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Prepared by: Lance Shields, P.E., Daniel Hindman, P.E., Ph.D,	
Title: Keyed Through Tenon Joints – Structural Design Guide	

Introduction

Both pegged joints and keyed through tenon (KTT) joints have been used in construction for centuries. In current design practice, these joints have been designed solely on mechanics principles and knowledge of timber strength values. Many previous research projects have been conducted on pegged mortise and tenon joints since the 1980's. Until 2011, no known research has been conducted on KTT joints. This document provides design guidance for KTT joints based on test observations from research performed at Virginia Tech by Shields (2011) and should be used in conjunction with the provisions of the *National Design Specification for Wood Construction* (NDS) (AWC 2015) and TFEC Bulletin 2016-08 *Keyed Through Tenon Joints* (Hindman and DeStefano 2016).

Design

Research conducted by Shields (2011) measured the strength of various KTT joints and developed limit state prediction models based on NDS values and mechanics principles. Applicable limit states for KTT joints include key bearing, key bending, mortise bearing, tenon bearing (at keyholes), tenon row tear-out (relish), tenon net-section tension, and tenon block shear. Key bearing, mortise bearing, tenon bearing, and key bending are ductile limit states. Tenon row tear-out (relish), tenon net-section tension, and tenon block shear are non-ductile limit states and should never govern design capacity where life safety or substantial risk to public property is a concern.

The design equations are written in ASD format only. The limit states are written as adjustable strength values per connection (Z'), which are based on combinations of adjusted strength properties (i.e. F'_c , $F'_{c\perp}$, F'_t , F'_v) of the keys, mortise member, and tenon member. Changes from applied standard adjustment values are bearing area factor, C_b , and size factor, C_F , for the keys.

Basic KTT Joint Specifications

- 1) Keyed through tenon joints and their components shall be fabricated and assembled by craftsmen experienced in timber frame construction and timber frame carpentry techniques.
- 2) Keys (wedges) shall be fabricated from clear hardwood stock (TFEC 1).
- 3) Key slope of grain shall not exceed 1:6 on any face (TFEC 1).
- 4) Oven-dry specific gravity (SG) of keys shall equal or exceed that of the species group (as assigned in the NDS) of the secured members and shall not be less than 0.57 (TFEC 1).
- 5) Joints shall be detailed and assembled as required to prevent tenon splitting resulting from installation (TFEC 1).
- 6) Mortise wall thickness shall equal or exceed mortise width (TFEC 1).
- 7) Excessive key width shall be avoided that would cause tenon splitting at the keyhole from seasoning effects (TFEC 1 Commentary and TFEC Bulletin 2016-08).
- 8) Tenon thickness should not be less than 2.0 inches (TFEC Bulletin No. 2016-08) until determined otherwise by further testing of KTT joints (Shields 2011).
- 9) Key Taper should be 1:12 or shallower (TFEC Bulletin No. 2017-08A).

KTT Joint Diagram with Notation of Dimension Variables

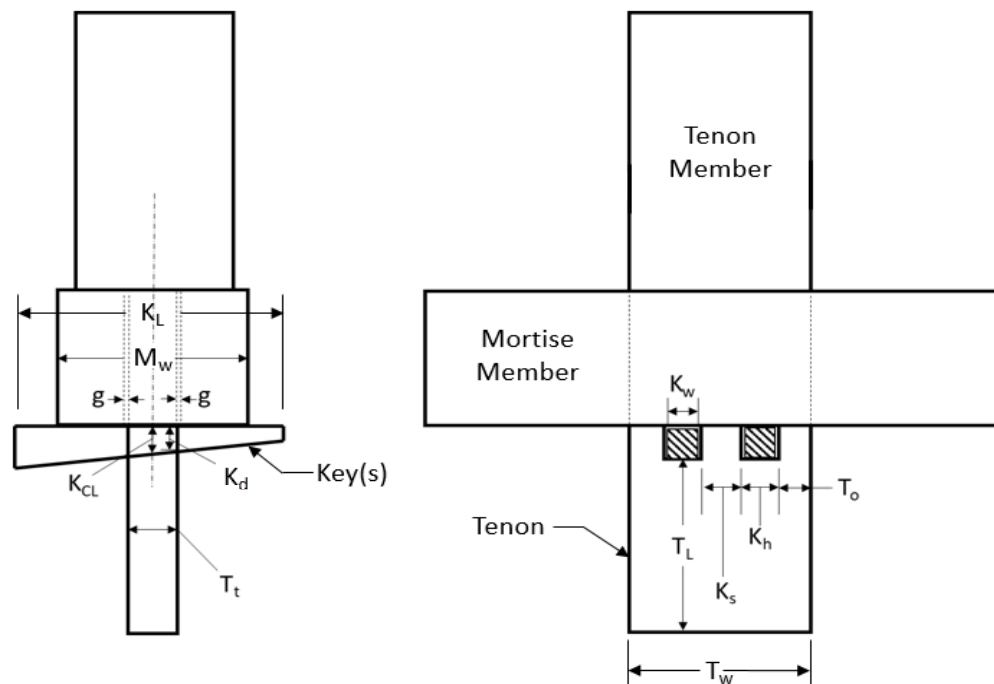


Figure 1: Cross-sectional and Side View of KTT Joint Showing Dimensions

Limit States of Key Through Tenon (KTT) Joints

Key, Mortise, and Tenon Bearing ($Z'_{B,k}$, $Z'_{B,m}$, $Z'_{B,t}$) are ductile limit states represented by equations 1, 2, and 3, respectively. Key bearing occurs when the key(s) crush at the key-to-tenon bearing interface and is the most likely bearing limit state to govern. Tenon bearing occurs when the tenon keyhole(s) crush at the key-to-tenon bearing interface and may govern in joints with relatively soft tenons or hard keys. Mortise bearing occurs when the mortise member crushes at the bearing interface between the key(s) and the mortise member. Mortise bearing will rarely govern design, however could govern when the key(s) and tenon member are extremely dense when compared to the mortise member or when key length is excessively short relative to the width of the face of the mortise member in contact with the key(s).

$$Z'_{B,k} = nF'_{c\perp,k}K_wT_t \quad (1)$$

$$Z'_{B,m} = nF'_{c\perp,m}K_w[\min(M_w, K_L) - T_t - 2g] \quad (2)$$

$$Z'_{B,t} = nF'_{c,t}K_wT_t \quad (3)$$

Where

$F'_{c\perp,k}$ = adjusted compression perpendicular to grain strength of key(s), psi

$F'_{c\perp,m}$ = adjusted compression perpendicular to grain strength of mortise member, psi

$F'_{c,t}$ = adjusted compression parallel to grain strength of tenon, psi

n = number of keys

g = tolerance gap around mortise and tenon interface (assumed to be 1/16 inch)

K_w = width of key(s), in

T_t = tenon thickness, in

M_w = width of mortise member face in contact with key(s), in

K_L = length of key(s), in

Key Bending (Z'_F) is a ductile limit state where bearing of the mortise and tenon against the key(s) produce capacity flexural stress in the key prior to key bearing capacity. Key bending is likely for relatively shallow keys and since keys are less constrained against flexure than pegs. Maximum moment in the key(s) occurs near the center tenon thickness and the greatest flexural stress in the key(s) is between the center tenon thickness and the tenon face with the lesser key depth. The equation for key bending (Equation 4) was developed from Technical Report 12: General Dowel Equations for Calculating Lateral Connection Values (AWC 2015) considering a dowel in bending with gaps between the mortise and tenon elements.

$$Z'_F = 2n \frac{-g(q_m q_s) + \sqrt{q_m q_s (g^2 q_m q_s + 2M_k (q_m + q_s))}}{q_m + q_s} \quad (4)$$

Where

q_m = [minimum ($F'_{c,t}$, $F'_{c\perp,k}$)] * K_w , key-to-tenon bearing strength, lb/in

q_s = [minimum ($F'_{c\perp,m}$, $F'_{c\perp,k}$)] * K_w , key-to-mortise bearing strength, lb/in

$F'_{c\perp,k}$ = adjusted compression perpendicular to grain strength of key, psi

$F'_{c,t}$ = adjusted compression parallel to grain strength of tenon, psi

$F'_{c\perp,m}$ = adjusted compression perpendicular to grain strength of mortise, psi

g = tolerance gap around mortise and tenon interface (assumed to be 1/16 inch)

$M_k = F'_{b,k} * K_w * K_d^2 / 6$, moment capacity of a single key, in-lb

Note: M_k applies to each key in joints with folding keys (two keys per keyhole)

$F'_{b,k}$ = bending strength of key, psi

K_d = shallowest key depth at either face of tenon for single keys, in

= key depth at center tenon thickness for double (folding) keys, in

Key dimensions ('rule-of-thumb') can be proportioned such that key bearing will likely govern over key bending. However, note that it is still prudent to check the key bending equation. These 'rule-of-thumb' dimensions are as follows (refer to Figure 2):

- Key depth (at center tenon thickness) to tenon thickness ratio of 1.1:1 or greater for joints with one key per keyhole.
- Key depth (at center tenon thickness) to tenon thickness ratio of 3:4 or greater per key in joints with two keys per keyhole (double or folding keys).

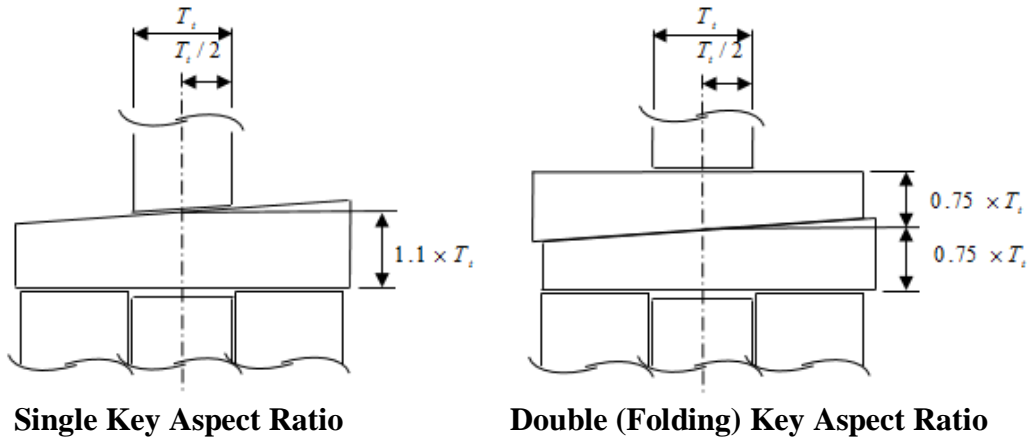


Figure 2: Minimum Aspect Ratio for Full Key Bearing

Tenon Row Tear-Out (Relish) (Z'_R) is a non-ductile limit state where the tenon shears along two shear planes at each key. NDS row tear-out uses one-half of the parallel-to-grain shear strength based on a triangular shear stress distribution assumption along shear planes. Through-tenons with keys sometimes demonstrated a tendency to spread perpendicular to the grain beyond the key(s) while the key(s) bear against the tenon keyhole(s) creating splits in the tenon beyond the key(s) prior to row tear-out failure (Shields 2011). Therefore an additional safety factor of 1.25 was added to the row tear-out limit state design equation in addition to the NDS triangular shear stress distribution assumption as shown in Equation 5. Equation 5 gives average safety factors of approximately 3.2 to 4.6 against relish when compare to test values at ultimate load. For design efficiency, the use of a several narrow keys will usually allow a shorter tenon length.

$$Z'_R = \frac{nT_t T_L F'_{v,t}}{1.25} \quad (5)$$

Where

$F'_{v,t}$ = adjusted shear strength of tenon, psi

T_L = minimum tenon length beyond key holes, in

Until future research shows otherwise, it is recommended that KTT joint tenons have at least two keyholes and that tenon end distance be at least 10.0 inches beyond the keys (TFEC Bulletin No. 2016-08) to prevent brittle splitting failure as demonstrated in testing (Shields 2011). The tenon of any KTT joint with only one keyhole should either be reinforced with screws across and parallel to the tenon width to avoid splitting and spreading or have a safety factor of 2.00 applied in the denominator of the row tear-out (relish) equation (instead of the current 1.25). The tenon of any KTT joint less than 10.0 inches beyond the keyholes should either be reinforced with screws across and parallel to the tenon width to avoid splitting and spreading or have a safety factor of 1.60 applied in the denominator of the row tear-out (relish) equation (instead of the current 1.25). If screws are used, care should be exercised in selecting screws to allow for tenon seasoning to avoid splitting.

Tenon Net-Section Tension (Z'_T) is a non-ductile limit state where the tenon ruptures across the tenon width at the keyholes (net-section).

$$Z'_T = F'_{t,t} T_t (T_w - n K_h) \quad (6)$$

Where

$F'_{t,t}$ = adjusted tension strength of tenon, psi

T_w = tenon width, in

K_h = width of tenon key holes (slightly larger than K_w , but practically the same for design purposes)

Tenon Block Shear (Z'_G) is a non-ductile limit state where a combination of tenon row tear-out (relish) and tenon net-section tension occur simultaneously. This limit state only applies to tenons with two or more key holes. Two block shear limit states apply (Figure 3). The first limit state occurs where the tenon ruptures (relishes) beyond the outer keys and pieces of tenon remain only between keys (Figure 3A). The other limit state occurs where only outer portions of tenon remain and a larger center piece of tenon ruptures and relishes beyond the keys (Figure 3B). Two equations, $Z'_{G,A}$ and $Z'_{G,B}$ are presented for the corresponding limit states. The minimum Z'_G value should be used. The block shear limit state equations assume that keys are of uniform width and spacing. Where tenon width is limited, tenons may be lengthened to increase shear plane capacity and allow tenon net-section tension to govern over the block shear limit states.

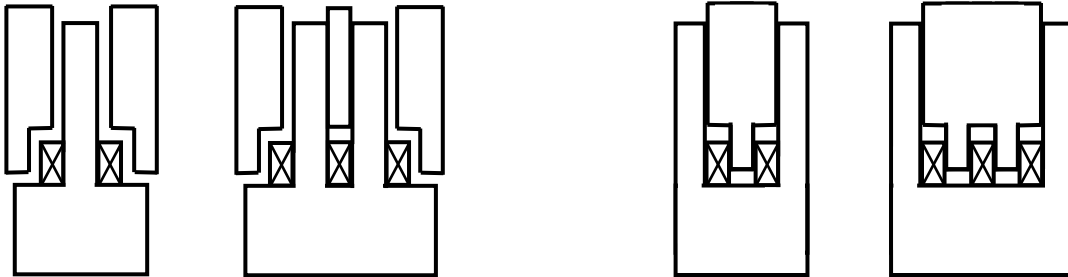


Figure 3: Tenon Block Shear Limit States A (left) and B (right) for KTT Joint with Two or more Keys

$$Z'_{G,A} = 2F'_{t,t} T_t T_o + \frac{(n-1)F'_{v,t} T_t T_L}{1.25} \quad (7)$$

Or

$$Z'_{G,B} = (n-1)F'_{t,t} T_t K_s + \frac{F'_{v,t} T_t T_L}{1.25} \quad (8)$$

Where

T_o = width of tenon beyond outer keyholes (key slots), in

K_s = spacing between key slots, in

Example 1: Anchor Beam Connection to Post

Given Information:

- Anchor Beam: 8x14 Southern Pine, No.1
- Column: 12x12 Southern Pine, No.1
- Keys: Red Oak, Select Structural (SS)
- All NDS Adjustment Factors other than C_D can be assumed to be 1.0

Detail a KTT joint for a maximum tension load of 11,500 lbs generated by wind only.

Solution:

Try (4) 1 ½" wide keys with uniform spacing and thickness in a 2" wide tenon:

Bearing Capacity (Key, Mortise, and Tenon):

Key bearing capacity at the tenon-key bearing interface: $Z'_{B,k} = nK_w T_t F'_{c\perp,k}$

n = number of keyholes = (4) keyholes

K_w = width of key(s) = 1.5in

T_t = tenon thickness = 2in

Note that the length of key(s) must satisfy NDS requirements to use the C_b factor by having the key(s) long enough so that each end extends at least 3 inches beyond each tenon face. Therefore, minimum key length to use the C_b factor is $K_L = T_t + 6"$ (in this example $K_L = 8"$ minimum). It is recommended that key length be longer to allow for fabrication tolerances.

$$C_b = (T_t + 0.375)/T_t = (2 + 0.375)/2 = 1.188$$

$$F'_{c\perp,k} = C_b * F_{c\perp,k} = 1.188 * 820 = 974 \text{ psi}$$

$$Z'_{B,k} = (4) * 1.5 * 2 * 974 = \underline{11,685 \text{ lbs}} (>11,500 \text{ lbs})$$

Mortise bearing capacity at the key-mortise bearing interface:

$$Z'_{B,m} = nK_w F'_{c\perp,m} \times [\min(M_w, K_L) - T_t - 2g]$$

g = tolerance gap around mortise and tenon interface (assumed to be 1/16 inch)

M_w = width of mortise member = 9.5in

K_L = length of key(s) = 8in (minimum for this example)

$$C_b = (K_w + 0.375)/K_w = (1.5 + 0.375)/1.5 = 1.25$$

$$F'_{c\perp,m} = C_b * F_{c\perp,m} = 1.25 * 375 = 469 \text{ psi}$$

$$Z'_{B,m} = (4) * 1.5 * 469 * [\min(9.5, 8) - 2 - 2 * 0.625] = \underline{16,523 \text{ lbs}} (>11,500 \text{ lbs})$$

Tenon bearing capacity at the tenon-key bearing interface: $Z'_{B,t} = nK_w T_t F'_{c,t}$

$$F'_{c,t} = C_D * F_{c,t} = 1.6 * 825 = 1,320 \text{ psi}$$

$$Z'_{B,t} = (4) * 1.5 * 2 * 1,320 = \underline{15,840 \text{ lbs}} (> 11,500 \text{ lbs})$$

Therefore, bearing capacity is governed by the keys at $Z'_{B,k} = \underline{11,685 \text{ lbs}}$ (> 11,500 lbs, OK)

Key Bending:

Key dimensions ('rule-of-thumb') can be proportioned such that key bearing will likely govern over key bending. However, note that it is still prudent to check the key bending equation. These 'rule-of-thumb' dimensions are as follows: KTT joints with single keys (one key per keyhole) should have at minimum a key depth at center tenon thickness equal to or greater than 1.1 times the tenon thickness or a minimum key depth of $\frac{3}{4}$ of the tenon thickness per individual key if using double (folding) keys, per "Keyed Through Tenon Joints – Design Guide" (TFEC Technical Bulletin 2017-08A). Therefore, for key bearing to govern over key bending, target key depths for a two-inch thick tenon as in this example need to be at least 2 $\frac{1}{4}$ " deep at the center of the two inch tenon thickness if using single keys and 1 $\frac{1}{2}$ " deep if using double (folding/stacked) keys.

Tenon Row Tear-out:

TFEC Bulletin 2016-08 *Keyed Through Tenon Joints* (Hindman and DeStefano 2016) states that tenons should extend at least 10 inches beyond the keys. Also note that having brittle limit states governing design is NOT recommended. Therefore, a tenon length should be established to allow the minimum of key, tenon, and mortise bearing and key bending limit states govern design:

$$Z'_R = \min(Z'_{B,k}, Z'_{B,m}, Z'_{B,t}, Z'_F) = 11,685 \text{ lbs}$$

$$T_L = \frac{1.25 * Z'_R}{n T_t F'_{v,t}} = \frac{1.25 * 11,685}{(4) * 2 * 264} = 6.92 \text{ in} (< 10 \text{ in}), \text{ therefore: } \underline{10 \text{ in beyond the keys}}$$

Tenon Net-Section Tension:

Note that having brittle limit states governing design is NOT recommended. Therefore, the joint capacity based on this limit state should be greater than that of the minimum of key, tenon, and mortise bearing and key bending limit states:

$$K_h = \text{width of keyhole (practically same as width of key for design purposes)} = 1.5 \text{ in}$$

$$F'_{t,t} = C_D * F_{t,t} = 1.6 * 900 = 1,440 \text{ psi}$$

$$Z'_T = F'_{t,t} T_t (T_w - n K_h) = 1,440 * 2 * [13.5 - (4) * 1.5] = \underline{21,600 \text{ lbs}} (> 11,685 \text{ lbs})$$

Tenon Block Shear:

Note that having brittle limit states governing design is NOT recommended. Therefore, the joint capacity based on this limit state should be greater than that of the minimum of key, tenon, and mortise bearing and key bending limit states:

T_o = width of tenon beyond outer keyholes = 1.5in (initial selection)

K_s = spacing between keyholes = 1.5in (initial selection)

T_L = required tenon length = 10in (see tenon row tear-out)

$$Z'_{G,A} = 2F'_{t,t}T_tT_o + \frac{(n-1)F'_{v,t}T_tT_L}{1.25}$$
$$= 2*1.6*900*2*1.5 + [(4)-1]*1.6*165*2*10]/1.25 = 21,312 \text{ lbs}$$

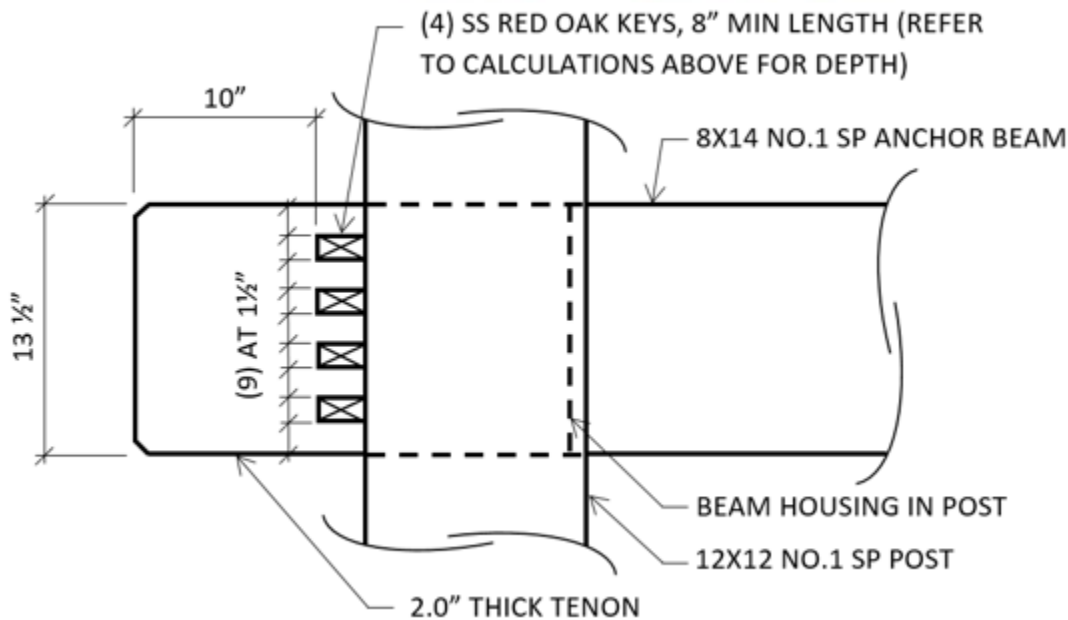
$$Z'_{G,B} = (n-1)F'_{t,t}T_tK_s + \frac{F'_{v,t}T_tT_L}{1.25}$$
$$= ((4)-1)*1.6*900*2*1.5 + [1.6*165*2*10]/1.25 = 17,184 \text{ lbs}$$

Therefore, block shear capacity is governed by $Z'_{G,B} = \underline{17,184 \text{ lbs}}$ (> 11,685 lbs, OK)

Conclusion:

The KTT joint is adequate to support the intended design load. Note that none of the brittle (non-ductile) limit states of tenon failure govern joint design which is required for KTT joint design where life safety or substantial risk to public property is a concern.

Detailed Joint: (Not to Scale)



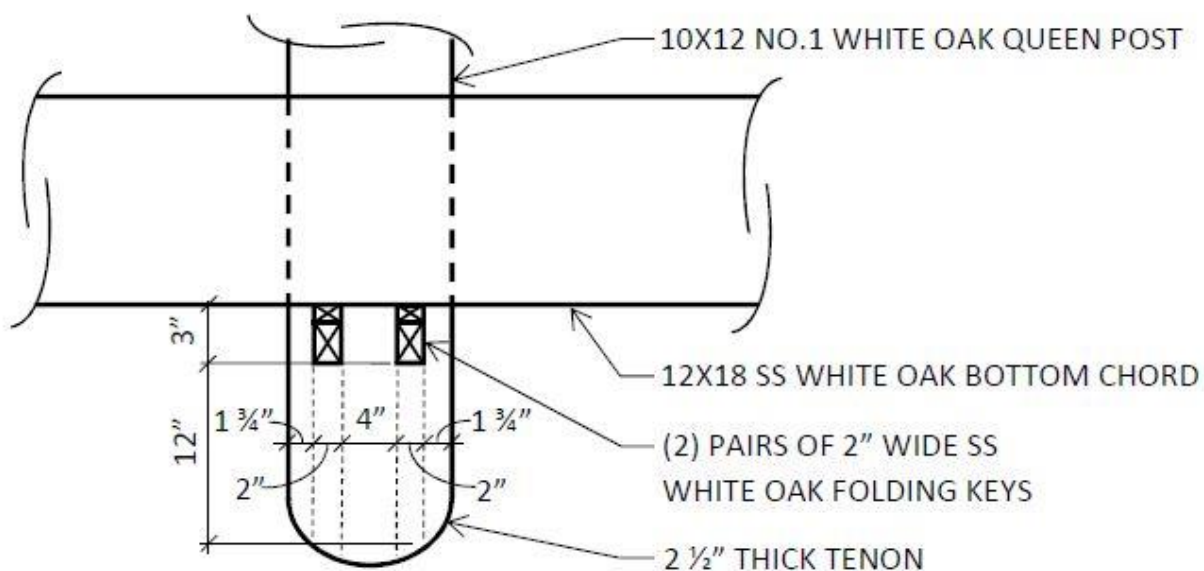
Example 2: Existing Queen Post and Bottom Chord KTT Joint Check

Given Information:

An existing timber framed horse barn is to be converted in to a residence. The structure is one-story with a gable roof. Roof framing is composed of uniformly spaced timber framed double queen post trusses forming a central isle along the entire length of the structure in the roof. The space between the queen posts and height between the bottom chord and collar beam allow for bedrooms, bathrooms and other necessary living spaces. All roof trusses are constructed of the same geometry, timber size and species, and joinery details. Modern-day strength values were used for simplicity and determined to be conservative. Field investigations provided the following information:

- Queen Posts: 10x12 white oak, No.1 (oriented so that tenon is 12 inches wide)
- Queen Post Tenon Length: 12in (beyond keys)
- Queen Post Tenon Thickness: 2.5in
- Key Species: white oak
- Number of Keys: (2) per joint (with enough length to allow use of C_b)
- Key Width: 2.0in
- Key Length: 12in
- Key Depth: 1.5in at center tenon thickness per key (3.0in total – folding keys)
- Bottom Chord: 12x18 white oak, SS
- Total Demand after Renovation: 7,600 lbs Dead and Live Load ($C_D = 1.0$) (each Queen Post)

Given that all members and other connections in the trusses were determined adequate or in need of additional support, determine if existing KTT joints of the queen posts into the bottom chords are adequate or if additional reinforcing is required. Below is the illustrated KTT joint:



Solution:

Bearing Capacity (Key, Mortise, and Tenon):

Key bearing capacity at the tenon-key bearing interface: $Z'_{B,k} = nK_w T_t F'_{c\perp,k}$

n = number of keyholes = (2) keyholes

K_w = width of key(s) = 2.0in

T_t = tenon thickness = 2.5in

Note that the length of key(s) must satisfy NDS requirements to use the C_b factor by having the key(s) long enough so that each end extends at least 3 inches beyond each tenon face. Therefore, minimum key length to use the C_b factor is $K_L = T_t + 6"$ (in this example $K_L = 12"$ which is greater than the required minimum or $8 \frac{1}{2}"$ for this example).

$$C_b = (T_t + 0.375)/T_t = (2.5 + 0.375)/2.5 = 1.15$$

$$F'_{c\perp,k} = C_b * F_{c\perp,k} = 1.15 * 800 = 920 \text{ psi}$$

$$Z'_{B,k} = (2) * 2 * 2.5 * 920 = \underline{9,200 \text{ lbs}} (>7,600 \text{ lbs})$$

Mortise bearing capacity at the key-mortise bearing interface:

$$Z'_{B,m} = nK_w F'_{c\perp,m} \times [\min(M_w, K_L) - T_t - 2g]$$

g = tolerance gap around mortise and tenon interface (assumed to be 1/16 inch)

M_w = width of mortise member = 11.5in

K_L = length of key(s) = 12in

$$C_b = (K_w + 0.375)/K_w = (2 + 0.375)/2 = 1.188$$

$$F'_{c\perp,m} = C_b * F_{c\perp,m} = 1.188 * 800 = 950 \text{ psi}$$

$$Z'_{B,m} = (2) * 2 * 950 * [\min(11.5, 12) - 2.5 - 2 * 0.625] = \underline{33,725 \text{ lbs}} (>7,600 \text{ lbs})$$

Tenon bearing capacity at the tenon-key bearing interface: $Z'_{B,t} = nK_w T_t F'_{c,t}$

$$F'_{c,t} = C_D * F_{c,t} = 1.0 * 775 = 775 \text{ psi}$$

$$Z'_{B,t} = (2) * 2 * 2.5 * 775 = \underline{7,750 \text{ lbs}} (>7,600 \text{ lbs})$$

Therefore, bearing capacity is governed by the keys at $Z'_{B,k} = \underline{7,750 \text{ lbs}} (>7,600 \text{ lbs, OK})$

Check Key Bending Capacity:

$$q_m = [\text{minimum}(F'_{c,t}, F'_{c\perp,k})] * K_w = [\text{minimum}(C_D F_{c,t}, C_b F_{c\perp,k})] * K_w:$$
$$= \min(1.0 * 775, 1.15 * 800) * 2.0 = \underline{1,550 \text{ lbs/in}}$$

$$q_s = [\text{minimum}(F'_{c\perp,m}, F'_{c\perp,k})] * K_w = [\text{minimum}(C_b F_{c\perp,m}, F_{c\perp,k})] * K_w:$$
$$= \min(1.188 * 800, 800) * 2.0 = \underline{1,600 \text{ lbs/in}}$$

Note that C_b only gets applied to the mortise bearing strength and not the key bearing strength for q_s since, at the key-mortise bearing interface, the keys are bearing at or nearly at their ends and the mortise member is not bearing nearly with three inches of its end. The bearing length on the mortise member is the width of the key(s).

g = tolerance gap around mortise and tenon interface (assumed to be 1/16 inch)

$$M_k = F'_{b,k} * K_w * K_d^2 / 6, F'_{b,k} = C_D C_F F_{b,k} = 1,800 \text{ psi:}$$
$$= 1,800 * 2 * (1.5^2) / 6 = 1,350 \text{ in-lb per individual key or } \underline{2,700 \text{ in-lb}} \text{ per key pair at}$$

each keyhole

Note:

- Grade SS and NDS Size Factor C_F of 1.5 applies to $F_{b,k}$ for most keys
- M_k is doubled for folding keys (two keys per keyhole) as shown above
- K_d is equal to the key depth at center tenon thickness for double (folding) keys. K_d is equal to the lesser key depth at either tenon face for single (individual) keys per keyhole.

$$Z'_F = 2n \frac{-g(q_m q_s) + \sqrt{q_m q_s (g^2 q_m q_s + 2M_k (q_m + q_s))}}{q_m + q_s} = \underline{8,050 \text{ lbs}} (> 7,600 \text{ lbs, OK})$$

Tenon Row Tear-out:

$$F'_{v,t} = C_D * F_{v,t} = 1.0 * 205 = 205 \text{ psi}$$

$$Z'_R = \frac{n T_t T_L F'_{v,t}}{1.25} = \frac{(2) * 2.5 * 12 * 205}{1.25} = \underline{\underline{9,840 \text{ lbs}}} (> 7,750 \text{ lbs, OK})$$

Note that the brittle limit-state capacities are being compared to the minimum ductile limit-state capacity.

Tenon Net-Section Tension:

$$K_h = \text{width of keyhole (practically same as width of key)} = 2 \text{ in}$$

$$F'_{t,t} = C_D * F_{t,t} = 1.0 * 575 = 575 \text{ psi}$$

$$Z'_T = F'_{t,t} T_t (T_w - n K_h) = 575 * 2.5 * [11.5 - (2) * 2] = \underline{\underline{10,780 \text{ lbs}}} (> 7,750 \text{ lbs, OK})$$

Tenon Block Shear:

$$T_o = \text{width of tenon beyond outer keyholes} = 1.75 \text{ in}$$

$$K_s = \text{spacing between keyholes} = 4 \text{ in}$$

$$F'_{v,t} = C_D * F_{v,t} = 1.0 * 205 = 205 \text{ psi}$$

$$F'_{t,t} = C_D * F_{t,t} = 1.0 * 575 = 575 \text{ psi}$$

$$\begin{aligned} Z'_{G,A} &= 2 F'_{t,t} T_t T_o + \frac{(n-1) F'_{v,t} T_t T_L}{1.25} \\ &= 2 * 575 * 2.5 * 1.75 + [(2)-1] * 205 * 2.5 * 12 / 1.25 = \underline{\underline{9,950 \text{ lbs}}} \end{aligned}$$

$$\begin{aligned} Z'_{G,B} &= (n-1) F'_{t,t} T_t K_s + \frac{F'_{v,t} T_t T_L}{1.25} \\ &= ((2)-1) * 575 * 2.5 * 4 + [205 * 2.5 * 12] / 1.25 = \underline{\underline{10,670 \text{ lbs}}} \end{aligned}$$

Therefore, block shear capacity is governed by $Z'_{G,A} = \underline{\underline{9,950 \text{ lbs}}} (> 7,750 \text{ lbs, OK})$

Conclusion:

The KTT joint is adequate to support the intended design load. Note that none of the brittle (non-ductile) limit states of tenon failure govern joint design which is required for KTT joint design where life safety or substantial risk to public property is a concern.

References

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Liability

The information in this example is general in nature and its application must be considered in the context of the unique circumstances of every design. It is intended that timber frame joints (such as the joint in this design example) be analyzed and design with competent engineering, constructed with accurate fabrication, and have adequate supervision of construction. The authors, Timber Frame Business Council, Timber Frame Engineering Council, the Timber Framers Guild, and any other associated organization do not assume any responsibility for errors or omissions in information presented in this bulletin, nor for engineering designs, plans, or construction prepared from it. Those applying the principals of design from this example assume all liability arising from their use. The design of engineered structures is within the scope of expertise of licensed engineers, architects, or other licensed professionals for applications to a particular structure.

Daniel Hindman, P.E., Ph.D. is an Associate Professor in the Department of Sustainable Biomaterials at Virginia Tech, Blacksburg, VA.

Lance Shields, P.E. is an associate at Dunbar Milby Williams Pittman & Vaughan, PLLC., Richmond, VA.