Wood Column Subject to Axial and Lateral Load

This application helps the structural engineer design a wood column.

There are checks on the vertical load, bending load, column interaction, shear load and the horizontal deflection.

References:
[1] National Design Specification® (NDS) for Wood Construction, 2018 edition, American Wood Council
[2] NDS Supplement, 2018, American Wood Council
[3] Design of Structural Glued Laminated Timber Columns, 2009, APA

Parameters from References [1], [2] and [3]

Table 4A – Base design values for visually graded dimension lumber (2in to 4in thick), p30, ref [2]

table4a :=

"Species & com grade"	"Size class"	"Bending Fb"	"Tension parallel to grain Ft"	"Shear parall
"Select Structural"	"N/A"	1500	1000	1
"No 1 & Btr"	"2in-4in thick"	1200	800	1
"No 1"	"N/A"	1000	675	1
"No 2"	"2in & wider"	900	575	1
"No 3"	"N/A"	525	325	1
"Stud"	"N/A"	700	450	1

Base design values for visually graded dimension lumber (5in x 5in thick and larger) Table 4A p32 ref[2]

table4d :=

"Species & com grade"	"Size class"	"Bending Fb"	"Tension parallel to grain Ft"	"Shear paral
"Dense Select Structural"	"N/A"	1750	1150	1
"Select structural"	"N/A"	1500	1000	1
"Dense No. 1"	"N/A"	1400	950	1
"No. 1"	"N/A"	1200	825	1
"Dense No. 2"	"N/A"	740	550	1
"No. 2"	"N/A"	750	475	1

Frequency Used Load Duration Factors, Table 2.3.2 p11 ref [1]

table232 :=

"Load Duration"	"CD"	"Typical Design Load"
"PERMANENT"	0.9	"DEAD LOAD"
"TEN YEARS"	1.0	"OCCUPANCY LIVE LOAD"
"TWO MONTHS"	1.2	"SNOW LOAD"
"SEVEN DAYS"	1.25	"CONSTRUCTION LOAD"
"TEN MINUTES"	1.6	"WIND/EARTHQUAKE LOAD"
"IMPACT"	2.0	"IMPACT LOAD"

Flat Use Factor Table 4F p57 ref [2]

table45 :=

"Width"	"Thickness"	""
""	"2in & 3in"	"4in"
"2in & 3in"	1.0	""
4	1.1	1.0
5	1.1	1.05
6	1.15	1.05
8	1.15	1.05
"10in & wider"	1.20	1.10

Euler Buckling Coefficients ref [3]

Euler_buckling_coeff :=

"KcE"	"CovE"	"Type"
0.3	"0.25"	"Visually graded lumber"
0.384	"0.15"	"Machine evaluated lumber"
0.418	"≤0.11"	"Glued laminated timber"

Flat Use Factor Table 4D p46 ref [2]

F_b_data :=

"Type"	"Fb"
"Dense SelectStructural"	1
"SelectStructural"	0.86
"Dense No. 1"	0.74
"No. 1"	0.74
"Dense No. 2"	1
"No. 2"	1

Size factor for lumber 2in to 5in thick, Table 4A p32 ref[2])

$$CF\_data := \begin{bmatrix} "" & "" & "Fb" & "Fb" & "Ft" & "Fc" \\ "GRADES" & "WIDTH" & "Thickness" & "Thickness" & "" & "" \\ "" & "" & "2in \& 3in" & "4in" & "" & "" \\ "" & "2in, 3in \& 4in" & 1.5 & 1.5 & 1.5 & 1.5 \\ "Select" & "5in" & 1.4 & 1.4 & 1.4 & 1.1 \\ "Structural" & "6in" & 1.3 & 1.3 & 1.3 & 1.1 \\ "No. 1 \& Btr" & "8in" & 1.2 & 1.3 & 1.2 & 1.05 \\ "No. 1, No. 2" & "10in" & 1.1 & 1.2 & 1.1 & 1.0 \\ "No. 3" & "12in" & 1.0 & 1.1 & 1.0 & 1.0 \\ "" & "14in and wider" & 0.9 & 1.0 & 0.9 & 0.9 \\ "Stud" & "2in, 3in \& 4in" & 1.1 & 1.1 & 1.1 & 1.05 \\ "" & "5in \& 6in" & 1.0 & 1.0 & 1.0 & 1.0 \\ "Construction,Standard" & "2in, 3in \& 4in" & 1.0 & 1.0 & 1.0 & 1.0 \\ "Utility" & "4in" & 1.0 & 1.0 & 1.0 & 1.0 \\ "" & "2in \& 3in" & 0.4 & "" & 0.4 & 0.6 \end{bmatrix}$$

$$CF\_value\_selection22 := \begin{cases} 1.5 & H < 5 \\ 1.5 & H = 5 \\ 1.3 & H = 6 \\ 1.2 & \text{And}(H = 8, B < 4) \\ 1.3 & \text{And}(H = 8, B > 4) \\ 1.1 & \text{And}(H = 10, B < 4) \\ 1.2 & \text{And}(H = 10, B > 4) \\ 1 & \text{And}(H = 12, B < 4) \\ 1.1 & \text{And}(H = 12, B > 4) \\ 0.9 & \text{And}(H \geq 14, B < 4) \\ 1 & \text{And}(H > 14, B > 4) \end{cases}$$

$$CF\_value\_selection23 := \begin{cases} CF\_data[4, 5] & H < 5 \\ CF\_data[5, 5] & H = 5 \\ CF\_data[6, 5] & H = 6 \\ CF\_data[7, 5] & H = 8 \\ CF\_data[8, 5] & H = 10 \\ CF\_data[9, 5] & H = 12 \\ CF\_data[10, 5] & H \geq 14 \end{cases}$$

$$CF\_value\_selection32 := \begin{cases} CF\_data[11, 3] & H < 5 \\ CF\_data[12, 3] & H \geq 5 \end{cases}$$

$$CF\_value\_selection33 := \begin{cases} CF\_data[11, 4] & H < 5 \\ CF\_data[12, 4] & H \geq 5 \end{cases}$$

$$CF\_value\_selection := \begin{bmatrix} "Value\ selection" & "Fb" & "Ft" & "Fc" \\ "other\ use" & CF\_value\_selection22 & CF\_value\_selection23 & CF\_value\_selectio \\ "stud" & CF\_value\_selection32 & CF\_value\_selection33 & CF\_value\_selectio \end{bmatrix}$$

Parameters

Member Type

1 - post
2 - stud
3 - king stud

memtype := 3

Geometry

Height

$h := 12.67$

Unbraced length

$Lexx := h = 12.670$

$Leyy := 0$

Loads

Dead load

$P_{DL} := 3000$

Live load

$P_{LL} := 3000$

Total

$P := P_{DL} + P_{LL} = 6000$

Lateral load

$w := 55$

Max section

$$M := \begin{cases} \frac{w \cdot Lexx^2}{8} & memtype \neq 1 \\ M & otherwise \end{cases} = 1.104 \times 10^3$$

$$V := \begin{cases} w \cdot \frac{Lexx}{2} & memtype \neq 1 \\ NULL & otherwise \end{cases} = 348.425$$

Design

Breadth and width

$B := 2$

$H := 6$

Load duration
1 Dead load
2 Occupancy live load
3 Snow load
4 Construction load
5 Wind/Earthquake load
6 Impact load

$ld := 2$

Number of sections

$n\_sec := 3$

Grade
1,2,3,4,5 or 6

$grade := 3$

$$wood\_type := \begin{cases} table4a[grade + 1, 1] & \min(B, H) < 5 \\ table4d[grade + 1, 1] & otherwise \end{cases}$$

$wood\_type = \text{"No 1"}$

Lumber grading type

$lumber\_grading := 1$

Shape type
1 - Sawn lumber
2 - glued laminated

$shape\_type := 1$

Wet or dry?
1 - Dry
2 - Wet

$wet\_dry := 1$

Analysis

Design Stresses

Compressive stress

$$F_c := \begin{cases} table4a[grade + 1, 7] & \min(B, H) < 5 \\ table4d[grade + 1, 7] & otherwise \end{cases} = 1500$$

Modulus of elasticity

$$E := 0.001 \cdot \begin{cases} table4a[grade + 1, 8] & \min(B, H) < 5 \\ table4d[grade + 1, 8] & otherwise \end{cases} = 1.700 \times 10^3$$

Bending stress (x-axis)

$$F_{bx} := \begin{cases} table4a[grade + 1, 3] & \min(B, H) < 5 \\ table4d[grade + 1, 3] & otherwise \end{cases} = 1000$$

Bending stress (y-axis)

$F_{by} := F_{bx}$

Shear stress

$$F_v := \begin{cases} table4a[grade + 1, 5] & \min(B, H) < 5 \\ table4d[grade + 1, 5] & otherwise \end{cases} = 180$$

Column Properties

Standard dressed size

$$dx := \begin{cases} H - 0.5 & H < 8 \text{ or } H > 12 \\ H - 0.75 & otherwise \end{cases} = 5.500$$

$dy := B - 0.5 = 1.500$

Cross-sectional area

$A := dx \cdot dy \cdot n\_sec = 24.750$

Length-depth ratio $Leyydy := \frac{Leyy \cdot 12}{dx} = 0.$

Section modulus about x $Lexxdx := \frac{Lexx \cdot 12}{dx} = 27.644$

$I_x := \frac{dx^3 \cdot dy}{12} \cdot n\_sec = 62.391$

Section modulus about y $S_y := \frac{dx \cdot dy^2}{6} \cdot n\_sec = 6.188$

$S_x := \frac{dx^2 \cdot dy}{6} \cdot n\_sec = 22.688$

Column parameter $c := \begin{cases} 0.8 & shape\_type = 1 \\ 0.9 & shape\_type = 2 \end{cases}$

Adjustment Factors

Duration factor $CD\_F_c := table232[ld + 1, 2] = 1.000$

$CD\_F_{by} := CD\_F_c = 1.000$

$CD\_F_{bx} := CD\_F_{by} = 1.000$

$CD\_F_v := CD\_F_{bx} = 1.000$

Beam stability $CL\_F_{bx} := 1$

$CL\_F_{by} := 1$

$CL\_F_{bx} = 1$

Repetitive member $Cr\_F_{bx} := \begin{cases} 1.15 & memtype = 2 \\ 1 & otherwise \end{cases} = 1$

$Cr\_F_{by} := \begin{cases} 1.15 & memtype = 2 \\ 1 & otherwise \end{cases} = 1$

Size factor $CF\_F_{bx} := \begin{cases} F\_b\_data[grade + 1] & \min(B, H) \geq 5 \\ CF\_value\_selection[2, 2] & otherwise \end{cases} = 1.300$

$CF\_F_{by} := \begin{cases} F\_b\_data[grade + 1] & \min(B, H) \geq 5 \\ CF\_F_{bx} & otherwise \end{cases} = 1.300$

$CF\_F_c := \begin{cases} CF\_value\_selection[2, 4] & \min(B, H) < 5 \\ 1 & otherwise \end{cases} = 1.100$

$$CF\_E := \begin{cases} 0.9 & \min(B, H) \geq 5 \text{ and grade} = 3 \text{ and } B > H \\ 1 & \text{otherwise} \end{cases} = 1$$

Incising Factor

$Ci\_F_{bx} := 1$ $Ci\_F_{by} := 1$ $Ci\_F_{c} := 1$

$Ci\_F_{v} := 1$ $Ci\_E := 1$

Moisture factor

$$CM\_F_{bx} := \begin{cases} 1 & \min(B, H) < 5 \text{ and } B > 4 \\ 1 & CF\_F_{bx} \cdot F_{bx} \leq 1150 \\ 1 & \text{wet\_dry} = 1 \\ 0.85 & \text{wet\_dry} = 0 \\ 0 & \text{otherwise} \end{cases} = 1$$

$$CM\_F_{by} := \begin{cases} 1 & \min(B, H) < 5 \text{ and } B > 4 \\ 1 & CF\_F_{bx} \cdot F_{by} \leq 1150 \\ 1 & \text{wet\_dry} = 1 \\ 0.85 & \text{wet\_dry} = 0 \\ 0 & \text{otherwise} \end{cases} = 1$$

$$CM\_F_{c} := \begin{cases} 1 & \min(B, H) < 5 \text{ and wet\_dry} = 1 \\ 0.91 & B > 4 \\ 1 & CF\_F_{bx} \cdot F_{c} \leq 7 \\ 0.8 & CF\_F_{bx} \cdot F_{c} > 750 \\ 1 & CF\_F_{bx} \cdot F_{c} \leq 750 \end{cases} = 1$$

$$CM\_F_{v} := \begin{cases} 0.97 & \min(B, H) < 5 \\ 1 & \text{otherwise} \end{cases} = 0.970$$

$$CM\_E := \begin{cases} 0.9 & \min(B, H) < 5 \\ 1 & \text{otherwise} \end{cases} = 0.900$$

Temperature factor

$Ct\_F_{bx} := 1$ $Ct\_F_{by} := 1$ $Ct\_F_{c} := 1$

$Ct\_F_{v} := 1$ $Ct\_E := 1$

Flat use factor

$Cfu\_F_{by} := \text{table45}[H + 1, \text{ifelse}(B < 4, 2, 3)] = 1.150$

Adjusted Properties

Modulus of Elasticity

$E_d := E \cdot CM\_E \cdot Ct\_E \cdot Ci\_E \cdot CF\_E = 1.530 \times 10^3$

Bending Stress X Axis

$F_{bxd} := F_{bx} \cdot CD\_F_{bx} \cdot CM\_F_{bx} \cdot Ct\_F_{bx} \cdot Ci\_F_{bx} \cdot CF\_F_{bx} \cdot CL\_F_{bx} = 1.300 \times 10^3$

Bending stress Y axis

$$F_{byd} := F_{by} \cdot CD\_F_{by} \cdot CM\_F_{by} \cdot Ct\_F_{by} \cdot Ci\_F_{by} \cdot CF\_F_{by} \cdot CL\_F_{by} \cdot Cfu\_F_{by} = 1.4$$

Euler buckling coefficient

$$K_{cE} := Euler\_buckling\_coeff[\, lumber\_grading + 1,\ 1\,] = 0.300$$

Critical Euler buckling design value
eq. 1 ref [2]

$$F_{cE} := \frac{K_{cE} \cdot E_d}{\max(Lexxdx,\ Leyydy)^2} \cdot 1000 = 600.651$$

$$F_{cs} := F_c \cdot CD\_F_c \cdot CM\_F_c \cdot Ct\_F_c \cdot Ci\_F_c \cdot CF\_F_c = 1.650 \times 10^3$$

Column stability
eq. 1 ref [2]

$$CP\_F_c := \begin{cases} 1 & Lexx = 0 \text{ and } L \\ \dfrac{1 + F_{cE}/F_{cs}}{2 \cdot c} - \sqrt{\dfrac{(1 + F_{cE}/F_{cs})^2}{c^2} - \dfrac{F_{cE}}{F_{cs} \cdot c}} & \text{otherwise} \end{cases}$$

Axial stress

$$F_{cd} := CP\_F_c \cdot F_{cs} = -1.177 \times 10^3$$

Shear stress

$$F_{vd} := F_v \cdot CD\_F_v \cdot CM\_F_v \cdot Ct\_F_v \cdot Ci\_F_v = 174.600$$

Actual Stresses

Axial Stress

$$f_c := \frac{P}{A} = 242.424$$

Bending Stress

$$f_{bx} := \begin{cases} 0 & memtype = 1 \\ \dfrac{M \cdot 12}{S_x} & \text{otherwise} \end{cases} = 583.741$$

Shear Stress

$$f_v := \frac{1.5 \cdot V}{A} = 21.117$$

Checks

Vertical load

$$\begin{cases} \text{"Good"} & \dfrac{f_c}{F_{cd}} < 1 \\ \text{"Reconsider Design"} & \dfrac{f_c}{F_{cd}} \geq 1 \text{ and } \dfrac{f_c}{F_{cd}} < 1.05 \\ \text{"Not Good"} & \text{otherwise} \end{cases} = \text{"Good"}$$

Bending load

$$\begin{cases} \text{"Good"} & \dfrac{f_{bx}}{F_{bxd}} < 1 \\ \text{"Reconsider Design"} & \dfrac{f_{bx}}{F_{bxd}} \geq 1 \text{ and } \dfrac{f_{bx}}{F_{bxd}} < 1.05 \\ \text{"Not Good"} & \text{otherwise} \end{cases} = \text{"Good"}$$

Interaction

$$\begin{cases} \text{"Good"} & \left(\frac{f_c}{F_{cd}}\right)^2 + \frac{1}{1-\left(f_c/F_{cE}\right)^2}\cdot\frac{f_{bx}}{F_{bxd}} \le 1 \\ \text{"Not Good"} & \text{otherwise} \end{cases} = \text{"Good"}$$

Shear load

$$\begin{cases} \text{"Good"} & f_v < F_{vd} \\ \text{"Not good"} & \text{otherwise} \end{cases} = \text{"Good"}$$

Deflection

$$\Delta := \frac{5\cdot\frac{w}{12}\cdot(h\cdot 12)^4}{384\cdot E_d\cdot 1000\cdot I_x} + \frac{2.4\cdot\frac{w}{12}\cdot(h\cdot 12)^2}{E_d\cdot 1000\cdot n\_sec\cdot dx\cdot dy} = 0.341$$

$$\text{cat}\left(\text{"}\Delta\text{=h/"}, \text{trunc}\left(\frac{h\cdot 12}{\Delta}\right)\right) = \text{"}\Delta\text{=h/446"}$$

el to grain Fv"	"Compression perpendicular to grain Fcg"	"Compression parallel to grain Fc"	"Modulus of elasticity
80	62	1700	1900000
80	625	5500	1800000
80	625	1500	1700000
80	62	1350	1600000
80	625	775	1400000
80	625	850	1400000

lel to grain Fv"	"Compression perpendicular to grain Fcg"	"Compression parallel to grain Fc"	"Modulus of elasticity
70	730	1350	1700000
70	625	1150	1600000
70	730	1200	1700000
70	625	1000	1600000
70	730	825	1400000
70	625	700	1300000

$$\text{CF\_value\_selection24} := \begin{cases} \text{CF\_data}[4,6] & H < 5 \\ \text{CF\_data}[5,6] & H = 5 \\ \text{CF\_data}[6,6] & H = 6 \\ \text{CF\_data}[7,6] & H = 8 \\ \text{CF\_data}[8,6] & H = 10 \\ \text{CF\_data}[9,6] & H = 12 \\ \text{CF\_data}[10,6] & H \geq 14 \end{cases}$$

$$\text{CF\_value\_selection34} := \begin{cases} \text{CF\_data}[11,5] & H < 5 \\ \text{CF\_data}[12,5] & H \geq 5 \end{cases}$$

$$\begin{bmatrix} n24 \\ n34 \end{bmatrix}$$

95×10^3

$eyy = 0$

e

E"	"Grading Rules Agency"
	"N/A"
	"N/A"
	"WCLIB"
	"WWPA"
	"N/A"
	"N/A"

E"	"Grading Rules Agency"
	"N/A"
	"N/A"
	"N/A"
	"WWPA"
	"N/A"
	"N/A"