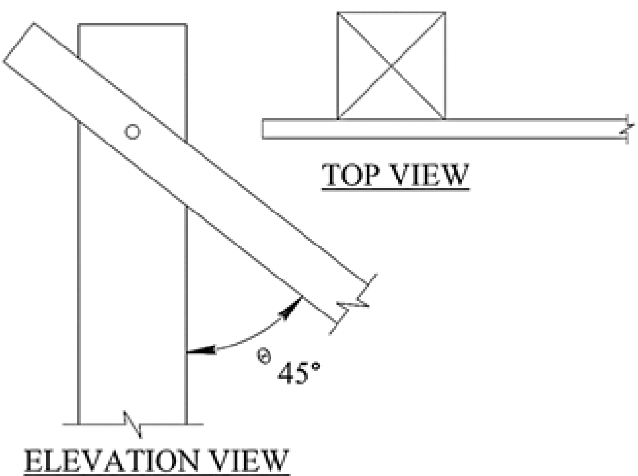
Appendix D Example 10 – Bolted Joints - Single Shear

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



Given Information

Posts:
12 x 12 Rough Douglas Fir-Larch #1
(G=0.50)

Diagonal Braces:
2 x 8 S4S Douglas Fir-Larch #2
(G=0.50)

Connectors:
¾" Ø Bolt

Figure D-10-1. Post and Brace Bolted Joint

Determine the connection capacity between brace and post for Wind Load

Main Member Properties

l_m = 12 in	*thickness (12 x 12)*
$t_m = l_m$ = 12 in	
θ_m= 45°	*angle between direction of loading & direction of grain*
G = 0.50	*Specific Gravity NDS Table 12.3.3*

Side Member Properties

l_s = 1.5 in	*thickness (2 x 8)*
$t_s = l_s$ = 1.5 in	
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 (See Footnote #2 NDS Table 12A)*
$F_{e.pll} = 11200G\ psi = 5600\ psi$	*Dowel Bearing Strength Parallel to Grain (NDS table 12.3.3 footnote 2)*
$F_{e.perp} = \dfrac{6100G^{1.45}}{\sqrt{\frac{D}{in}}} = 2578\ psi$	*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):

$$F_{em} = \frac{F_{e.pll}F_{perp}}{F_{e.pll}(\sin(\theta_m))^2 + F_{perp}(\cos(\theta_m))^2} = 3531\ psi$$

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

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

$\theta = \max(\theta_m, \theta_s) = 45°$	*Maximum angle between direction of load and direction of grain for any member in connection (See Table 12.3.1B)*
$K_\theta = 1 + 0.25\dfrac{\theta}{90\ deg} = 1.125$	
$R_{d\_I} = 4\ K_\theta = 4.50$	*Reduction Term for Yield Mode I_m and I_s*
$R_{d\_II} = 3.6\ K_\theta = 4.05$	*Reduction Term for Yield Mode II*
$R_{d\_III.IV} = 3.2\ K_\theta = 3.60$	*Reduction Term for Yield Mode III_m, III_s, and IV*

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

$$R_e = \frac{F_{em}}{F_{es}} = 0.6305$$

$$R_t = \frac{l_m}{l_s} = 8$$

$$k_1 = \frac{\sqrt{R_e + 2R_e^2(1 + R_t + R_t^2) + R_t^2 R_e^3} - R_e(1 + R_t)}{(1 + R_e)} = 1.8210$$

$$k_2 = -1 + \sqrt{2(1 + R_e) + \frac{2F_{yb}(1 + 2R_e)D^2}{3F_{em}l_m^2}} = 0.8265$$

$$k_3 = -1 + \sqrt{\frac{2(1 + R_e)}{R_e} + \frac{2F_{yb}(2 + R_e)D^2}{3F_{em}l_s^2}} = 2.2801$$

$$Z_{Im} = \frac{Dl_m F_{em}}{R_{d\_I}} = 7062 \text{ lb}$$ *NDS Eqn 12.3-1*

$$Z_{Is} = \frac{Dl_s F_{es}}{R_{d\_I}} = 1400 \text{ lb}$$ *NDS Eqn 12.3-2*

$$Z_{II} = \frac{k_1 D l_s F_{es}}{R_{d\_II}} = 2833 \text{ lb}$$ *NDS Eqn 12.3-3*

$$Z_{IIIm} = \frac{k_2 D l_m F_{em}}{(1 + 2R_e)R_{d\_III.IV}} = 3227 \text{ lb}$$ *NDS Eqn 12.3-4*

$$Z_{IIIs} = \frac{k_3 D l_s F_{em}}{(2 + R_e)R_{d\_III.IV}} = 956 \text{ lb}$$ *NDS Eqn 12.3-5*

$$Z_{IV} = \frac{D^2}{R_{d\_III.IV}}\sqrt{\frac{2F_{em}F_{yb}}{3(1 + R_e)}} = 1259 \text{ lb}$$ *NDS Eqn 12.3-6*

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

$Z_{control} = \min(Z_{Im}, Z_{Is}, Z_{II}, Z_{IIIm}, Z_{IIIs}, Z_{IV}) = 956$ lb (Yield Mode IIIs controls)

Find Adjusted Lateral Design Value, Z':

Adjustment factors from NDS Table 11.3.1:

$C_D = 1.60$	*Duration Factor for wind load*
$C_M = 1.0$	*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 $Z' = Z(C_D)(C_M)(C_t)(C_g)(C_\Delta) = 1530$ lb