STRUCTURAL CALCULATIONS

FOR

Poly Canyon Observation Deck
Senior Project
Spring 2018

Students: Emir Kuljancic & Sitora Vaxidova
Advisor: Kevin Dong

California Polytechnic State University
San Luis Obispo, California
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SAN LUIS OBISPO, CA

5 June 2018

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Project Description & Design Criteria ................................................................. T1
Vertical Loads ........................................................................................................ T2
Roof Framing Design........................................................................................... R1-R13
Floor Framing Design........................................................................................ F1-F6
Column Design..................................................................................................... C1
Lateral Design...................................................................................................... L1-L11
Foundation Design............................................................................................. FD1
Miscellaneous...................................................................................................... M1-M3
Project Overview

Poly Canyon Observation Platform is a proposed CM/ARCE interdisciplinary senior project with a goal of providing an observation point/rest stop for hikers and bikers. The platform has a shaded cover and seating area overlooking Poly Canyon for a rewarding experience after a long trek out to the lookout point.

The proposed location (see below) for the Poly Canyon Observation Platform is in the Poly Canyon below and to the right of the Blue Metal Stick Structure. This location will serve as a daytime/sunset observation point that overlooks Poly Canyon and adjacent structures.

The proposed structure will have timber framing and utilize cast in place concrete pier footings. The proposed dimensions for the observation deck are 12 feet by 12 feet. The open sides of the structure will include steps up to the deck and possibly an access ramp to meet ADA compliance requirements if required. A light framed shade structure is planned to be constructed out of 2x2 Redwood framing. The proposed connections heavily utilize Simpson Strong Tie connectors as well as some custom SST column bases and caps that connect multiple girders at different angles.

The following documents are included in the final permit package:

- Gravity Calculations (Dead/Live load)
- Lateral Calculations (Wind/Seismic load)
- Connection Design
- Framing plans, Elevations, Sections
- Typical Connection Details
Project Description:
This project is an observation deck. It consists of a redwood deck construction. The roof is made up of red wood structural members supported by red wood posts. The deck is also supported by the red wood posts. These posts bear on circular concrete footings. The floor joists are made up of 2x6s supported by girders. The floor deck is made up of wooden planks which are nailed to the joists and girders. The deck, trellis and posts are coated with a fire proof sealant. The lateral system consists of 2x4 wood kickers.

Design Criteria:
Building Type:
Timber framed structure.
Type I - 2 hour fire rated, without sprinklers
Occupancy Category: A
Location: San Luis Obispo, CA
Design Code: 2015 IBC, ASCE 7-10, NDS 2015
Wind Criteria:
Risk Category I
Exposure C
See Lateral Design Calculations for detailed wind criteria. (100mph)
Seismic Criteria:
Class D
I=1.0
R =1.0

Foundation Criteria:
Allowable Bearing: 2000psf
Lateral Pressure: 150psf/ft.
**Roof Loads**

<table>
<thead>
<tr>
<th>Description</th>
<th>Calculation</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x2 Rafters @ 4&quot; o.c.</td>
<td>35pcf x1.5&quot;x1.5&quot;x12&quot;/(144&quot;x4&quot; o.c.)</td>
<td>200 lbs</td>
</tr>
<tr>
<td>People Hanging</td>
<td></td>
<td>1psf</td>
</tr>
</tbody>
</table>

**Floor Loads**

<table>
<thead>
<tr>
<th>Description</th>
<th>Calculation</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x6 Decking</td>
<td></td>
<td>2psf</td>
</tr>
<tr>
<td>2x Floor Joists</td>
<td>35pcf x1.5&quot;x5.5&quot;x12&quot;/(144&quot;x24&quot; o.c.)</td>
<td>1psf</td>
</tr>
<tr>
<td>Bench</td>
<td></td>
<td>10psf</td>
</tr>
</tbody>
</table>

**Live Load**

- 20psf (REDUCABLE)
- 30psf (MINIMUM)
- 50psf (DESIGN)

**Building Weight:** 2582 (lbs)
ROOF KEY PLAN

- B1, typ.
- RG1
- RB1
- RB2
- RB3
Roof Beam RB | Risa Input:

Risa Input
Member Primary Data:

<table>
<thead>
<tr>
<th>Label</th>
<th>I Joint</th>
<th>J Joint</th>
<th>Type</th>
<th>Design List</th>
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<tbody>
<tr>
<td>M1</td>
<td>A1</td>
<td>A2</td>
<td>No. 2 Red Wood</td>
<td>Rectangular</td>
</tr>
<tr>
<td>M2</td>
<td>A2</td>
<td>A3</td>
<td>No. 2 Red Wood</td>
<td>Rectangular</td>
</tr>
<tr>
<td>M3</td>
<td>A3</td>
<td>A4</td>
<td>No. 2 Red Wood</td>
<td>Rectangular</td>
</tr>
</tbody>
</table>

Joint Coordinate:

<table>
<thead>
<tr>
<th>Label</th>
<th>x(ft)</th>
<th>y(ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>A2</td>
<td>2</td>
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<tr>
<td>A3</td>
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<td>0</td>
</tr>
<tr>
<td>A4</td>
<td>16</td>
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</table>

Boundary Conditions:

<table>
<thead>
<tr>
<th>Label</th>
<th>x-dir</th>
<th>y-dir</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Free</td>
<td>Free</td>
</tr>
<tr>
<td>A2</td>
<td>Reaction</td>
<td>Reaction</td>
</tr>
<tr>
<td>A3</td>
<td>Free</td>
<td>Reaction</td>
</tr>
<tr>
<td>A4</td>
<td>Free</td>
<td>Free</td>
</tr>
</tbody>
</table>

Basic Load Cases:

<table>
<thead>
<tr>
<th>BLC</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dead Load</td>
</tr>
<tr>
<td>3</td>
<td>Point Load 1</td>
</tr>
<tr>
<td>5</td>
<td>Point Load 2</td>
</tr>
<tr>
<td>6</td>
<td>Live Load All</td>
</tr>
</tbody>
</table>

Unfactored Live Load = -60PLF
Unfactored Dead Load = -6PLF
Unfactored Point Load = -200 #

Load Combinations:

<table>
<thead>
<tr>
<th>Description</th>
<th>BLC</th>
<th>Factor</th>
<th>BLC</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>D+L</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Skip Load 1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Skip Load 2</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>
Roof Beam Calculations (RB1, See Key Plan)

M1  M2  M3
A1  A2  A3  A4

Load Combinations:

D+L

Wc = -60 PLF
Wb = -6 PLF

Skip Load 1

W0 = 6 PLF

Skip Load 2

P = 200#
Roof Beam (RB1) Shear and Moment Output:

\[ V(\#) \]

\[ M(\#) \]

\[ M_u = 1056 \text{ ft-lb} \]

\[ V_u = 396 + 212 = 608 \text{ ft-lb} \]

**DESIGN FOR BENDING**

No. 2 Redwood

- \( F_b = 925 \text{ psi} \)
- \( F_v = 160 \text{ psi} \)
- \( F_t = 525 \text{ psi} \)

Find \( f_b \):

\[ f_b = \frac{M}{S_{req}} \]

\[ S_{req} = 1056 \text{ ft-lb} (12''/ft) = 13.7 \text{ in}^3 \]

\[ f_b = \frac{1056 \text{ ft-lb}}{925 \text{ psi}} = 1.14 \text{ in}^3/\text{psi} \]

Try: No. 2 Redwood 3x8

- \( S = 21.90 \text{ in}^3 > 13.7 \text{ in}^3 \) OK

- \( f_b = \frac{M}{S} = \frac{1056 \text{ ft-lb} (12''/ft)}{21.90 \text{ in}^3} = 57.6 \text{ psi} \)
F_b' = F_b C_b C_m L C_L C_F F_{u} F_i R_e

- D+L LOAD COMBO GOVERNS : C_b = 1.0
- C_F = 1.0
- F_b C_F = 925 psi(1.0) = 925 psi ≤ 1150 psi ; C_m = 1.0

FIND C_L:

\[
\frac{I_c}{d} = \frac{12'' \times 12''}{1'} = 19.9 \geq 7 \therefore I_c = 1.84 I_n
\]

\[
I_c = 1.84(12'' \times 12'' \times 1') = 265.0''
\]

\[
R_b = \sqrt{\frac{I_c d}{b^2}} = \sqrt{\frac{265.0''(7.25'')}{(25)''^2}} = 17.5 \leq 50 \text{ OK}
\]

\[
F_{bE} = \frac{1.20 E'_{min}}{R_b^2}
\]

\[
E'_{min} = E_{min} \frac{i}{\sigma_k (4'' \times 4'' \times 1') R_7 = 440,000 psi}
\]

\[
F_{bE} = \frac{1.20 (440,000 psi)}{(175)''^2} = 1727.1 psi
\]

F_b = 925 psi(1.2) = 1110 psi \rightarrow NO C_L, C_V

\[
C_L = 1 + \left(\frac{F_{bE}}{F_b X}\right) \sqrt{\left[1 + \left(\frac{F_{bE}}{F_b X}\right)\right]^2 - \frac{F_{bE}}{F_b X}}
\]

\[
F_{bE}/F_b = 1.55
\]

\[
C_L = 1 + 1.55 \frac{1.9}{1.9} - \sqrt{\left[1 + 1.55\right]^2 - \frac{1.55}{0.95}} = 0.93
\]

C_L = 0.87

\[
F_b' = 925 psi(1.2)(0.93) = 1032.5 psi
\]

\[
F_b' \geq F_b \rightarrow 1032.5 psi > 578.6 psi \text{ OK}
\]

Adequate in bending
SHEAR CHECK

\[ F_v = \frac{1.5 \cdot V}{b \cdot d} \]
\[ V_u = 608 \, \# \]
\[ F'_u = \frac{1.5 \cdot (608 \, \#) \times 25^\circ}{7.25^\circ} = 50.3 \, \text{psi} \]
\[ F'_v = F_v \times c \times c' = 160 \, \text{psi} \]
\[ F'_v > F_v \quad 160 \, \text{psi} > 50.3 \, \text{psi} \quad \text{OK} \]

DEFLECTION CHECK

WORST CASE (200# HANGING LOAD)

ASSUME SIMPLY SUPPORTED BEAM WITH POINT LOAD & MIDSPAN (CONSERVATIVE)

\[ \Delta_D = \frac{5wL^4}{384EI} = \frac{5 \times 200 \times (12')^4 \times (12''/12')^3}{384 \times (1,209,000) \times (79.39 \text{in}^4)} = 0.35'' \]
\[ \Delta_L = \frac{P L^3}{98EI} = \frac{200 \times (12\times12''/12')^3}{48 \times (1,209,000) \times (79.39 \text{in}^4)} = 0.13'' \]

\[ \Delta_{DL} = \Delta_D + \Delta_L = 0.35'' + 0.13'' = 0.48'' \]
\[ \Delta_{DL, allow} = \frac{12'' \times 12''/12'}{120} = 1.2'' > 0.48'' \quad \text{OK} \]
\[ \Delta_{allow} = \frac{12'' \times 12''/12'}{180} = 0.8'' > 0.13'' \quad \text{OK} \]

Adequate in deflection

PROVIDE No.2 REDWOOD 3x8 ROOF BEAM, RBI
Roof Beam RB2 Risa Input:

Risa Input
Member Primary Data:

<table>
<thead>
<tr>
<th>Label</th>
<th>J Joint</th>
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*Nominal Dimensions*

Joint Coordinate:

<table>
<thead>
<tr>
<th>Label</th>
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<th>y(ft)</th>
</tr>
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<tbody>
<tr>
<td>A1</td>
<td>0</td>
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</tr>
<tr>
<td>A2</td>
<td>1.66</td>
<td>0</td>
</tr>
<tr>
<td>A3</td>
<td>11.66</td>
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</tr>
<tr>
<td>A4</td>
<td>13.33</td>
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<tr>
<td>2</td>
<td>Live Load</td>
</tr>
<tr>
<td>3</td>
<td>Hanging End</td>
</tr>
<tr>
<td>4</td>
<td>Midspan</td>
</tr>
</tbody>
</table>

Unfactored Live Load= -120PLF
Unfactored Dead Load= -12PLF
Hanging Point Load= -200#

Load Combinations:

<table>
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<tr>
<th>Description</th>
<th>BLC</th>
<th>Factor</th>
<th>BLC</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>D+L</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Hanging Ends</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Hanging Midspan</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>
REFERENCE

ROOF BEAM CALCULATIONS (RBZ) SEE KEY PLAN

LOAD COMBINATIONS:

D+L

\[ w_e = 12.0 \text{ PLF} \]

\[ w_0 = 12 \text{ PLF} \]

\[ P = 200 \text{#} \]

\[ w_0 = 12 \text{ PLF} \]

\[ P = 200 \text{#} \]

\[ w_0 = 12 \text{ PLF} \]
Roof Beam RB2 Output:

\[ M_{u} = -1467 \#' \]
\[ V_{u} = 659.8 + 219.9 = 879.7 \# \]

**DESIGN FOR BENDING**

*USE NO. 2 REDWOOD*

**FIND** \( f_{b} = \frac{M}{S_{eq}} \)

\[ S_{eq} = \frac{1467\#' \times 12'/(144) \times 19.03in}{925psi} \]

**TRY:** \( 8 \times 8 \) NO. 2 REDWOOD

\[ S = 21.90in^{2} \geq 17.03in^{2} \text{ OK} \]

\[ f_{b} = \frac{M}{S} = \frac{1467\#' \times 12'/(144)}{21.90in^{2}} = 820.23psi \]

\[ F_{b} = F_{u} \frac{C_{b}}{C_{m} C_{t} C_{L} C_{P} C_{u} C_{t} C_{r}} \]

- \( C_{b} = 1.25 \)
- \( C_{m} C_{t} = 1.2 \)
- \( F_{b} (C_{P}) = 925psi \times 1.2 = 1,110 \leq 1,150 \text{ psi} \) \( C_{r} = 1.0 \)
\[
\text{REFERENCE}
\]

\[
\text{FIND} \quad c_L
\]

\[
\frac{L_u}{d} = \frac{10' (12"/ft)}{2.25''} = 16.6 \geq 7 : \quad L_e = 1.84L_u
\]

\[
L_e = 1.84 (10') (12"/ft) = 220.8''
\]

\[
R_b = \frac{\sqrt{\frac{L_e d}{b^2}}}{b} = \frac{\sqrt{220.8'' (3.25'')}}{2.25''} = 16.00 \leq 50 \text{ OK}
\]

\[
F_{be} = 1.20 \frac{E'_m}{R_b^2}
\]

\[
E'_m = E_m \sigma_m \alpha_i \alpha_i L_i = 449,000 \text{ psi}
\]

\[
F_{be} = 1.20 \left( \frac{449,000}{(16.00)^2} \right) = 2062.5 \text{ psi}
\]

\[
F_{b'} = 925 \text{ psi} \quad (1.2) (1.25) = 1337.5 \text{ psi}
\]

\[
\frac{F_{be}}{F_{b'}} = 1.49
\]

\[
c_L = \sqrt{1 + \frac{1.49}{1.9}} = \frac{1.99}{0.95} = 2.093
\]

\[
F_b = 925 \text{ psi} \quad (1.2) (0.93) (1.2) = 1290.4 \text{ psi}
\]

\[
F_b \geq f_b \quad 1290.4 \text{ psi} \geq 797.3 \text{ psi} \quad \text{OK}
\]

\[
\begin{align*}
\text{SHEAR CHECK} \\
F_v &= 1.5V \\ 
V_u &= 747.6 \text{ft lb} \\
F_v &= 1.5 \left( \frac{879.7 \text{fl lb}}{1.5'' (3.25'')} \right) = 121.9 \text{ psi} \\
F_v &= F_v \sigma_s \sin \theta \cos \phi = 160 (1.25) = 200 \text{ psi} \\
F_v &\geq f_v \quad 200 \text{ psi} \geq 121.9 \text{ psi} \quad \text{OK}
\end{align*}
\]

\[
\begin{align*}
\text{2x8 is adequate in bending.} \\
\text{3x8 is adequate in shear.}
\end{align*}
\]
DEFLECTION CHECK

1. WORST CASE = 200# HANGING LOAD

2. ASSUME SIMPLY SUPPORTED BEAM WITH POINT LOAD AT MIDSPAN (CONSERVATIVE)

\[ \Delta_0 = \frac{5Wl^4}{384EI} = \frac{5(48# / ft)(10')^4(12''/ft)^3}{384 \times (1200000)(79.39 \text{ in}^4)} = 0.01'' \]

\[ \Delta_l = \frac{PL^3}{48EI} = \frac{200# (10' \times 12''/ft)^3}{48(79.39 \text{ in}^4)(1200000)} = 0.08'' \]

\[ \Delta_{D+L} : \text{SUPERIMPOSE} \quad \Delta_{D+L} = \Delta_0 + \Delta_l = 0.01'' + 0.08'' = 0.09'' \]

\[ \Delta_{allow} = \frac{l}{120} = \frac{10'(12''/ft)}{120} = 1.0'' \geq 0.09'' \text{ OK} \]

\[ \Delta_{allow} = \frac{l}{180} = \frac{10'(12''/ft)}{180} = 0.67'' \geq 0.08'' \text{ OK} \]

**PROVIDE 3X8 NO. 2 REDWOOD ROOF BEAM, RBZ**
REFERENCE

ROOF GIRDER DESIGN, RG1

\[ W_D = 494 \text{ lb} \]

\[ P_{RB2} = 879.7 \text{ lb} \]

\[ V = \frac{W_D}{2} + \frac{P}{2} \]

\[ V_u = \frac{W_D}{2} + \frac{P}{2} = 464 \text{ lb} \]

\[ M_u = 490 \times (6) + 24 \times (6) \times (6) \]

\[ M_u = 2,712 \times (6) \]

DESIGN FOR BENDING

\[ \frac{f_b}{f_{eq}} = \frac{M}{S_{eq}} \]

\[ S_{eq} = \frac{2,712 \times 12}{925 \text{ psi}} = 35.1 \text{ in}^3 \]

TRY 3 x 10 No. 2 REDWOOD

\[ S = 35.65 \text{ in}^3 \geq 35.1 \text{ in}^3 \checkmark \text{ OK} \]

\[ f_b = \frac{M}{S} = \frac{2,712 \times 12}{35.65 \text{ in}^3} = 9.15 \text{ psi} \]

\[ F_b = \frac{f_b}{f_{eq}} \]

\[ D + C_r \text{ governs} \]

\[ C_d = 1.25 \]

\[ C_e = 1.1 \]

\[ C_f = \frac{925 \text{ psi}}{1.1} = 1017.5 \text{ psi} \leq 1,150 \text{ psi} \checkmark \]

\[ C_m = 1.0 \]
FIND $C_L$:

$$I_e = 1.11 I_w = 1.11 (6')(12''/ft) = 79.92''$$

$$R_b = \sqrt{\frac{I_e d}{b^2}} = \sqrt{\frac{79.92'' (9.25''/2.5'')}{(2.5'')} = 10.9 \leq 5.0 \text{ VOK}$$

$$F_{bE} = \frac{1.20 E'_m}{R_b^2}$$

$$E'_m = E_{min} \cdot \gamma' (k) \cdot \gamma' (l) \cdot \gamma' (t) = 429,000 \text{ psi}$$

$$F_{bE} = \frac{1.20 (429,000 \text{ psi})}{(10.9)^2} = 444.1 \text{ psi}$$

$$F_b = 925 \text{ psi} (1.25) (1.1) = 1271.9 \text{ psi}$$

$$F_{bE}/F_b = 3.49$$

$$C_L = 1 + 3.49 - \sqrt{(1 + 3.49)^2 - 3.49^2} = 0.98$$

$$C_L = 0.98$$

SHEAR CHECK

$$f_v = \frac{1.5 \sqrt{f}}{b d}$$

$$V_u = (1.6') \cdot 464' = 764'$$

$$f_v = \frac{1.5 (764')}{2.5'' (9.25'')} = 30 \text{ psi}$$

$$F_v = F_v \cdot \gamma_b \cdot \gamma_t \cdot \gamma_e = 160 \text{ psi} (1.25) = 200 \text{ psi}$$

$$F_v \geq f_v = 200 \text{ psi} > 30 \text{ psi VOK}$$

\(3x10\) ADEQUATE IN SHEAR
DEFLECTION CHECK

\[
\Delta_D = \frac{5wL^4}{384EI} = \frac{5(44/lb)(12')^4(12''/ft)^3}{384(1,200,000)(164.9in^4)} = 0.01''
\]

\[
\Delta_L = \frac{pL^3}{98EI} = \frac{879.7#(12'x12''/ft)^3}{98(1,200,000)(164.9in^4)} = 0.28''
\]

\[
\Delta_D_{HL} = 0.01'' + 0.28'' = 0.29''
\]

\[
\Delta_D_{allow} = \frac{1}{120} = \frac{12'(12''/ft)}{120} = 1.0'' \geq 0.29'' OK
\]

\[
\Delta_L_{allow} = \frac{1}{180} = \frac{12'(12''/ft)}{180} = 0.8'' \geq 0.28'' OK
\]

\[\therefore 3\times 10 \text{ ADEQUATE IN DEFLECTION} \]

\[\text{Provide 3\times 10 No. 2 REDWOOD ROOF GIRDER, RG 1} \]
**Typical Column, C1**

\[ p = p_{\text{proof}} + p_{\text{flour}} = 1006\# + 798.4\# = 1804.4\# \]

Use No. 2 Redwood

\[ f_e = 950\text{psi} \]

Find \( A_{\text{req}} \):

\[ A_{\text{req}} = \frac{1804.4\#}{950\text{psi}} = 1.90\text{in}^2 \]

Try: 4x4 No. 2 Redwood

\[ A = 12.25\text{in}^2 \geq 1.90\text{in}^2 \]

\[ f_e = \frac{p}{A} = \frac{1804.4\#}{12.25\text{in}^2} = 131.87\text{psi} \]

\[ f'_e = \frac{f_e}{c_0 c_m c_e c_i c_p} \]

\[ c_0 = 1.25 \]

\[ c_e = 1.15 \]

\[ C_i = C_f = 1.15(950\text{psi}) = 1092.5 \]

\[ f'_{\text{min}} = f_m c_m c_e C_i = 449,000\text{psi}(0.8) = 352,000\text{psi} \]

\[ f_{ce} = 0.822 \frac{f'_{\text{min}}}{(d_f)^2} = 0.822 \frac{352,000\text{psi}}{(4.5\text{in})^2} = 1491.0\text{psi} \]

\[ f_{ce}/f_e = 0.13 \]

\[ c_p = 0.13 \]

\[ F_e = 925\text{psi}(1.25)(1.1)(0.8) = 1017.5\text{psi} \]

\[ F_{\text{min}} = F_m c_m c_e C_i = 949,000\text{psi}(0.8) = 767,000\text{psi} \]

\[ F_{ce} = 0.822 \frac{F_{\text{min}}}{(d_f)^2} = 0.822 \frac{767,000\text{psi}}{(4.5\text{in})^2} = 1481.0\text{psi} \]

\[ F'_e \geq f_e 138.3\text{psi} \geq 131.87\text{psi} \]

Provide 4x4 No. 2 Redwood

**Typical Column, C1**
INITIAL TOLERANCES (FOR FLOOR MEMBERS)

REDWOOD: NO. 2
- Fb = 925 PSI
- Fv = 160 PSI
- E = 1,220,000 PSI
- Emin = 440,000 PSI

BENDING FACTORS:
- Go = 1.25 (CONSTR. LOAD)
- Gm = 1.00 (MC < 19%)
- Ct = 0.8 (100°F ≤ T ≤ 125°F)
- Cu = 1.0 (ABOUT STRONG AXIS)
- Ci = 1.0 (NOT INCISED)
- Cr = 1.00 (NON REP. MEMBER)

SHEAR FACTORS:
- Go = 1.25 (CONSTR. LOAD)
- Gm = 1.00 (MC < 19%)
- Ct = 0.80 (100°F ≤ T ≤ 125°F)
- Ci = 1.00 (NOT INCISED)

ELASTICITY FACTORS:
- Gm = 1.00 (MC < 19%)
- Ct = 0.80 (100°F ≤ T ≤ 125°F)
- Ci = 1.00 (NOT INCISED)

FACTORED TOLERANCES:
- E1' = 925 PSI (EXCLUDES Ci; Go)
- E1v = 160 PSI
- E1 = 960,000 PSI
- Emin = 2,520,000 PSI
LOADS TO FLOOR JOISTS:

FJ1

84 PLF

\[ L = 6\,\text{ft}, \quad Wt = 24\,\text{in}, \quad W = 63\,\text{psf}(2) = 126\,\text{plf} \]

\[ V(\#1) \]

\[ M(\#1) \]

\[ V = \frac{WE}{2} = \frac{126\,\text{plf}(6)}{2} = 378\,\text{#} \]

\[ M = \frac{WE^2}{8} = \frac{126\,\text{plf}(6)^2}{8} = 567\,\text{#}-\text{in} \]

\[ \Delta mn = \frac{L}{360} = \frac{12\,\text{in}}{360} = 0.2\,\text{in} \]

\[ \Delta act = \frac{5WE^4}{384EI} = \frac{5(126\,\text{plf})(6\times12)^2(12)}{384(1.2\times10^6\,\text{psi})} = 3.06 \]

\[ J_{req} = \frac{15.31}{3.06} = 5 \]

\[ S_{req} = \frac{M}{F_{16}} = \frac{6804\,\text{#}-\text{in}}{925\,\text{psi}} = 7.34 \]

\[ A_{req} = \frac{3V}{2F} = \frac{3(378\#)}{2(160\,\text{psi})} = 3.54\,\text{in}^2 \]

TRY 2\times6 FOR ALL TYPICAL JOISTS

\( @ \) 24\,\text{in} OC.
CHECK 2x6 JOIST

\[ S = 7.563, \text{in}^3 \geq 6.401, \text{in}^3 \quad \checkmark \]
\[ I = 20.8, \text{in}^4 \geq 15.31, \text{in}^4 \quad \checkmark \]
\[ A = 8.25, \text{in}^2 \geq 3.54, \text{in}^2 \quad \checkmark \]

\[ F_{\text{bmr}} = F_b (C_L)(C_f) = 1,202.5 \text{ PSI} \]

\[ C_L = \frac{1 + F_{\text{Re}}/F_b^{k}}{1.9} - \frac{\sqrt{1 + (F_{\text{Re}}/F_b^{k})^2}}{1.9} = 1.0 \]

\[ F_{\text{Re}} = 1.20E_{\text{min}} = 9,090.9 \text{ PSI} \]

\[ K_b = \frac{L_{\text{ed}}}{R_b^{2}} = 6.82 \]

\[ C_f = 1.3 \]

\[ F_{\text{act}} = \frac{M}{S} = \frac{6,804 \text{#}-\text{in}}{7.563 \text{ in}^2} = 902 \text{ PSI} \]

\[ F_{\text{act}} = \frac{3(V)}{2(A)} = \frac{3(378 \#)}{2(8.25 \text{ in}^2)} = 69 \text{ PSI} \]

\[ 902 \text{ PSI} < 1,202.5 \text{ PSI} \checkmark \]

\[ 69 \text{ PSI} < 160 \text{ PSI} \checkmark \]

\[ \Delta a = \frac{5 W L^4}{384 E I} = \frac{5(126 \text{ Plf})(6)^4}{384(960 \text{ PSI})(20 \text{ in}^4)} = 0.184 \text{ in} \]

\[ 0.184 \text{ in} < 0.2 \text{ in} \checkmark \]

\[ \therefore \text{ USE 2x6 FOR AN FLOOR JOIST AT 24" O.C.} \]
LOADS TO FLOOR GIRDER

F61

$390 \text{ PLF}$

$P = 15 \text{ PSF}$

$V = 50 \text{ PSF}$

$w = 6'$

$L = 10'$

$14,625 \# - \text{in}$

$1950\#$

$19,625 \# - \text{in}$

$V(x)$

$M(x)$

$V = \frac{wL}{2} = \frac{390 \text{ PLF}(10')}{2} = 1950\#$

$W = \frac{wL^2}{8} = \frac{390 \text{ PLF}(10')^2}{8} = 14,625 \# - \text{in}$

$\Delta m = \frac{10'(12)}{360} = \frac{333}{360}''$

$1950\#$

$1950\#$

$19,620 \# - \text{m}$

$1170\#$

$12'$

$tw = 3'$

$L = 12'$

$19,530 \# - \text{m}$

$M(x)$

$V = \frac{wL}{2} = \frac{1950 \text{ PLF}(12')}{2} = 1170\#$

$W = \frac{wL^2}{8} = \frac{1950 \text{ PLF}(12')^2}{8} = 10,530 \# - \text{in}$

$\Delta m = \frac{12'(12)}{360} = 0.4''$

CHOOSE MEMBER W/ GREATER MOMENT TO DESIGN. USE MEMBER SIZE FOR OTHER MEMBERS.

=> MIDDLE GIRDER W/10' SPAN & 6' TRIB WIDTH
FOR 10' SPAN & 6' TRIB. WIDTH

\[ \Delta_{\text{act}} = \frac{5WL^4}{384EI} = \frac{5(3900\text{psf})(10')^4}{12(384)(12''100\text{psf})I} = \frac{73.125}{1} \]

\[ 0.333'' = 13.125\text{in}^3/I \quad I = 219.38\text{in}^4 \]

\[ S_{\text{req'd}} = \frac{14,625\# \cdot \text{in}}{925\text{psi}} = \frac{15.81\text{in}^3}{1} \]

\[ A_{\text{req'd}} = \frac{3(1950\#)}{2(160\text{psi})} = 8.28\text{in}^2 \]

TRY 3\times 12

\[ S = \frac{52.73\text{in}^3}{\geq 15.81\text{in}^3} \checkmark \]

\[ A = \frac{28.13\text{in}^2}{\geq 18.28\text{in}^2} \checkmark \]

\[ I = \frac{296.66\text{in}^4}{\geq 219.38\text{in}^4} \checkmark \]

\[ F_{\text{pan}} = F_{\text{flb}}G(C)(CF) = 925\text{psi} \]

\[ CL = 1.0 \]

\[ F_{\text{pe}} = \frac{1.2E\text{min}}{R_b^2} = 9,490.5\text{psi} \]

\[ R_b = \sqrt{\frac{F_{\text{reqt}}}{6}} = 6.61 \]

\[ CP = 1.0 \]

\[ F_{\text{act}} = \frac{M}{S} = \frac{14,625\# \cdot \text{in}}{52.73\text{in}^3} = 277.9\text{ksi} \]

\[ F_{\text{reqt}} = \frac{3V}{2A} = \frac{3(1950\#)}{2(28.13\text{in}^2)} = 104\text{ksi} \]

\[ \Delta_{\text{act}} = \frac{5WL^4}{384EI} = \frac{(5)(3900\text{psf})(10')^4(12')^3}{384(12''100\text{psf})(296.66\text{in}^4)} = 0.308 \]

\[ 277.9\text{ksi} < 925\text{psi} \checkmark \]

\[ 104\text{ksi} < 160\text{psi} \checkmark \]

\[ 0.308'' < 0.333'' \checkmark \]

\[ \therefore \text{USE 3\times 12 FOR ALL FLOOR LIRDEKS.} \]
Seismic Analysis

\[ C_s = \frac{50g}{10} = 0.785g = 0.785 \]

\[ T = C_t h_n x = 0.02 (11')^{0.95} = 0.125 \]

\[ T \leq 0.12 \leq 0.8 \]

\[ C_s = \frac{50}{0.947} = 3.725 \]

\[ C_s = 0.044 \frac{50}{0.947} \geq 0.01 \]

\[ C_s = 0.044 (0.785) \geq 0.01 \]

\[ 0.0345 \geq 0.01 \]

\[ R = 1 \text{ in N/S & E/W directions} \]

\[ C_s = 0.785 \]

Base Shear

\[ V_b = C_s W \]

\[ W = 2520 \text{ lb} \]

\[ V_b = 0.785 (2520 \text{ lb}) = 1978 \approx 2.0 \text{ k} \]
WIND ANALYSIS (BUILDING ENCLOSED)

Risk category: I

$V = 100 \text{ mph} \ (45 \text{ m/s})$

SURFACE ROUGHNESS: C

EXPOSURE: C

$f_{ref} = 1.0$

ASSUME BUILDING IS ENCLOSED (CONSERVATIVE)

$\frac{L}{B} = \frac{12}{12} = 1.0$

$h = 11' \Rightarrow USE h = 15'$

$p_b = 25.2 \text{ psf}$

$p_h = 25.2 \text{ psf}$

$Pr = -23.7 \text{ psf}$ (WORST CASE)
WIND ANALYSIS (BUILDING OPEN)

N/S FACING WALL:

\[ A_0 = 11'(12') = 13.5'(12')(1/144) \]

\[ A_0 = 10.70SF \]

\[ A_y = 11'(12') = 132SF \]

\[ A_0 \geq 0.8A_y \]

\[ A_0 \geq 0.8(132SF) \]

\[ 10.70SF \geq 105.6SF \quad \text{OK} \]

\[ = \text{BUILDING IS OPEN} \]

RISK CATEGORY: 1

\[ V = 100 \text{ mph (45 m/s)} \]

\[ K_d = 0.85 \]

EXPOSURE CATEGORY: C

\[ K_{zt} \quad \text{DOES NOT SATISFY ASCE 7-10 §26.8.1} \]

\[ K_{zt} = 1 \]

\[ G = 0.85 \]

OPEN BUILDING:

\[ G_{c_0} = 0.00 \]

\[ K_{z}, K_h : z = 11', \text{EXPOSURE C}, r : K_b = 0.85, K_h = 0.85 \]

\[ q_{z} = 0.00256K_bK_{zt}K_dV^2 \]

\[ q_{z} = 0.00256(0.85)(17)(0.85)(100)^2 \]

\[ q_{z} = 28.5 \]

\[ C_p = 0.8 \quad \text{(OVERHANG)} \]

\[ \rho = q_{h}G_{c_n} \]

\[ \rho = 18.5(0.85)(0.8) \]

\[ \rho = 12.58 \text{ psf} \]

\[ \rho = \rho_n = 25.2 \text{ psf} \]

\[ V_b = 12'(11')(25.2 \text{ psf}) = 3326.4 \# \sim 3.3 \quad \text{K} \]

\[ 3.3K > 2K \quad \text{WIND GOVERNS} \]
Lateral Analysis, Grid A

Risa Input

Member Primary Data:

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<thead>
<tr>
<th>Label</th>
<th>I Joint</th>
<th>J Joint</th>
<th>Design List</th>
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<td>N1</td>
<td>N2</td>
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<td>N4</td>
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<td>N7</td>
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<tr>
<td>M6</td>
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<td>N5</td>
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Joint Coordinate:

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Boundary Conditions:

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<td>Reaction</td>
<td>Reaction</td>
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<tr>
<td>N5</td>
<td>Reaction</td>
<td>Reaction</td>
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<tr>
<td>N10</td>
<td>Reaction</td>
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Basic Load Cases:

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<th>Description</th>
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<tr>
<td>2</td>
<td>Roof Live</td>
</tr>
<tr>
<td>3</td>
<td>Floor Live</td>
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<td>4</td>
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Load Combinations:

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<th>Factor</th>
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<th>Factor</th>
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<th>Factor</th>
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<td>5</td>
<td>1</td>
<td>1</td>
<td>0.6</td>
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<td>D+0.75L+0.75Lr</td>
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<td>5</td>
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<td>1</td>
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<td>0.6</td>
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<td>0.6</td>
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REFERENCE

Risa Output (Grid A):

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<tr>
<td>M1</td>
<td>min 0</td>
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<tr>
<td>M2</td>
<td>max 869.804</td>
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<tr>
<td>M2</td>
<td>min -308.74</td>
</tr>
<tr>
<td>M3</td>
<td>max 721.361</td>
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<td>M3</td>
<td>min -449.604</td>
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<td>M4</td>
<td>max 498.196</td>
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<td>M4</td>
<td>min -161.339</td>
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<tr>
<td>M5</td>
<td>max 131.918</td>
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<tr>
<td>M5</td>
<td>min -645.388</td>
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<tr>
<td>M6</td>
<td>max 1279.892</td>
</tr>
<tr>
<td>M6</td>
<td>min 885.244</td>
</tr>
</tbody>
</table>

*Negative values indicate members in tension*
LATERAL DESIGN BRACE B1

\[ P_u = 1279.89 \text{# (C)} \]
\[ 645.39 \text{# (T)} \]

CHECK COMPRESSION

USE NO. 2 REDWOOD

\[ F_c = 950 \text{ psi} \]

\[ F_c = \frac{P}{A} \]
\[ A = \frac{1279.89 \times 1.35 \text{ in}^2}{950 \text{ psi}} \]

TRY 2x4 NO. 2 REDWOOD

\[ A = 5.25 \text{ in}^2 \geq 1.35 \text{ in}^2 \]

\[ F_c = \frac{P}{A} = \frac{1279.89 \times 1.35}{5.25 \text{ in}^2} = 248.8 \text{ psi} \]

\[ F_c' = F_c \cdot C_D \cdot C_F \cdot C_E \cdot C_t \]
\[ C_D = 1.25 \]
\[ C_F = 1.15 \]
\[ C_t = \frac{115}{1.15} = 100 \]

\[ C_E = 1.15 (950) = 1092.5 \text{ psi} \]

\[ C_t = 440,000 \text{ psi} \]
\[ E_{min} = 440,000 \text{ psi} \]
\[ c = 0.8 \]
\[ F_{ce} = 0.822 (440,000 \text{ psi}) \]
\[ = 306.15 \text{ psi} \]

\[ F_{ce} = 950 (1.25) (1.15) (0.8) = 1092.5 \text{ psi} \]

\[ F_{ce} / F_{ce} = 2.81 \]

\[ C_t = \frac{1 + 2.81}{1.6} - \sqrt{\left(\frac{1 + 2.81}{1.6}\right)^2 - \frac{2.81}{0.8}} = 0.91 \]

\[ F_c' = 950 \text{ psi} (1.25) (1.15) (0.8) (0.91) = 994.2 \text{ psi} \]

\[ F_c' \geq F_c = 248.8 \text{ psi} \]

Adequate in compression.
CHECK TENSION

\[ f_t = \frac{P}{A} = \frac{675.9 \text{ lb}}{5.25 \text{ in}^2} = 127.9 \text{ psi} \]

\[ F'_{t} = F_{t} \frac{C_{D} C_{n}}{C_{e} C_{f} C_{i}} \]

\( C_{D} = 1.25 \)
\( C_{n} = 1.5 \)
\( C_{e} = 1.0 \)
\( F'_{t} = 52.5 \text{ psi} \times (1.25)(1.5) = 984.4 \text{ psi} \)

\[ F'_{t} \geq f_t \quad 984.4 \text{ psi} \geq 127.9 \text{ psi} \]

[Note: The reference suggests that the wood provided (2x4 No. 2 Redwood) is adequate in tension.]

Provide 2x4 No. 2 Redwood Brace, by
CHORD & ROOF (RB3) (3x8 No. 2 REDWOOD)

**BIAXIAL BENDING**

**ASD LOAD COMBOS:**

\[ D = 0.75(0.6w) + 0.75 L_r \] (GOVERNS)

\[ D = 2 \text{ psf} \]

\[ w = 0.75(0.6)(25.2 \text{ psf}) = 18.34 \text{ psf} \]

\[ L_r = 0.75(20 \text{ psf}) = 15 \text{ psf} \]

\[ w_{wind} = 11.34 \text{ psf} \left( \frac{1}{3} \right) = 3.8 \text{ psf} \]

\[ w_o = 2 \text{ psf} \left( \frac{1}{3} \right) = 0.67 \text{ psf} \]

\[ w_{Lr} = 15 \text{ psf} \left( \frac{1}{3} \right) = 5 \text{ psf} \]

\[ f_{b1} = \frac{p}{A} \]

\[ \frac{f_{b1}}{f_{b1}'} + \frac{f_{b2}}{f_{b2}' - \left( \frac{f_{b1}}{f_{b2}} \right)^2} \leq 1.0 \]

\[ f_{b1}' = \left( \frac{w_o + w_{wind}}{B} \right) \frac{1}{3} \frac{(6 + 45)(8)^2}{21.90 \text{ in}^2} = 2682.7 \text{ psi} \]

\[ f_{b2}' = \frac{w_{wind} l^2}{B} \frac{1}{3} \frac{56.3 \text{ psf} \left( \frac{1}{3} \right)^2}{21.90 \text{ in}^2} = 2982.6 \text{ psi} \]

\[ f_{bf} = 7042.9 \text{ psi} \] (FROM GRAVITY CALC)
REFERENCES

\[ F'_{b1} = F_b \frac{C_b}{C_m} \frac{G_m}{G_e} C_e \frac{C_e}{G_e} \frac{G_e}{C_e} G_e \]
\[ C_b = 1.25 \quad C_m = 1.25 \]
\[ C_e = 1.25 \quad C_e = 1.2 \]
\[ F'_{b1} = 9.25 \text{ psi} \times (1.25) (0.93) (1.2) = 129.0 \text{ psi} \]

\[ F'_{b2} = F_b \frac{C_b}{C_m} \frac{G_m}{G_e} C_e \frac{C_e}{G_e} \frac{C_e}{G_e} \frac{G_e}{C_e} G_e \]
\[ C_b = 1.25 \quad C_m = 1.0 \]
\[ C_e = 1.15 \quad C_e = 1.2 \]
\[ F'_{b2} = 9.25 \text{ psi} \times (1.25) (0.8) (1.2) = 110 \text{ psi} \]

\[ F_b = 925 \text{ psi} \times (1.25) (0.8) (1.2) = 1263.9 \text{ psi} \]

\[ F_{b1} = 129.0 \text{ psi} \]

\[ F_{b2} = 1263.9 \text{ psi} \]

\[ R_b = \frac{163.98^2 \times 2.5}{(7.25)^2} = 23.8 \pm 50 \text{ Jok} \]

\[ E_{min} = E_{min} \frac{45}{45} \frac{G}{G_e} \frac{G_e}{G_e} = 44,900 \times 0.8 = 352,000 \text{ psi} \]

\[ F_{b1} = 1.20 \times (352,000 \text{ psi}) = 694.2 \text{ psi} \]

\[ F_{b2} = \frac{1.20 \times (352,000 \text{ psi})}{(7.8)^2} = 694.2 \text{ psi} \]

\[ F_{b1} = 1.0 \]

\[ F_{b1} = 129.0 \text{ psi} \]

\[ F_{b2} = 1263.9 \text{ psi} \]

\[ \ell_e = 163.98^2 \]

\[ E_{min} = 352,000 \text{ psi} \]

\[ F_{b1} = 129.0 \text{ psi} \]

\[ F_{b2} = 1263.9 \text{ psi} \]

\[ 1263.9 \times (\frac{2683.7 \text{ psi}}{1290.0 \text{ psi}})^2 = -1.17 < 1.0 \text{ Jok} \]

\[ 3\times8 \text{ NO. 2 REDWOOD IS ADEQUATE IN BIAXIAL BENDING, RB3} \]
**California Polytechnic State University**

Senior Project - Spring 2018
Emir Kuljancic & Sitara Vaxidova
Advisor: Kevin Dong

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**REFERENCE**

**Typ. Column, C1 (Overturning Forces)**

![Diagram of column forces]

- $P_{grw} = 1006\#$
- $P_{int. c} = 869.8\#$
- $P_{int. t} = -161.9\#$

**CHECK COMPRESSION**

$$F_c = \frac{P}{A} = \frac{1006 + 869.8}{12.25\,\text{m}^2} = 153.1\,\text{psi}$$

$$F_c' = F_c C_e C_m C_f C_p C_i' C_p'$$

- $C_0 = 1.25$
- $C_f = 1.15$
- $C_p F_p = 1.15(1500\,\text{psi}) = 1725\,\text{psi} \leq 750\,\text{psi}$

**Found $P_e$**

$$K_e = 1.3$$

$$L_e = K_e L = 1.3(10') = 13''$$

$$d = \frac{13''}{3.5'} = 4.11' \leq 50\,\text{vsk}$$

$$F_{c,1500} = 1500\,\text{psi}(0.25)(1.1)(0.8) = 1650\,\text{psi}$$

$$E_{min} = E_{min}(n_a, n_b, n_c) = 1.40(0.000)(0.8) = 1120\,\text{psi}$$

$$F_{ce} = 0.822\left(\frac{1120}{1.12\times10^6}\right)^{0.5} = 545.0\,\text{psi}$$

**Check $F_{ce} > 0.33$**

$$C_p = \frac{1 + 0.33}{1.6} - \sqrt{\left(\frac{0.33}{1.6}\right)^2 - \frac{0.33}{0.8}} = 0.30$$

$$F_c = 1650\,\text{psi}(0.3) + 495\,\text{psi} = 153.1\,\text{psi} \leq 750\,\text{psi}$$

**Provide select structural redwood 4x4 typical column, C1**
FOUNDATION

REFER TO ACI 318 FOR DETAILING
IBC 2015 FOR PROPERTIES

ELEVATION

#3 SPIRAL REINFORCING
#4 REINFORCING

min 2"

#4 BAR DIAMETER = 0.25"
#3 BAR DIAMETER = 0.375"

b = (3")(2)+(2")(2)+(5")+(2") +
+ (3.75")(2)+2.5"+1" = 16.25"

USE b = 16" FOR PER FOOTING

FED IBS F5 SECTION 1807.3.2:
NON CONSTRAINED =

\[ d = 0.5A \left( 1 + \left( 1 + 4.36 \frac{h}{A} \right)^{0.5} \right) \]

\[ A = 2.34 \frac{k}{\sqrt{b}} \]

\[ A = 2.34 \left( 0.5 \frac{k}{\sqrt{b}} \right) \left( 5 \text{ psf} / \text{A} \right) = 5.2 \text{ sf} \]

\[ d = 0.5 \left( 5.2 \text{ sf} \right) \left( h \left( 1 + 4.36 \frac{6}{5.2 \text{ sf}} \right)^{0.5} \right) = 5.097 \text{ ft} = 68.65 \text{ in} \]
Floor Joist to Girder

2x6 TYP JOIST
3x12 TYP GIRDER
SST LUS26 JOIST HANGER
2-10d DOUBLE SHEAR NAILS
TYP 4-10d NAILS

LUS26 CAPACITY: 865#
DEMAND: 378#
865# > 378#

* Use LUS26 for all Floor Joist to Girder Connections
REFERENCE

ROOF BEAM RB2 TO GIRDER R61

2-10d DOUBLE SHEAR NAILS
TYP 3x8 JOIST
TYP 3x10 GIRDER
SST W38 JOIST HANGER
TYP 2-10d NAILS

W38 HANGER CAPACITY: 2900 k
DEMAND: 439.9 k

2,900 k > 139.9 k /

:: USE W38 FOR ALL ROOF ANGLED CONNECTION INCLUDING RB2 OVERHANG
REFERENCE

BENCH DETAILING:

CHECKING 2"x6 BENCH FRAMING FOR DEFLECTION TO DETERMINE BENCH SUPPORT SPACING:

FOR 2"x6

\[ I_{xx} = 20.81 \text{in}^4 \]
\[ I_{yy} = 1.6471 \text{in}^4 \]

\[ \Delta_{u} = \frac{P\ell}{360} \]
\[ \Delta_{a} = \frac{PE^3}{48EI} \]

\[ \frac{\ell}{360} = \frac{200\# (0.3)}{48(900 \text{ksi})(1.5471 \text{in}^4)} \]

990.081in²: \( P^2 \)
\( \ell = 31.471 \text{in} \)

IN ORDER TO AVOID HAVING \( \Delta_{u} = \Delta_{a} \)

AN INSTEAD \( \Delta_{u} > 2\Delta_{a} \)

USE \( \ell = 24.9 \)

6" PLACE BENCH SUPPORT FRAMES FOR 2"x6 BENCH MEMBERS AT 24" O.C.