Appendix D Example 28 – Pile Penetration Failure – Type II Bent

Refer to *Falsework Manual,* Section -8-6.06A, *Failure to Attain Required Penetration.* When the D/H ratio is less than 0.75 but greater than or equal to 0.45 for pile foundations an alternative procedure is used for analysis of piles (Reference Section 8-6.06A). This condition will increase rotation of the falsework bent which will reduce bending resistance and overall load-carrying capacity. This example demonstrates the alternate procedure for pile analysis.

Given Information

Refer the example in Section D-25, *Type II Pile,* and assume the critical pile in this example has the following as-driven values:

	Planned	Actual
D	14 ft (min)	10 ft
△	6 in (max.)	6 in
e_1	4 in (max.)	8 in at 60° angle (relative brg.) with △

Determine Adequacy of Pile (See Section 8-6.05E(2))

1. Check adequacy of pile penetration

   $$\frac{D}{H} = \frac{10}{16} = 0.625$$

   $0.45 \leq 0.625 \leq 0.75$ Determine stiffness reducing coefficient (Q)

   From Figure 8-29, Q = 1.10 (for normal soil)

2. Find new values for Y_2 and L_2

   $Y_2 = Q(Y_2) = (1.10)(6.25) = 6.88$ ft

   $L_2 = H + Y_2 = 16.0 + 6.88 = 22.88$ ft

3. Check bent type

L_u = Dist. FG to Brace + Y_2 = 6 + 6.88 = 12.88 ft

$$\frac{L_u}{d} = \frac{(12.88)(12)}{15} = 10.30$$ 8 < 10.3 ≤ 15 (Eq 8-6.05E-2) Still Type II bent

4. Calculate stress due to pile pull

$$F_2 = \frac{3EI\triangle}{(12L_2)^3} = \frac{3(1.7 \text{ x } 10^6)(2485)(6)}{(12 \text{ x } 22.88)^3} = 3674 \text{ lbs}$$

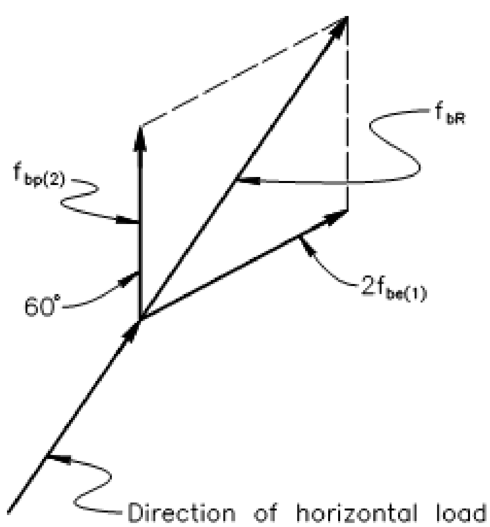
$$f_{bp\,(2)} = \frac{F_2(12L_2)}{S} = \frac{(3674)(12 \text{ x } 22.88)}{331} = 3048 \text{ psi}$$

Note that it is not necessary to calculate the initial bending stress for this pile because △ is unchanged. (The longer L_1 length will give a corresponding lower value for $f_{bp(1)}$).

5. Calculate stress due to pile lean (see example D-25 for vertical load)

$$f_{be(1)} = \frac{P_v(e_1)}{S} = \frac{(36000)(8)}{331} = 870 \text{ psi}$$

6. Calculate stress resultant – See Section 8-6.06C



$f_{bp(2)}$ = 3048 psi

2 $f_{be(1)}$ = 1740 psi (load factor = 2)

Solve stress vector triangles to find the resultant stress

$f_{bR} = \sqrt{3048^2 + 1740^2 + 2(3048)(1740)\text{Cos } 60}$

f_{bR} = 4198 psi

7. Calculate stress due to design horizontal load (H)

H = 720 lbs (2%(DL) from example D-25)

L_u = 12.88 ft (See step 3)

$$f_{bH} = \frac{H(12L_u)}{S} = \frac{(720)(12)(12.88)}{331} = 336 \text{ psi}$$

8. Calculate horizontal displacement

$$X = \frac{H(12L_u)^3}{3EI} = \frac{(720)(12 \text{ x } 12.88)^3}{3(1.7 \text{ x } 10^6)(2485)} = 0.21 \text{ in} = e_2$$

9. Calculate stress due to e_2

$$f_{be(2)} = \frac{P_v(e_2)}{S} = \frac{(36000)(0.21)}{331} = 22.8 \text{ psi}$$

10. Determine allowable compressive stress

Note: actual f_c is unchanged at 203 psi (see step 6 example D-25)

$L_u = L_2$ = 22.88 ft (long. direction governs)

Capacity in compression:

Reference design value in compression F_c = 1300 psi (NDS supplement table 6A)

Adjustment factors from NDS table 6.3.1:

C_D = 1.25	*Duration Factor for 2% lateral loading*
C_M = 1.0	*Wet Service Factor NDS 6.3.3*
C_t = 1.0	*Temperature Factor NDS 6.3.4 (Temp up to 100ºF)*
C_{ct} = 1.0	*Conditioning Treatment Factor NDS 6.3.5 (air dried)*
C_{cs} = 1.01	*Critical Section Factor NDS 6.3.9 (L_c = 3.12 ft)*
C_P = 0.577	*Column Stability Factor NDS 3.7.1 (Eff length* 22.88 *)*
C_{ls} = 1.11	*Load sharing Factor NDS 6.3.11*

Adjusted design compression value $F_c' = F_c (C_D)(C_M)(C_t)(C_{ct})(C_{cs}) (C_P)(C_{ls})$ = 1051 psi

Capacity in compression:

Reference design value Fb = 2050 psi (NDS supplement table 6A)

Adjustment factors from NDS table 6.3.1:

C_D = 1.25	*Duration Factor for 2% lateral loading NDS 6.3.2*
C_t = 1.0	*Temperature Factor NDS 6.3.4 (Temp up to 100ºF)*
C_{ct} = 1.0	*Condition Treatment factor NDS 6.3.5*
C_F = 0.99	*Size Factor NDS 6.3.7*
C_{ls} = 1.08	*Load Sharing Factor NDS 6.3.11 (analyze individual pile capacity)*

Adjusted design compression value $F_{b'} = F_b\,(C_D)(C_t)(C_{ct})\,(C_F)(C_{ls})$ = 2740 psi

Solve combined stress equation

$$\frac{f_{bR} + 2(f_{bH} + f_{be\,(2)})}{3F'_b} + \frac{2f_c}{3F'_c} \leq 1.0$$

$$\frac{4198 + 2(336 + 22.8)}{3(2740)} + \frac{2(203)}{3(1051)} \leq 1.0$$

0.60 + 0.13 = 0.73 ≤ 1.0 **<u>OK</u>**