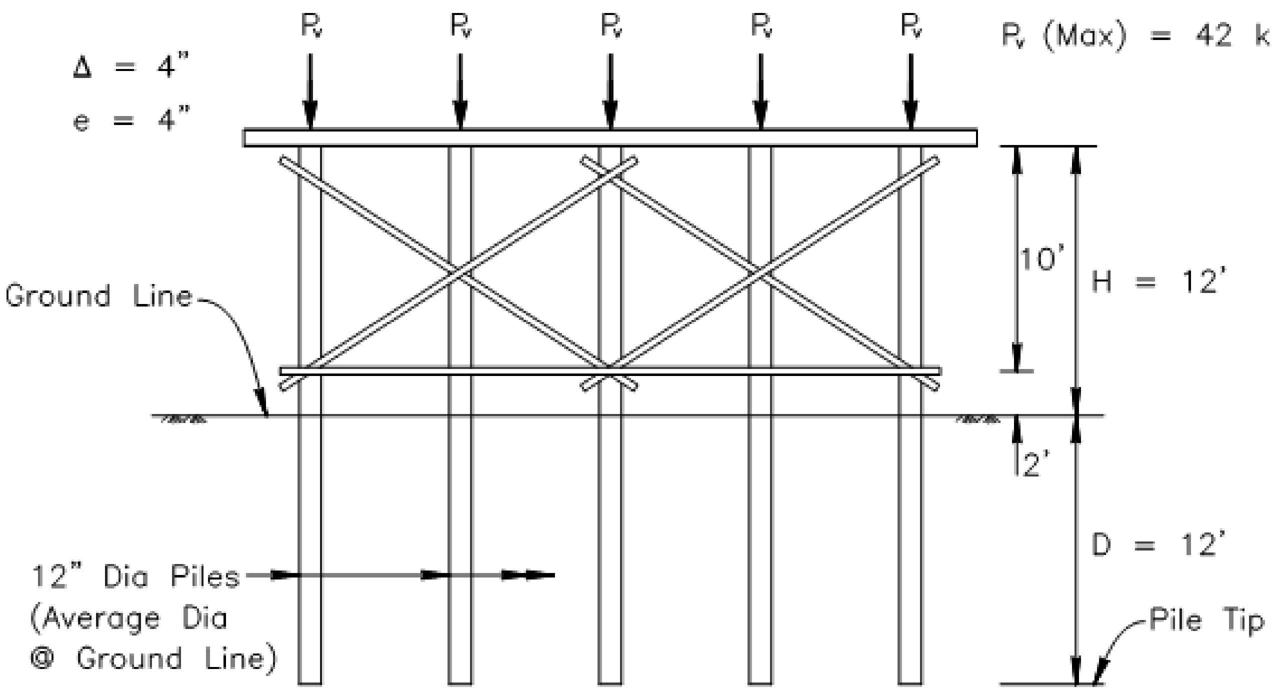
Appendix D Example 24 – Timber Pile Bents – Type I Bent

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 I falsework bents are analyzed in this example.

Given Information



Preliminary Calculations and Assumptions

Identify pertinent properties of the pile selected, ground conditions encountered, and driving tolerances of the pile to be used in the falsework bent.

1. Pile properties ($\emptyset = 12$ in; R = 6 in)

   A $= \pi R^2 = 113$ in^2

S $= \frac{\pi R^3}{4} = 170$ in^3

I $= \frac{\pi R^4}{4} = 1018$ in^4

2. Required Pile Penetration (Section 8-6.04A)

   Minimum $\frac{D}{H} \geq 0.75$; design $\frac{D}{H} = \frac{12}{12} = 1.0$ OK

   Minimum D for construction = (0.75)(12.0) = 9.0 ft

3. Soil Relaxation Factor (Section 8-6.04D)

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

   From Soil Factor Chart (Fig. 8-24) R=1.25

4. Point of Pile Fixity (Section 8-6.04B & 8-6.04D)

   Y_1 = kd

   d = 1 ft (pile diam. @ ground line)

   k = 4 (for medium hard to medium soft soil) (8-6.04B-2)

   Y_1 = (4)(1.0) = 4.0 ft

   Y_2 = (Y_1)(soil relax. Factor from fig 8-24) = (4.0)(1.25) = 5.0 ft

5. Driving Tolerances (Section 8-6.04C)

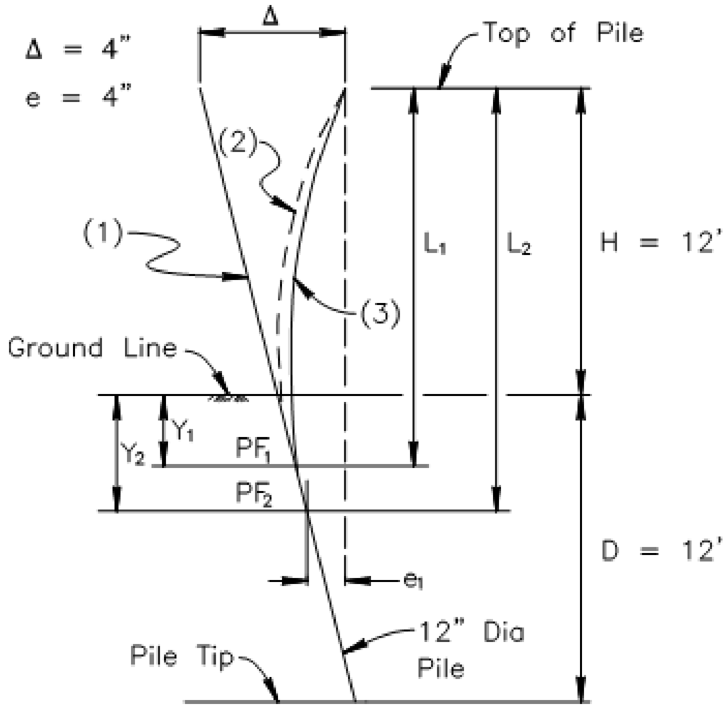
   Max. pile pull = △ = 4 in
   Max. pile lean = e_1 = 4 in
   } Values from F/W drawings

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

$L_1 = H + Y_1 = 12.0' + 4.0' = 16.0'$

$L_2 = H + Y_2 = 12.0' + 5.0' = 17.0$

1. Calculate F_1 = force to pull pile into line

$$F_1 = \frac{3EI\triangle}{(12L_1)^3} = \frac{3(1.7x\,10^6)(\,1018)(4)}{(12\,x\,16.0)^3} = 2934 \text{ lbs}$$

2. Calculate the initial bending stress

$$f_{bp(1)} = \frac{F_1(12L_1)}{S} = \frac{(2934)(16)(12)}{170} = 3314 \text{ psi}$$

3314 psi < 4000 psi allowed (per Section 8-6.05A), therefore OK

3. Calculate F_2 = force after soil relaxes

$$F_2 = \frac{F_1(L_1)^3}{(L_2)^3} = \frac{2934(16.0)^3}{(17.0)^3} = 2446 \text{ lbs}$$

4. Calculate bending stress remaining in pile after soil relaxation (final condition)

$$f_{bp(2)} = \frac{F_2(12L_2)}{S} = \frac{2446(17)(12)}{170} = 2935 \text{ psi}$$

Evaluate System Adequacy (Section 8-6.05E)

1. Determine bent type

   $L_u = Y_2 + (12.0 – 10.0) = 5.0 + 2.0 = 7.0$ ft (the distance from PF_2 to bottom of X-brace)

   $\frac{L_u}{d} = \frac{7.0}{1.0} = 7 < 8$ ∴ Type I bent (Bending stress produced by the horizontal design load may be neglected per Section 8-6.05E(1))

2. Calculate bending stress due to vertical load eccentricity

   Since it's a Type I bent follow Section 8-6.05E(1)

   $f_{be(1)} = \frac{(P_v e_1)}{S} = \frac{(42000)(4)}{170} = 988$ psi

3. Calculate stress due to axial compression

   $f_c = \frac{P_v}{A} = \frac{42000}{113} = 371$ psi

4. Determine allowable compressive stress (Use NDS)

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

   L_u (in longitudinal direction) = L_2 = 17.0 ft (pile is unrestrained in longitudinal direction)

   Equivalent "d" = $r\sqrt{12} = 3\sqrt{12} = 10.39$ in (r = radius of gyration= D/4; NDS C6.3.8)

   $\frac{L_u}{d} = \frac{(17)(12)}{10.39} = 19.63$

   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 = 0.631 *Column Stability Factor NDS 6.3.8 (Eff length* $17\ ft$*)*
C_{cs} = 1.03 *Critical Section Factor NDS 6.3.9 (tip to point of fixity 7 ft)*
C_{ls} = 1.11 *Load Sharing Factor NDS 6.3.11 (assume continuous cap)*

Adjusted design compression value $F_c' = F_c (C_D)(C_t)(C_{ct})(C_P)(C_{cs})(C_{ls})$ = 1172 psi

5. Solve combined stress expression

$$\frac{f_{bp(2)}+2f_{be(1)}}{3F_b'}+\frac{2f_c}{3F_c'}\leq 1.0 \qquad \text{(8-6.05E(1)-1)}$$

Need to calculate F_b' using NDS

Reference design value 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 = 1.0 *Size Factor NDS 6.3.7*
C_{ls} = 1.08 *Load Sharing Factor NDS 6.3.11 (assume continuous cap)*

Adjusted design compression value $F_b' = F_b (C_D)(C_t)(C_{ct})(C_F)(C_{ls})$ = 2768 psi

Substitute values and solve combined stress equation

$$\frac{2935+2(988)}{3(2768)}+\frac{2(371)}{3(1172)}$$

$0.59 + 0.21 = 0.80 \leq 1.0$ System is adequate!!

Options available if combined stress > 1:

a. Use larger diameter pile
b. Reduce allowable values for $\triangle$ and/or e_1
c. Shorten F/W span to reduce P_v