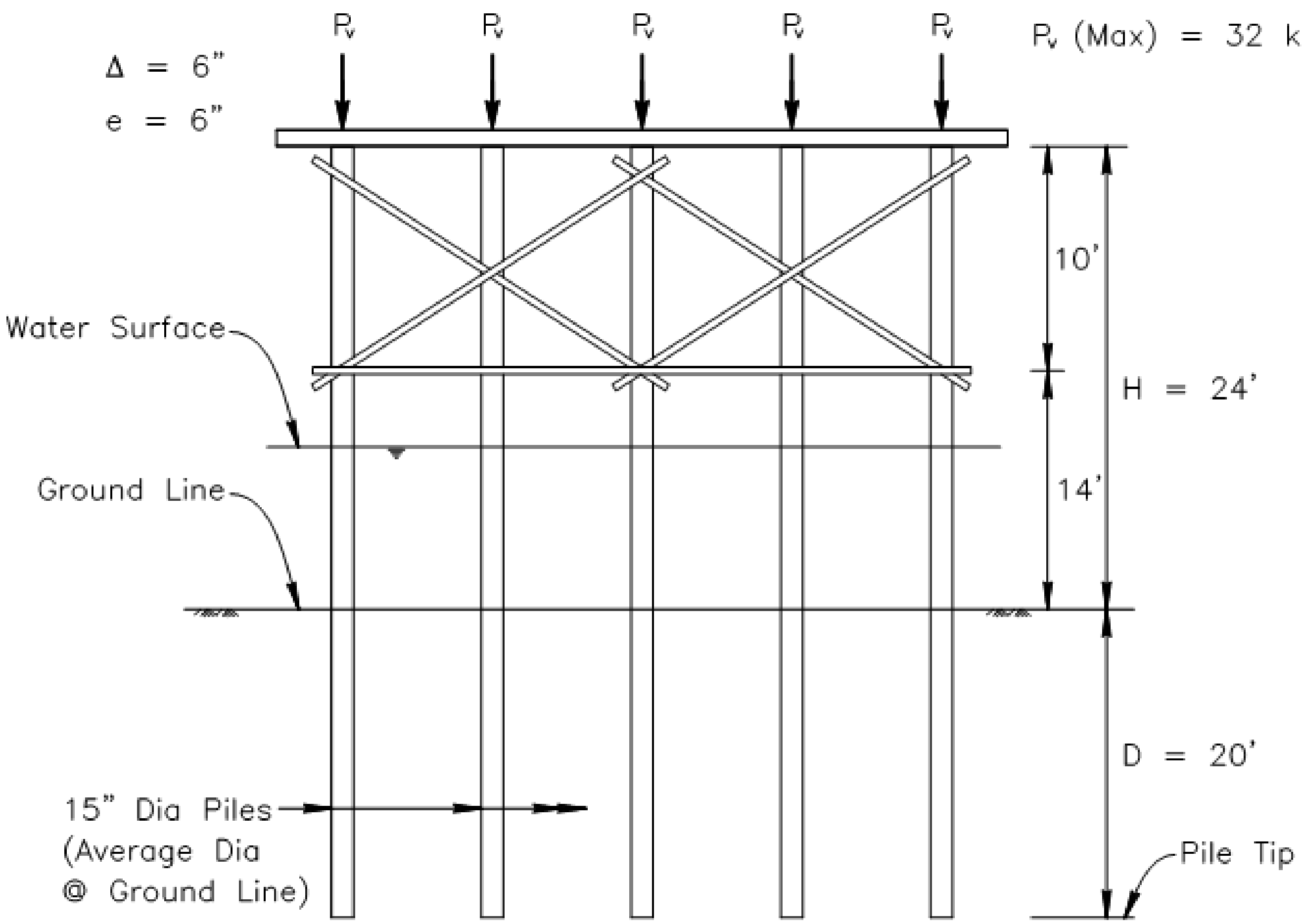
Appendix D Example 26 – Timber Pile Bents – Type III Bent

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 III falsework bents are analyzed in this example.

Given Information



Preliminary Calculations and Assumptions

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

   A = πR^2 = 177 in^2

   S = $\frac{\pi R^3}{4} = 331$ 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 $\frac{D}{H} = \frac{20}{24} = 0.83$ OK

   Minimum D for construction = (0.75)(24)= 18.0 ft

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

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

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

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

   Y_1 = (4)(ground line pile diameter) = (4)(1.25) = 5.0 ft

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

5. Driving tolerances (Section 8-6.04C)

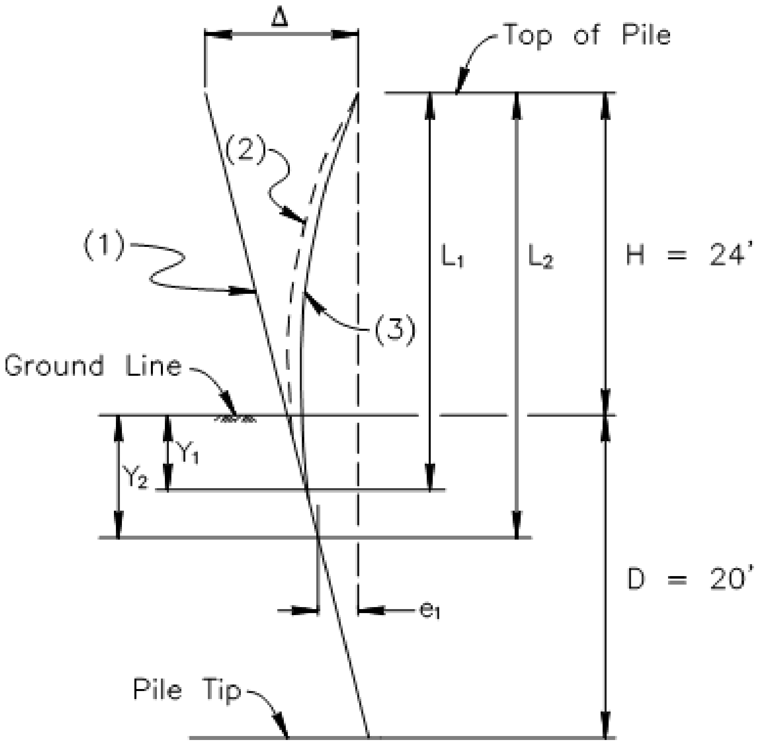
   Max. pile pull = △ = 6in
   Max. pile lean = e_1 = 6in
   } Values from F/W drawings

6. Modulus of Elasticity (NDS Table 6A):

   Assume Pacific Coast Doulas Fir: E = 1,700,000 psi

Investigate the Effect of Pile Pull

Pile Schematic (no scale)



(1) = *Driven position*

(2) = *Initial pulled position*

(3) = *Position when* P_V *is applied*

Y_1 = 5.0' ; Y_2 = 6.25ft

$L_1 = H + Y_1$ = 29.0ft

$L_2 = H + Y_2$ = 30.25ft

1. Calculate force to pull pile into line (Section 8-6.05A)

$$F_1 = \frac{3EI\triangle}{(12L_1)^3} = \frac{3(1.7 \text{ x } 10^6)(2485)(6)}{(12 \text{ x } 29.0)^3} = 1804 \text{ lbs}$$

2. Calculate the initial bending stress

$$f_{bp(1)} = \frac{F_1(12L_1)}{S} = \frac{(1804)(12 \text{ x } 29.0)}{331} = 1897 \text{ psi}$$

1897 < 4000 psi allowed. <u>OK</u>

3. Calculate force remaining when P_v is applied

$$F_2 = \frac{F_1(L_1)^3}{(L_2)^3} = \frac{1804(29.0)^3}{(30.25)^3} = 1589 \text{ lbs}$$

4. Calculate the relaxed bending stress

$f_{bp(2)} = \frac{F_2(12L_2)}{S} = \frac{(1589)(12 \text{ x } 30.25)}{331} = 1743$ psi

Evaluate System Adequacy (Section 8-6.05E)

1. Determine bent type

   $L_u = Y_2 + (24.0 - 10.0) = 6.25 + 14.0 = 20.25$ ft

   $\frac{L_u}{d} = \frac{20.25}{1.25} = 16.2 > 15$, ∴ Type III bent

   Consider P-delta effect – See Section 8-6.05E(3)

2. Calculate stress due to pile lean

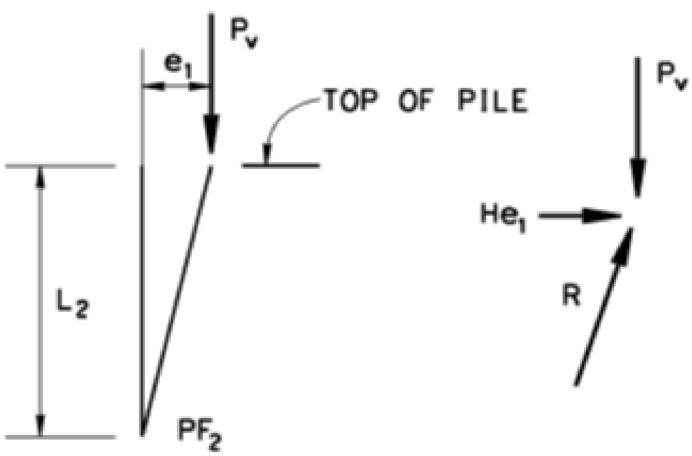
   $f_{be(1)} = \frac{P_v(e_1)}{S} = \frac{(32000)(6)}{331} = 580$ psi

3. Calculate stress due to design H (2% of gravity load for lateral load)

   H = (0.02)(32,000) = 640 lbs

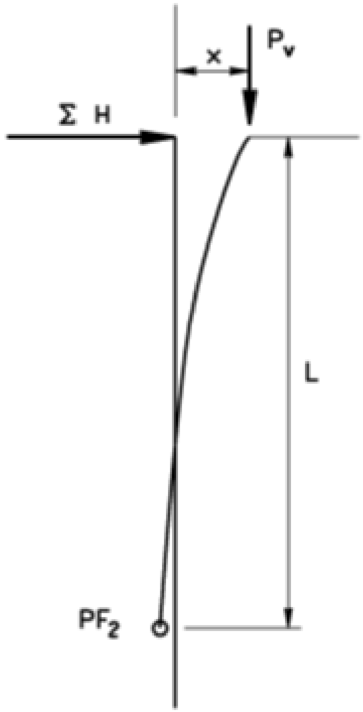
   $f_{bH} = \frac{(H)(L_u)}{S} = \frac{(640)(12*20.25)}{331} = 470$ psi

4. Calculate horizontal component of P_v reaction



$$He_1 = \frac{P_v(e_1)}{12\,L_2} = \frac{(32000)(6)}{12(30.25)} = 529 \text{ lbs}$$

5. Calculate total horizontal displacement (e_3):



X = displacement due to total H load

$$X = \frac{\sum H\,(L)^3}{3EI}$$

$$\sum H = \text{design H} + He_1$$

= 640 + 529 = 1169 lbs

$12L_u$ = 12(20.25 ft = 243 in

3EI = 3(1.7x10^6 x 2485) =1.267x10^{10} lb-in^2

Refer to Section 8-6.05E(3)

X = $\frac{(1169)(243)^3}{3EI}$ =1.32	H_1 = 1169 + $\frac{(32000)(1.32)}{243}$ =1343 lbs
X_1 = $\frac{(1343)(243)^3}{3EI}$ =1.52	H_2 = 1343 + $\frac{(32000)(1.52-1.32)}{243}$ =1369 lbs
X_2 = $\frac{(1369)(243)^3}{3EI}$ =1.55	Values within 5% STOP

6. Calculate bending stress due to ΣH displacement

$$f_{be3} = \frac{P_v(e_3)}{S} = \frac{(32000)(1.55)}{331} = 150 \text{ psi}$$

7. Calculate stress due to axial compression

$$f_c = \frac{P_v}{A} = \frac{32000}{177} = 181 \text{ psi}$$

8. Determine allowable compressive stress (Use NDS)

Note: Bent is supported at the cap in the longitudinal direction.

L_u (in longitudinal direction) = L_2 = 30.25'

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

$$\frac{L_u}{d} = \frac{12 \text{ x } 30.25}{13} = 27.9$$

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 = 0.351 C*olumn Stability Factor NDS 6.3.8 (Eff length* $30.25f$*)*

C_{cs} = 1.06 *Critical Section Factor NDS 6.3.9 (tip to point of fixity 13.75 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}) = **671 psi**

9. 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**

10. Check pile adequacy using combined stress expression

$$\frac{f_{bp(2)}+2f_{be(1)}+2(f_{bH}+f_{be(3)})}{3F'_b} + \frac{2f_c}{3F'_c} \nless 1.0$$

$$\frac{1743+2(580)+2(470+150)}{3(2740)}+\frac{2(181)}{3(671)}$$

0.50+ 0.18= 0.68 < 1.0

System is adequate!