

# Recitation 3

Wood Column Analysis

# Homework problem

Wood Column Analysis

### 3. Wood Column Analysis

For the given dimensioned lumber column with 1/3 point weak axis bracing, determine the maximum load capacity of the given load type. Moisture Content = 15%.  $C_t = C_i = 1.0$ . Assume pinned end conditions ( $K=1$ ).

DATASET: 1

-2-

-3-

Wood Species

SPRUCE-  
PINE-FIR

Wood Grade

No.1/No.2

Strong Axis Length, L1

11 FT

Weak Axis Length, L2

3.666666667 FT

Narrow Width, d2

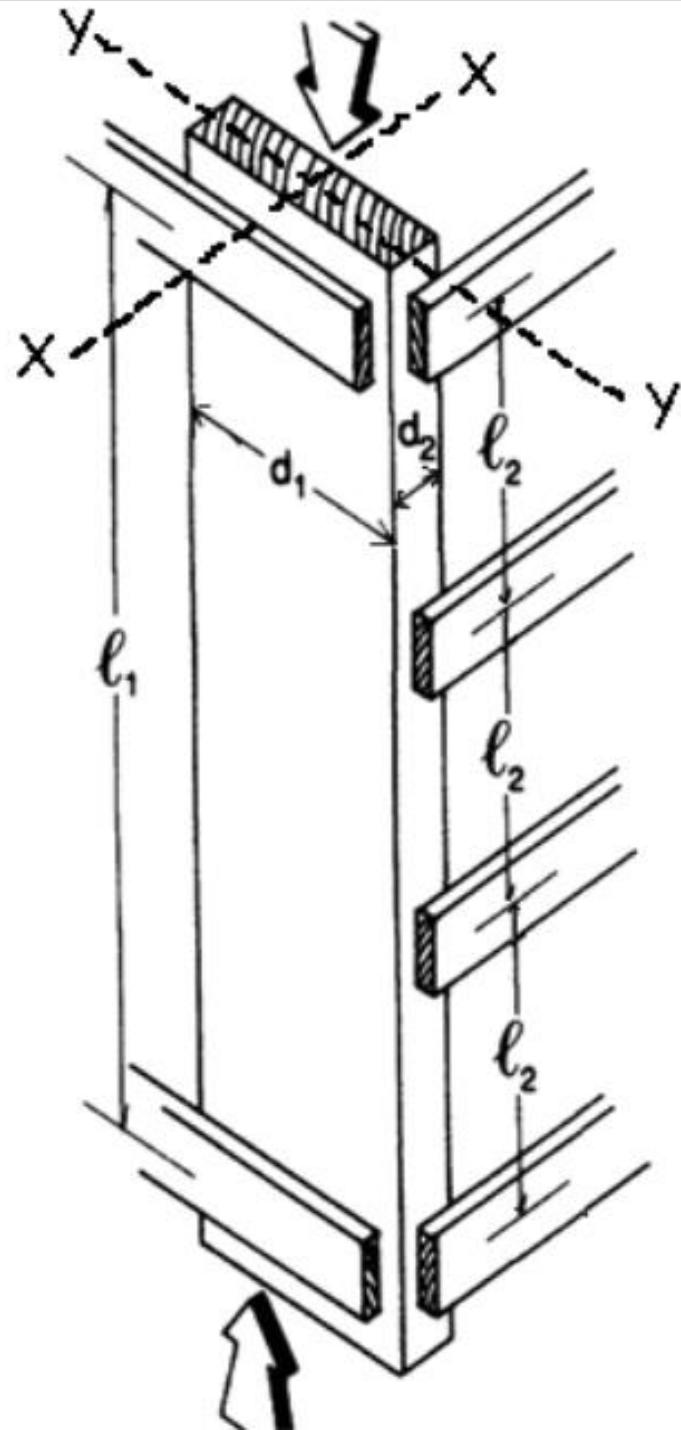
2 IN

Wide Width, d1

8 IN

LoadType

Live Load



Reaction B - wood column analysis.

Givens: Dimensioned lumber with  
1/3 point weak axis bracing

Moisture content = 15%.

$$C_t = C_i = 1$$

pinned end conditions ( $K=1$ ).

wood species = spruce pine fir.

wood grade = No. 1 / No. 2.

strong Axis length,  $L_1$  = 11 FT.

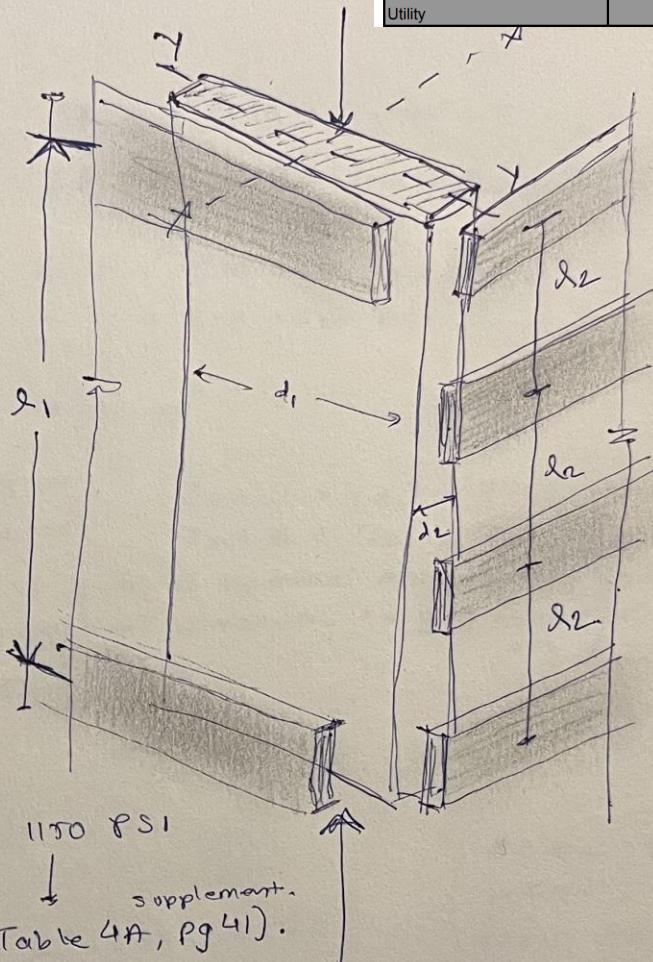
weak Axis length,  $L_2$  = 3.66666667 ft

Narrow width ( $d_2$ ) = 2 IN.

Wide width ( $d_1$ ) = 8 IN.

load Type = live load.

X ————— X —————



(Q1) Tabulated Allow. compressive stress ( $F_c$ ) = 1150 psi

<sup>supplement.</sup>  
(use Table 4A, pg 41).

(Q2) Tabulated Minimum Modulus of Elasticity ( $E_{min}$ ) = 510,000 psi (use Table 4A, <sup>supplement</sup> pg 41).

(Q3) Load duration factor ( $C_D$ ) = 1.0 (use Table 2.3.2 → NDS code).

(Q4) size factor ( $C_F$ ) = 1.05 (use Table → size factor → on page 32).  
<sup>supplement</sup>

SPRUCE-PINE-FIR		1,250	700	135	425	1,400	1,500,000	550,000		
Select Structural	2" & wider	875	450	135	425	1,150	1,400,000	510,000		
No. 1/ No. 2										
No. 3		500	250	135	425	650	1,200,000	440,000		
Stud	2" & wider	675	350	135	425	725	1,200,000	440,000		
Construction										
Standard	1,000	500	135	425	1,400	1,300,000	470,000			
Utility	2" - 4" wide	550	275	135	425	1,150	1,200,000	440,000		
		275	125	135	425	750	1,100,000	400,000		
									0.42	NLGA

Size Factor,  $C_F$

Tabulated bending, tension, and compression parallel to grain design values for dimension lumber 2" to 4" thick shall be multiplied by the following size factors:

Size Factors, $C_F$			
		$F_b$	$F_t$
		Thickness (breadth)	
Grades		Width (depth)	
Select		2" & 3"	4"
	Structural,	1.5	1.5
	No. 1 & Btr,	1.4	1.4
	No. 1, No. 2,	1.3	1.3
	No. 3	1.2	1.2
	10"	1.1	1.1
	12"	1.0	1.0
Stud	14" & wider	0.9	0.9
	2", 3", & 4"	1.1	1.1
	5" & 6"	1.0	1.0
Construction, Standard	8" & wider	Use No. 3 Grade tabulated design values and size factors	
	2", 3", & 4"	1.0	1.0
Utility	4"	1.0	1.0
	2" & 3"	0.4	0.4
			0.6

**Table 2.3.2 Frequently Used Load Duration Factors,  $C_D^1$**

Load Duration	$C_D$	Typical Design Loads
Permanent	0.9	Dead Load
Ten years	1.0	Occupancy Live Load
Two months	1.15	Snow Load
Seven days	1.25	Construction Load
Ten minutes	1.6	Wind/Earthquake Load
Impact <sup>2</sup>	2.0	Impact Load

1. Load duration factors shall not apply to reference modulus of elasticity, E, reference modulus of elasticity for beam and column stability,  $E_{min}$ , nor to reference compression perpendicular to grain design values,  $F_{cpl}$ , based on a deformation limit.

2. Load duration factors greater than 1.6 shall not apply to structural members pressure-treated with water-borne preservatives (see Reference 30), or fire retardant chemicals. The impact load duration factor shall not apply to connections.

Q5) factored Allow. modulus of elasticity ( $E_{min}$ ) =

$$E'_{min} = E_{min} (C_M \cdot C_b \cdot C_i \cdot C_T)$$

↓      ↓      ↓  
 1      1      given.  
 ↗      ↗      used in case of  
 + load.

If m.c  $\leq$  19.1, then  $C_{M+E} = 1.0$

If m.c  $>$  19.1, then  $C_{M+E} = 0.9$ .

$$\begin{aligned} E'_{min} &= 510\,000 \text{ (1x1x1)} \\ &= 510\,000 \text{ psi} \end{aligned}$$

Q6) Strong Axis (x-x) Slenderness Ratio,  $\lambda_{x-x} =$

$$\begin{aligned} d_1 = \text{nominal} &= 8 \text{ in} & d_{actual} = (d_1) &= 7.25 \text{ in.} \\ d_2 = \text{nominal} &= 2 \text{ in.} & d_{actual} = (d_2) &= 1.5 \text{ in.} \end{aligned}$$

(Note:  $d_1$  is given in nominal dimensions, use actual dimensions to get correct ans.)

$$\frac{\lambda_{x-x}}{d_{actual}} = \frac{11}{7.25} \times \frac{12}{1} = 18.20689655.$$

Table 1B Section Properties of Standard Dressed (S4S) Sawn Lumber

Nominal Size b x d	Standard Dressed Size (S4S) b x d in. in.	Area of Section A in. <sup>2</sup>	X-X AXIS		Y-Y AXIS		Approximate weight in pounds per linear foot (lbs/ft) of piece when density of wood equals:					
			Section Modulus S <sub>xx</sub> in. <sup>3</sup>	Moment of Inertia I <sub>x</sub> in. <sup>4</sup>	Section Modulus S <sub>yy</sub> in. <sup>3</sup>	Moment of Inertia I <sub>y</sub> in. <sup>4</sup>	25 lbs/ft <sup>3</sup>	30 lbs/ft <sup>3</sup>	35 lbs/ft <sup>3</sup>	40 lbs/ft <sup>3</sup>	45 lbs/ft <sup>3</sup>	50 lbs/ft <sup>3</sup>
<b>Boards<sup>1</sup></b>												
1 x 3	3/4 x 2-1/2	1.875	0.781	0.977	0.234	0.088	0.326	0.391	0.456	0.521	0.586	0.651
1 x 4	3/4 x 3-1/2	2.625	1.531	2.680	0.328	0.123	0.456	0.547	0.638	0.729	0.820	0.911
1 x 6	3/4 x 5-1/2	4.125	3.781	10.40	0.516	0.193	0.716	0.859	1.003	1.146	1.289	1.432
1 x 8	3/4 x 7-1/4	5.438	6.570	23.82	0.680	0.255	0.944	1.133	1.322	1.510	1.699	1.888
1 x 10	3/4 x 9-1/4	6.938	10.70	49.47	0.867	0.325	1.204	1.445	1.686	1.927	2.168	2.409
1 x 12	3/4 x 11-1/4	8.438	15.82	88.99	1.055	0.396	1.465	1.758	2.051	2.344	2.637	2.930
<b>Dimension Lumber (see NDS 4.13.2) and Decking (see NDS 4.13.5)</b>												
2 x 3	1-1/2 x 2-1/2	3.750	1.56	1.953	0.938	0.703	0.651	0.781	0.911	1.042	1.172	1.302
2 x 4	1-1/2 x 3-1/2	5.250	3.06	5.359	1.313	0.984	0.911	1.094	1.276	1.458	1.641	1.823
2 x 5	1-1/2 x 4-1/2	6.750	5.06	11.39	1.688	1.266	1.172	1.406	1.641	1.875	2.109	2.344
2 x 6	1-1/2 x 5-1/2	8.250	7.56	20.80	2.063	1.547	1.432	1.719	2.005	2.292	2.578	2.865
2 x 8	1-1/2 x 7-1/4	10.88	13.14	47.63	2.719	2.039	1.888	2.266	2.643	3.021	3.398	3.776
2 x 10	1-1/2 x 9-1/4	13.88	21.39	98.93	3.469	2.602	2.409	2.891	3.372	3.854	4.336	4.818
2 x 12	1-1/2 x 11-1/4	16.88	31.64	178.0	4.219	3.164	2.930	3.516	4.102	4.688	5.273	5.859
2 x 14	1-1/2 x 13-1/4	19.88	43.89	290.8	4.969	3.727	3.451	4.141	4.831	5.521	6.211	6.901
3 x 4	2-1/2 x 3-1/2	8.75	5.10	8.932	3.646	4.557	1.519	1.823	2.127	2.431	2.734	3.038
3 x 5	2-1/2 x 4-1/2	11.25	8.44	18.98	4.688	5.859	1.953	2.344	2.734	3.125	3.516	3.908

(check table 1B for actual dimensions)  
Page - 14.  
(supplement).

Q7) weak Axis (y-y) slenderness ratio,  $\lambda_{y-y} =$

$$\frac{\lambda_{y-y}}{d_{actual}} = \frac{8.6666667 \text{ ft}}{1.5} \times \frac{12}{1} = 29.33333336.$$

(\* Note d<sub>2</sub> given is nominal, get the actual from table 1B.) and use this value to get correct ans).

Q8) Controlling slenderness factor ( $\alpha_e/d$ ) :-

use larger value from  $\alpha_s$  and  $\alpha_f$ , in my case  $\alpha_f$  has larger value).

$\therefore$  value = 29.33333333.

Q9) Critical Buckling Design Value for compression, ( $F_{ce}$ ) :-

$$F_{ce} = \frac{0.822 \times E'_{min}}{\left(\frac{\alpha_e}{d^2}\right)} = \frac{0.822 \times 510\ 000}{(29.33333333)} = 487.2133264 \text{ psi}$$

*(use value from question Q8)*

Q10) Reference Compression Design Value, ( $F_c^*$ ) =

$$F_c^* = F_c (C_0 \times C_m \times C_t \times C_F \times C_i)$$

↓      ↓      ↓      ↓  
1      1.05      1  
from Q3.    given    (Q4).    given

then  $C_{m,c} = 1.0$

if m.c.  $\leq 1.0$ . ~~then~~

m.c.  $> 1.0$ . and  $\begin{cases} (F_c)(C_F) \leq 750 \text{ psi}, \text{ then } C_{m,c} = 1. \\ (F_c)(C_F) > 750 \text{ psi}, \text{ then } C_{m,c} = 0.8 \end{cases}$

$$F_c^* = \cancel{1150} 1150 (1 \times 1 \times 1 \times 1.05 \times 1) = 1207.5 \text{ psi}$$

Q.11) Constant for Sawn lumber, (c)

$$\boxed{c = 0.8.} \rightarrow \text{(use it from class notes).}$$

Q.12) Column stability factor ( $C_p$ ).:-

$$C_p = \frac{1 + (F_{ce} / F_c^*)}{2c} - \sqrt{\left[ \frac{1 + (F_{ce} / F_c^*)}{2c} \right]^2 - \frac{F_{ce} / F_c^*}{c}}$$

~~$F_{ce} / F_c^* = \frac{487.2133264}{1207.5} = 0.40348929$~~

$$C_p = \frac{1 + 0.40348929}{2 \times 0.8} - \sqrt{\left( \frac{1 + 0.40348929}{2 \times 0.8} \right)^2 - \frac{0.40348929}{c}}$$

↓  
(Q.11)

$$= 0.87718080625 - \sqrt{0.769446166 - \cancel{0.40348929}} \\ 0.50436161$$

$$C_p = 0.362317185$$

Calculate  $C_p$

$$C_p = \frac{1 + (F_{ce} / F_c^*)}{2c} - \sqrt{\left[ \frac{1 + (F_{ce} / F_c^*)}{2c} \right]^2 - \frac{F_{ce} / F_c^*}{c}} \quad (3.7-1)$$

where:

$F_c^*$  = reference compression design value parallel to grain multiplied by all applicable adjustment factors except  $C_p$  (see 2.3), psi

$$F_{ce} = \frac{0.822 E_{min}'}{(\ell_e / d)^2}$$

c = 0.8 for sawn lumber

c = 0.85 for round timber poles and piles

c = 0.9 for structural glued laminated timber or structural composite lumber

Q<sub>13</sub>) Factored Allow. (compressive stress) ( $F'_c$ ) =

$$\begin{aligned}F'_c &= F_c \times C_p \\&= 1207.5 \times 0.362317185 \\&= 437.4980 \text{ PSI}\end{aligned}$$

Q<sub>14</sub>) Column Area (A) :-

$$\begin{aligned}A &= d_{\text{actual}} \times d_{\text{actual}} \\&= 7.25 \times 1.5 \\&= 10.875 \text{ in}^2\end{aligned}$$

Q<sub>15</sub>) Maximum allowable axial load capacity,  $P_{\max}$

$$\begin{aligned}P_{\max} &= F'_c \times A \\&= 437.4980 \times 10.875 \\&= 4757.49075 \text{ CBS.}\end{aligned}$$

# LAB – 2

Wood Column Analysis

LAB 2 → columns

1/16" × 1/4" → basswood column

L = 6"

Calculate :- controlling slenderness ratio.

K = 1.0.

$$\sigma_{min} = 1,650,000 \text{ psi}$$

$$F_c = 4745 \text{ psi}$$

$$\text{Area} = 0.015625 \text{ in}^2$$

Case i) L = 6"

ii) L = 3"

iii) L = 1"

$$d_1 = 0.25 \text{ in}$$

$$d_2 = 0.0625 \text{ in.}$$

i)

L = 6"

$$L/d = 6/0.0625$$

$$= 96.$$

$$P_{cr} = F_{ce} \times A \leftarrow \text{compression/bending.}$$

$$\begin{aligned} F_{ce} &= \frac{0.822 \times 1,650,000}{(96)^2} \\ &= 147.167 \cdot 451 \end{aligned}$$

$$\begin{aligned} P_{cr} &= 147.167 \times A \\ &= 147.167 \times 0.015625 \\ &= 2.293 \text{ kips.} \end{aligned}$$

$$P_{max} = F_c \times A \leftarrow \text{crushing}$$

$$\begin{aligned} P_{max} &= 4745 \times 0.015625 \\ &= 74.14 \text{ kips} \end{aligned}$$

$$c = 3^4$$

$$l/d = 3/0.0625$$

$$= 48.$$

$$F_{ce} = \frac{0.822 \times 1,650,000}{(48)^\leftarrow}$$

$$= \frac{1356300}{2304} = 588.671875 \text{ psi}$$

$$P_{cr} = 588.671875 \times 0.015625$$

$$= 9.197 \text{ lbs.}$$

$C = 1''$

$$\frac{1}{d} = \frac{1}{0.0625}$$

$$= 16.$$

$$F_{ce} = \frac{0.82e \times 1,250,000}{(16)^2}$$

$$= \frac{1356300}{256} = 5298.046875$$

(3)

$$l_{cr} = 5298.046875 \times 0.015625$$

$$= 82.781 \text{ g } \text{dia.}$$

