.00      -7.00    300.00         7
         185.00     -10.00    300.00         7
         225.00      -7.00    150.00         7
         225.00     -10.00    150.00         7
         400.00      -7.00    150.00         7
         400.00     -10.00    150.00         7
            .00      -40.00    320.00         12
            .00     -45.00    450.00         12
```

```
          185.00      -40.00    320.00         12
          185.00     -45.00    450.00         12
          225.00      -40.00    320.00         12
          225.00     -45.00    450.00         12
          400.00      -40.00    320.00         12
          400.00     -45.00    450.00         12
             .00      -10.00    300.00         8
             .00     -22.00    300.00         8
          185.00      -10.00    300.00         8
          185.00     -22.00    300.00         8
          225.00      -10.00    150.00         8
          225.00     -22.00    270.00         8
          400.00      -10.00    150.00         8
          400.00     -22.00    270.00         8


ANALYSIS/COMPUTATION
     Noncircular Search
         135.00       4.00
         150.00      -3.00
         166.00     -10.00
         190.00     -17.00
         205.00     -20.00
         234.00     -22.00
         262.00     -20.00
         281.00     -16.40
         302.00     -10.00
         312.80      -5.80

           2.00       0.50     50.00
SINgle-stage Computations
LONg-form output
SORt radii
CRItical
PROcedure for computation of Factor of Safety
SPENCER

GRAPH
COMPUTE
```

Attachment 2 – UTexas analysis with unbalanced load that results in Figure 4.

```
HEADING
    T-wall Deep Seated Analysis
    Step 2 Analysis With Unbalanced Load

PROFILE LINES
         1    5 Profile 5
                 .00      3.30
              130.00      3.30
              170.00      4.00
              180.00      4.00

         3    1 T-wall
              180.00      4.00
              186.50      4.00
              186.51     17.00
              188.50     17.00
              188.51      4.00
              190.00      4.00

         2    5 Profile 5 PS
              190.00      8.00
              195.00      8.00
              198.00      7.00
              210.00      5.80
              216.20      4.00
              219.50      3.03
              219.60      3.00
              223.00      2.00

         6    6 Profile 6 - FS
                 .00      2.00
              180.00      2.00

         7    6 Profile 6 - Under Wall
              180.00      1.00
              190.00      1.00

         8    6 Profile 6 - PS
              190.00      2.00
              223.00      2.00
              225.00      1.47
              241.00     -2.80
              271.00     -6.00
              281.00     -7.00

         9    7 Profile 7
                 .00     -7.00
              281.00     -7.00
              295.00     -9.00
              305.00     -9.00
              311.00    -10.00

        10    8 Profile Line 8
                 .00    -10.00
```

```
            311.00    -10.00
            324.00    -11.37
            330.00    -12.00
            337.50    -11.50
            345.00    -11.00
            351.00    -10.50
            358.00     -9.30
            400.00     -9.30

      11     9 Profile Line 9
               .00    -22.00
            400.00    -22.00

      12    10 Profile Line 10
               .00    -27.00
            400.00    -27.00

      13    12 Profile Line 12
               .00    -40.00
            400.00    -40.00

      14    13 Profile Line 13
               .00    -45.00
            400.00    -45.00


MATERIAL PROPERTIES
     1 T-wall
          0.00 Unit Weight
          Very Strong
     5 Material 5
          108.00 Unit Weight
          Conventional Shear
              400.00       .00
          No Pore Pressure
     6 Material 6
          86.00 Unit Weight
          Interpolate Strengths
              150.00    300.00
          No Pore Pressure
     7 Material 7
          98.00 Unit Weight
          Interpolate Strengths
              150.00    300.00
          No Pore Pressure
     8 Material 8
          100.00 Unit Weight
          Interpolate Strengths
              150.00    300.00
          No Pore Pressure
     9 Material 9
          120.00 Unit Weight
          Conventional Shear
                 .00     30.00
          Piezometric Line
          1
     10 Material 10
```

```
          100.00 Unit Weight
          Conventional Shear
              320.00       .00
          Piezometric Line
          1
     12 Material 12
          100.00 Unit Weight
          Interpolate Strengths
              320.00    450.00
          No Pore Pressure
     13 Material 13
          100.00 Unit Weight
          Conventional Shear
                 .00    450.00
          No Pore Pressure

PIEZOMETRIC LINES
         1      62.40 Water Level
                 .00     17.00
              180.00     17.00
              180.00      1.00
              190.00      1.00
              190.00      8.00
              195.00      8.00
              198.00      7.00
              210.00      5.80
              223.00      2.00
              241.00     -2.80
              281.00     -7.00
              400.00     -7.00


DISTRIBUTED LOADS
      1
LINE LOAD
   1 185.0 -9.0 -3800 0 1

INTERPOLATION DATA
Su - Undrained Shear Strength
            .00        2.00    300.00         6
            .00       -7.00    300.00         6
         185.00        2.00    300.00         6
         185.00       -7.00    300.00         6
         225.00        2.00    150.00         6
         225.00       -7.00    150.00         6
         400.00        2.00    150.00         6
         400.00       -7.00    150.00         6
            .00       -7.00     300.00         7
            .00      -10.00     300.00         7
         185.00       -7.00     300.00         7
         185.00      -10.00     300.00         7
         225.00       -7.00     150.00         7
         225.00      -10.00     150.00         7
         400.00       -7.00     150.00         7
         400.00      -10.00     150.00         7
            .00       -40.00     320.00         12
            .00      -45.00     450.00         12
```

```
         185.00      -40.00    320.00         12
         185.00     -45.00    450.00         12
         225.00      -40.00    320.00         12
         225.00     -45.00    450.00         12
         400.00      -40.00    320.00         12
         400.00     -45.00    450.00         12
            .00      -10.00    300.00          8
            .00     -22.00    300.00          8
         185.00      -10.00    300.00          8
         185.00     -22.00    300.00          8
         225.00      -10.00    150.00          8
         225.00     -22.00    270.00          8
         400.00      -10.00    150.00          8
         400.00     -22.00    270.00          8

ANALYSIS/COMPUTATION
     Noncircular  Search
         143.39       3.53
         150.64      -2.36
         164.69     -13.63
         189.61     -18.28
         205.04     -21.72
         234.03     -21.59
         261.62     -17.99
         280.42     -13.65
         301.55      -9.10
         301.65      -9.00

           2.00       0.50     50.00
SINgle-stage Computations
LONg-form output
SORt radii
CRItical
PROcedure for computation of Factor of Safety
SPENCER

GRAPH
COMPUTE
```

UPDATED 23 OCT 07

Attachment 3 Structural Loads for CPGA and Group Analyses

US Army Corps of Engineers Saint Paul Distict	PROJECT TITLE: T-Wall Design Example	COMPUTED BY: KDH	DATE: 07/03/07	SHEET:
	SUBJECT TITLE: Gainard Woods, Pervious	CHECKED BY:	DATE:	

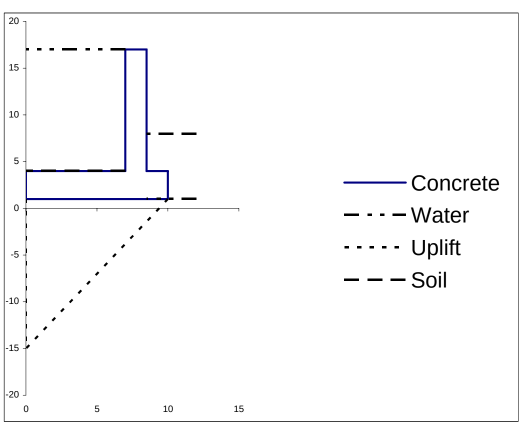
Input for CPGA pile analysis **Pervious Foundation Assumption**

Upstream Water Elevation	17 ft		Back Fill Soil Elevation	4	ft
Downstream Water Elevation	1 ft		Front Fill Soil Elevation	8	ft
Wall Top Elevation	17 ft		Gamma Water	0.0625	kcf
Structure Bottom Elevation	1 ft		Gamma Concrete	0.15	kcf
Base Width	10 ft		Gamma Soil	0.108	kcf
Toe Width	1.5 ft		Distance to Backfill Break	0.0	ft
Wall Thickness	1.5 ft		Slope of Back Fill	0.00	
Base Thickness	3 ft		Soil Elevation at Heel	4.00	ft

Vertical Forces								
Component	Height	x1	x2	Gamma	Force	Arm	Moment	
Stem Concrete	13	7	8.5	0.15	2.93	7.75	22.7	
Heel Concrete	3	0	8.5	0.15	3.83	4.25	16.3	
Toe Concrete	3	8.5	10	0.15	0.68	9.25	6.2	
Heel Water	13	0	7	0.0625	5.69	3.5	19.9	
Toe Water	0	8.5	10	0.0625	0.00	9.25	0.0	
Heel Soil	0	0	7	0.108	0.00	3.5	0.0	
-Triangle	0.00	0	7.0	-0.046	0.00	2.33	0.0	
Toe Soil	4	8.5	10	0.108	0.65	9.25	6.0	
Rect Uplift	0	0	10	0.0625	0.00	5	0.0	
Tri Uplift	-16	0	10	0.0625	-5.00	3.3	-16.7	
Sum Vertical Forces					8.8		54.4	ft-k

Horizontal Forces								
Component	H1	H2	Gamma	Lat. Coeff.	Force	Arm	Moment	
Driving Water	17	1	0.0625	1	8.00	5.33	42.67	
Resisting Water	1	1	0.0625	1	0.00	0.00	0.00	
Driving Soil	4	1	0.046	1	0.20	0.50	0.10	
Resisting Soil	8	1	0.108	1	-2.65	1.83	-4.85	
Sum Horizontal Forces					5.56	6.82	37.92	ft-k

Total Structural Forces	Net Vert. Force	Arm	Moment	
About Heel	8.76	10.54	92.32	ft-k



Net Vertical Arm		ft
From Toe	-0.54	

Moment About Toe
4.7 ft-k

Model Width
5 ft

Calculation of Unbalanced Force

Unbalanced Force. F_{ub}	3,800	lb/ft	From UTexas Analysis
Elevation of Critical Surface	-22	ft	From UTexas Analysis
Length - Ground to Crit. Surface, Lu	26.0	ft	(assume failure surface is normal to pile)
Length - Base to Crit. Surface, Lp	23	ft	
Pile Moment of Inertia. I	904	in^4	
Pile Modulus of Elasticity E	29,000,000	lb/in^2	
Soil Modulus of Subgrade Reaction, k	120	lb/in^2	
Soil Stiffness Parameter, R	122	in	$(EI / k)^{1/4}$
Equivalent Unbalanced Force	2,653	lb/ft	$F_{ub} * (L_u/2 + R) / (L_p + R)$

CPGA Input

PX	-41.06	kips
PY		
PZ	43.80	kips
MX	0	
MY	23.58	kip-ft
MZ	0	

Group Input

2 Pile Rows Parallel to Wall Face

Unbalanced Loading on Piles for Group Analysis

Total	61	lb/in	F_{ub} * Model Width /L_u
50%	30	lb/in	For Pile on Protected Sied
50%	30	lb/in	

Note: Applied to length of pile from bottom of cap to top of critical surface. 23

Unbalanced Loads on Wall for Group Analysis of Just Unbalanced Forces

Distance From Base to Ground Surface, Ds 3.00 ft

PX	0	lb	
PY	2,192	lb	F_{ub} * Model Width / L_u * Ds
PZ	0	lb	
MX	0		
MY	0		
MZ	-39,462	lb-in	-PZ * Ds/2

Total Loads for Group Analysis

PX	43,803	lb	
PY	29,986	lb	PYub + Sum Horizontal * Model Width
PZ	0	lb	
MX	0		
MY	0		
MZ	-322,384	lb-in	

US Army Corps of Engineers Saint Paul Distict	PROJECT TITLE: T-Wall Design Example	COMPUTED BY: KDH	DATE: 07/03/07	SHEET:
	SUBJECT TITLE: Gainard Woods, Impervious	CHECKED BY:	DATE:	

Input for CPGA pile analysis **Impervious Foundation Assumption**

Upstream Water Elevation	17 ft		Back Fill Soil Elevation	4 ft	
Downstream Water Elevation	1 ft		Front Fill Soil Elevation	8 ft	
Wall Top Elevation	17 ft		Gamma Water	0.0625 kcf	
Structure Bottom Elevation	1 ft		Gamma Concrete	0.15 kcf	
Base Width	10 ft		Gamma Soil	0.108 kcf	
Toe Width	1.5 ft		Distance to Backfill Break	0.0 ft	
Wall Thickness	1.5 ft		Slope of Back Fill	0.00	
Base Thickness	3 ft		Soil Elevation at Heel	4.00 ft	

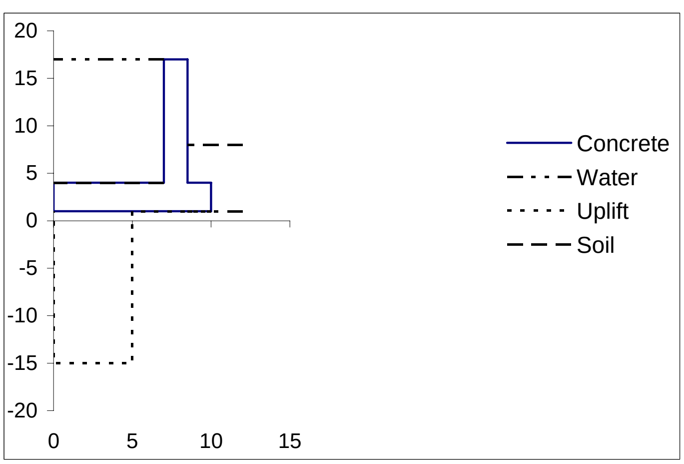
Vertical Forces

Component	Height	x1	x2	Gamma	Force	Arm	Moment
Stem Concrete	13	7	8.5	0.15	2.93	7.75	22.7
Heel Concrete	3	0	8.5	0.15	3.83	4.25	16.3
Toe Concrete	3	8.5	10	0.15	0.68	9.25	6.2
Heel Water	13	0	7	0.0625	5.69	3.5	19.9
Toe Water	0	8.5	10	0.0625	0.00	9.25	0.0
Heel Soil	0	0	7	0.108	0.00	3.5	0.0
-Triangle	0.00	0	7.0	-0.046	0.00	2.33	0.0
Toe Soil	4	8.5	10	0.108	0.65	9.25	6.0
Prot. Side Uplift	0	5	10	0.0625	0.00	7.5	0.0
Flood Side Uplift	-16	0	5	0.0625	-5.00	2.5	-12.5
Sum Vertical Forces					8.8	kip	58.6 ft-k

Horizontal Forces

Component	H1	H2	Gamma	Lat. Coeff.	Force	Arm	Moment
Driving Water	17	1	0.0625	1	8.00	5.33	42.67
Resisting Water	1	1	0.0625	1	0.00	0.00	0.00
Driving Soil	4	1	0.046	1	0.20	0.50	0.10
Resisting Soil	8	1	0.108	1	-2.65	1.83	-4.85
Sum Horizontal Forces					5.56	kip	37.92 ft-k

Total Structural Forces	Net Vert. Force	Arm	Moment
About Heel	8.76	11.01	96.49 ft-k



Net Vertical Arm		
From Toe	-1.01	ft

Moment About Toe
8.9 ft-k

Model Width
5 ft

Calculation of Unbalanced Force

Unbalanced Force. F_{ub}	*3,800*	lb/ft	From UTexas Analysis
Elevation of Critical Surface	*-22*	ft	From UTexas Analysis
Length - Ground to Crit. Surface, Lu	26	ft	(assume failure surface is normal to pile)
Length - Base to Crit. Surface, Lp	23	ft	
Pile Moment of Inertia. I	*904*	in^4	HP14x73
Pile Modulus of Elasticity E	*29,000,000*	lb/in^2	
Soil Modulus of Subgrade Reaction, k	*120*	lb/in^2	
Soil Stiffness Parameter, R	122	in	$(EI / k)^{1/4}$
Equivalent Unbalanced Force	2,653	lb/ft	F_{ub} * $(L_u/2 + R) / (L_p + R)$

CPGA Input

PX	-41.06	kips
PY		
PZ	43.80	kips
MX	0	
MY	44.41	kip-ft
MZ	0	

Group Input

2 Pile Rows Parallel to Wall Face

Unbalanced Loading on Piles for Group Analysis

Total	61	lb/in	F_{ub} * Model Width /L_u
50%	30	lb/in	For Pile on Protected Sied
50%	30	lb/in	

Note: Applied to length of pile from bottom of cap to top of critical surface. 23 ft

Unbalanced Loads on Wall for Group Analysis of Just Unbalanced Forces

Distance From Base to Ground Surface, Ds 3.00 ft

PX	0	lb	
PY	2,192	lb	F_{ub} * Model Width / L_u * Ds
PZ	0	lb	
MX	0		
MY	0		
MZ	-39,462	lb-in	-PZ * Ds/2

Total Loads for Group Analysis

PX	43,803	lb	
PY	29,986	lb	PYub + Sum Horizontal * Model Width
PZ	0	lb	
MX	0		
MY	0		
MZ	-572,384	lb-in	

Attachment 4 - Preliminary Analysis with CPGA

Input File

```
10 Gainard Woods T-wall, Example
15 3.0 ft slab, hp 14 x 89 piles, pinned head,
20 PROP 29000 326 904 26.1 0.5 0 all
30 SOIL ES 0.046 "TIP" 100 0 all
40 PIN all
50 ALLOW H 65.0 65.0 362.5  362.5  1108  3275 all
70 BATTER 2 1 2
80 ANGLE 180 1
180 PILE 1  1.2500 0.00 0.00
201 PILE 2  8.750 0.00 0.00
230 LOAD 1 -41.06  0.0  43.8  0.00  23.58
240 LOAD 2 -41.06  0.0  43.8  0.00  44.41
334 FOUT 1 2 3 4 5 6 7 GWex3.out
335 PFO ALL
```

Output

```
*********************************
 * CASE PROGRAM   #  X0080       *  CPGA - CASE PILE GROUP ANALYSIS PROGRAM
 * VERSION NUMBER # 1993/03/29   *  RUN DATE 27-JUL-2007   RUN TIME 12.58.29
 *********************************


 GAINARD WOODS T-WALL, EXAMPLE


 THERE ARE     2 PILES AND
               2 LOAD CASES IN THIS RUN.

 ALL PILE COORDINATES ARE CONTAINED WITHIN A BOX
                                    X          Y          Z
                                  -----      -----      -----
 WITH DIAGONAL COORDINATES = (      1.25 ,      .00 ,      .00 )
                             (      8.75 ,      .00 ,      .00 )


 ********************************************************************************

          PILE PROPERTIES AS INPUT


       E            I1            I2            A            C33           B66
      KSI          IN**4         IN**4        IN**2
   .29000E+05   .32600E+03   .90400E+03   .26100E+02   .50000E+00   .00000E+00

 THESE PILE PROPERTIES APPLY TO THE FOLLOWING PILES -

     ALL


 ********************************************************************************
```

SOIL DESCRIPTIONS AS INPUT

ES	ESOIL	LENGTH	L	LU
	K/IN**2		FT	FT
	.46000E-01	T	.10000E+03	.00000E+00

THIS SOIL DESCRIPTION APPLIES TO THE FOLLOWING PILES -

ALL

****

PILE GEOMETRY AS INPUT AND/OR GENERATED

NUM	X	Y	Z	BATTER	ANGLE	LENGTH	FIXITY
	FT	FT	FT			FT	
1	1.25	.00	.00	2.00	180.00	111.80	P
2	8.75	.00	.00	2.00	.00	111.80	P

						223.61	

****

APPLIED LOADS

LOAD CASE	PX K	PY K	PZ K	MX FT-K	MY FT-K	MZ FT-K
1	-41.1	.0	43.8	.0	23.6	.0
2	-41.1	.0	43.8	.0	44.4	.0

****

ORIGINAL PILE GROUP STIFFNESS MATRIX

.12087E+03	.49431E-05	.41211E-12	.00000E+00	-.99740E+04	.74146E-04
.49431E-05	.77891E+01	-.96883E-05	.00000E+00	.14533E-03	.46735E+03
.41211E-12	-.96883E-05	.45334E+03	.00000E+00	-.27200E+05	-.14533E-03
.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00	.00000E+00
-.99740E+04	.14533E-03	-.27200E+05	.00000E+00	.25500E+07	.21799E-02
.74146E-04	.46735E+03	-.14533E-03	.00000E+00	.21799E-02	.43814E+05

S(4,4)=0. PROBLEM WILL BE TREATED AS TWO DIMENSIONAL IN THE X-Z PLANE.

LOAD CASE 1. NUMBER OF FAILURES = 0. NUMBER OF PILES IN TENSION = 1.

LOAD CASE 2. NUMBER OF FAILURES = 0. NUMBER OF PILES IN TENSION = 1.

****

PILE CAP DISPLACEMENTS

LOAD CASE	DX IN	DZ IN	R RAD
1	-.7541E+00	-.2047E+00	-.5023E-02
2	-.5370E+00	-.4687E-01	-.2391E-02

****

ELASTIC CENTER INFORMATION

ELASTIC CENTER IN PLANE X-Z	X FT	Z FT
	5.00	-6.88

LOAD CASE	MOMENT IN X-Z PLANE
1	.76399E+04
2	.30736E+05

****

PILE FORCES IN LOCAL GEOMETRY

M1 & M2 NOT AT PILE HEAD FOR PINNED PILES
* INDICATES PILE FAILURE
# INDICATES CBF BASED ON MOMENTS DUE TO
(F3*EMIN) FOR CONCRETE PILES
B INDICATES BUCKLING CONTROLS

LOAD CASE - 1

PILE	F1 K	F2 K	F3 K	M1 IN-K	M2 IN-K	M3 IN-K	ALF	CBF
1	3.7	.0	62.5	.0	-259.0	.0	.96	.25
2	-4.1	.0	-13.7	.0	289.5	.0	.21	.13

LOAD CASE - 2

PILE	F1 K	F2 K	F3 K	M1 IN-K	M2 IN-K	M3 IN-K	ALF	CBF
1	2.4	.0	65.0	.0	-171.6	.0	1.00	.23
2	-2.9	.0	-16.2	.0	202.1	.0	.25	.11

****

PILE FORCES IN GLOBAL GEOMETRY

LOAD CASE - 1

PILE	PX K	PY K	PZ K	MX IN-K	MY IN-K	MZ IN-K
1	-31.2	.0	54.2	.0	.0	.0
2	-9.8	.0	-10.4	.0	.0	.0

LOAD CASE - 2

PILE	PX K	PY K	PZ K	MX IN-K	MY IN-K	MZ IN-K
1	-31.2	.0	57.0	.0	.0	.0
2	-9.8	.0	-13.2	.0	.0	.0

Attachment 5 – Group 7 Summary Output for Pervious Condition

```
===============================================================================

                GROUP for Windows, Version 7.0.7

                 Analysis of A Group of Piles
              Subjected to Axial and Lateral Loading

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                     All Rights Reserved

===============================================================================


This program is licensed to:

k
c

Path to file locations:      C:\KDH\New Orleans\T-walls\Group\Adeles\
Name of input data file:     GW Example Perv 3.gpd
Name of output file:         GW Example Perv 3.gpo
Name of plot output file:    GW Example Perv 3.gpp
Name of runtime file:        GW Example Perv 3.gpr
Name of output summary file: GW Example Perv 3.gpt


-------------------------------------------------------------------------------
                          Time and Date of Analysis
-------------------------------------------------------------------------------

               Date:  July  9, 2007     Time:  16:21:51
 PILE GROUP ANALYSIS PROGRAM-GROUP
 PC VERSION 6.0 (C) COPYRIGHT ENSOFT,INC. 2000

 THE PROGRAM WAS COMPILED USING MICROSOFT FORTRAN
 POWERSTATION 4.0 (C) COPYRIGHT MICROSOFT CORPORATION, 1996.


     Gainard Woods:  F.S. 17.0, P.S. 1, Pervious


                ******     INPUT INFORMATION     *****



     * TABLE C *  LOAD AND CONTROL PARAMETERS


     UNITS--

          V LOAD,LBS     H LOAD,LBS    MOMENT,LBS-IN
```

```
     0.4380E+05      0.2999E+05     -0.5724E+06

  GROUP NO. 1


                 DISTRIBUTED LOAD CURVE           2 POINTS

                            X,IN       LOAD,LBS/IN
                            0.00         0.310E+02
                          308.00         0.310E+02

  GROUP NO. 2


                 DISTRIBUTED LOAD CURVE           2 POINTS

                            X,IN       LOAD,LBS/IN
                            0.00         0.310E+02
                          308.00         0.310E+02


* THE LOADING IS STATIC *


    KPYOP =  0      (CODE TO GENERATE P-Y CURVES)

    ( KPYOP = 1 IF P-Y YES; = 0 IF P-Y NO; = -1 IF P-Y ONLY )


* CONTROL PARAMETERS *
    TOLERANCE ON CONVERGENCE OF FOUNDATION REACTION      =  0.100E-04 IN
    TOLERANCE ON DETERMINATION OF DEFLECTIONS            =  0.100E-04 IN
    MAX NO OF ITERATIONS ALLOWED FOR FOUNDATION ANALYSIS =     100
    MAXIMUM NO. OF ITERATIONS ALLOWED FOR PILE ANALYSIS  =     100



* TABLE D *    ARRANGEMENT OF PILE GROUPS

  GROUP   CONNECT   NO OF PILE PILE NO  L-S CURVE  P-Y CURVE
    1       PIN          1         1         1           0
    2       PIN          1         1         1           0

  GROUP          VERT,IN      HOR,IN     SLOPE,IN/IN   GROUND,IN SPRING,LBS-IN



* TABLE E *    PILE GEOMETRY AND PROPERTIES
               PILE TYPE = 1 - DRIVEN PILE
                         = 2 - DRILLED SHAFT

  PILE  SEC  INC        LENGTH, IN      E  ,LBS/IN**2 PILE TYPE
    1     1  100        0.1006E+04      0.2900E+08        1

  PILE    FROM,IN      TO,IN      DIAM,IN    AREA,IN**2    I,IN**4
```

```
    1  0.0000E+00  0.1006E+04  0.1400E+02  0.2610E+02  0.9040E+03

      * THE PILE ABOVE IS OF LINEARLY ELASTIC MATERIAL *


* TABLE F *   AXIAL LOAD VS SETTLEMENT

(THE LOAD-SETTLEMENT CURVE OF SINGLE PILE IS GENERATED INTERNALLY)

  NUM OF CURVES  1

   CURVE  1          NUM OF POINTS = 19

       POINT       AXIAL LOAD,LBS      SETTLEMENT, IN
         1         -0.8554E+05         -0.2075E+01
         2         -0.8546E+05         -0.1075E+01
         3         -0.8542E+05         -0.5748E+00
         4         -0.8888E+05         -0.1784E+00
         5         -0.8583E+05         -0.1246E+00
         6         -0.2191E+05         -0.2768E-01
         7         -0.1092E+05         -0.1377E-01
         8         -0.2183E+04         -0.2753E-02
         9         -0.2183E+03         -0.2753E-03
        10          0.0000E+00          0.0000E+00
        11          0.2185E+03          0.2755E-03
        12          0.2185E+04          0.2755E-02
        13          0.1093E+05          0.1377E-01
        14          0.2193E+05          0.2769E-01
        15          0.8589E+05          0.1247E+00
        16          0.8897E+05          0.1785E+00
        17          0.8576E+05          0.5753E+00
        18          0.8595E+05          0.1075E+01
        19          0.8624E+05          0.2076E+01


* TABLE H *   SOIL DATA FOR AUTO P-Y CURVES


SOILS INFORMATION

     AT THE GROUND SURFACE          =     -36.00 IN

    8 LAYER(S) OF SOIL
    THE SOIL IS A SOFT CLAY
    X AT THE TOP OF THE LAYER         =     -36.00 IN
    X AT THE BOTTOM OF THE LAYER      =     -12.00 IN
    MODULUS OF SUBGRADE REACTION      =  0.300E+02 LBS/IN**3
    THE SOIL IS A SOFT CLAY
    X AT THE TOP OF THE LAYER         =     -12.00 IN
    X AT THE BOTTOM OF THE LAYER      =      96.00 IN
    MODULUS OF SUBGRADE REACTION      =  0.300E+02 LBS/IN**3
    THE SOIL IS A SOFT CLAY
    X AT THE TOP OF THE LAYER         =      96.00 IN
    X AT THE BOTTOM OF THE LAYER      =     132.00 IN
```

```
MODULUS OF SUBGRADE REACTION     =  0.300E+02 LBS/IN**3
THE SOIL IS A SOFT CLAY
X AT THE TOP OF THE LAYER        =     132.00 IN
X AT THE BOTTOM OF THE LAYER     =     276.00 IN
MODULUS OF SUBGRADE REACTION     =  0.300E+02 LBS/IN**3
THE SOIL IS A SAND
X AT THE TOP OF THE LAYER        =     276.00 IN
X AT THE BOTTOM OF THE LAYER     =     336.00 IN
MODULUS OF SUBGRADE REACTION     =  0.300E+02 LBS/IN**3
THE SOIL IS A SOFT CLAY
X AT THE TOP OF THE LAYER        =     336.00 IN
X AT THE BOTTOM OF THE LAYER     =     492.00 IN
MODULUS OF SUBGRADE REACTION     =  0.300E+02 LBS/IN**3
THE SOIL IS A SOFT CLAY
X AT THE TOP OF THE LAYER        =     492.00 IN
X AT THE BOTTOM OF THE LAYER     =     552.00 IN
MODULUS OF SUBGRADE REACTION     =  0.300E+02 LBS/IN**3
THE SOIL IS A STIFF CLAY BELOW THE WATER TABLE
X AT THE TOP OF THE LAYER        =     552.00 IN
X AT THE BOTTOM OF THE LAYER     =    1440.00 IN
MODULUS OF SUBGRADE REACTION     =  0.300E+02 LBS/IN**3
```

DISTRIBUTION OF EFFECTIVE UNIT WEIGHT WITH DEPTH
12 POINTS

X,IN	WEIGHT,LBS/IN**3
-36.0000	0.2600E-01
-12.0000	0.2600E-01
-12.0000	0.1400E-01
96.0000	0.1400E-01
96.0000	0.2000E-01
132.0000	0.2000E-01
132.0000	0.2200E-01
276.0000	0.2200E-01
276.0000	0.3300E-01
336.0000	0.3300E-01
336.0000	0.2200E-01
1440.0000	0.2200E-01

DISTRIBUTION OF STRENGTH PARAMETERS WITH DEPTH
16 POINTS

X IN	C LBS/IN**2	PHI,DEGREES	E50	FMAX LBS/IN**2	TIPMAX LBS/IN**2
-36.00	0.1890E+01	0.000	0.2000E-01	0.1000E+00	0.0000E+00
-12.00	0.1890E+01	0.000	0.2000E-01	0.1000E+00	0.0000E+00
-12.00	0.1420E+01	0.000	0.2000E-01	0.1000E+00	0.0000E+00
96.00	0.1420E+01	0.000	0.2000E-01	0.1000E+00	0.0000E+00
96.00	0.1420E+01	0.000	0.2000E-01	0.1000E+00	0.0000E+00
132.00	0.1420E+01	0.000	0.2000E-01	0.1000E+00	0.0000E+00
132.00	0.1420E+01	0.000	0.2000E-01	0.1000E+00	0.0000E+00
276.00	0.1420E+01	0.000	0.2000E-01	0.1000E+00	0.0000E+00
276.00	0.0000E+00	30.000	0.0000E+00	0.1500E+01	0.0000E+00
336.00	0.0000E+00	30.000	0.0000E+00	0.1700E+01	0.0000E+00
336.00	0.2220E+01	0.000	0.2000E-01	0.2220E+01	0.0000E+00

492.00	0.2220E+01	0.000	0.2000E-01	0.2220E+01	0.0000E+00
492.00	0.3130E+01	0.000	0.2000E-01	0.3130E+01	0.0000E+00
552.00	0.3130E+01	0.000	0.2000E-01	0.3130E+01	0.0000E+00
552.00	0.3130E+01	0.000	0.2000E-01	0.3130E+01	0.0000E+00
1440.00	0.3130E+01	0.000	0.2000E-01	0.3130E+01	0.0000E+00

REDUCTION FACTORS FOR CLOSELY-SPACED PILE GROUPS

GROUP NO	P-FACTOR	Y-FACTOR
1	1.00	1.00
2	0.97	1.00

Gainard Woods: F.S. 17.0, P.S. 1, Pervious

***** COMPUTATION RESULTS *****

VERT. LOAD, LBS	HORI. LOAD, LBS	MOMENT,IN-LBS
0.4380E+05	0.2999E+05	-0.5724E+06

DISPLACEMENT OF GROUPED PILE FOUNDATION

VERTICAL,IN	HORIZONTAL,IN	ROTATION,RAD
0.1133E+00	0.9562E-02	-0.1230E-02

NUMBER OF ITERATIONS = 5

* TABLE I * COMPUTATION ON INDIVIDUAL PILE

* PILE GROUP * 1

PILE TOP DISPLACEMENTS AND REACTIONS

THE GLOBAL STRUCTURE COORDINATE SYSTEM

XDISPL,IN	YDISPL,IN	SLOPE	AXIAL,LBS	LAT,LBS	BM,LBS-IN	STRESS,LBS/IN**2
0.949E-01	0.956E-02	0.600E-03	0.575E+05	0.246E+05	0.000E+00	0.239E+04

```
       THE LOCAL MEMBER COORDINATE SYSTEM
       ------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN  STRESS,LBS/IN**2

 0.891E-01 -0.339E-01 0.600E-03 0.624E+05-0.368E+04 0.000E+00   0.239E+04


       * PILE GROUP *  2


 PILE TOP DISPLACEMENTS AND REACTIONS


       THE GLOBAL STRUCTURE COORDINATE SYSTEM
       ----------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN  STRESS,LBS/IN**2

-0.158E-01  0.956E-02 0.211E-03-0.137E+05 0.534E+04 0.000E+00   0.560E+03


       THE LOCAL MEMBER COORDINATE SYSTEM
       ------------------------------------

 XDISPL,IN   YDISPL,IN   SLOPE   AXIAL,LBS  LAT,LBS  BM,LBS-IN  STRESS,LBS/IN**2

-0.184E-01  0.147E-02 0.211E-03-0.146E+05-0.134E+04 0.000E+00   0.560E+03
```

Attachment 6 – UTexas analysis with piles as reinforcement (Figure 12).

```
HEADING
    T-wall Deep Seated Analysis
    Step 7 Check with Group 7 Pile Forces

PROFILE LINES
         1    5 Profile 5
                 .00      3.30
              130.00      3.30
              170.00      4.00
              180.00      4.00

         3    1 T-wall
              180.00      4.00
              186.50      4.00
              186.51     17.00
              188.50     17.00
              188.51      4.00
              190.00      4.00

         2    5 Profile 5 PS
              190.00      8.00
              195.00      8.00
              198.00      7.00
              210.00      5.80
              216.20      4.00
              219.50      3.03
              219.60      3.00
              223.00      2.00

         6    6 Profile 6 - FS
                 .00      2.00
              180.00      2.00

         7    6 Profile 6 - Under Wall
              180.00      1.00
              190.00      1.00

         8    6 Profile 6 - PS
              190.00      2.00
              223.00      2.00
              225.00      1.47
              241.00     -2.80
              271.00     -6.00
              281.00     -7.00

         9    7 Profile 7
                 .00     -7.00
              281.00     -7.00
              295.00     -9.00
              305.00     -9.00
              311.00    -10.00

        10    8 Profile Line 8
                 .00    -10.00
```

```
            311.00    -10.00
            324.00    -11.37
            330.00    -12.00
            337.50    -11.50
            345.00    -11.00
            351.00    -10.50
            358.00     -9.30
            400.00     -9.30

      11     9 Profile Line 9
               .00    -22.00
            400.00    -22.00

      12    10 Profile Line 10
               .00    -27.00
            400.00    -27.00

      13    12 Profile Line 12
               .00    -40.00
            400.00    -40.00

      14    13 Profile Line 13
               .00    -45.00
            400.00    -45.00


MATERIAL PROPERTIES
     1 T-wall
          0.00 Unit Weight
          Very Strong
     5 Material 5
          108.00 Unit Weight
          Conventional Shear
            400.00       .00
          No Pore Pressure
     6 Material 6
          86.00 Unit Weight
          Interpolate Strengths
            150.00    300.00
          No Pore Pressure
     7 Material 7
          98.00 Unit Weight
          Interpolate Strengths
            150.00    300.00
          No Pore Pressure
     8 Material 8
          100.00 Unit Weight
          Interpolate Strengths
            150.00    300.00
          No Pore Pressure
     9 Material 9
          120.00 Unit Weight
          Conventional Shear
               .00     30.00
          Piezometric Line
          1
     10 Material 10
```

```
          100.00 Unit Weight
          Conventional Shear
              320.00       .00
          Piezometric Line
          1
     12 Material 12
          100.00 Unit Weight
          Interpolate Strengths
              320.00    450.00
          No Pore Pressure
     13 Material 13
          100.00 Unit Weight
          Conventional Shear
                 .00    450.00
          No Pore Pressure

PIEZOMETRIC LINES
         1     62.40 Water Level
                 .00     17.00
              180.00     17.00
              180.00      1.00
              190.00      1.00
              190.00      8.00
              195.00      8.00
              198.00      7.00
              210.00      5.80
              223.00      2.00
              241.00     -2.80
              281.00     -7.00
              400.00     -7.00


DISTRIBUTED LOADS
      1
REINFORCEMENT LINES
      1        .00          2
140.50 -80.00  292.   2020.
181.00    1.00  292. 2020.

      2         .00         2
189.00    1.00 -78. 1840.
229.50 -80.00  -78. 1840.

      3         .00         2
5.00       1.00  0.  0.
5.00    -10.50   0.  0.

INTERPOLATION DATA
Su - Undrained Shear Strength
            .00      2.00    300.00         6
            .00     -7.00    300.00         6
         185.00      2.00    300.00         6
         185.00     -7.00    300.00         6
         225.00      2.00    150.00         6
         225.00     -7.00    150.00         6
         400.00      2.00    150.00         6
         400.00     -7.00    150.00         6
```

.00	-7.00	300.00	7
.00	-10.00	300.00	7
185.00	-7.00	300.00	7
185.00	-10.00	300.00	7
225.00	-7.00	150.00	7
225.00	-10.00	150.00	7
400.00	-7.00	150.00	7
400.00	-10.00	150.00	7
.00	-40.00	320.00	12
.00	-45.00	450.00	12
185.00	-40.00	320.00	12
185.00	-45.00	450.00	12
225.00	-40.00	320.00	12
225.00	-45.00	450.00	12
400.00	-40.00	320.00	12
400.00	-45.00	450.00	12
.00	-10.00	300.00	8
.00	-22.00	300.00	8
185.00	-10.00	300.00	8
185.00	-22.00	300.00	8
225.00	-10.00	150.00	8
225.00	-22.00	270.00	8
400.00	-10.00	150.00	8
400.00	-22.00	270.00	8

ANALYSIS/COMPUTATION

Noncircular

143.39	3.53
150.64	-2.36
164.69	-13.63
189.61	-18.28
205.04	-21.72
234.03	-21.59
261.62	-17.99
280.42	-13.65
301.55	-9.10
301.65	-9.00

SINgle-stage Computations
LONg-form output
SORt radii
CRItical
PROcedure for computation of Factor of Safety
SPENCER

GRAPH
COMPUTE