(A0007191)

| PROJECT ORLEANS LAKEFRONT GDM | Page 1 of — | COMPUTED BY JAR | DATE 5 JAN 83 |
|---|---|---|---|
| SUBJECT T-WALL @ SAILBOAT BAY APTS. | | CHECKED BY CT | DATE 3 FEB 83 |

# 3-D PILE ANALYSIS

## LOAD CASES

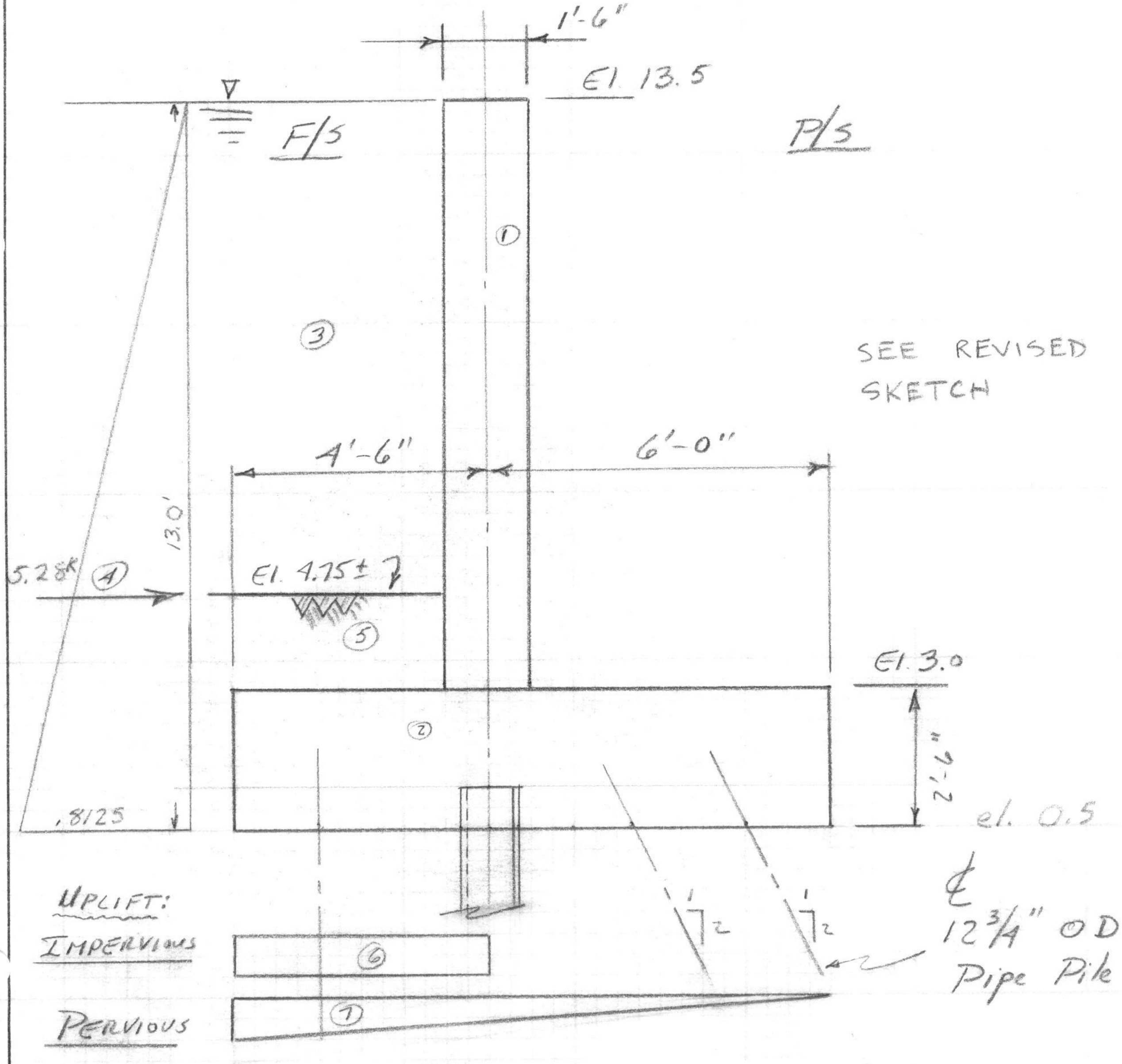
I - Water to El. 13.5, No wind, Impervious

II - Water to El. 13.5, No wind, Pervious

III - No water, No wind, DL only

IV - No water, Wind from P/S (75% of Forces)

V - No water, Wind from F/S (75% of Forces)




LMV FORM 1 AUG 68 107a

COMPUTATION SHEET

| PROJECT ORLEANS LKFT GDM | Page 3 of — | COMPUTED BY JAR | DATE 6 JAN 83 |
|---|---|---|---|
| SUBJECT T-WALL @ SAILBOAT BAY APTS | | CHECKED BY LT | DATE 3 FEB 83 |

## Vertical Loads

| ITEM | COMPUTATIONS | $F_z$ | $ARM_y$ | $M_x$ | $ARM_x$ | $M_y$ |
|---|---|---|---|---|---|---|
| | **Concrete** | | | | | |
| ① | 1.5 x 10.5 x 30 x 0.150 | 70.88 | -4.5 | -318.96 | 15.0 | -1063.20 |
| ② | 2.5 x 10.5 x 30 x 0.150 | 118.13 | -5.25 | -620.16 | 15.0 | -1771.88 |
| A | SUBTOTAL CONCRETE | 189.01 | | -939.12 | | -2835.08 |
| | **Water WEIGHT** | | | | | |
| ③ | 3.75 x 10.5 x 30 x 0.0625 | 73.83 | -1.88 | -138.80 | 15.0 | -1107.45 |
| B | SUBTOTAL WATER WEIGHT | 73.83 | | -138.80 | | -1107.45 |
| | **Impervious Uplift** | | | | | |
| ⑥ | -13.0 x 0.0625 x 4.5 x 30 | -109.69 | -2.25 | 246.80 | 15.0 | 1645.35 |
| C | SUBTOTAL IMPERVIOUS UPLIFT | -109.69 | | 246.80 | | 1645.35 |
| | **Pervious Uplift** | | | | | |
| ⑦ | -½ x 13.0 x 0.0625 x 10.5 x 30 | -127.97 | -3.5 | 447.90 | 15.0 | 1919.55 |
| D | SUBTOTAL PERVIOUS UPLIFT | -127.97 | | 447.90 | | 1919.55 |
| | **Soil: Saturated Weight** | | | | | |
| ⑤ | 1.75 x 3.75 x 30 x 0.110 | 21.66 | -1.88 | -40.72 | 15.0 | -324.90 |
| E | SUBTOTAL: SOIL, SATURATED Wt | 21.66 | | -40.72 | | -324.90 |
| | **Soil: Submerged Weight** | | | | | |
| ⑤ | 1.75 x 3.75 x 30 x 0.0475 | 9.35 | -1.88 | -17.58 | 15.0 | -140.25 |
| F | SUBTOTAL: SOIL, SUBMERGED Wt | 9.35 | | -17.58 | | -140.25 |

| PROJECT | Page | COMPUTED BY | DATE |
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| ORLEANS LAKEFRONT GDM | Page 3 of __ | JAR | 6 JAN 83 |
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| T-WALL @ SAILBOAT BAY APTS | | LT | 3 FEB 83 |

## Horizontal Loads

| ITEM | COMPUTATIONS | $F_Y$ | $ARM_Z$ | $M_X$ | $ARM_X$ | $M_Z$ |
|---|---|---|---|---|---|---|
| | **Water** | | | | | |
| (4) | $-\frac{1}{2} \times \overline{13.0}^2 \times 0.0625 \times 30$ | −158.44 | −4.33 | −686.05 | 15.0 | −2376.60 |
| G | SUBTOTAL: WATER LOAD | −158.44 | | −686.05 | | −2376.60 |
| | **Wind from P/S** | | | | | |
| | $10.5 \times 30 \times 0.050$ | 15.75 | −7.75 | 122.06 | 15.0 | 236.25 |
| H | SUBTOTAL: WIND FROM P/S | 15.75 | | 122.06 | | 236.25 |
| | **Wind from F/S** | | | | | |
| | $8.75 \times 30 \times 0.050$ | −13.13 | −8.63 | −113.31 | 15.0 | −196.95 |
| I | SUBTOTAL: WIND FROM F/S | −13.13 | | −113.31 | | −196.95 |

LOADING SUMMARY:

| CASE | LOADING | $F_X$ | $F_Y$ | $F_Z$ | $M_X$ | $M_Y$ | $M_Z$ |
|---|---|---|---|---|---|---|---|
| I | A+B+C+F+G | 0.00 | −158.44 | 162.5 | −1534.75 | −2437.75 | −2376.60 |
| II | A+B+D+F+G | 0.00 | −158.44 | 144.22 | −1333.65 | −2364.9 | −2376.60 |
| III | A+E | 0.00 | 0.00 | 210.67 | −979.84 | −3159.98 | 0.00 |
| IV | (A+E+H) x 75% | 0.00 | 11.81 | 158.00 | −643.31 | −2369.99 | 177.19 |
| V | (A+E+I) x 75% | 0.00 | −9.85 | 158.00 | −819.86 | −2369.99 | −147.71 |

# BETHLEHEM
# KING PILE SYSTEM

Bethlehem Steel Corporation's King Pile System utilizes a combination of standard WF or HP shapes and sheet piling sections to produce retaining structures of greater depth than can be achieved by sheet piling alone. A typical arrangement is shown in Figure 1. Standard sheet piling male and female interlocks are continuously welded to one flange of a wide-flange shape to form the King Pile, and two sections of standard sheet piling are used between adjacent King Piles to produce a high capacity retaining structure. It sometimes may be economical to reinforce the King Pile with a coverplate on one flange, as shown in Figure 1. A wide variety of combinations of wide-flange shapes and sheet piling is possible to accommodate various loading conditions. The system is intended for use with the pressure acting in the direction shown.

In analyzing the composite system, it is assumed that bending deflections of the King Pile and sheet piling are equal along the interlock line, but each component is considered to bend about its own neutral axis. Based on these assumptions, load is carried by the King Pile and the sheet piling in direct proportion to their respective moments of inertia. For the case shown in Figure 1, the modular dimension L, in feet, is

$$L = L1 + L2 \qquad \text{(Eq. 1)}$$

where L1 = width of the King Pile, in feet
and L2 = width of two sheet piling Z-sections, in feet.

The load per foot of depth acting on the module is pL where p = pressure acting on the system in pounds per square foot.

The portion of the total load carried by the King Pile is

$$\text{Load on King Pile per foot of depth} = \left(\frac{I_{kx}}{I_{kx} + 2I_{zx}}\right) pL \qquad \text{(Eq. 2)}$$

where $I_{kx}$ = moment of inertia of the King Pile about its x-axis in $inches^4$

and $I_{zx}$ = moment of inertia of each section of sheet piling about its x-axis in $inches^4$.

Similarly, the load carried by the two pieces of sheet piling is

$$\text{Load on Sheet Piling per foot of depth} = \left(\frac{2I_{zx}}{I_{kx} + 2I_{zx}}\right) pL \qquad \text{(Eq. 3)}$$

The section modulus and material yield strength of the King Pile and sheet piling are selected to resist the calculated applied moment.

Simplified Design Procedure

The design calculations can be simplified by using an average moment of inertia over the modular distance L:

$$I_{avg} = \frac{I_{kx} + 2I_{zx}}{L} \qquad \text{(Eq. 4)}$$

where $I_{avg}$ is in $inches^4$ per foot of cross section width (that is, barrier length). For most practical configurations the maximum stress in the King Pile will govern the design. This stress can be determined from

$$f = \frac{Mc}{I_{avg}} \qquad \text{(Eq. 5)}$$

where f = the longitudinal bending stress, in pounds per square inch

M = the moment obtained for the given pressure diagram, in inch-pounds per foot of width

c = the distance from the neutral axis of the King Pile to the extreme fiber, in inches

33

and $I_{avg}$ = the average moment of inertia determined from Equation 4, in $inches^4$ per foot of width.

The longitudinal bending stress in the sheet piling also can be determined from Equation 5 by substituting the appropriate c-value for the sheet piling about its own bending axis.

The required section modulus for a module can be obtained from

$$\text{Required } S^* = \frac{M}{F_b} \qquad \text{(Eq. 6)}$$

where $F_b$ = the allowable bending stress.

The corresponding section modulus of the module is obtained from

$$S^* = \frac{I_{avg}}{c} \qquad \text{(Eq. 7)}$$

where all terms are as defined above. For a satisfactory design, S* must be equal to or greater than Required S*.

The transverse bending stress and the biaxial stresses in the sheet piling and in the flanges of the King Pile also should be checked.

In accordance with common practice, the intermediate sheet piling does not have to be driven to the same depth as the King Pile. The system can be designed so that active and surcharge pressure is resisted by the sheet piling and the King Piles, while the passive pressure is resisted by the King Piles alone. Despite the spacing of the King Piles, the passive pressure usually can be assumed to be acting on a continuous wall, except where soil characteristics are poor and a reduction of the coefficient of passive pressure is required.

A design example follows to illustrate the procedures described above.

Bethlehem Steel Corporation can provide engineering assistance in the use of the King Pile System.

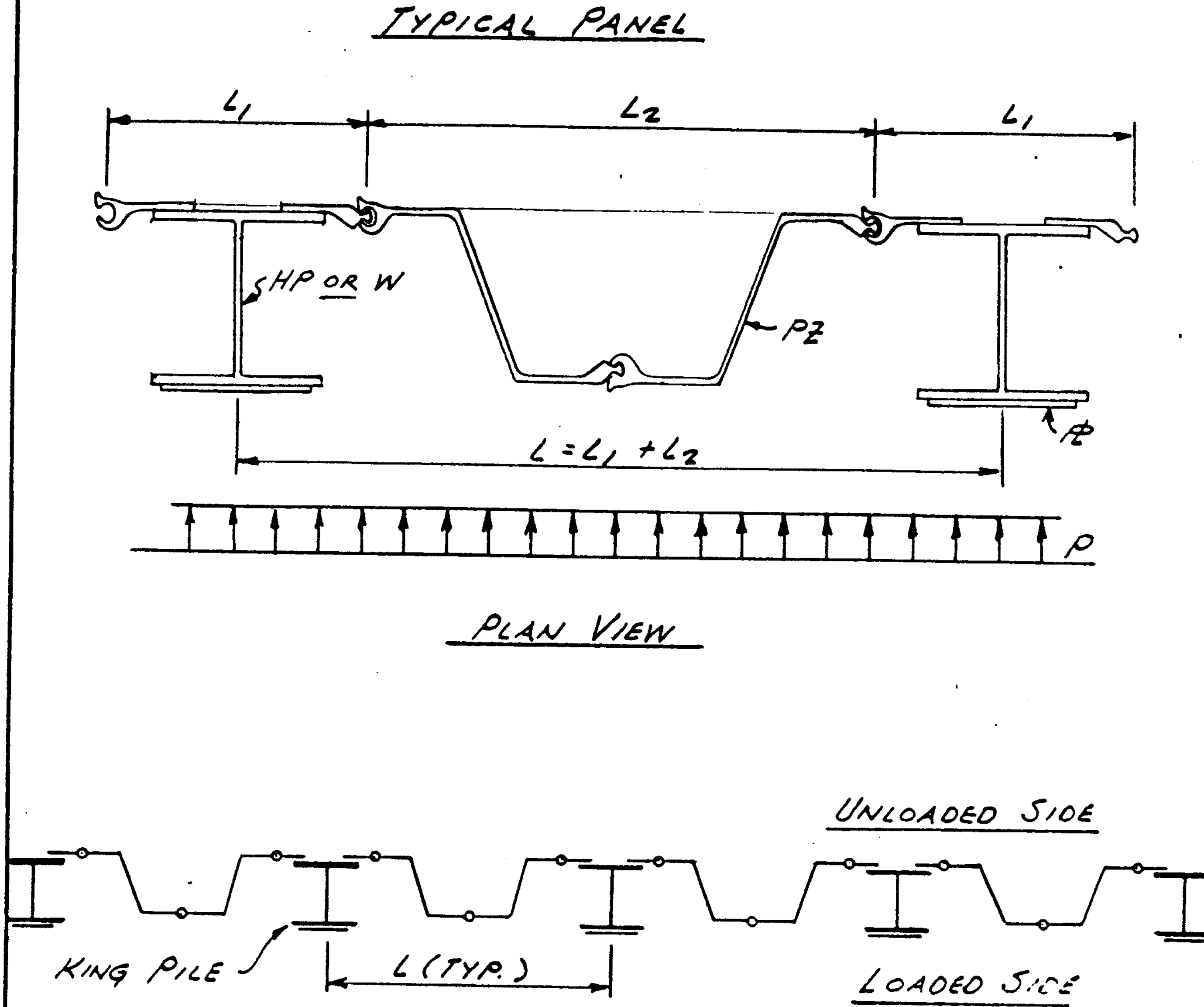
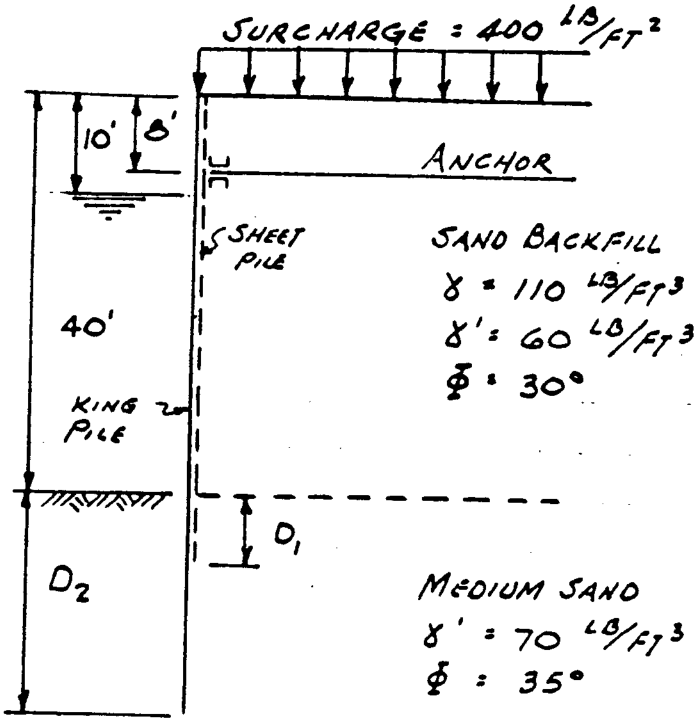


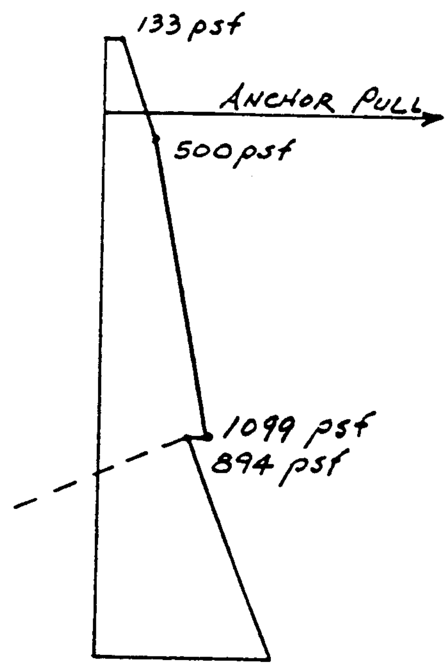

FIGURE 1

BETHLEHEM KING PILE SYSTEM

DESIGN A KING PILE SYSTEM FOR THE LOADING CONDITIONS AND PRESSURE DIAGRAM SHOWN IN FIG. 2




LOADING DIAGRAM




ACTIVE PRESSURE DIAGRAM

FIGURE 2

| | | |
|---|---|---|
| SUBJECT KING PILE SYSTEM DESIGN EXAMPLE | FILE NO. | DATE 5-3-83 |
| | PROJECT | PREPARED BY LA |
| | | SHEET 3 OF 7 |

USING THE EQUIVALENT BEAM METHOD, THE LOAD, SHEAR AND MOMENT DIAGRAMS ARE DETERMINED AS SHOWN BELOW FOR A ONE-FOOT WIDTH OF WALL.

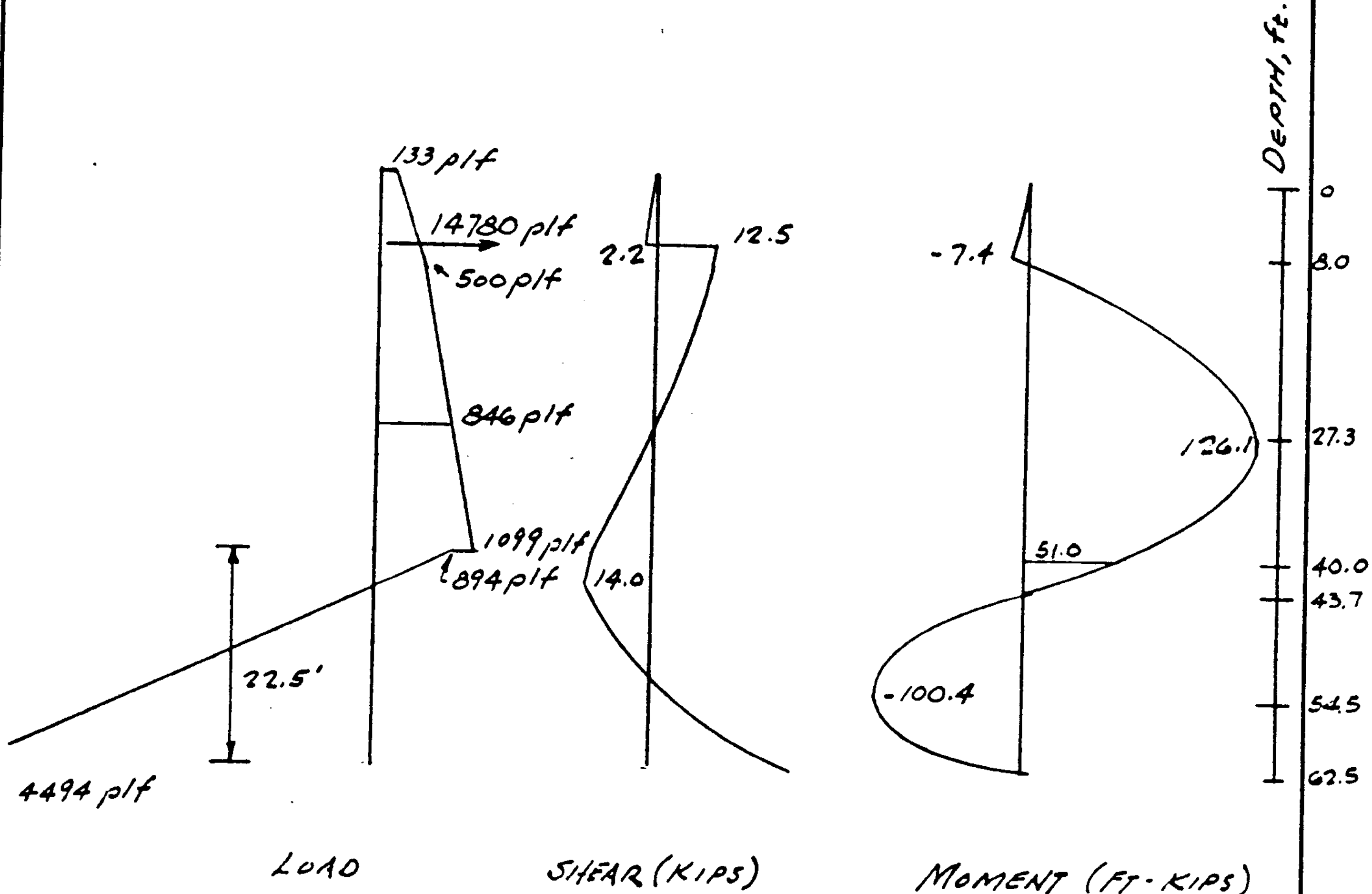



FIGURE 3

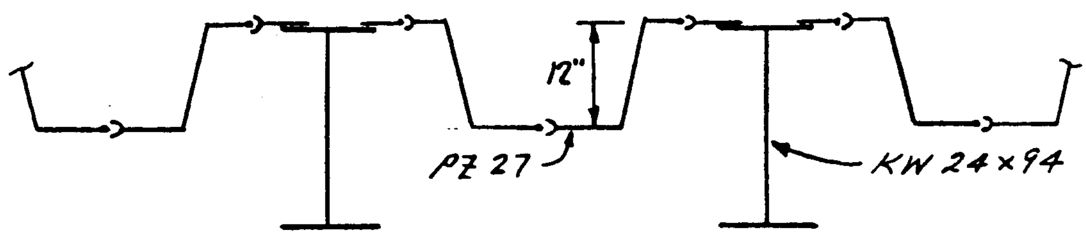
USE THE SIMPLIFIED CALCULATION METHOD.
FROM THE MOMENT DIAGRAM,

MAX. MOMENT = 126 FT-KIPS PER FOOT OF WIDTH

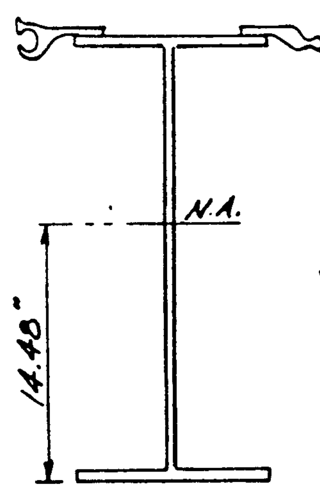
ASSUME ASTM A36 STEEL FOR THE KING PILE, $F_b = 24$ KSI

(EQ. 6) REQ'D. $S^* = \frac{M}{F_b} = \frac{126(12)}{24} = 63$ $IN^3$ PER FOOT OF WIDTH

A. TRY KW24x94 & TWO PZ27 SECTIONS




| SECTION | AREA | Y(BOTT) | AY |
|---|---|---|---|
| W24x94 | 27.7 | 12.16 | 336.7 |
| TABS | 6.6 | 24.21 | 159.8 |
| | 34.3 | | 496.5 |




W24x94
$A = 27.7$ $IN^2$
$d = 24.31$ IN
$b_f = 9.065$ IN
$I_x = 2700$ $IN^4$
$S_x = 222$ $IN^3$

$\bar{Y} = \frac{496.5}{34.3} = 14.48"$

$Y' = (24.31 + 0.375) - 14.48 = 10.21$

$\bar{I} = \Sigma I + \Sigma Ad^2$

$\bar{I} = 2700 + I_{TABS}\ (\to 0) + 27.7(14.48 - 12.16)^2 + 6.6(10.21 - .48)^2$

$\bar{I} = 2700 + 149 + 625 = 3474$ $IN^4$

ADD 2 PZ27 SHEET PILING SECTIONS

(EQ.4) $I_{AVG} = \dfrac{3474 + 2(276.3)}{9.065" + 6" + 36"} = \dfrac{4026.6}{4.26 \text{ FT}} = 945 \text{ IN}^4/\text{FT. OF WALL}$

(EQ.7) $S^* = \dfrac{I_{AVG}}{c} = \dfrac{945}{14.48} = 65.3 \text{ IN}^3/\text{FT} > 63.0 \text{ REQ'D.}$ OK

BENDING STRESS IN KW 24 x 94

(EQ.5) $f_b = \dfrac{Mc}{I_{AVG}} = \dfrac{(126)(12)(14.48)}{945} = 23.2 \text{ KSI} < 24 \text{ KSI}$ OK

WEIGHT $= \dfrac{94 + 2(40.5) + 22.5}{4.26} = \dfrac{197.5}{4.26} = 46.4 \text{ lb/FT}^2$

B. THE MAXIMUM NEGATIVE BENDING MOMENT FROM THE MOMENT DIAGRAM IS 100.4 FT-KIPS PER FOOT OF WIDTH AT A DEPTH OF 54.5 FT.

REQ'D. $S^* = \dfrac{M}{F_b} = \dfrac{100.4 \times 12}{24} = 50.2 \text{ IN}^3/\text{FT. OF WIDTH}$

ASSUMING SATISFACTORY SOIL CONDITIONS, CHECK THE ADEQUACY OF THE W SHAPES TO CARRY THIS MOMENT WITHOUT THE USE OF THE SHEET PILING AT THIS DEPTH.

W 24 x 94 $S_x = 222 \text{ IN}^3$

$S^* = \dfrac{222}{4.26} = 52 \text{ IN}^3/\text{FT. OF WIDTH} > 50.2 \text{ REQ'D.}$ OK

C. CHECK STRESSES IN PZ27 SECTIONS

AT 27.3 FT: $p = 846$ psf, $M = 126$ FT-K/FT, $V = 0$

LONGITUDINAL BENDING STRESS ($F_y = 39$ KSI, $F_b = 25$ KSI)

$f_b = \dfrac{Mc}{I_{AVG}} = \dfrac{126(12)(6.0)}{945} = 9.6 \text{ KSI} < 25.0 \text{ KSI}$ OK

SUBJECT: KING PILE SYSTEM — FILE NO. — DATE: 5-4-83

DESIGN EXAMPLE — PROJECT — PREPARED BY: SJE

SHEET 6 OF 7

TRANSVERSE BENDING STRESS (NEGLECT ANY BRIDGING ACTION BY THE SOIL)

(AISC 1.5.1.4.3) $F_b = 0.75 F_y = 0.75(39) = 29 \text{ KSI}$

$f_{tb} = \dfrac{3k\alpha p L_2^2}{t^2}$ ; $k = 0.157$ FOR PZ 27 SECTIONS

$$\alpha = 1 - \frac{\left(1 + \frac{L_1}{L_2}\right)}{\left(1 + \frac{I_1}{I_2}\right)} = 1 - \frac{\left(1 + \frac{15.065}{36}\right)}{\left(1 + \frac{3474}{552.6}\right)} = 1 - \frac{1.418}{7.287} = 0.805$$

$$f_{tb} = \frac{3(0.157)(0.805)(846)(36)^2}{(.375)^2\,(144)} = 20{,}600 \text{ psi} = 20.6 \text{ KSI} < 29 \text{ KSI}$$

OK

SHEAR STRESS = 0

COMBINED STRESSES: COMPUTE THE EQUIVALENT STRESS USING THE VON MISES YIELD CRITERION.

$$f_e = \sqrt{f^2 + f_{tb}^2 - f_{tb} f_b + 3 f_v^2}$$

FOR $f$ AND $f_{tb}$ OF UNLIKE SIGN

$$f_e = \sqrt{(9.6)^2 + (20.6)^2 + (9.6)(20.6)} = 26.7 \text{ KSI}$$

$F_Y / f_e = 39/26.7 = 1.46$ OK

AT 40 FT: $p = 1099$ psf, $M = 51.0$ FT-K/FT, $V = 12.4$ K

LONGITUDINAL BENDING STRESS

$$f_b = \frac{Mc}{I_{AVG.}} = \frac{(51)(12)(6.0)}{945} = 3.9 \text{ KSI}$$

TRANSVERSE BENDING STRESS (NEGLECT ANY BRIDGING ACTION BY THE SOIL)

$$f_{tb} = \frac{3k\alpha p L_2^2}{t^2} = \frac{3(0.157)(0.805)(1099)(36)^2}{(.375)^2\ (144)}$$

$$= 26{,}700\ psi = 26.7\ ksi < 29\ ksi$$ OK

SHEAR STRESS

$$f_V = \frac{V}{A_V} = \frac{12.4}{(2)(.375)(12.6)} = 1.31\ ksi$$

COMBINED STRESSES

$$f_e = \sqrt{f^2 + f_{tb}^2 - f_{tb} f + 3 f_V^2}$$

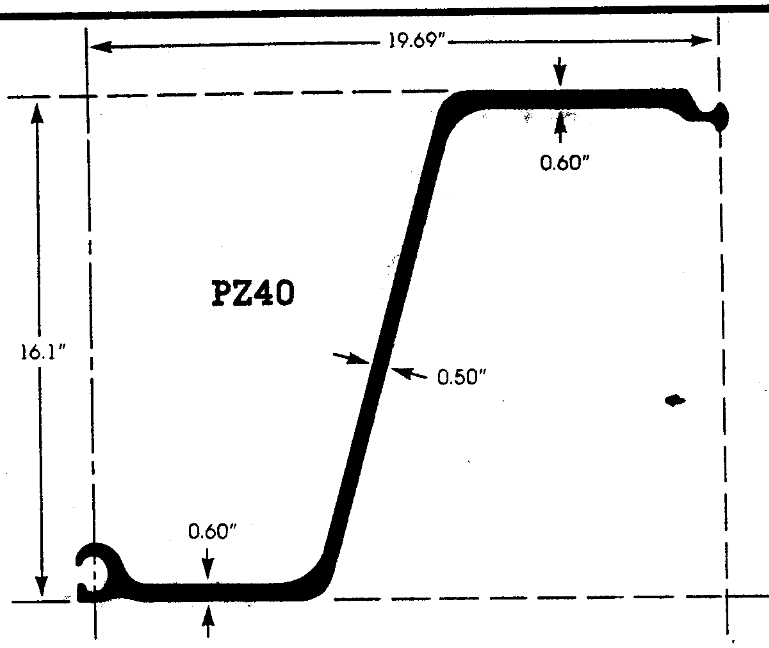
$$f_e = \sqrt{(3.9)^2 + (26.7)^2 + (26.7)(3.9) + 3(1.3)^2} = 28.9\ ksi$$

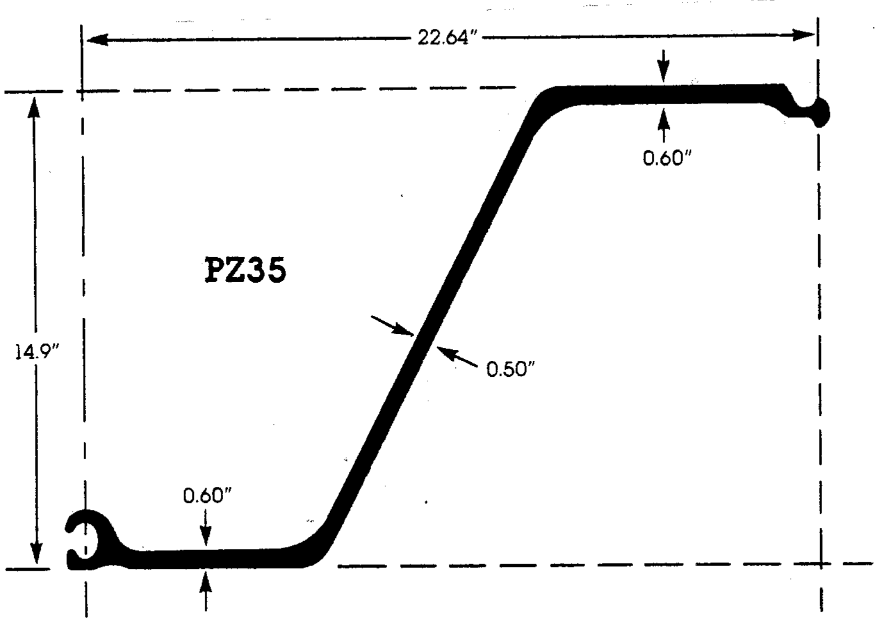
$$F_Y/f_e = 39/28.9 = 1.35$$ OK

RECOMMENDED SOLUTION:

USE KW 24 x 94 KING PILES AND PZ27 SECTIONS TO A DEPTH OF 50 FEET AND W24 x 94 SECTIONS TO A DEPTH OF 67 FEET. HENCE, IN FIGURE 2, D1 = 10 FT. AND D2 = 27 FT.

# Two New Bethlehem Sections



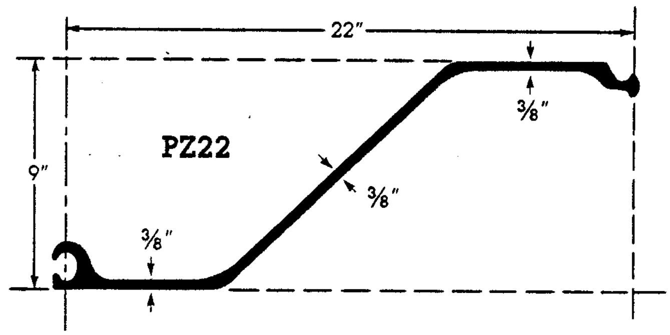



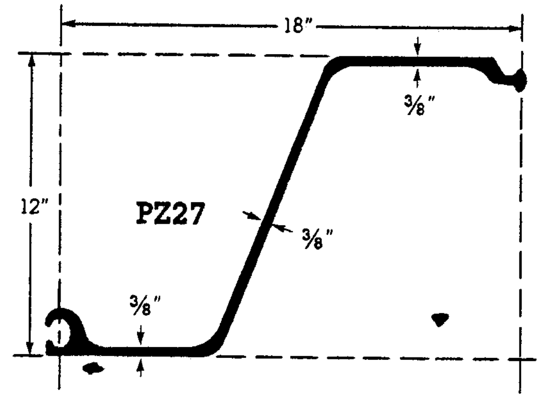

**PZ40** is 30% stronger than any sheet previously available from Bethlehem. Its 60.7 in.$^3$/ft section modulus expands the range of sheet piling . . . lets you build deeper bulkheads . . . design for higher loads in cofferdams. Saves you money.

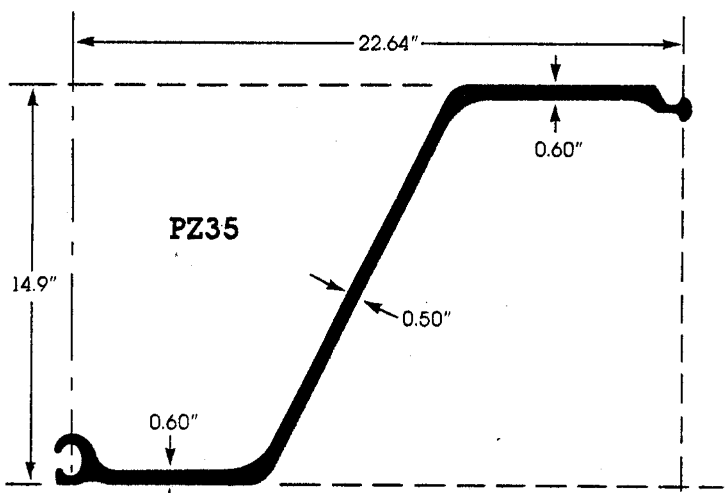
**PZ35** replaces our old PZ38 . . . is 3 lb/ft$^2$ lighter and has a driving width 25% greater. Lets you do the same job with fewer sheets. Saves you money.

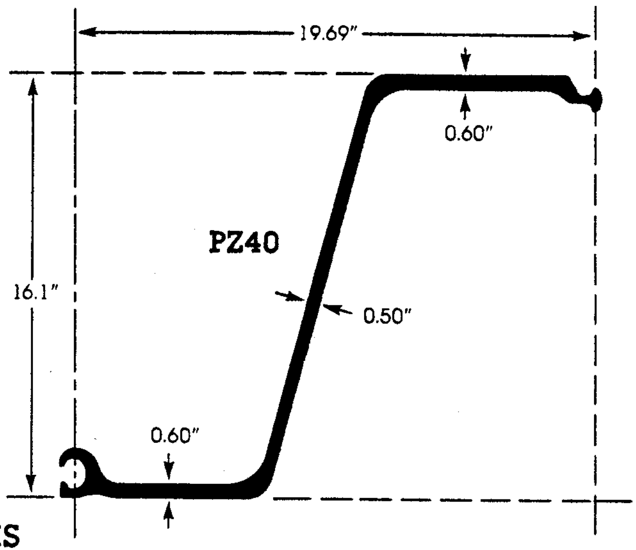
**Bethlehem**

# Now...
# 4 sheet piling sections from Bethlehem Steel




## Properties and Weights

| Section Designation | Area, sq in. | Nominal Width, in. | Weight in Pounds: Per lin ft of bar | Weight in Pounds: Per sq ft of wall | Moment of Inertia, in.[4] | Section Modulus, in.[3]: Single Section | Section Modulus, in.[3]: Per lin ft of wall | Surface Area, sq ft per lin ft of bar: Total Area | Surface Area, sq ft per lin ft of bar: Nominal Coating Area* |
|---|---|---|---|---|---|---|---|---|---|
| PZ22 | 11.86 | 22 | 40.3 | 22.0 | 154.7 | 33.1 | 18.1 | 4.94 | 4.48 |
| PZ27 | 11.91 | 18 | 40.5 | 27.0 | 276.3 | 45.3 | 30.2 | 4.94 | 4.48 |
| PZ35 | 19.41 | 22.64 | 66.0 | 35.0 | 681.5 | 91.4 | 48.5 | 5.83 | 5.37 |
| PZ40 | 19.30 | 19.69 | 65.6 | 40.0 | 805.4 | 99.6 | 60.7 | 5.83 | 5.37 |

Note: All sections interlock with one another.

*Excludes bowl and ball of interlock.

For more information, call your nearest Bethlehem sales office. Or write Construction Products Sales, Bethlehem Steel Corporation, Bethlehem, PA 18016.

**Bethlehem**

Descriptive Sheet 3814
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