

Hand Calculation

Problem Statement:

Determine if 2 x 6 at 16in OC wood stud is safe and meet all the required loading demands per NDS

Stud size: 2 x 6

Stud width

$$b := 1.5 \text{ in}$$

Stud depth

$$d := 5.5 \text{ in}$$

Stud height

$$h := 12 \text{ ft}$$

Stud spacing

$$S := 16 \text{ in OC}$$

Area of stud

$$A := b \cdot d = 8.25 \text{ in}^2$$

Moment of inertia

$$I_x := 20.8 \text{ in}^4$$

Section Modulus

$$S_x := 7.56 \text{ in}^3$$

Radius of Gyration

$$r_x := 1.59 \text{ in}$$

Wood species: **Douglas Fir-Larch (North)**

Wood Minimum Modulus of Elasticity

$$E_{min} := 580 \text{ ksi}$$

Compression reference design value

$$F_c := 1350 \text{ psi}$$

Bending reference design value

$$F_{bx} := 900 \text{ psi}$$

Shear reference design value

$$F_v := 180 \text{ psi}$$

Dead load (including self-weight)

$$DL := 20 \text{ psf}$$

Live load

$$LL := 40 \text{ psf}$$

Lateral Wind load (1.0 W)

$$W := 30 \text{ psf}$$

Tributary Width

$$TW := 10 \text{ ft}$$

Buckling about the Y-Y axis (Weak direction): Fully braced

Buckling about the X-X axis (Strong direction): Unbraced

$$K_x := 1 \text{ and } L_x := 144 \text{ in}$$

$$K_y := 1 \text{ and } L_y := 0 \text{ in}$$

$$\text{Beam stability unbraced length (For bending)} \quad L_{ux} := 12 \text{ ft}$$

Solution:

ANALYSIS (Step 1 to Step 4)

Step 1: Calculate Applied Loads

$$P_{DL} := DL \cdot S \cdot TW = 0.267 \text{ kip}$$

$$P_{LL} := LL \cdot S \cdot TW = 0.533 \text{ kip}$$

$$W_w := W \cdot S = 0.040 \text{ klf}$$

Step 2: Calculate Applied Axial Stress

$$\text{Total applied axial load is: } P := P_{DL} + P_{LL} = 0.8 \text{ kip}$$

$$\text{Total applied axial stress is: } f_c := \frac{P}{A} = 96.97 \text{ psi}$$

Step 3: Calculate Applied Bending Stress

$$\text{Total applied moment is: } M_w := 0.6 \cdot W_w \cdot \frac{L_{ux}^2}{8} = 0.432 \text{ ft}\cdot\text{kip}$$

$$\text{Applied bending stress is: } f_{bx} := \frac{M_w}{S_x} = 685.714 \text{ psi}$$

Step 4: Calculate Applied Shear Stress

$$\text{Total applied shear force is: } V := \frac{0.6 \cdot W_w \cdot h}{2} = 144 \text{ lbf}$$

$$\text{Total applied shear stress is: } f_{vx} := \frac{3 \cdot V}{2 \cdot b \cdot d} = 26.18 \text{ psi}$$

DESIGN CHECKS (Step 5 to Step 9)
Step 5: Calculate Compression Capacity

Wet use factor	$C_M := 1.0$
Wet use factor (Modus of Elasticity)	$C_{MEmin} := 1.0$
Temperature factor	$C_t := 1.0$
Temperature factor (Modus of Elasticity)	$C_{tEmin} := 1.0$
Temperature factor (Compression)	$C_{tFc} := 1.0$
Incising factor	$C_i := 1.0$
Incising factor (Modus of Elasticity)	$C_{iEmin} := 1.0$
Buckling stiffness factor	$C_T := 1.0$
Size factor (Compression)	$C_F := 1.1$
Live load duration factor	$C_{DLive} := 1.0$
Constant for column stability factor equation for sawn lumber	$c := 0.8$

Stud is fully braced against buckling about the Y-Y axis (weak direction). Hence, it is only required to examine the slenderness ratio of the buckling about the X-X axis (strong direction)

Slenderness ratio is:

$$S_r := \frac{K_x \cdot L_x}{d} = 26.182 < 50 \text{ PASS } \checkmark \text{ per NDS section 3.7.1.4}$$

Adjusted modulus of elasticity for column stability is:

$$E'_{min} := E_{min} \cdot C_{MEmin} \cdot C_{tEmin} \cdot C_{iEmin} \cdot C_T = 580000 \text{ psi}$$

Adjusted reference compression design value multiplied by all applicable adjustment factors except C_p is:

$$F'_c := F_c \cdot C_{DLive} \cdot C_M \cdot C_{tFc} \cdot C_F \cdot C_i = 1485 \text{ psi}$$

Critical buckling design value for compression members is:

$$F_{cE} := \frac{0.822 \cdot E'_{min}}{\left(\frac{L_x}{d}\right)^2} = 695.505 \text{ psi}$$

Column stability factor is:

$$C_P := \frac{1 + \left(\frac{F_{cE}}{F'_c}\right)}{2 \cdot c} - \sqrt{\left(\left(\frac{1 + \left(\frac{F_{cE}}{F'_c}\right)}{2 \cdot c}\right)^2 - \frac{F_{cE}}{F'_c}\right)} = 0.411$$

ASD Design adjusted compression strength is:

$$F'_c := F_c \cdot C_{DLive} \cdot C_M \cdot C_t \cdot C_F \cdot C_i \cdot C_P = 610.33 \text{ psi}$$

Step 6: Calculate Flexural Capacity

Wind load duration factor	$C_{DWind} := 1.6$
Temperature factor	$C_{tFb} := 1$
Size factor (Bending)	$C_F := 1.3$
Flat use factor	$C_{fu} := 1$
Repetitive member factor	$C_r := 1.15$

Adjusted modulus of elasticity for column stability is

$$E'_{min} := E_{min} \cdot C_{MEmin} \cdot C_{tEmin} \cdot C_{iEmin} \cdot C_T = 580000 \text{ psi}$$

Slenderness ratio for strong axis bending:

From NDS Table 3.3.3 Effective Length, l_e , for single span spanning members with seven or more equal concentrated loads evenly spaced, we conclude that:

$$l_e := 1.84 \cdot L_{ux} = 264.96 \text{ in} \quad R_B := \sqrt{\frac{l_e \cdot d}{b^2}} = 25.45$$

Critical buckling design value for strong axis bending is

$$F_{bE} := \frac{1.2 \cdot E'_{min}}{R_B^2} = 1074.6 \text{ psi}$$

Reference strong axis bending design value multiplied by all applicable adjustment factors except C_L is

$$F'_{bx} := F_{bx} \cdot C_{DWind} \cdot C_M \cdot C_{tFb} \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 2152.8 \text{ psi}$$

Beam stability factor for strong axis bending is:

$$C_L := \frac{1 + \frac{F_{bE}}{F'_{bx}}}{1.9} - \sqrt{\left(\left(\frac{1 + \frac{F_{bE}}{F'_{bx}}}{1.9} \right)^2 - \frac{F_{bE}}{0.95 F'_{bx}} \right)} = 0.477$$

ASD design adjusted bending strength about strong axis:

$$F'_{bx} := F_{bx} \cdot C_{DWind} \cdot C_M \cdot C_{tFb} \cdot C_L \cdot C_F \cdot C_{fu} \cdot C_i \cdot C_r = 1027.67 \text{ psi}$$

Step 7: Calculate Shear Capacity

Temperature factor (Shear) $C_{tFv} := 1$

ASD design adjusted shear strength about strong axis is:

$$F'_{vx} := F_v \cdot C_{DWind} \cdot C_M \cdot C_{tFv} \cdot C_i = 288 \text{ psi}$$

Step 8: Demand to Capacity Ratio (DCR) Check

Compressive check:

$$DCR_{comp} := \frac{f_c}{F'_c} = 0.159 < 1 \text{ PASS } \checkmark$$

Flexure check:

$$DCR_{flex} := \frac{f_{bx}}{F'_{bx}} = 0.667 < 1 \text{ PASS } \checkmark$$

Shear check:

$$DCR_{shear} := \frac{f_{vx}}{F'_{vx}} = 0.091 < 1 \text{ PASS } \checkmark$$

Step 9: Combined Loads Check

ENERCALC runs the combined loads check for every load combination and then reports the controlling value. This example will perform the calculation for load combination 1.0D + 0.6W. This combination will require recalculation of the applied compression stress and capacity

Compression:

$$P_{DL} = 0.267 \text{ kip} \quad \text{calculated from previous steps}$$

$$f_c := \frac{P_{DL}}{A} = 32.323 \text{ psi}$$

$$E'_{min} = 580000 \text{ psi} \quad \text{calculated from previous steps}$$

$$C_{DWind} = 1.6$$

$$C_F := 1.1$$

Reference compression design value parallel to grain multiplied by all applicable adjustment factors except C_p is

$$F'_c := F_c \cdot C_{DWind} \cdot C_{tFc} \cdot C_F \cdot C_i = 2376 \text{ psi}$$

Now, we recalculate C_p based on the new values. Column stability factor is:

$$C_p := \frac{1 + \left(\frac{F_{cE}}{F'_c}\right)}{2 \cdot c} - \sqrt{\left(\left(\frac{1 + \left(\frac{F_{cE}}{F'_c}\right)}{2 \cdot c}\right)^2 - \frac{F_{cE}}{F'_c}\right)} = 0.272$$

ASD Design adjusted compressive strength is

$$F'_c := F_c \cdot C_{DWind} \cdot C_M \cdot C_{tFc} \cdot C_F \cdot C_i \cdot C_p = 647.07 \text{ psi}$$

NDS Equation 3.9-3 governs the combination check for members subject to compression and bending loads. We have gathered all of the values needed for the combination equation. Please note that general form of this equations includes compression as well as bending about the X and Y axis. However, since the our example has compression and bending about 1 axis, we reduce the equation and removed the zero component.

Summary of calculated values from previous steps :

$$f_c = 32.323 \text{ psi}$$

$$F'_c = 647.07 \text{ psi}$$

$$f_{bx} = 685.714 \text{ psi}$$

$$F'_{bx} = 1027.672 \text{ psi}$$

$$F_{cE} = 695.505 \text{ psi}$$

$$CL := \left(\frac{f_c}{F'_c}\right)^2 + \frac{f_{bx}}{F'_{bx} \cdot \left(1 - \frac{f_c}{F_{cE}}\right)} = 0.702 < 1 \text{ PASS} \quad \checkmark \text{ The combined loads check controls the design}$$

See the following ENERCALC printed calc report for comparison



Wood Column

Project File: Wood Column.ec6

LIC#: KW-06000215, Build:20.26.05.05

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DESCRIPTION: Wood Stud

Code References

Governing Code : IBC 2024
 Referenced Design Standard(s) : NDS 2024
 Load Combinations Used : ASCE 7-22 / IBC 2024

Rho (or Omega) = 1.00

General Information

Analysis Method	Allowable Stress Design	Wood Section Name	2x6
End Fixities	Top & Bottom Pinned	Wood Grading/Manuf.	Graded Lumber
Overall Column Height	12 ft	Wood Member Type	Sawn
<i>(Used for non-slender calculations)</i>			
Wood Species	Douglas Fir-Larch	Exact Width	1.50 in Allow Stress Modification Factors
Wood Grade	No.2	Exact Depth	5.50 in Cf or Cv for Bending 1.30
Fb +	900.0 psi	Area	8.250 in^2 Cf or Cv for Compression 1.10
Fb -	900.0 psi	Ix	20.797 in^4 Cf or Cv for Tension 1.30
Fc - Prll	1,350.0 psi	Iy	1.547 in^4 Cm : Wet Use Factor 1.0
Fc - Perp	625.0 psi		Ct : Temperature Fact 1.0
E : Modulus of Elasticity . . .	x-x Bending y-y Bending Axial		Cfu : Flat Use Factor 1.0
	Basic 1,600.0 1,600.0 1,600.0 ksi		Kf about Y 1.0
	Minimum 580.0 580.0		Kf about X 1.0
Column Buckling Condition:			Use Cr : Repetitive ? Yes
	ABOUT X-X Axis: Lux = 12 ft, Kx = 1.0		
	Fully braced against buckling ABOUT Y-Y Axis		

Applied Loads

Service loads entered. Load Factors will be applied for calculations.

AXIAL LOADS . . .
 Gravity Load: Axial Load at 12.0 ft, D = 0.2667, L = 0.5333 k
 BENDING LOADS . . .
 Lateral Load: Lat. Uniform Load creating Mx-x, W = 0.040 k/ft

DESIGN SUMMARY

Bending & Shear Check Results

PASS Max. Axial+Bending Stress Ratio = **0.7020 : 1**
 Load Combination +D+0.60W
 Governing NDS Formula Comp + Mxx, NDS Eq. 3.9-3
 Location of max.above base 5.960 ft
 At maximum location values are .
 Applied Axial 0.2667 k
 Applied Mx 0.4320 k-ft
 Applied My 0.0 k-ft
 Fc : Allowable 647.07 psi

PASS Maximum Shear Stress Ratio = **0.09091 : 1**
 Load Combination +D+0.60W
 Location of max.above base 0.0 ft
 Applied Design Shear 26.182 psi
 Allowable Shear 288.0 psi

Maximum SERVICE Lateral Load Reactions . .
 Top along Y-Y 0.240 k Bottom along Y-Y 0.240 k
 Top along X-X 0.0 k Bottom along X-X 0.0 k

Maximum SERVICE Load Lateral Deflections . . .
 Along Y-Y 0.5669 in at 6.040 ft above base
 for load combination : W Only L/ 254.0
 Along X-X 0.0 in at 0.0 ft above base
 for load combination : n/a L/

Other Factors

	<u>Bending</u>	<u>Compression</u>	<u>Shear</u>
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Load Combination Results

Load Combination	Controlling Cp			Maximum Axial + Bending Stress Ratios			Maximum Shear Ratios		
	C _D	Value	About	Stress Ratio	Status	Location	Stress Ratio	Status	Location
D Only	0.900	0.448	X Axis	0.05401	PASS	12.0 ft	0.0	PASS	12.0 ft
+D+L	1.000	0.411	X Axis	0.1589	PASS	0.0 ft	0.0	PASS	12.0 ft
+D+0.750L	1.250	0.340	X Axis	0.1281	PASS	0.0 ft	0.0	PASS	12.0 ft
+D+0.60W	1.600	0.272	X Axis	0.7020	PASS	5.960 ft	0.09091	PASS	0.0 ft
+D+0.750L+0.450W	1.600	0.272	X Axis	0.5816	PASS	5.960 ft	0.06818	PASS	12.0 ft
+0.60D+0.60W	1.600	0.272	X Axis	0.6870	PASS	5.960 ft	0.09091	PASS	0.0 ft
+0.60D	1.600	0.272	X Axis	0.02997	PASS	12.0 ft	0.0	PASS	12.0 ft



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Maximum Reactions

Note: Only non-zero reactions are listed.

Load Combination	Rx (k)		Ry (k)		Axial (k)	My (k-ft)		Mx (k-ft)	
	@ Base	@ Top	@ Base	@ Top	@ Base	@ Base	@ Top	@ Base	@ Top
D Only					0.267				
+D+L					0.800				
+D+0.750L					0.667				
+D+0.60W			-0.144	-0.144	0.267				
+D+0.750L+0.450W			-0.108	-0.108	0.667				
+0.60D+0.60W			-0.144	-0.144	0.160				
+0.60D					0.160				
L Only					0.533				
W Only			-0.240	-0.240					

Extreme Reactions

Item	Extreme Value	Axial (k)		Rx (k)		Ry (k)		Mx (k-ft)		My (k-ft)	
		@ Base	@ Top	@ Base	@ Top	@ Base	@ Top	@ Base	@ Top	@ Base	@ Top
Axial, Base Max	0.800										
Axial, Base Min											
Rx, Base Max											
Rx, Base Min											
Rx, Top Max											
Rx, Top Min											
Ry, Base Max											
Ry, Base Min						-0.240					
Ry, Top Max											
Ry, Top Min											-0.240

Maximum Deflections for Load Combinations

Load Combination	Max. X-X Deflection		Max. Y-Y Deflection	
	Distance		Distance	
D Only	0.0000 in	0.000ft	0.000 in	0.000ft
+D+L	0.0000 in	0.000ft	0.000 in	0.000ft
+D+0.750L	0.0000 in	0.000ft	0.000 in	0.000ft
+D+0.60W	0.0000 in	0.000ft	0.340 in	6.040ft
+D+0.750L+0.450W	0.0000 in	0.000ft	0.255 in	6.040ft
+0.60D+0.60W	0.0000 in	0.000ft	0.340 in	6.040ft
+0.60D	0.0000 in	0.000ft	0.000 in	0.000ft
+0.60W	0.0000 in	0.000ft	0.340 in	6.040ft
+0.420W	0.0000 in	0.000ft	0.238 in	6.040ft
L Only	0.0000 in	0.000ft	0.000 in	0.000ft
W Only	0.0000 in	0.000ft	0.567 in	6.040ft

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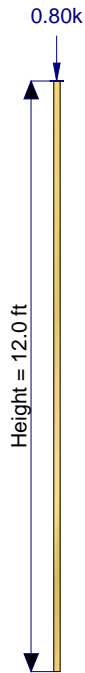
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Sketches

My Loads - Looking along Y-Y Axis



Mx Loads - Looking along X-X Axis

