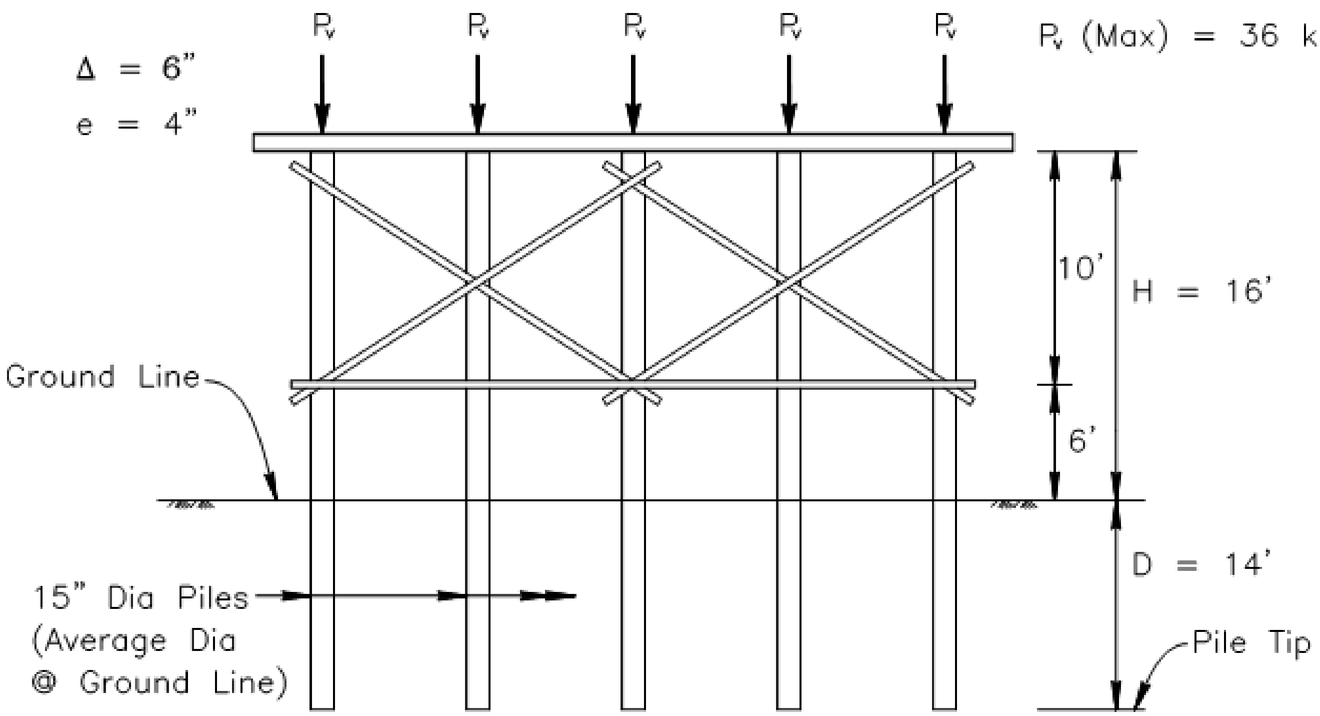
Appendix D Example 25 – Timber Pile Bents – Type II Bent

Refer to *Falsework Manual,* Section 8-6.05, *Analysis of Timber Pile Bents.* Occasionally pile foundations will be used for falsework systems due to poor soil conditions, having to traverse over water, and to mitigate differential settlement. As-built conditions of the driven piles will dictate the bent capacity to resist horizontal loads. Type II falsework bents are analyzed in this example.

Given Information



Preliminary Calculations and Assumptions

1. Pile properties (15"∅ pile; R = 7.5″)

$$A = \pi R^2 = 177 \text{ in}^2$$

$$S = \frac{\pi R^3}{4} = 331 \text{ in}^3$$

I $= \frac{\pi R^4}{4} = 2485$ in^4

2. Required pile penetration (Section 8-6.04A)

   Minimum $\frac{D}{H} = 0.75$; design $\frac{D}{H} = \frac{14}{16} = 0.875$ OK

   Minimum D for construction = (0.75)(16.0)= 12.0'

3. Soil relaxation factor (Section 8-6.04D)

   Assumptions: (1) normal (average) soil & (2) 30-day time period

   From Soil Factor Chart (Figure 8-12) R = 1.25

4. Point of pile fixity (Section 8-6.04B 8-6.04D):

   Y_1 = (4)(pile diameter @ ground line) = (4)(1.25) = 5.0'

   Y_2 = (Y_1)(soil relax. factor) = (5.0)(1.25) = 6.25'

5. Driving tolerances (Section 8-6.04C)

   Max. pile pull = $\triangle$ = 6″ } Values from F/W drawings

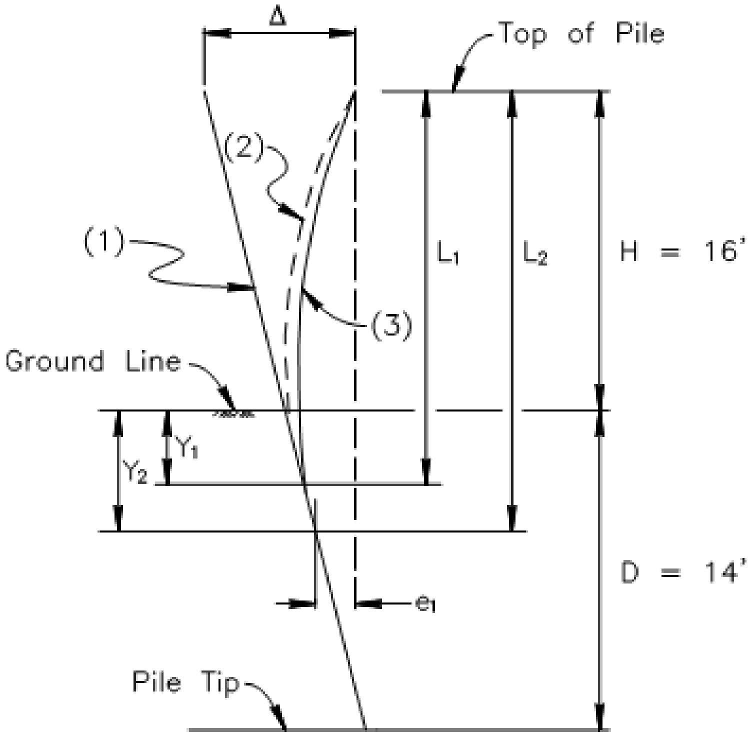
   Max. pile lean = e_1 = 4″

6. Modulus of Elasticity (NDS Table 6A)

   Assume Pacific Coast Douglas fir: E = 1,700,000 psi

Investigate the Effect of Pile Pull (Section 8-6.05A)

Pile Schematic (no scale)



(1) = Driven position

(2) = Initial pulled position

(3) = Position when P_V is applied

Y_1 = 5.0' ; Y_2 = 6.25'

$L_1 = H + Y_1 = 21.0'$

$L_2 = H + Y_2 = 22.25'$

1. Calculate force to pull pile into line

$$F_1 = \frac{3EI\triangle}{(12L_1)^3} = \frac{3(1.7 \text{ x } 10^6)(2485)(6)}{(12 \text{ x } 21.0)^3} = 4752 \text{ lbs}$$

2. Calculate the initial bending stress

$$f_{bp(1)} = \frac{F_1(12L_1)}{S} = \frac{(4752)(12 \text{ x } 21.0)}{331} = 3618 \text{ psi}$$

3618 psi < 4000 psi allowed. OK

3. Calculate force remaining when P_v is applied

$$F_2 = \frac{F_1(L_1)^3}{(L_2)^3} = \frac{4752(21.0)^3}{(22.25)^3} = 3995 \text{ lbs}$$

4. Calculate relaxed bending stress

$$f_{bp(2)} = \frac{F_2(12L_2)}{S} = \frac{3995(12 \text{ x } 22.25)}{331} = 3223 \text{ psi}$$

Evaluate System Adequacy (Section 8-6.05E)

1. Determine bent type

   $L_u = Y_2 + (16.0 - 10.0) = 6.25 + 6.0 = 12.25$ ft

   $\frac{L_u}{d} = \frac{12.25}{1.25} = 9.8$; ∴ Type II bent

   Consider H but not P-delta - See Section 8-6.05F(2)

2. Calculate stress due to pile lean or load eccentricity

   $f_{be(1)} = \frac{P_v(e_1)}{S} = \frac{36000(4)}{331} = 435$ psi

3. Calculate stress due to design H

   H = (0.02)(36000) = 720 lbs - See Standard Specifications Section 48-2.02B(2)

   $f_{bH} = \frac{(H)(L_u)}{S} = \frac{(720)(12.25 \text{ x } 12)}{331} = 320$ psi

4. Calculate horizontal displacement

   $X = \frac{H(12L_u)^3}{3EI} = \frac{720(12 \text{ x } 12.25)^3}{3(1.7 \text{ x } 10^6)(2485)} = 0.18 \text{ in} = e_2$

5. Calculate stress due to additional P_v eccentricity

   $f_{be(2)} = \frac{P_v(e_2)}{S} = \frac{36000(0.18)}{331} = 19.6$ psi

6. Calculate stress due to axial compression

   $f_c = \frac{P_v}{A} = \frac{36000}{177} = 203$ psi

7. Determine allowable compressive stress (Use NDS)

   Note: bent supported at the cap in the longitudinal direction.

L_u (in longitudinal direction) = L_2 = 22.25 ft (pile is unrestrained in longitudinal direction)

Equivalent "d" = $r\sqrt{12} = 3.75\sqrt{12} =$ 13 in (r = radius of gyration= D/4; NDS C6.3.8)

$$\frac{L_u}{d} = \frac{(22.25)(12)}{13} = 20.54$$

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 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_P = 0.593 *Column Stability Factor NDS 6.3.8 (Eff length* $22.25\ ft$*)*

C_{cs} = 1.03 *Critical Section Factor NDS 6.3.9 (tip to point of fixity 7.75 ft)*

C_{ls} = 1.11 *Load Sharing Factor NDS 6.3.11 (assume continuous cap)*

Adjusted design compression value F_c' = F_c (C_D)(C_t)(C_{ct}) (C_P)(C_{cs}) (C_{ls}) = **1102 psi**

8. Determine allowable bending stress (Use NDS)

   Reference design value in compression F_b = 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 (assume continuous cap & note that this value is different depending on Compression or Bending!)*

   Adjusted design bending value F_b' = F_c (C_D)(C_t)(C_{ct}) (C_F) (C_{ls}) = **2740 psi**

9. Check pile adequacy using combined stress expression

$$\frac{f_{bp(2)} + 2f_{be(1)} + 2\left[f_{bH} + f_{be(2)}\right]}{3F'_b} + \frac{2f_c}{3F'_c} \ngtr 1.0$$

$$\frac{3223 + 2(435) + 2(320 + 19.6)}{3(2740)} + \frac{2(203)}{3(1102)}$$

0.58 + 0.12 = 0.70 < 1.0

System is adequate!