Workshop calculations

February 19, 2024

Contents

Notes

- In "Imported variables" we don't include those which just get the imperial string for variables defined elsewhere. These aren't important enough to count as genuine imported variables.
- There should be **no** variables for mortise thickness, only tenon thickness. This is to prevent inadvertent differing definitions of tenon and mortise thicknesses. When the time to cut comes, use the slick to shave off tenon depth until we get a tight fit.

1 Ridge shape and dimensions

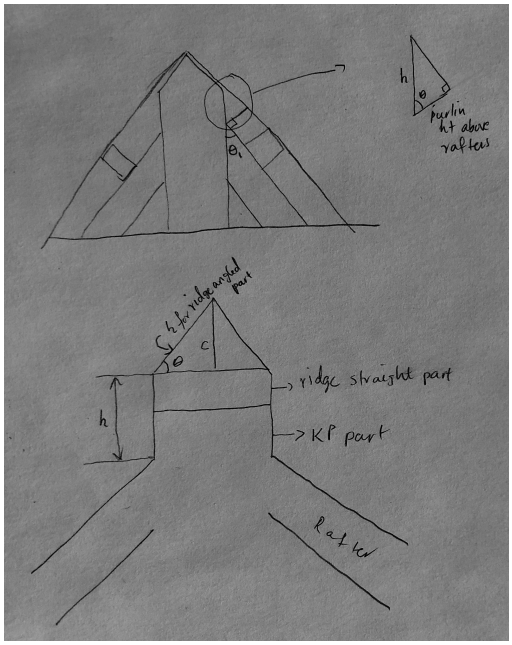
1.1 Assumptions

```
rise <- 10
run <- 12
theta <- atan(rise/run)
theta_degrees <- rads_to_degs(theta)
theta1 <- atan(run/rise)
theta1_degrees <- rads_to_degs(theta1)

purlin_height <- 7
purlin_pocket <- 1
purlin_height_above_rafter <- purlin_height - purlin_pocket

kp_width <- 8 # at the top
ridge_width <- kp_width
kp_part <- 4.5 # straight part above rafters
```

1.2 Imported variables

- None.

1.3 Calculations



Start by knowing only roof pitch and purlin height above rafters. These determine the value of h in the diagram:

$$h = 7.8102.$$

We set KP part to a reasonable amount (cf §1.1), and this dictates that

$$\text{ridge straight part} = 3.3102.$$

The height for ridge angled part is dictated by roof pitch and ridge width:

$$c = 3.3333$$

which means that

$$\boxed{\text{Ridge total height} = 6.6436 = 0\text{' } 6\text{" } 21/32}$$

and this is the milling height for this beam. Finally, ridge cross-sectional area = 39.8153, volume = 5733.4076, which in board feet is 39.8153. Divide cross-sectional area by beam width to find "equivalent" height. We find that this pentagonal beam is equivalent to a 8×4.9769 beam for the purposes of F_b calculations.

2 Kingpost length and and collar tie rough length

2.1 Assumptions

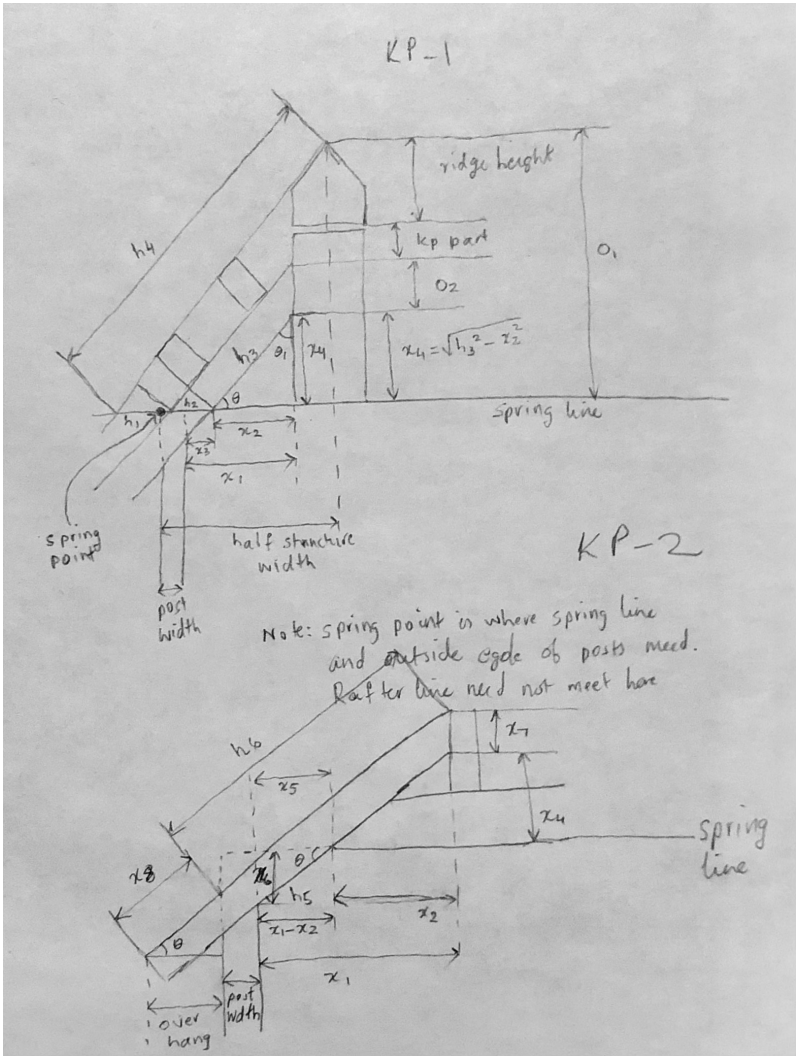
```
width_of_structure <- 15*12
width_of_structure_half <- width_of_structure/2
post_width <- 6
rafter_height <- 8
collar_tie_height <- 8
kp_through_tenon_length <- 2
kp_top_tenon_length <- 3
```

We start with purlin height above rafters, and the width of the structure. Ignore collar tie for now.

2.2 Imported variables

- `kp_width` = 8 from §1.1.
- `purlin_height_above_rafter` = 6 from §1.1.
- `kp_part` = 4.5 from §1.1.

2.3 Calculations



The variable x_1 can be found by inspection; just subtract post width and half KP width from half the structure width:

$$x_1 = 80$$

and we have

$$o_2 = \text{rafter height}/\sin\theta_1 = 10.4137$$

Then,

$$h_2 = \text{rafter height}/\sin\theta = 12.4964$$
$$x_3 = h_2 - \text{post width} = 6.4964$$
$$x_2 = x_1 - x_3 = 73.5036$$
$$h_3 = x_2/\cos\theta = 95.6802$$
$$x_4 = \sqrt{h_3^2 - x_2^2} = 61.253$$

Using x_4 from above, KP from top (excluding tenon) to spring line is

$$\begin{aligned}\text{kp part (cf §1.1)} \ + o_2 + x_4 &= 76.1667 \\ &= 6\text{' } 4\text{" } 5/32\end{aligned}$$

We can also calculate for later:

$$\begin{aligned}h_1 &= \text{purlin height above rafters}/\sin\theta = 9.3723 \\ h_4 &= (h_1 + \text{post width} + x_1 + \text{kingpost width}/2)/\cos\theta = 129.3537 \\ o_1 &= \sqrt{h_4^2 - (h_1 + \text{post width} + x_1 + \text{kingpost width}/2)^2} = 82.8102\end{aligned}$$

Calculating o_1 a different way: add up ridge height, kp part, o_2, and x_4, to get 82.8102, which should match the above. For diagram 2, we have $x_5 = x_1 - x_2 = 6.4964 \implies h_5 = x_5/\cos\theta = 8.4564$, which is enough space between post and collar tie. Since KP from top (excluding tenon) to spring line is 76.1667, and bottom of collar tie is at the spring line, KP length excluding **both** tenons is 76.1667 - 8 (collar tie height) = 68.1667. Assuming a 2-inch through tenon at bottom and 3-inch tenon at the top, we have

$$\boxed{\text{KP length } = 68.1667 + 8 + 2 + 3 = 81.1667 = 6\text{' } 9\text{" } 5/32}.$$

Roughly, collar tie length, assuming 5-inch tenons, is $x_2 \times 2 + \text{KP width} + \text{tenon lengths} = 165.0072$. See §7 for more accurate calculations.

3 Post length excluding tenons and rough rafter length

3.1 Assumptions

```
structure_height <- 15*12 # top of ridge to base
overhang_sides <- 24 # inches
rafter_tenons_preliminary <- 3 # assuming 3 inch tenons; to be made precise later
```

3.2 Imported variables

- h_5 from §2.3.
- x_5 from §2.3.
- "top of ridge to spring line" is comprised of "kp height to spring line excl top tenon" from §2.3 and "ridge height" from §1.3.
- Post width is from §2.1.
- x_1 is from §2.3.

3.3 Calculations

The diagram for this section is in the previous section.

The triangle above with x_5 and h_5 has a third side, call it x_6, for which we have

$$x_6 = \sqrt{h_5^2 - x_5^2} = 5.4137.$$

From base to spring line is

$$\begin{aligned}\text{structure height - (top of ridge to spring line)} &= 180 - 82.8102 \\ &= 97.1898 \\ &= 8\text{' } 1\text{" } 3/16\end{aligned}$$

Now, x_6 extends from spring line to the higher side of where the post meets rafters. Therefore, post height excluding tenons is

$$97.1898 - 5.4137 = 91.7761 = 7' \ 7'' \ 25/32$$

See §9 for measurements including tenons.

The structure has an overhang on both sides, which we take to be 24 (cf §3.1), and this allows us to calculate x_8 in the diagram:

$$x_8 = \frac{24}{\cos\theta} = 31.241.$$

The variable h_6 is just post width + x_1 divided by the cosine, so we have

$$h_6 = \frac{\text{post width} + x_1}{\cos\theta} = 111.9469$$

So **rough** rafter length, assuming 3-inch tenons is

$$x_8 + h_6 + 3 = 146.1879 = 12' \ 2'' \ 3/16.$$

See §4.3 for more precise measurements.

4 Kingpost/rafter joints and rafter final length

4.1 Assumptions

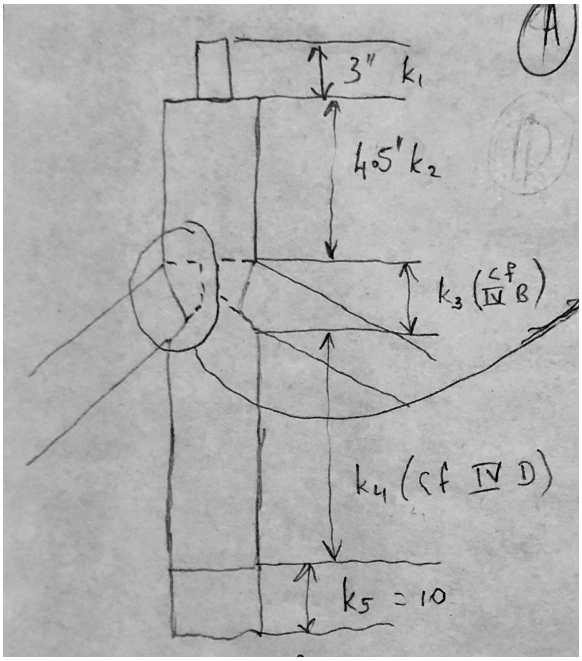
```
kp_rafter_shoulder_depth <- 1 # along the x axis
rafter_tenon_depth_into_kp <- 3 # along the x axis
rafter_tenon_thickness <- 2
# In this section assume no KP flare
```

4.2 Imported variables

- `kp_top_tenon_length` = 3 from §2.1. Here `k_1`.
- `kp_part` = 4.5 from §1.1.
- `rafter_height` = 8 from §2.1.
- `collar_tie_height` = 8 from §2.1.
- `kp_through_tenon_length` = 2 from §2.1
- `kp_total_height` = 81.1667 from §2.3
- `x8` = 31.241 from §3.3
- `h6` from 111.9469 from §3.3

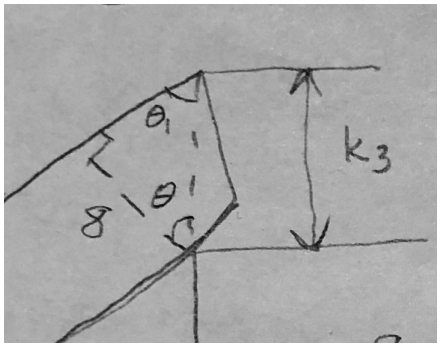
4.3 Calculations

Ignore anything in these diagrams following that isn't relevant, like hardcoded values.



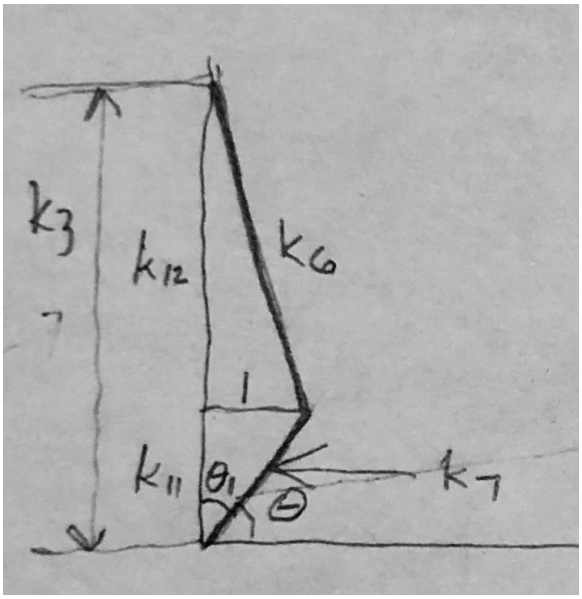
The variable for "KP part" was not labeled in §1.1; here we label it as k_2; its value is 4.5. The KP tenon height into ridge (k_1) is 3 (cf §4.2). The variable k_3 is just rafter height divided by the cosine, which is

$$k_3 = \text{rafter height}/\cos\theta = 10.4137.$$



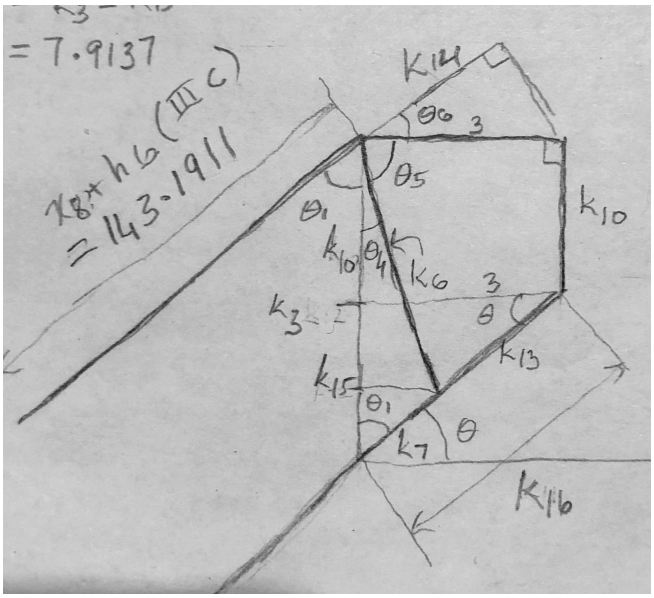
The variable k_5 is given by collar tie height + through tenon length; here we have $k_5 = 10$. Then we have

$$k_4 = \text{KP total length} - k_1 - k_2 - k_3 - k_5 = 53.253.$$



The variables defined around the rafter-to-kp-shoulder are

$$k_7 = 1.3017$$
$$k_{11} = 0.8333$$
$$k_{12} = 9.5803$$
$$k_6 = 9.6324$$



The variables around rafter tenon/shoulder[1] are

$$
\begin{aligned}
k_{16} &= \text{rafter tenon depth into KP}/\cos\theta = 3.9051 \\
k_{13} &= k_{16} - k_7 = 2.6034 \\
\theta_4 &= \arccos\left(\frac{k_{12}}{k_6}\right) = 5.959 \\
\theta_5 &= 90 - \theta_4 = 84.041 \\
\theta_6 &= 180 - \theta_1 - \theta_4 - \theta_5 = 39.8056 \\
k_{14} &= \text{rafter tenon depth into KP} \times \cos\theta_6 = 2.3047 \\
k_{15} &= k_{16} \times \sin\theta = 2.5 \\
k_{10} &= k_3 - k_{15} = 7.9137
\end{aligned}
$$

Now, we can calculate rafter length more precisely than in §3.3, where we just estimated the tenon length. We have

$$\boxed{\text{Rafter length} = x_8 + h_6 + k_{14} = 145.4926 = 12\text{' } 1\text{" } 1/2.}$$

5 Rafter connections

5.1 Assumptions

```
post_tenon_depth_into_rafter <- 4
post_rafter_shoulder_depth <- 1
collar_tie_rafter_shoulder_depth <- 1
collar_tie_tenon_into_rafter_thickness <- 2
collar_tie_tenon_into_rafter_depth <- 4
post_tenon_into_rafter_thickness <- 2
```

5.2 Imported variables

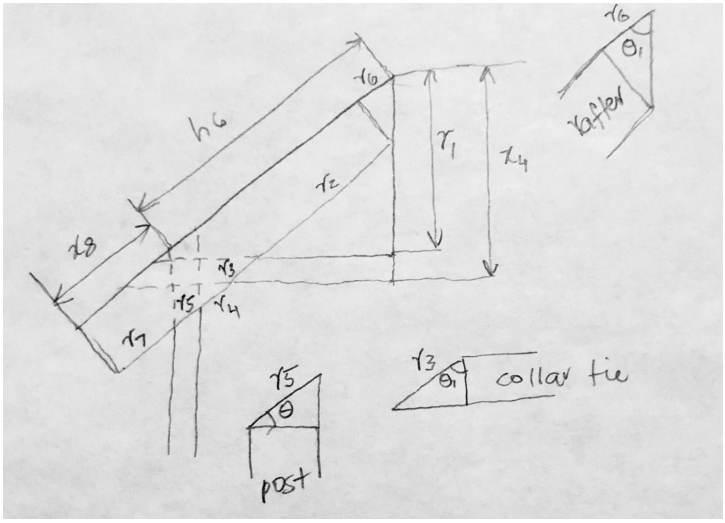
- `x8` = 31.241 from §3.3.
- `h6` = 111.9469 from §3.3.
- `rafter_height` = 8 from §2.1.
- `collar_tie_height` = 8 from §2.1.
- `h3` = 95.6802 from §2.3.
- `h5` = 8.4564 from §2.3.
- `post_width` = 6 from §2.1.

5.3 Calculations

```
r6 <- rafter_height/tan(theta1)
r8 <- x8 + h6 - r6
r3 <- collar_tie_height/cos(theta1)
r2 <- h3 - r3
r5 <- post_width/cos(theta)
r4 <- h5
r7 <- r8 - r5 - r4 - r3 - r2

theta2 <- atan(post_rafter_shoulder_depth/r5)
```

[1] It would seem that variable names k_8 and k_9 were never used in the paper drawings.

```
theta2_degrees <- rads_to_degs(theta2)
r6 <- post_rafter_shoulder_depth/sin(theta2)
r12 <- post_tenon_depth_into_rafter/tan(theta1)
r13 <- r5 - r12

theta3 <- atan(collar_tie_rafter_shoulder_depth/r3)
theta3_degrees <- rads_to_degs(theta3)
theta4_degrees <- theta_degrees - theta3_degrees
r9 <- collar_tie_tenon_into_rafter_depth/sin(theta)
r10 <- sqrt(r9^2 - collar_tie_tenon_into_rafter_depth^2)
r11 <- r3 - r10
```



First, we calculate rafter length on underside, which is

$$r_8 = x_8 + h_6 - r_6 = x_8 + h_6 - (\text{rafter height}/\tan\theta_1) = 136.5212.$$

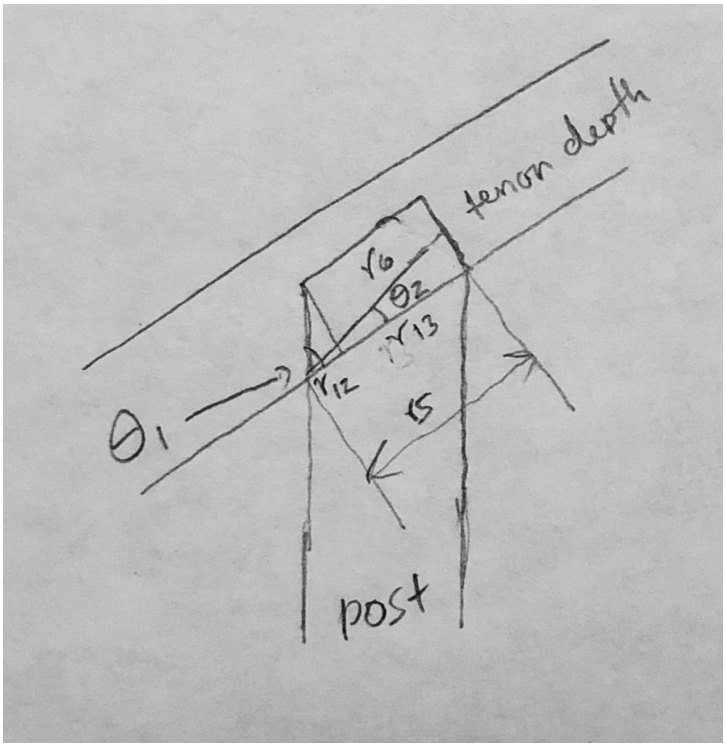
Then we have the following

$$\begin{aligned} r_3 &= \text{collar tie height}/\cos\theta_1 = 12.4964 \\ r_2 &= h_3 - r_3 = 83.1838 \\ r_5 &= \text{post width}/\cos\theta = 7.8102 \\ r4 &= h_5 = 8.4564 \end{aligned}$$

which implies that

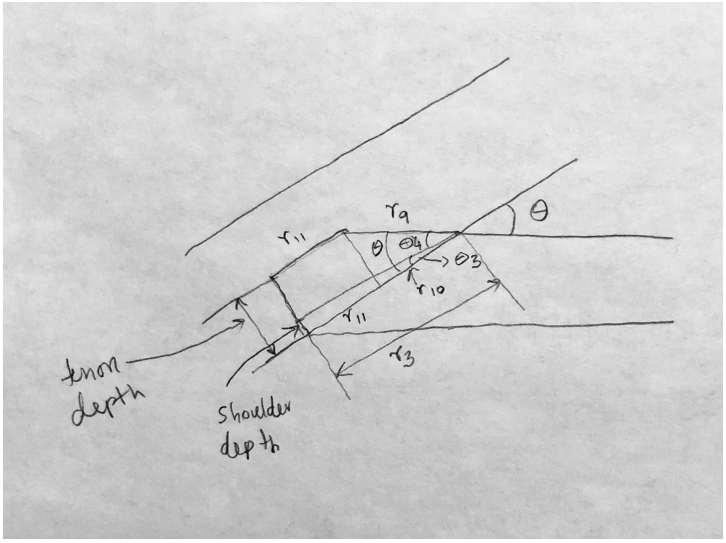
$$r_7 = r_8 - r_5 - r_4 - r_3 - r_2 = 24.5743.$$

It might seem surprising that $r_7 = 24.5743$ is more than the overhang $= 24$, but it does check out if drawn to scale.



For post tenons into rafters at 2-in thick, we have

$$\theta_2 = \arctan\left(\frac{\text{shoulder depth}}{r_5}\right) = 7.2963$$
$$r_6 = \frac{\text{shoulder depth}}{\sin\theta_2} = 7.874$$
$$r_{12} = \frac{\text{tenon depth}}{\tan\theta_1} = 3.3333$$
$$r_{13} = r_5 - r_{12} = 4.4769$$



For collar tie tenons into rafters at 2-in thick,

$$\theta_3 = \arctan\left(\frac{\text{shoulder depth}}{r_3}\right) = 4.5752^\circ$$
$$\theta_4 = \theta - \theta_3 = 35.2303^\circ$$
$$r_9 = \frac{\text{tenon depth}}{\sin\theta} = 6.2482$$
$$r_{10} = \sqrt{r_9^2 - (\text{tenon depth})^2} = 4.8$$
$$r_{11} = r_3 - r_{10} = 7.6964$$

6 Strut/KP connections

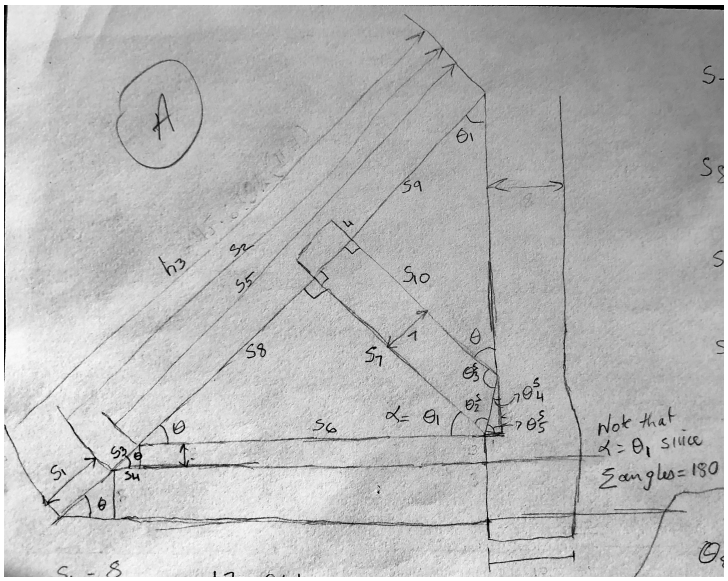
6.1 Assumptions

```
strut_height_above_collar_tie <- 3
kp_width_bottom <- 10 # flared bottom
kp_flare <- (kp_width_bottom - kp_width)/2 # flare on each side
strut_width <- 7
strut_tenon_into_rafter_thickness <- 1.5
strut_tenon_into_kp_depth <- 2
strut_tenon_into_kp_thickness <- 1.5
strut_tenon_into_rafter_depth <- 4
```

6.2 Imported variables

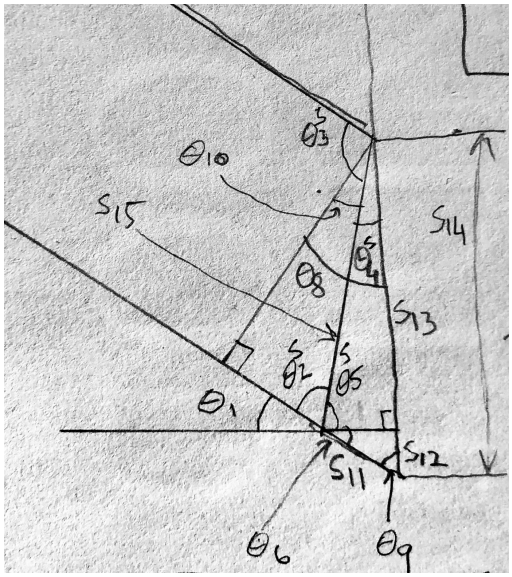
- `h3` = 95.6802 from §2.3.
- `collar_tie_height` = 8 from §2.
- `kp_width` = 8 from §1.1.
- `r2` = 83.1838 from §5.3.
- `r3` = 12.4964 from §5.3.

6.3 Calculations



The calculations for the first diagram are

$$
\begin{aligned}
s_1 &= (\text{collar tie height})/\sin\theta = 12.4964.\\
s_2 &= h_3 - s_1 = 83.1838.\\
s_3 &= \text{strut height above collar tie}/\sin\theta = 4.6861.\\
s_4 &= \text{strut height above collar tie}/\tan\theta = 3.6.\\
s_5 &= s_2 - s_3 = 78.4977.\\
s_6 &= \cos\theta \times s_5 - \text{KP flare at bottom} = 59.3036.\\
s_7 &= \cos\theta_1 \times s_6 = 37.9652.\\
s_8 &= \tan\theta_1 \times s_7 = 45.5583.\\
s_9 &= s_5 - s_8 - \text{strut width} = 25.9394.\\
s_{10} &= s_9/\tan\theta = 31.1273.
\end{aligned}
$$



For the second diagram, we have

$$
\begin{aligned}
s_{12} &= \sqrt{s_{11}^2 - \text{kp flare}^2} = 0.8333\\
\theta_8 &= 90 - \theta_9 = \theta_1 = 50.1944\\
s_{14} &= \text{strut width}/\cos\theta_8 = 10.9343\\
\theta_9 &= \arcsin(\text{strut width}/s_{14}) = 39.8056\\
s_{13} &= s_{14} - s_{12} = 10.101\\
s_{15} &= \sqrt{s_{13} + \text{kp flare}^2} = 10.1504\\
\theta_5^s &= \arccos(\text{kp flare}/s_{15}) = 84.3461\\
\theta_2^s &= \arcsin(\text{strut width}/s_{15}) = 43.6007\\
\theta_4^s &= \arcsin(\text{kp flare}/s_{15}) = 5.6539\\
\theta_{10} &= \arccos(\text{strut width}/s_{15}) = 46.3993\\
\theta_3^s &= 90 + \theta_{10} = 136.3993
\end{aligned}
$$

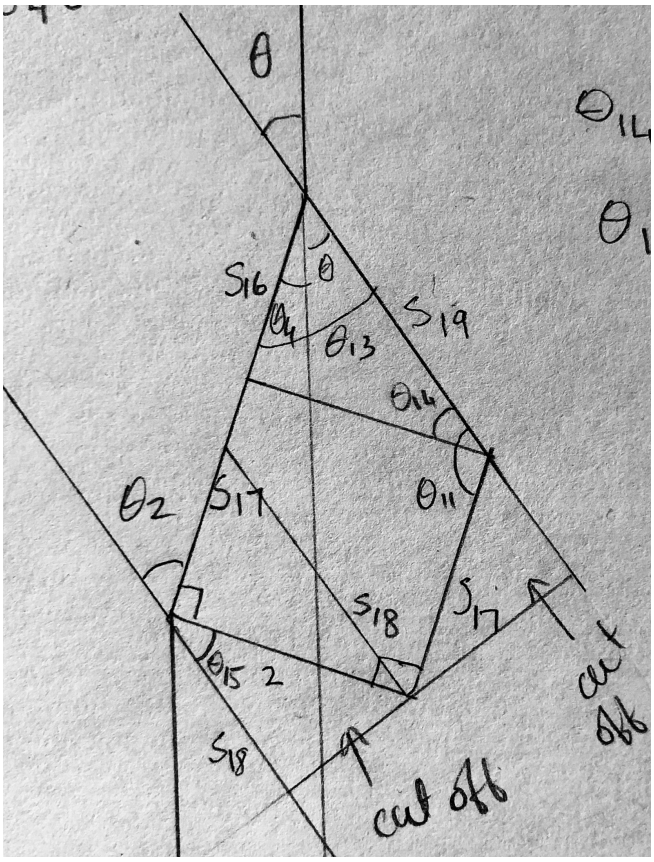
Check: Does $s_2 = r_2$? TRUE.

Check: Does $s_1 = r_3$? TRUE.

Check: Does $\theta_9 = \theta$? TRUE.

6.4 Strut tenons into KP

There seems to be an extra s_{18} in the diagram in the middle - not sure what that is.



The calculations are

$$\theta_{13} = \theta + \theta_4^2 = 45.4594$$
$$\theta_{11} = 360 - 90 - 90 - \theta_{13} = 134.5406$$
$$s_{19} = \text{strut tenon into kp depth} / \sin\theta_{13} = 2.806$$
$$\theta_{14} = \theta_{11} - 90 = 44.5406$$
$$\theta_{15} = 180 - \theta_s^2 - 90 = 46.3993$$
$$s_{16} = \sqrt{s_{19}^2 - \text{strut tenon into kp depth}^2} = 1.9682$$
$$s_{17} = s_{15} - s_{16} = 8.1822$$
$$s_{18} = \cos\theta_{15} \times \text{strut tenon into kp depth} = 1.3793$$

7 Collar tie final length

7.1 Assumptions

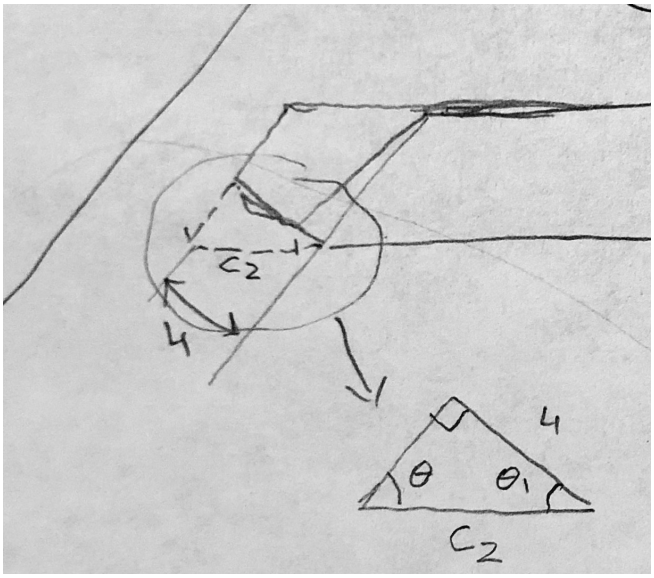
```
collar_tie_tenon_into_rafter_depth <- 4 # at 90 degrees to rafter face
collar_tie_depth <- 6 # beam depth
kp_through_tenon_thickness <- 2
```

7.2 Imported variables

- `x2` = 73.5036 from §2.3
- `kp_flare` = 1 from §6.1
- `kp_width_bottom` = 10 from §6.1
- `r11` = 7.6964 from §5.3
- `r9` = 6.2482 from §5.3
- `collar_tie_height` = 8 from §2.1
- `collar_tie_rafter_shoulder_depth` = 1 from §5.1
- `collar_tie_tenon_into_rafter_thickness` = 2 from §5.1
- `kp_width` = 8 from §1.1
- `theta3_degrees` = 4.5752 from §5.3

7.3 Calculations

The diagram has a hardcoded value - ignore.



Since tenon depth = 4, we have $c_2 = 6.2482$. Since KP width at bottom is 10, we modify from above (§1.1) where KP width was 8 (§1.1):

$$\text{New } x_2 = c_1 = x_2 - 1 = 72.5036.$$

Then

$$\boxed{\text{CT length } = c_1 \times 2 + 10 + c_2 \times 2 = 167.5036 = 13\text{' } 11\text{" } 1/2.}$$

8 Braces

8.1 Assumptions

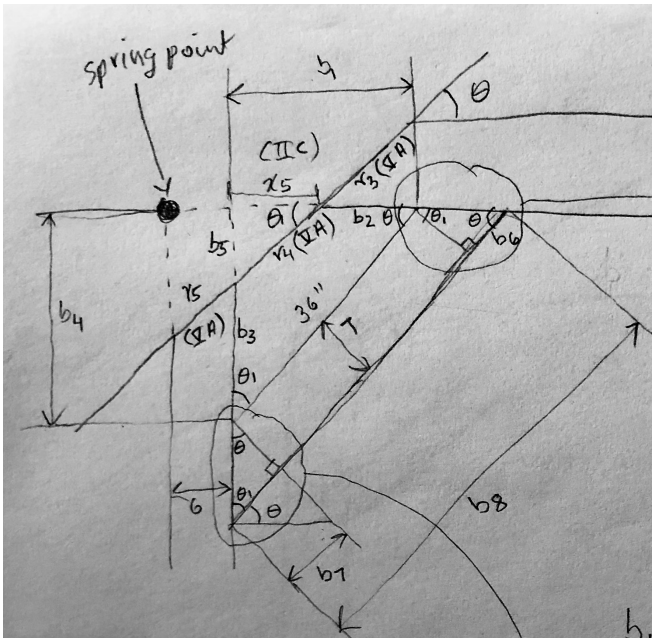
```
brace_width <- 7
brace_exposed_length_top <- 36
brace_tenon_depth_into_collar_tie <- 3
brace_tenon_depth_into_post <- 3
```

8.2 Imported variables

- `x5` = 6.4964 from §2.3.
- `r4` = 8.4564 from §5.3.

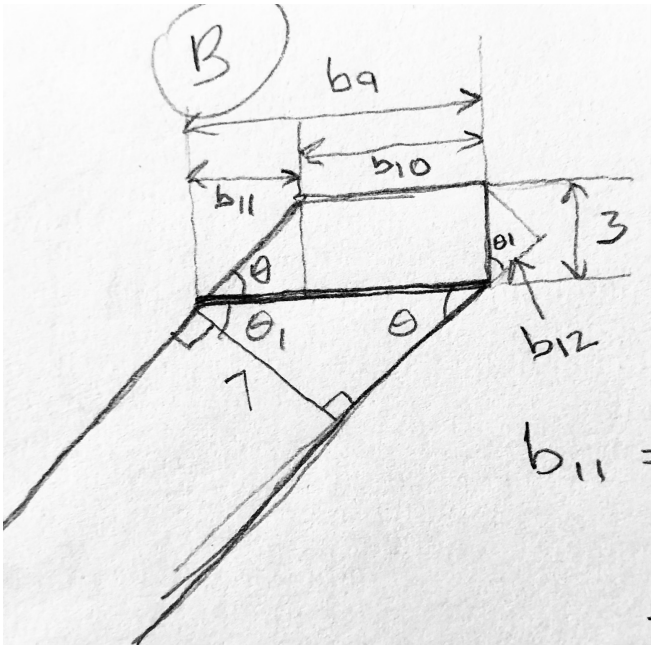
8.3 Calculations

The diagrams have some hardcoded values - ignore those.



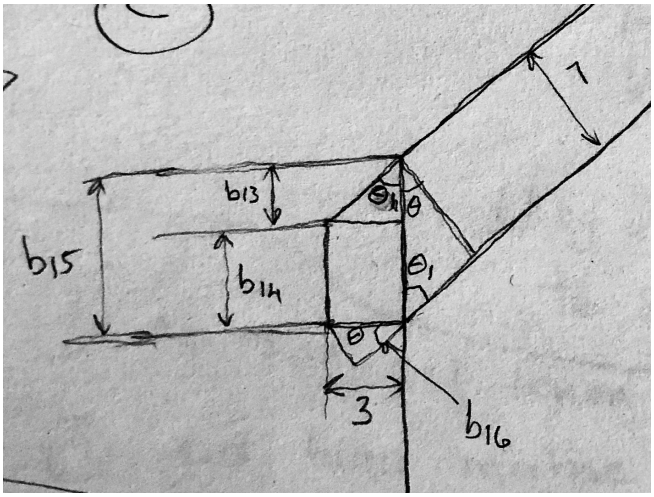
For the overall diagram, the calculations are

$$b_1 = \cos\theta \times \text{brace exposed length at top} = 27.656$$
$$b_2 = b_1 - x_5 = 21.1596$$
$$b_5 = \sin\theta_1 \times r_4 = 6.4964$$
$$b_4 = \sin\theta \times \text{brace exposed length at top} = 23.0466$$
$$b_3 = b_4 - b_5 = 16.5502$$
$$b_6 = \tan\theta_1 \times \text{brace width} = 8.4$$
$$b_7 = \tan\theta \times \text{brace width} = 5.8333$$
$$b_8 = \text{brace exposed length at top} + b_6 + b_7 = 50.2333$$



For braces into collar tie,

b_{11} = brace tenon depth into collar tie/ $\tan\theta = 3.6$
b_9 = brace width/ $\cos\theta_1 = 10.9343$
$b_{10} = b_9 - b_{11} = 7.3343$
b_{12} = brace tenon depth into collar tie $\times \cos\theta_1 = 1.9206$



For braces into post,

b_{13} = brace tenon depth into post/ $\tan\theta_1 = 2.5$
b_{15} = brace width/ $\cos\theta = 9.112$
$b_{14} = b_{15} - b_{13} = 6.612$
$b_{16} = \cos\theta \times$ brace tenon depth into post $= 2.3047$

9 Posts

9.1 Assumptions

```
post_stub_tenon_length <- 2
```

9.2 Imported variables

Imports:

- `post_tenon_depth_into_rafter` = 4 from §5.1.
- `r12` = 3.3333 from §5.3, here called p_1.
- `r5` = 7.8102 from §5.3, here called p_3.
- `post_width` = 6 from §2.1.
- `post_tenon_depth_into_rafter` = 4 from §5.1.
- `post_height_excluding_tenons` = 91.7761 from §3.3.
- `b3` = 16.5502 from §8.3.
- `b15` = 9.112 from §8.3.

9.3 Calculations

Some of the calculations were covered above in §5 from the perspective of the mortise. Here, we concentrate on the tenons. Some variables are imports from the section mentioned. For the others,

$$p_2 = \sqrt{p_3^2 - \text{post width}^2} = 5$$

$$p_4 = \cos\theta \times \text{post tenon depth into rafter} = 3.0729$$

From §3.3, post height excluding tenons is 91.7761, so total post height = post height excluding tenons + stub tenon length + p_4, which is

$$\boxed{96.849 = 8\text{'}\ 0\text{''}\ 27/32.}$$

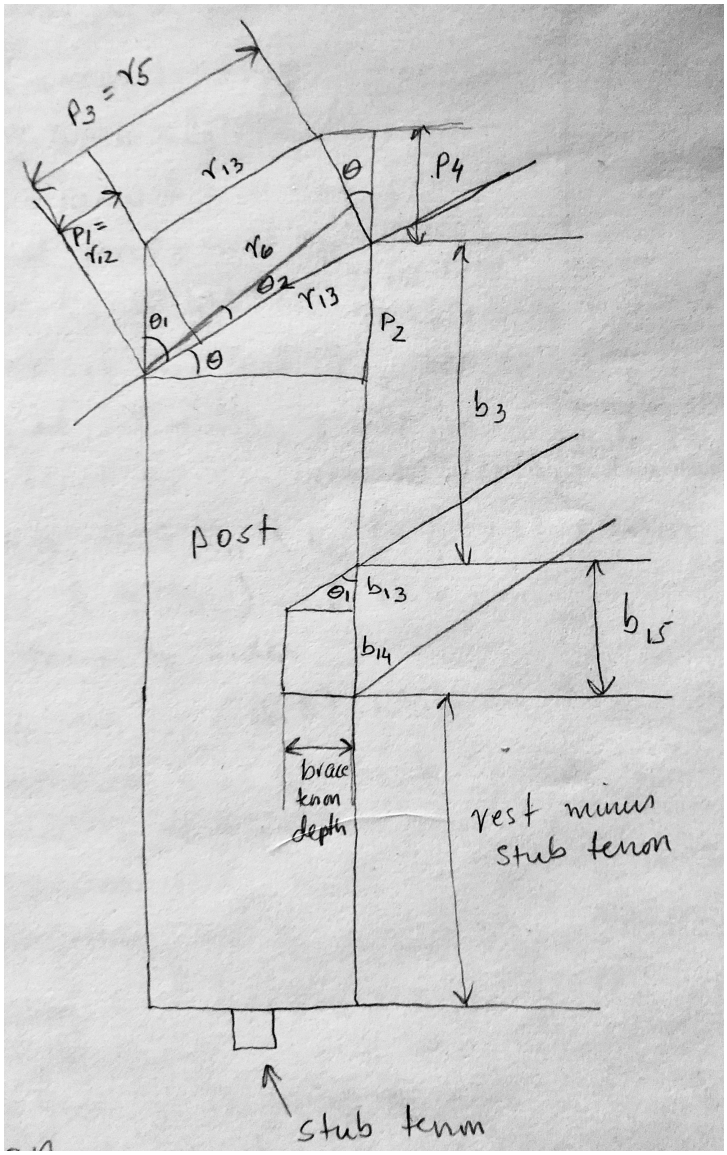


Figure 1: Posts layout

10 Cut plans

Calibrate all measuring instruments against each other before starting.

10.1 Posts

Layout & cut steps:

1. Cut a 6×6 beam to 8' 0" 27/32.
2. Mark out
   - p_4 = 0' 3" 1/16
   - b_3 = 1' 4" 9/16
   - b_{15} = 0' 9" 1/8, then
   - the rest minus stub tenon = 5' 6" 1/8, and
   - verify 2 inches left over for stub tenon.
3. At top, cut shouldered tenon as in diagram:
   - Mark out $\theta = 39.8$ as shown on the right side and mark out tenon depth = 4.
   - At 90°, measure out p_3 = 0' 7" 13/16, and extend line from left side and verify p_1 = 0' 3" 11/32.
   - Verify that straight part is r_{13} = 0' 4" 15/32.
   - Mark out shoulder = 1 and verify that $\theta_2 = 7.3$ and r_6 = 0' 7" 7/8; **this is the tenon cut line**.
   - Create tenon at 2-in thick.
4. Cut brace mortise:
   - Mark out
     - b_{13} = 0' 2" 1/2 and
     - b_{14} = 0' 6" 5/8.
   - Drill straight at b_{14} to depth of 3, and angled mortise at b_{13} at an angle of θ_1
5. Cut stub tenon such that when raising, the long axis of tenon is along direction of pulling, else it could break while being raised. Perhaps the stub should be 2×2×2, with placement TBD.

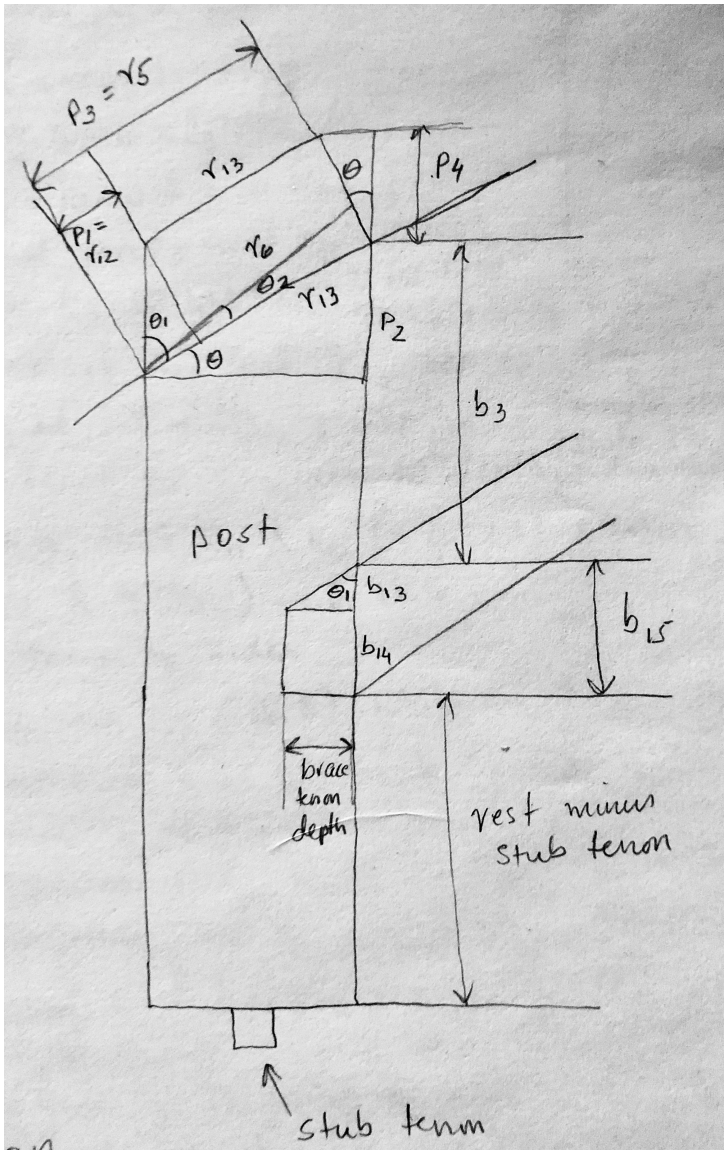


Figure 2: Posts layout

10.2 Rafters

10.2.1 Assumptions

```
rafter_width <- 6
collar_tie_rafter_shoulder_depth <- 1
```

10.2.2 Rafter overall

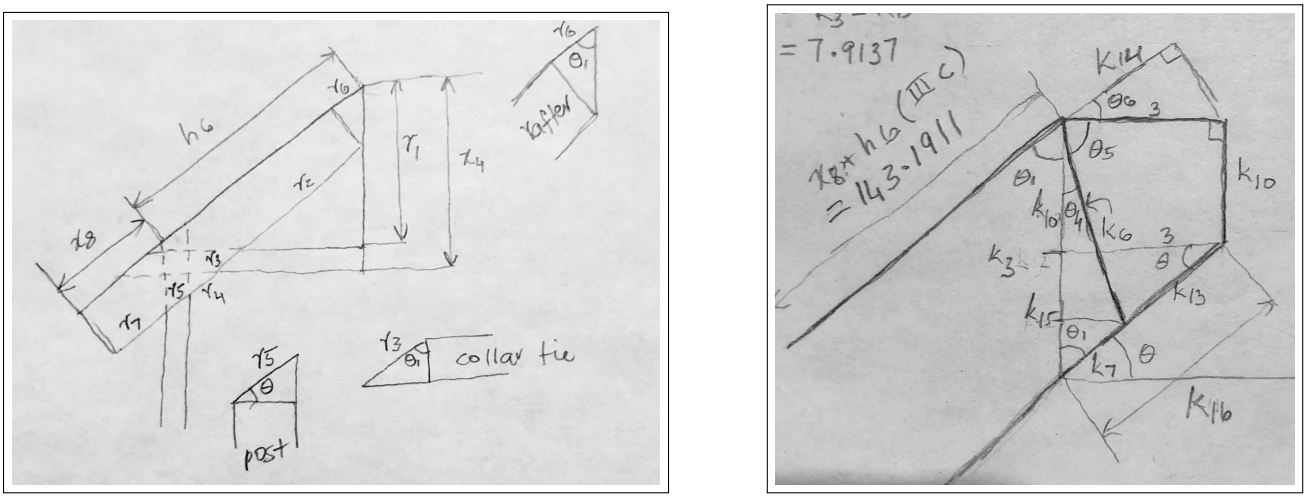


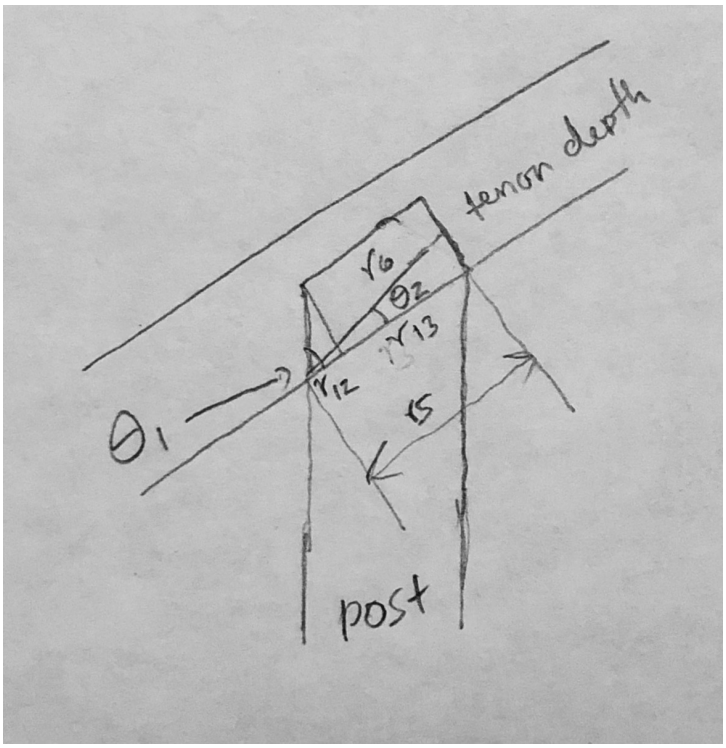
Figure 3: Rafter marks

1. Measure out 6×8×12' 1" 1/2.
2. On top side mark out (left to right) $x_8 = 2'\ 7"\ 1/4$ and $h_6 = 9'\ 3"\ 15/16$. Verify that $k_{14} = 0'\ 2"\ 5/16$.
3. On the bottom, mark out (left to right) the following:

$$r_7 = 2'0"9/16$$
$$r_5 = 0'7"13/16$$
$$r_4 = 0'\ 8"\ 15/32$$
$$r_3 = 1'0"1/2$$
$$r_2 = 6'11"3/16$$

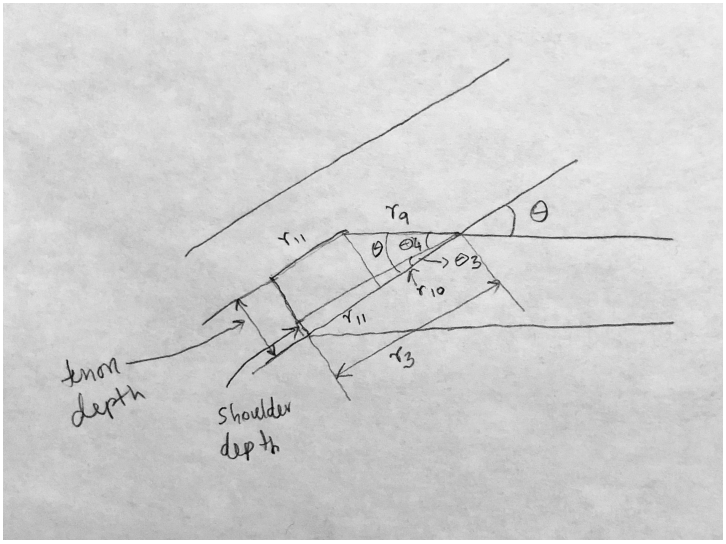
and verify that what's left over = 0' 8" 31/32.

10.2.3 Mortise for post tenon



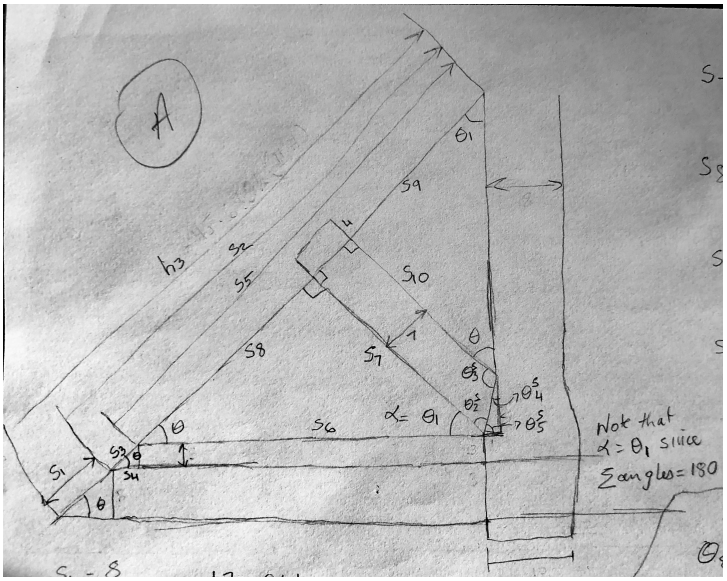
At r_5, mark out 1-in shoulder, verify that $\theta_2 = 7.3$ and all other variables in diagram.

10.2.4 Mortise for collar tie tenon



At r_3, mark out 1-in shoulder and verify that $\theta_3 = 4.6$ and all other variables in diagram.

10.2.5 Mortise for strut tenon

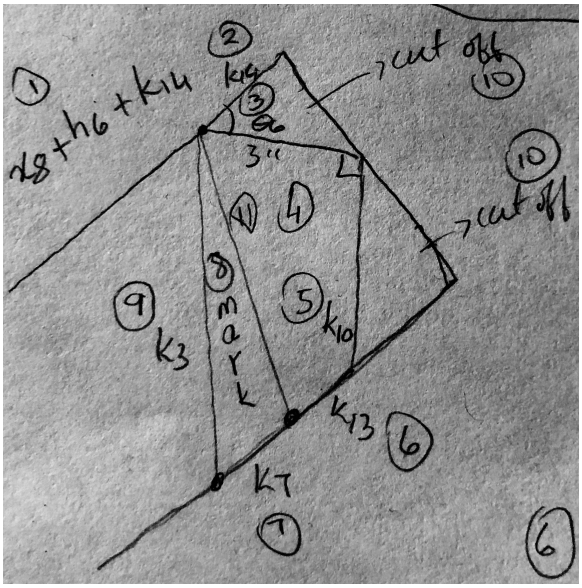


For strut mortises into rafter, measure $s_3 + s_8$ from end of collar tie mortise (sans shoulder), which is

$$s_3 + s_8 = 50.2444 = 4'2"1/4.$$

Mortise/tenon is 1.5-in thick, 7-in wide, and 4-in deep. Verify that s_9 = 2' 1" 15/16.

10.2.6 Tenon for KP mortise



Numbers below correspond to diagram. **There are 11 steps. The diagram hardcodes 3", ignore that.**

1. k_{14} = 0' 2" 5/16 should have been marked out already.
2. Mark out $\theta_6 = 39.8$ and verify rafter tenon depth into KP (0' 3").
3. Mark 90° (**this angle is hardcoded as 90**).
4. Verify k_{10} = 0' 7" 29/32.
5. Measure k_{13} = 0' 2" 19/32.
6. Measure k_7 = 0' 1" 5/16.

7. Mark up to k_{14} point.
8. Verify $k_3 = 0$' 10" 13/32.
9. Cut off sections.
10. Create tenons at 2-in thick.

TODO rafters will house purlins - account for those also when purlin nos is finalized.

10.3 Kingpost

10.3.1 Assumptions

```
kp_depth <- 6
kp_top_tenon_thickness <- 1.5
```

The diagrams have some hardcoded values - ignore those.

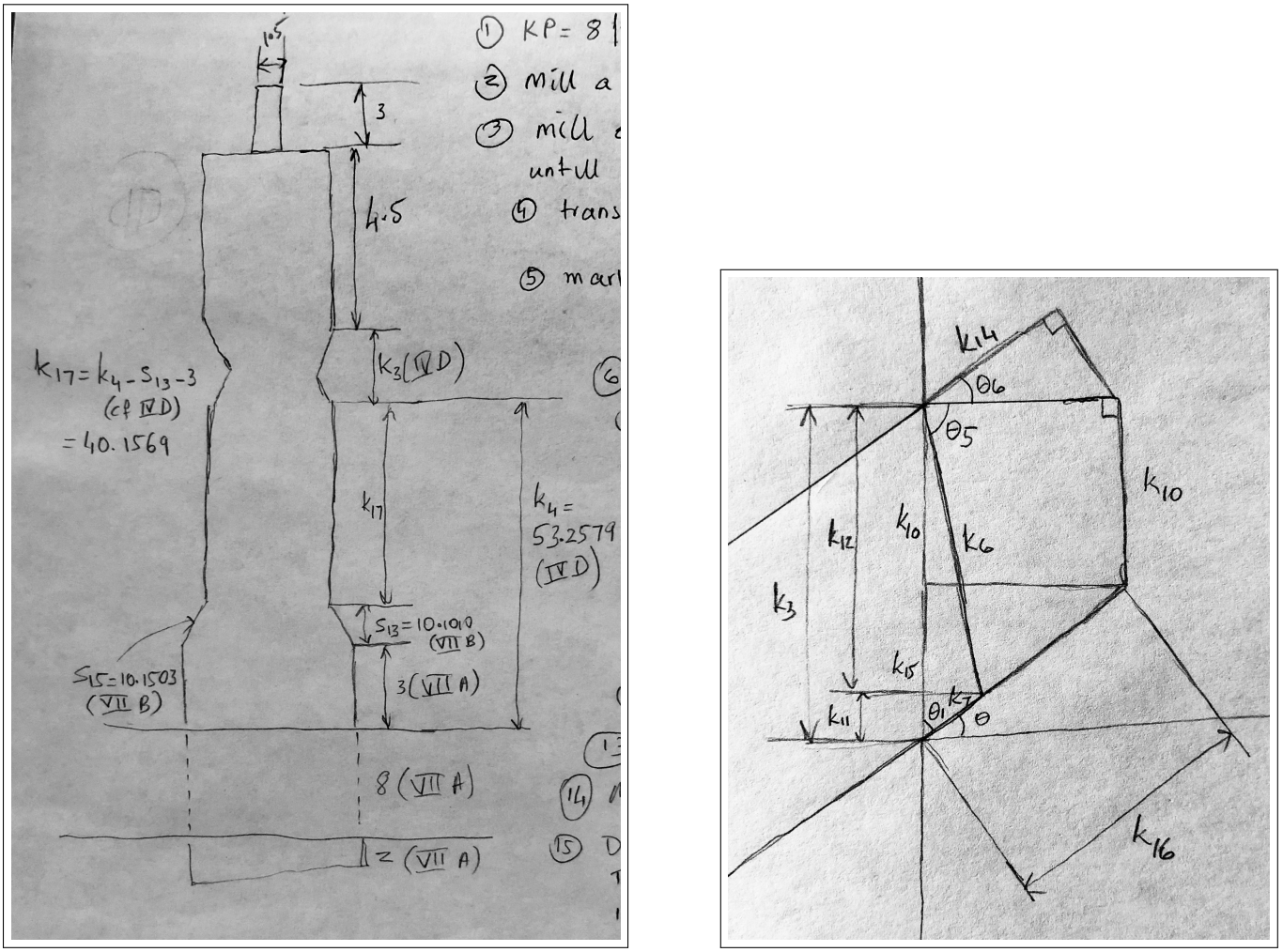


Figure 4: Overall cuts + mortise for rafter

1. KP total length = 6’ 9” 5/32.
2. Mill a 6×10, with length as above.
3. Mill off 1 inch on both sides, from top until 58.0657 = 4’ 10” 1/16.
4. Transitional area = s_{13} = 0’ 10” 3/32; chisel or saw this out, and verify that s_{15} = 0’ 10” 5/32.
5. Mark out from top: KP top tenon length = 3, KP part = 4.5, k_3 = 0’ 10” 13/32, verify that k_{17} = 3’ 4” 5/32. Mark s_{13} = 0’ 10” 3/32, strut height above collar tie = 3, and collar tie height = 8, and finally, through tenon length = 2.
6. Cut top tenon at thickness = 1.5 and length 3.
7. Cut bottom tenon at 10 inches long.
8. At k_3 mortise, mark out k_{11} = 0’ 0” 27/32 and k_{12} = 0’ 9” 19/32.

9. Mark out 1 inch shoulder down the sides.
10. Mark k_{10} = 0' 7" 29/32 and k_{15} = 0' 2" 1/2.
11. Drill straight at k_{10}, 2-inch mortise and create angled mortise at k_{15}.
12. Create shoulder using k_{11} and k_{12} measurements above.
13. For strut mortises, verify s_{15} = 0' 10" 5/32.
14. Mark out s_{16} = 0' 1" 31/32 and s_{17} = 0' 8" 3/16. Note that $s_{15} = s_{16} + s_{17}$.
15. Drill 1.5-inch thick mortises at 90° along s_{17} and angled along s_{16}. Mortises are 2 inches deep. Use some sort of right-angle guide for the drill since the face being drilled into is at an angle.

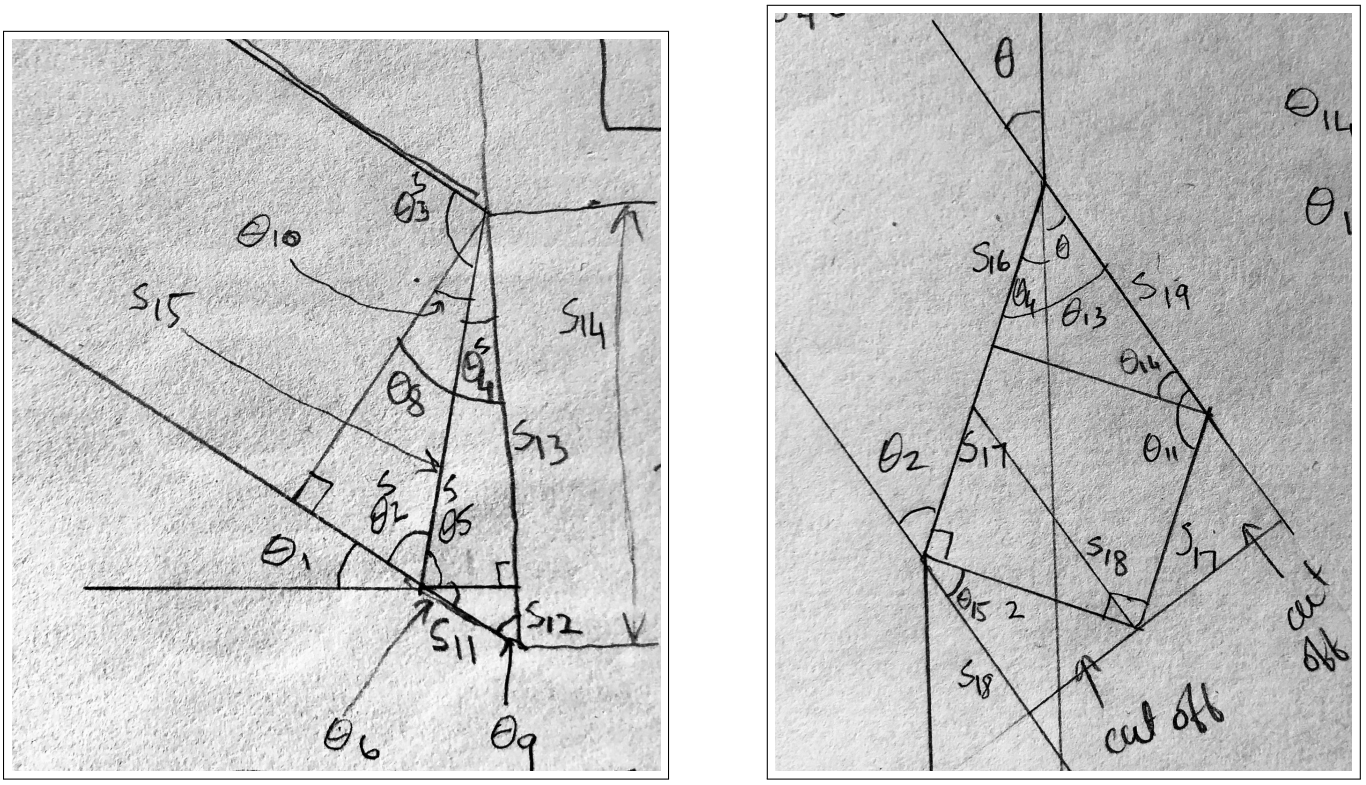


Figure 5: Mortises for struts into KP (the one on the right is actually for tenons but usable for mortises)

10.4 Collar tie

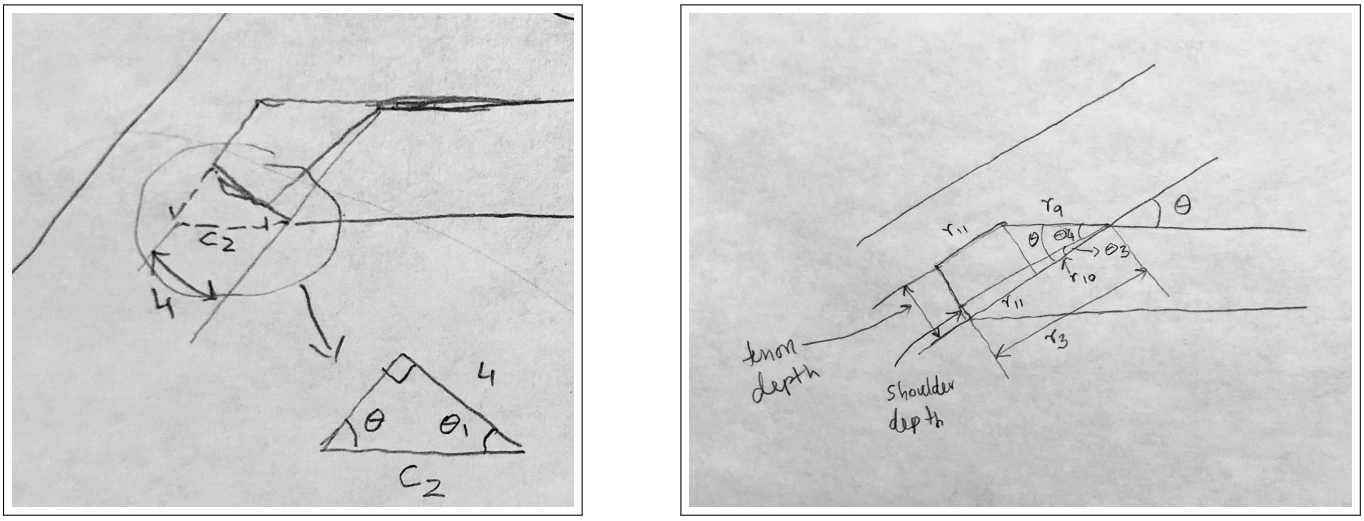


Figure 6: Tenons into rafters

1. Cut beam to 6×8 at 13' 11" 1/2 long. Note that CT length $= c_1 \times 2 + 10 + c_2 \times 2$.
2. Mark out $c_2 = 0'\ 6"\ 1/4$ at both ends.
3. Mark out on the sides, shoulder depth = 1 and full tenon depth = 4.
4. Mark $r_{11} = 0'\ 7"\ 11/16$ and then $r_9 = 0'\ 6"\ 1/4$.
5. Connect line to shoulder and verify that $\theta_3 = 4.6$.
6. Cut off sections and create 2-inch thick tenons.
7. Mark out $c_1 = 6'\ 0"\ 1/2$ from both sides and verify that the middle section measures 10 inches.
8. Cut through mortise at 2-in thick.
9. Mark out $b_2 = 1'\ 9"\ 5/32$, $b_9 = 0'\ 10"\ 15/16$, and verify that distance between brace end to kp mortise beginning is 3' 4" 13/32.
10. Cut mortises for braces as shown.

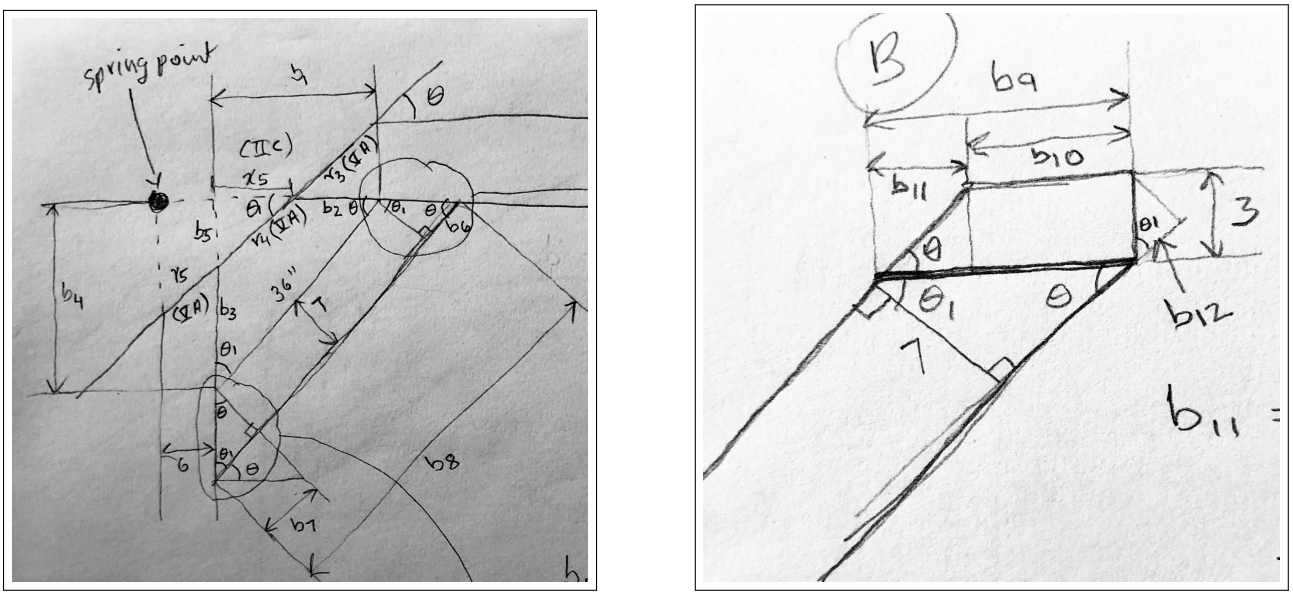


Figure 7: Mortises for knee braces

10.5 Struts

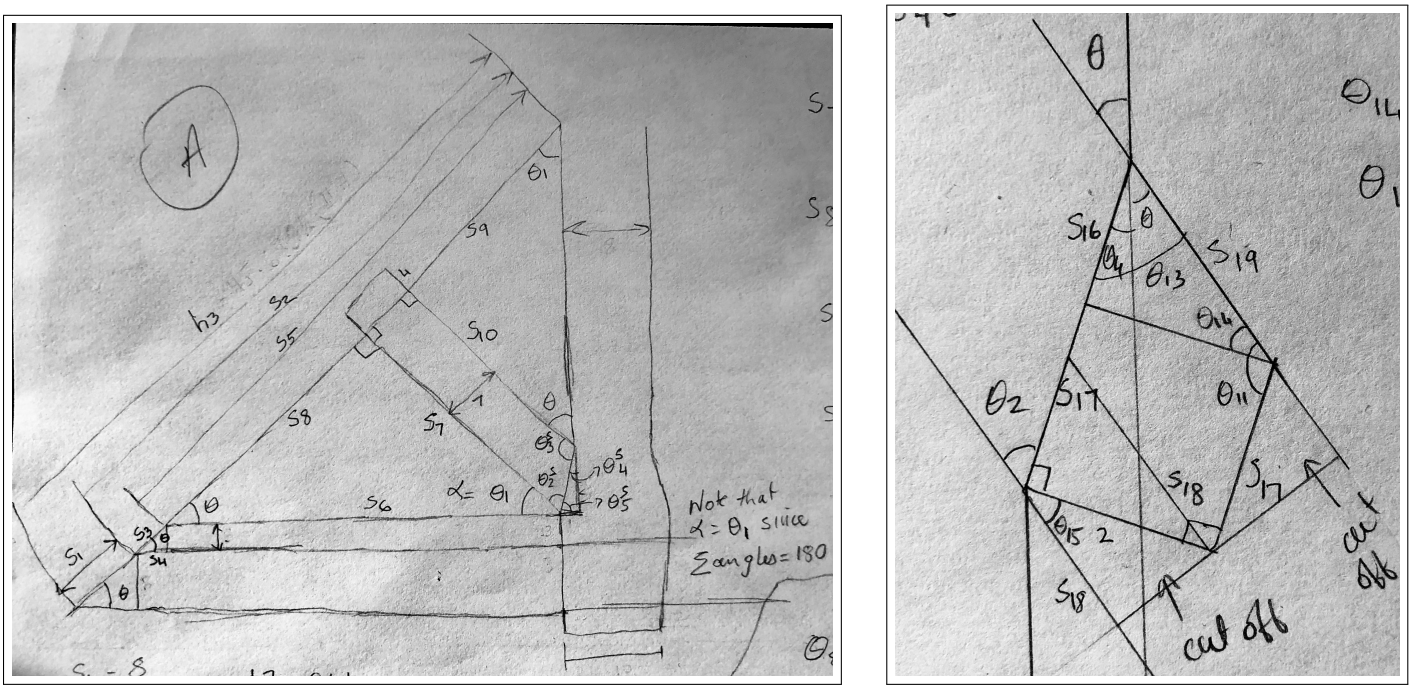


Figure 8: Strut cuts

There seems to be an extra s_{18} in the diagram in the middle - not sure what that is.

1. Strut length = strut tenon into rafter depth $+s_7 + s_{18} = 43.3445 =$ 3' 7" 11/32.
2. At s_{18}, mark out $\theta_{15} = 46.4$.
3. At 2-in mark 90° and measure $s_{17} =$ 0' 8" 3/16.
4. Connect from s_{17} end to other side of strut and verify s_{19} =0' 2" 13/16.
5. Verify $\theta_{11} = 134.5$ and $\theta_{13} = 45.5$.
6. Draw tenon line, verify length is $s_{16} + s_{17} =$ 0' 10" 5/32.
7. Cut off sections shown.
8. Create tenons at 2 inches deep and 1.5 inches thick.
9. For strut tenons into rafter: tenon is 1.5-in thick, 7-in wide, and 4-in deep.

10.6 Braces

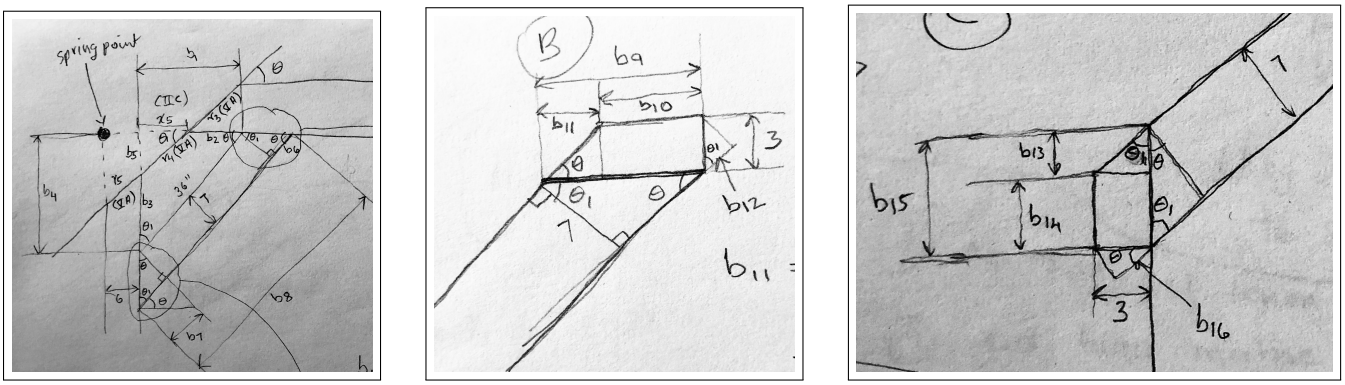


Figure 9: Braces

1. Brace length = $b_8 + b_{12} + b_{16} = 4$' 6" 15/32.
2. There are no shoulders; just cut according to diagrams/calculations above and verify the important b_X variables.

11 Measurements for scale diagram

Angles:

- $\theta = 39.8$
- $\theta_1 = 50.2$

Scale for lengths is 1 cm = 10 inches.

- $b_2 = 2.1$
- $b_3 = 1.7$
- $b_8 = 5$
- $h_1 = 0.9$
- $h_2 = 1.2$
- $h_4 = 12.9$
- $k_3 = 1$
- $k_{17} = 4$
- $s_3 = 0.5$
- $x_1 = 8$
- $x_2 = 7.4$
- $x_3 = 0.6$
- $x_6 = 0.5$
- $x_8 = 3.1$
- base to spring line = 9.7
- brace width = 0.7
- collar tie height = 0.8
- ct/rafter shoulder = 0.1
- kp part = 0.4
- KP width at bottom = 1
- KP width at top = 0.8
- kp/rafter shoulder = 0.1
- post width = 0.6
- post/rafter shoulder = 0.1
- purlin height = 0.7
- purlin pocket depth = 0.1
- rafter height = 0.8
- ridge ht = 0.7
- ridge straight part = 0.3
- straight part KP below flare = 0.3
- structure height = 18
- structure width = 18
- strut width = 0.7
- through tenon length = 0.2