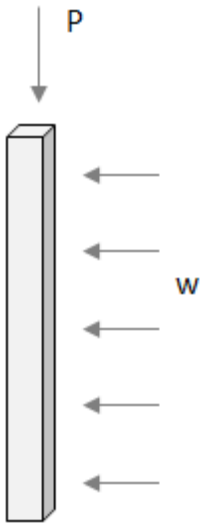
Wood Column Subject to Axial and Lateral Load

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), p32, ref [2]

table4a :=

"Species & com grade"	"Size class"	"Bending Fb"	"Tension parallel to grain Ft"	"Shear paral
"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])

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

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

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

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

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

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

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 yy $S_y := \frac{dx \cdot dy^2}{6} \cdot n\_sec = 6.188$

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

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

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

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

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

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

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

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 $F_{byd} := F_{by} \cdot CD\_F_{by} \cdot CM\_F_{by} \cdot Ct\_F_{by} \cdot Ci\_F_{by} \cdot CF\_F_{by} \cdot CL\_F_{by} \cdot Cfu\_F_{by} = 1.$

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

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

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

Checks

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

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