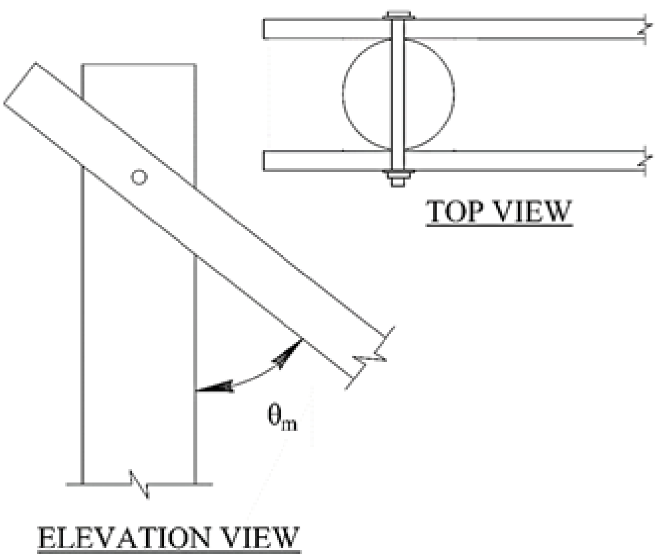
Appendix D Example 11 – Bolted Joints - Double Shear

Refer to *Falsework Manual,* Section 5-3, *Timber Fasteners*. This example demonstrates how to calculate the capacity of the connection between a double diagonal brace and post. For this example, 2 % dead load is the governing load.

Given Information



Posts:
12" Diameter Pole

Diagonal Braces:
2x8 S4S Douglas Fir-Larch #2
(G=0.50)

Connectors:
¾" Ø Bolt

Figure D-11-1. Post and Double Brace Bolted Joint

Determine the connection capacity between brace and post for 2% Dead Load

Main Member Properties		Side Member Properties	
d_{pole} = 12 in	*diameter*	l_s = 1.5 in	*thickness (2x8)*
$\theta_m = \tan^{-1}(\frac{4}{3}) = 53.13°$	*angle between direction of loading & direction of grain*	$t_s = l_s$ = 1.5 in	
G = 0.50	*Specific Gravity NDS Table 12.3.3*	θ_s= 0°	*angle between direction of loading & direction of grain*

Connector Properties

$D = 0.75$ in *connector diameter*

$F_{yb} = 45000$ psi *Yield Strength (NDS table 12A footnote 2)*

Find equivalent square section width of pole:

$$l_m = \sqrt{\pi \left(\frac{d_{pole}}{2}\right)^2} = 10.63 \text{ in } (\textit{NDS 3.7.3})$$

$t_m = l_m = 10.63$ in

Find Dowel Bearing Strength at an Angle to Grain (NDS Section 12.3.4):

$F_{e.pll} = 11200G$ psi $= 5600$ psi *Dowel Bearing Strength Parallel to Grain (NDS table 12.3.3 footnote 2)*

$$F_{e.perp} = \frac{6100G^{1.45}}{\sqrt{D}} = 2578 \text{ psi}$$

Dowel Bearing Strength Perpendicular to Grain (NDS table 12.3.3 footnote 2)

Compare values to NDS Table 12.3.3:

$F_{e.pll\ (NDS\ Table\ 12.3.3)} = 5600$ psi

$F_{e.perp\ (NDS\ Table\ 12.3.3)} = 2600$ psi

Use calculated value for $F_{perp} = 2578$ psi

Find Dowel Bearing Strength at an Angle to Grain (NDS Section 12.3.4):

$$F_{em} = \frac{F_{e.pll}F_{perp}}{F_{e.pll}(\sin(\theta_m))^2 + F_{perp}(\cos(\theta_m))^2} = 3200 \text{ psi}$$

$$F_{es} = \frac{F_{e.pll}F_{perp}}{F_{e.pll}(\sin(\theta_s))^2 + F_{perp}(\cos(\theta_s))^2} = 5600 \text{ psi}$$

Find Reduction Term, R_d (NDS Table 12.3.1B):

$\theta = \max(\theta_m, \theta_s) = 53.13°$ — *Maximum angle between direction of load and direction of grain for any member in connection (See Table 12.3.1B)*

$K_\theta = 1 + 0.25 \frac{\theta}{90\ \text{deg}} = 1.15$

$R_{d\_I} = 4\ K_\theta = 4.59$ — *Reduction Term for Yield Mode I_m and I_s*

$R_{d\_II} = 3.6\ K_\theta = 4.13$ — *Reduction Term for Yield Mode II*

$R_{d\_III.IV} = 3.2\ K_\theta = 3.67$ — *Reduction Term for Yield Mode III_m, III_s, and IV*

Find Yield Limit Equations for Single Shear (NDS Table 12.3.1A):

$R_e = \frac{F_{em}}{F_{es}} = 0.571$

$R_t = \frac{l_m}{l_s} = 7.09$

Note: Values for k_1 and k_2 not required for double shear

$$k_3 = -1 + \sqrt{\frac{2(1 + R_e)}{R_e} + \frac{2F_{yb}(2 + R_e)D^2}{3F_{em}l_s^2}} = 2.3951$$

$$Z_{Im} = \frac{Dl_mF_{em}}{R_{d\_I}} = 5558\ \text{lb}$$ *NDS Eqn 12.3-7*

$$Z_{Is} = \frac{2Dl_sF_{es}}{R_{d\_I}} = 2745\ \text{lb}$$ *NDS Eqn 12.3-8*

$$Z_{IIIs} = \frac{2k_3Dl_sF_{em}}{(2 + R_e)R_{d\_III.IV}} = 1826\ \text{lb}$$ *NDS Eqn 12.3-9*

$$Z_{IV} = \frac{2D^2}{R_{d\_III.IV}}\sqrt{\frac{2F_{em}F_{yb}}{3(1 + R_e)}} = 2394\ \text{lb}$$ *NDS Eqn 12.3-10*

The controlling value is the minimum double shear capacity from the above equations.

$Z_{control} = \min(Z_{Im}, Z_{Is}, Z_{IIIs}, Z_{IV}) = 1826\ \text{lb}$ *(Yield Mode IIIs controls)*

Find Adjusted Lateral Design Value, Z':

Adjustment factors from NDS Table 11.3.1:

$C_D = 1.25$ *Duration Factor for 2% lateral loading*

$C_M = 1.0$ *Wet Service Factor NDS 11.3.3 (Assume < 19% moisture content)*

$C_t = 1.0$ *Temperature Factor NDS 11.3.4 (Temp up to 100ºF)*

$C_g = 1.0$ *Group Action Factor NDS 11.3.6 (Single Fastener)*

$C_\Delta = 1.0$ *Geometry Factor NDS 12.5.1 (Assume End Dist. & spacing meet NDS Tables 12.5.1A and 12.5.1B)*

$C_{eg} = 1.0$ *End Grain Factor NDS 12.5.2 (Does not apply)*

$C_{di} = 1.0$ *Diaphragm Factor NDS 12.5.3 (Does not apply)*

$C_{tn} = 1.0$ *Toe Nail Factor NDS 12.5.4 (Does not apply)*

Adjusted lateral design value $Z' = Z(C_D)(C_M)(C_t)(C_g)(C_\Delta) = 2283$ lb