Arch 324
Structures II

Winter 2026 Recitation 004

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GSI Info :)

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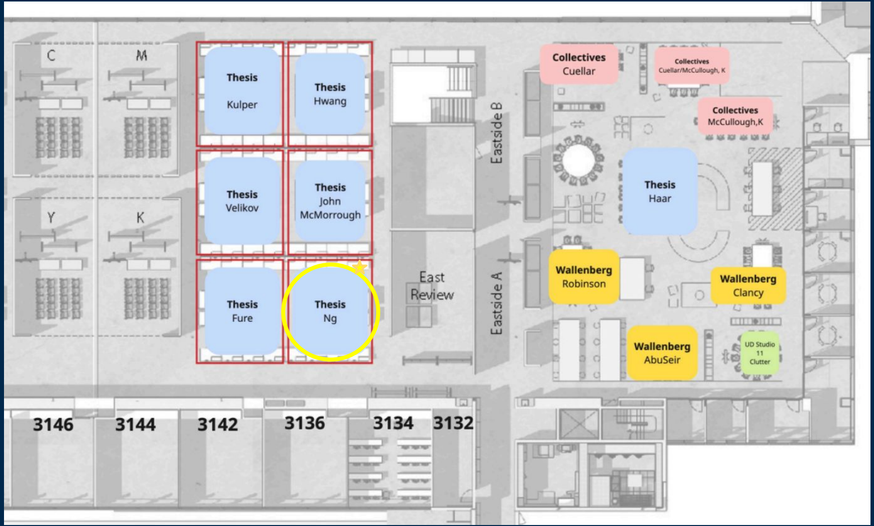

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Recitation 004

Welcome to session 3!

- Tower Heads up
- Quick Lecture Recap
- Homework #3 Wood Column Design
- Lab: Wood Columns

Feel free to ask questions anytime

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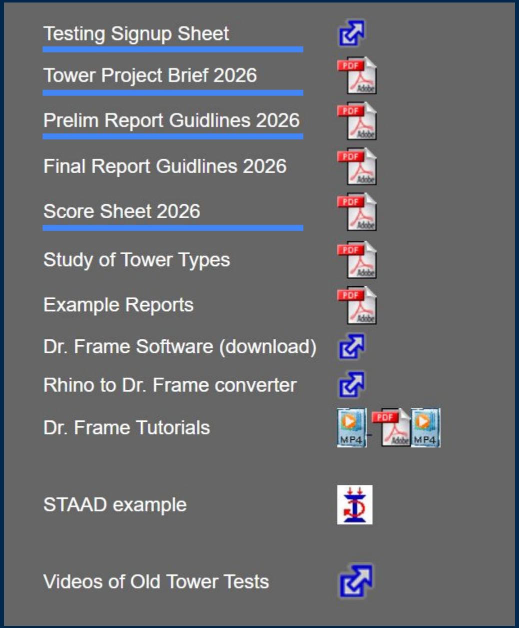
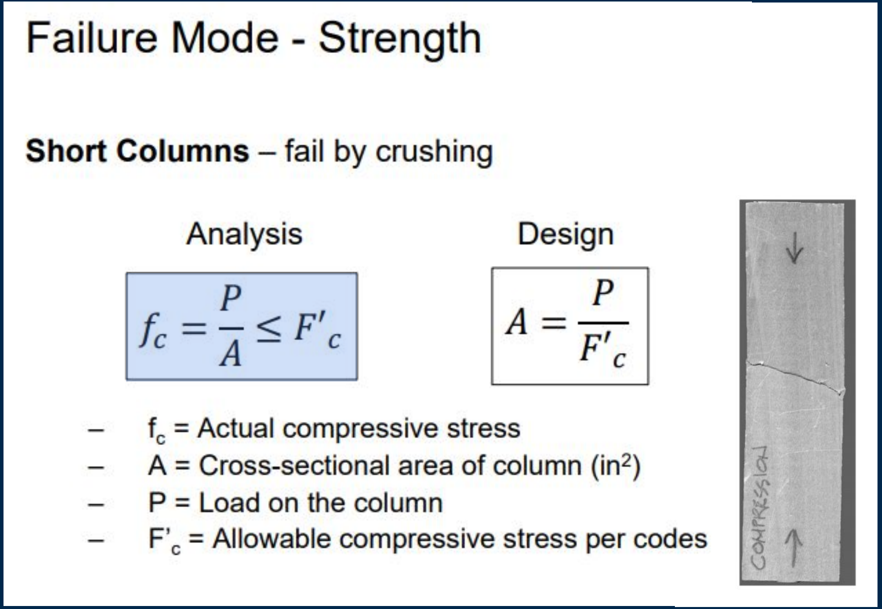
Tower!!


Testing Signup Sheet
Tower Project Brief 2026
Prelim Report Guidlines 2026
Final Report Guidlines 2026
Score Sheet 2026
Study of Tower Types
Example Reports
Dr. Frame Software (download)
Rhino to Dr. Frame converter
Dr. Frame Tutorials
STAAD example
Videos of Old Tower Tests

Lecture: Wood Column Design



Failure Mode - Strength

Short Columns – fail by crushing

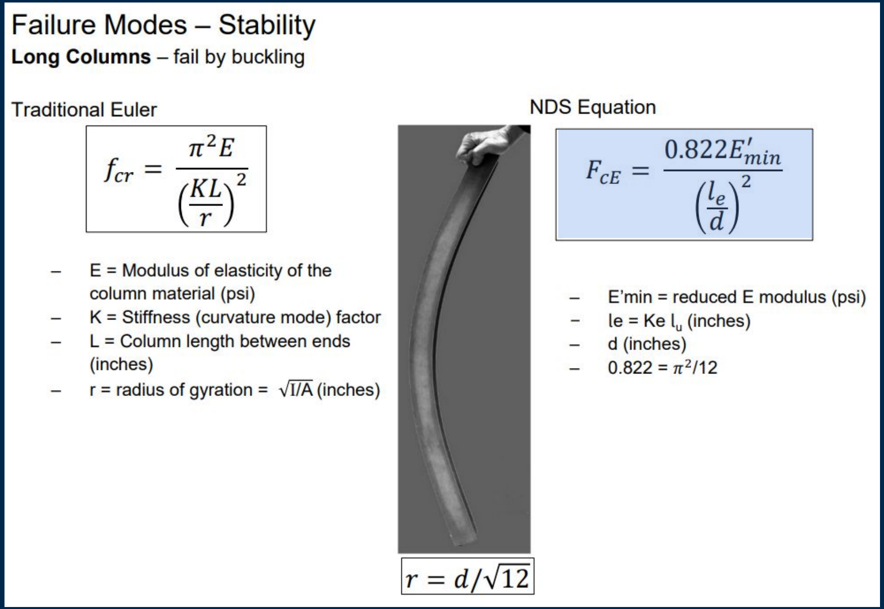
Analysis

$$\boxed{f_c = \frac{P}{A} \leq F'_c}$$

Design

$$\boxed{A = \frac{P}{F'_c}}$$

- f_c = Actual compressive stress
- A = Cross-sectional area of column (in^2)
- P = Load on the column
- F'_c = Allowable compressive stress per codes



Failure Modes – Stability

Long Columns – fail by buckling

Traditional Euler

$$\boxed{f_{cr} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}}$$

- E = Modulus of elasticity of the column material (psi)
- K = Stiffness (curvature mode) factor
- L = Column length between ends (inches)
- r = radius of gyration = $\sqrt{I/A}$ (inches)

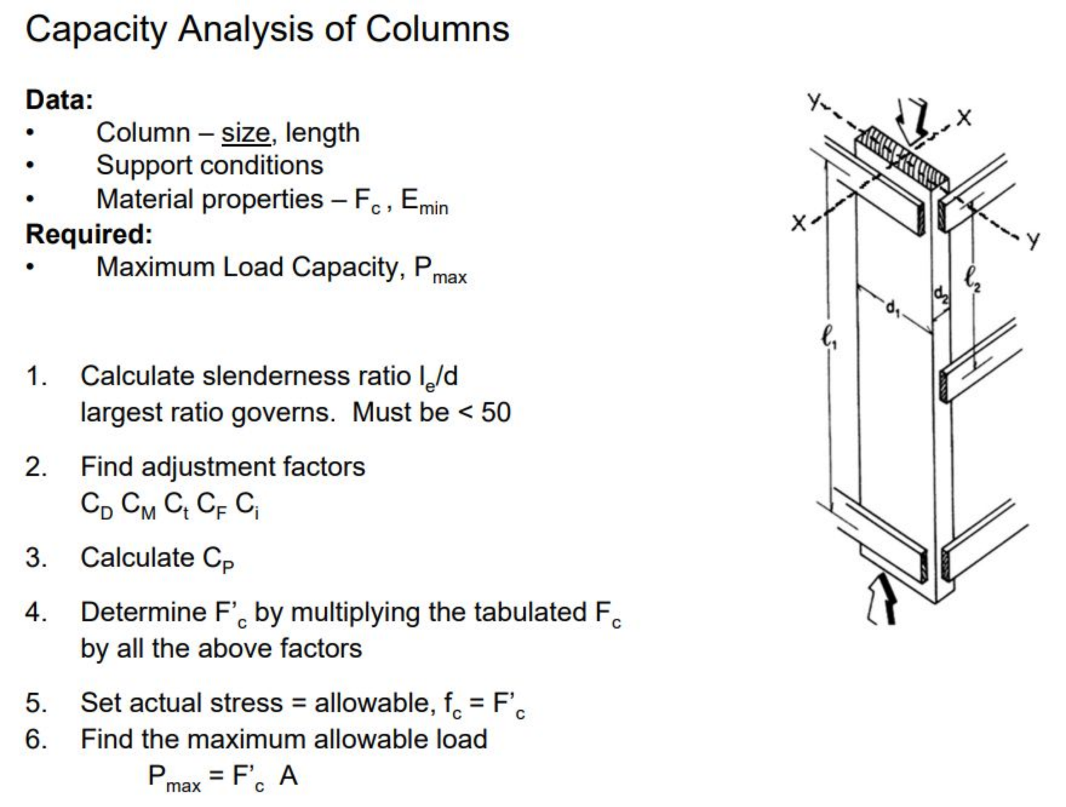
$$\boxed{r = d/\sqrt{12}}$$

NDS Equation

$$\boxed{F_{cE} = \frac{0.822E'_{min}}{\left(\frac{l_e}{d}\right)^2}}$$

- E'min = reduced E modulus (psi)
- le = Ke l_u (inches)
- d (inches)
- 0.822 = $\pi^2/12$

Lecture: Wood Column Design



Capacity Analysis of Columns

Data:

- Column – <u>size</u>, length
- Support conditions
- Material properties – F_c , E_{min}

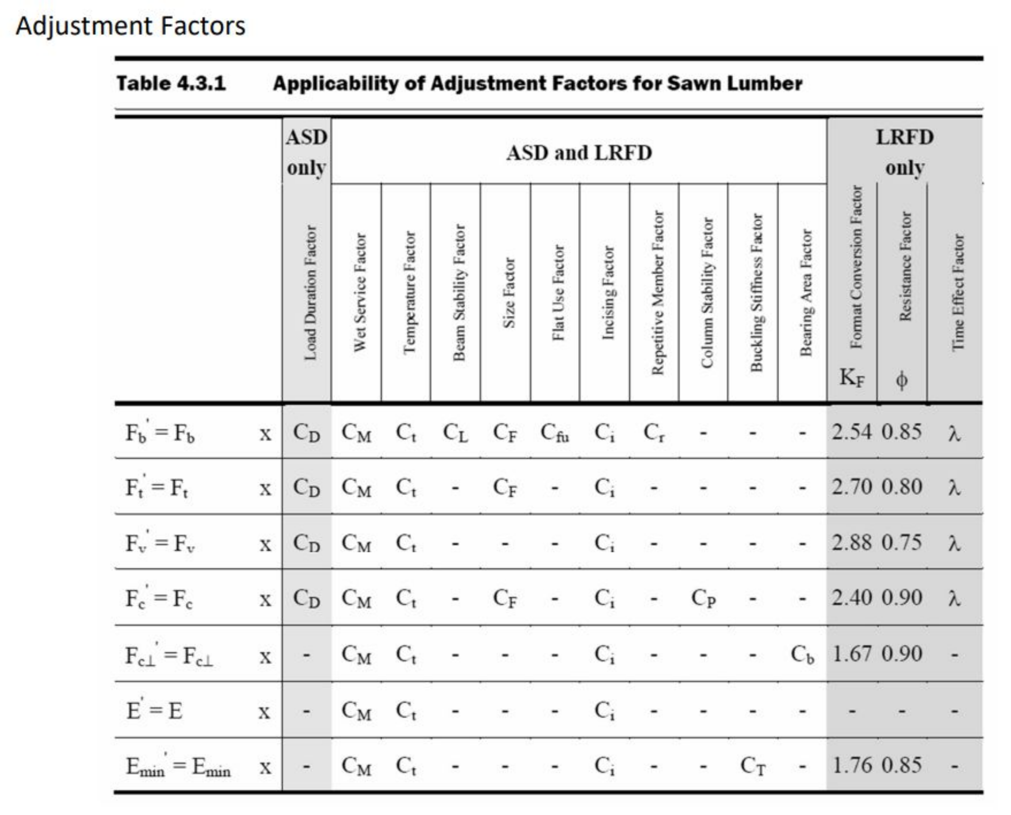
Required:

- Maximum Load Capacity, P_{max}

1. Calculate slenderness ratio l_e/d
   largest ratio governs. Must be < 50
2. Find adjustment factors
   C_D C_M C_t C_F C_i
3. Calculate C_P
4. Determine F'_c by multiplying the tabulated F_c
   by all the above factors
5. Set actual stress = allowable, $f_c = F'_c$
6. Find the maximum allowable load

$$P_{max} = F'_c \; A$$

Lecture: Wood Column Design

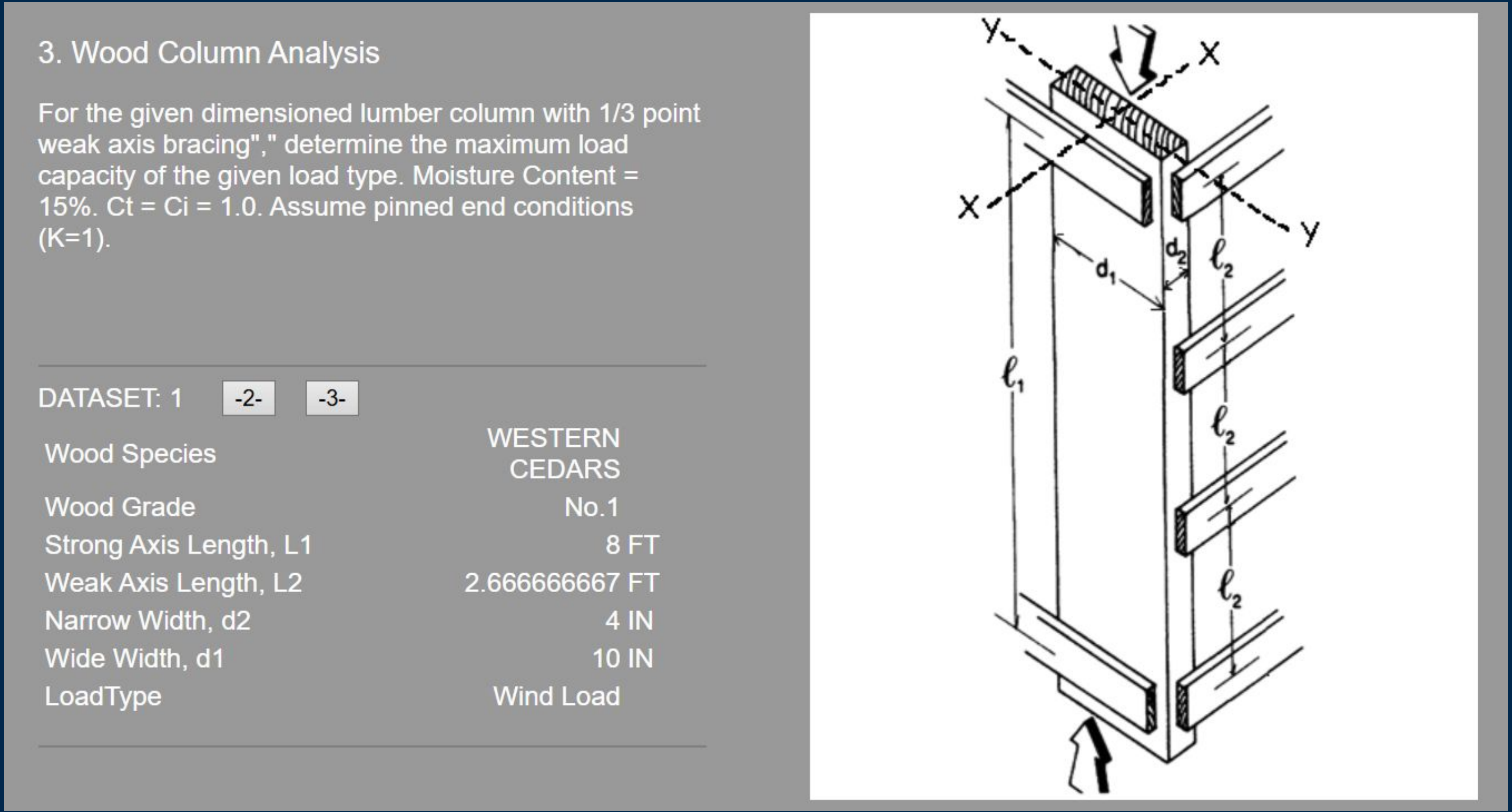


Adjustment Factors

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		ASD only	ASD and LRFD										LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	-	-	-	2.54	0.85	λ
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	2.70	0.80	λ
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	C_i	-	-	-	-	2.88	0.75	λ
$F_c' = F_c$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	C_P	-	-	2.40	0.90	λ
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_b	1.67	0.90	-
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	1.76	0.85	-

HW #3: Wood Column Design



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%. Ct = Ci = 1.0. Assume pinned end conditions (K=1).

DATASET: 1 -2- -3-

Wood Species	WESTERN CEDARS
Wood Grade	No.1
Strong Axis Length, L1	8 FT
Weak Axis Length, L2	2.666666667 FT
Narrow Width, d2	4 IN
Wide Width, d1	10 IN
LoadType	Wind Load

HW #3: Wood Column Design

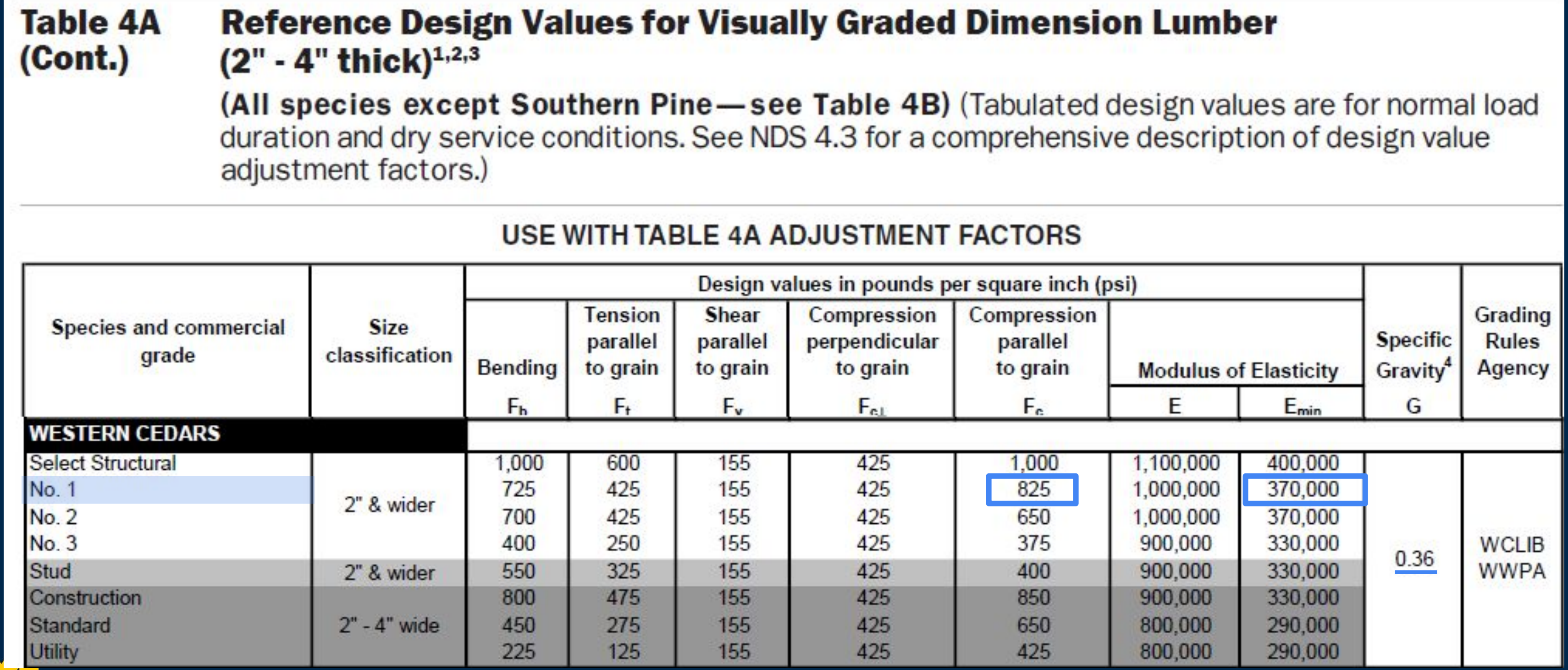


Table 4A (Cont.) **Reference Design Values for Visually Graded Dimension Lumber (2" - 4" thick)[1,2,3]**

(All species except Southern Pine—see Table 4B) (Tabulated design values are for normal load duration and dry service conditions. See NDS 4.3 for a comprehensive description of design value adjustment factors.)

USE WITH TABLE 4A ADJUSTMENT FACTORS

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)							Specific Gravity[4]	Grading Rules Agency
		Bending	Tension parallel to grain	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain	Modulus of Elasticity			
		F_b	F_t	F_v	$F_{c\perp}$	F_c	E	E_{min}	G	
WESTERN CEDARS										
Select Structural	2" & wider	1,000	600	155	425	1,000	1,100,000	400,000	0.36	WCLIB WWPA
No. 1		725	425	155	425	825	1,000,000	370,000		
No. 2		700	425	155	425	650	1,000,000	370,000		
No. 3		400	250	155	425	375	900,000	330,000		
Stud	2" & wider	550	325	155	425	400	900,000	330,000		
Construction	2" - 4" wide	800	475	155	425	850	900,000	330,000		
Standard		450	275	155	425	650	800,000	290,000		
Utility		225	125	155	425	425	800,000	290,000		

Q1

Q2

HW #3: Wood Column Design

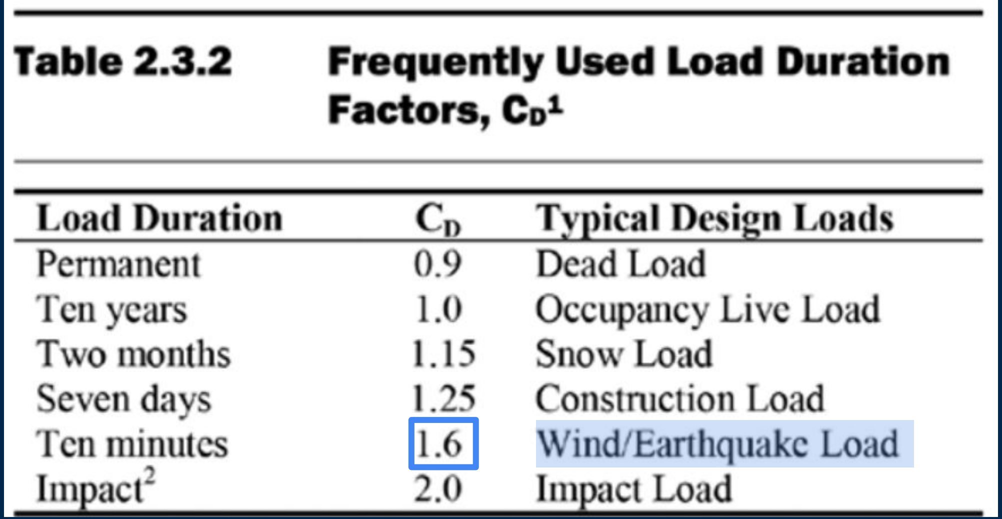


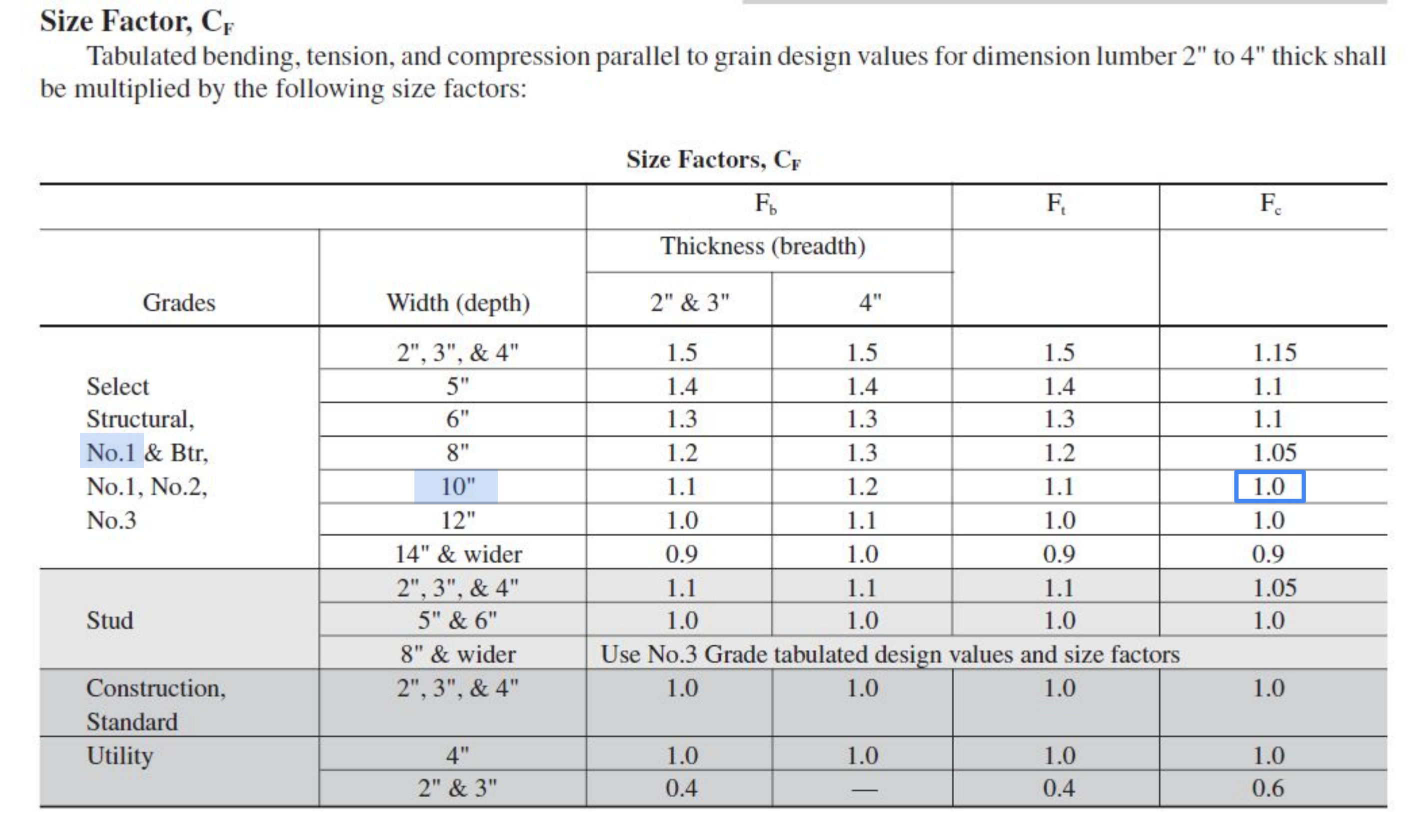
Table 2.3.2 Frequently Used Load Duration Factors, C_D[1]

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[2]	2.0	Impact Load

Q3

LoadType	Wind Load

HW #3: Wood Column Design



Size Factor, C_F

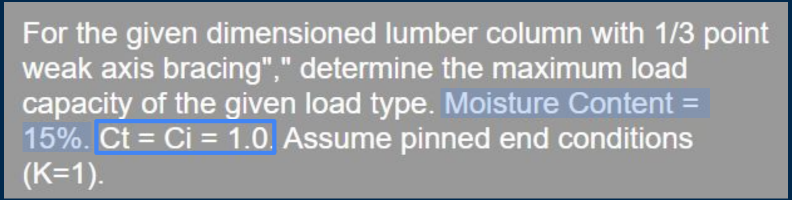
Tabulated bending, tension, and compression parallel to grain design values for dimension lumber 2" to 4" thick shall be multiplied by the following size factors:

Size Factors, C_F

		F_b		F_t	F_c
		Thickness (breadth)			
Grades	Width (depth)	2" & 3"	4"		
Select Structural, No.1 & Btr, No.1, No.2, No.3	2", 3", & 4"	1.5	1.5	1.5	1.15
	5"	1.4	1.4	1.4	1.1
	6"	1.3	1.3	1.3	1.1
	8"	1.2	1.3	1.2	1.05
	10"	1.1	1.2	1.1	1.0
	12"	1.0	1.1	1.0	1.0
	14" & wider	0.9	1.0	0.9	0.9
Stud	2", 3", & 4"	1.1	1.1	1.1	1.05
	5" & 6"	1.0	1.0	1.0	1.0
	8" & wider	Use No.3 Grade tabulated design values and size factors			
Construction, Standard	2", 3", & 4"	1.0	1.0	1.0	1.0
Utility	4"	1.0	1.0	1.0	1.0
	2" & 3"	0.4	—	0.4	0.6

Q4

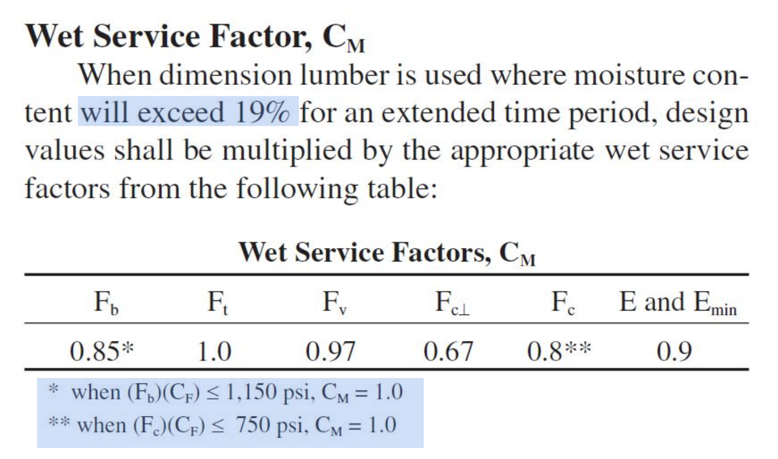
HW #3: Wood Column Design



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%. Ct = Ci = 1.0. Assume pinned end conditions (K=1).

$C_t = 1.0$
$C_i = 1.0$

$C_M = 1.0$



Wet Service Factor, C_M

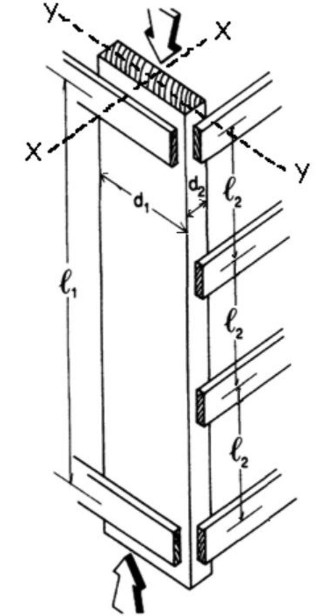
When dimension lumber is used where moisture content will exceed 19% for an extended time period, design values shall be multiplied by the appropriate wet service factors from the following table:

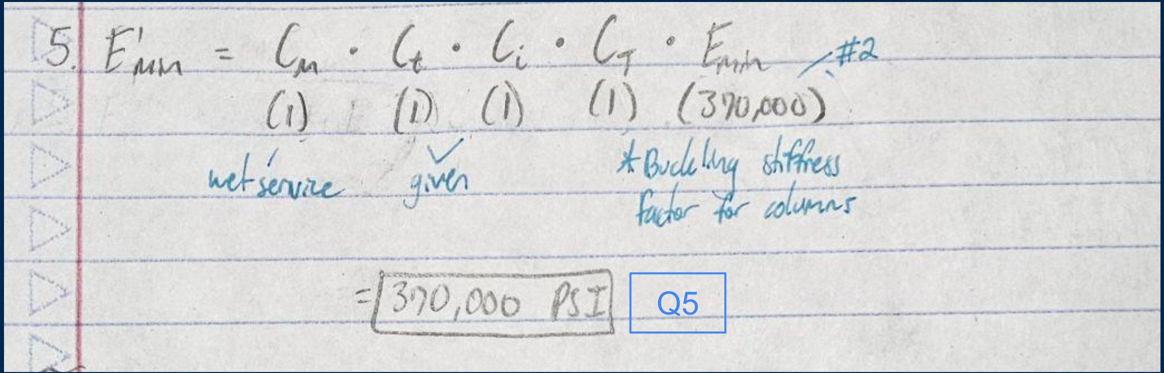
Wet Service Factors, C_M

F_b	F_t	F_v	$F_{c\perp}$	F_c	E and E_{min}
0.85*	1.0	0.97	0.67	0.8**	0.9

* when $(F_b)(C_F) \leq 1{,}150$ psi, $C_M = 1.0$
** when $(F_c)(C_F) \leq 750$ psi, $C_M = 1.0$

HW #3: Wood Column Design





5. $E'_{MM} = C_M \cdot C_t \cdot C_i \cdot C_T \cdot E_{min}$ #2

(1) (1) (1) (1) (370,000)

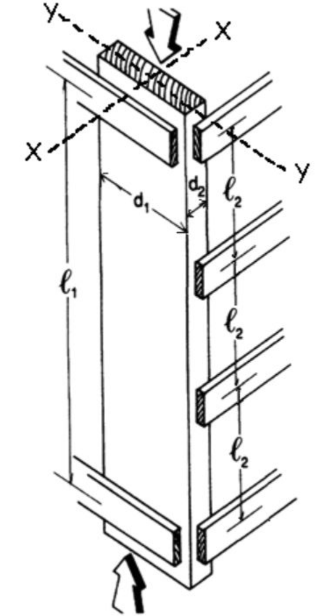
wet service given ✓

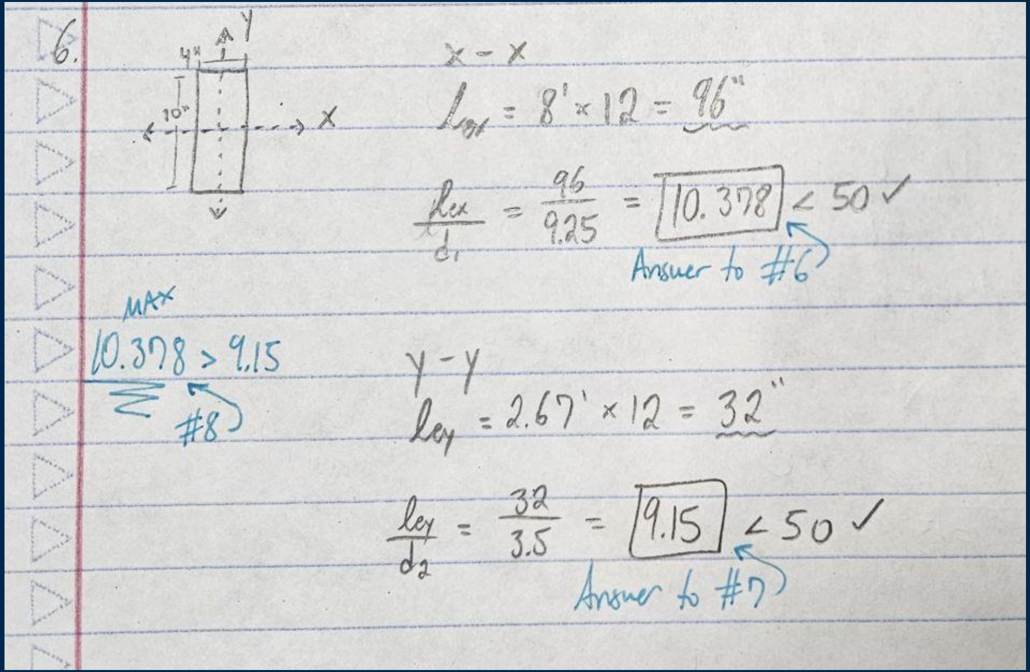
*Buckling stiffness factor for columns

$= \boxed{370,000 \text{ PSI}}$

Q5

HW #3: Wood Column Design





6.

x - x

$l_{ex} = 8' \times 12 = 96''$

$\frac{l_{ex}}{d_1} = \frac{96}{9.25} = \boxed{10.378} < 50$ ✓

Answer to #6

MAX

$10.378 > 9.15$

#8

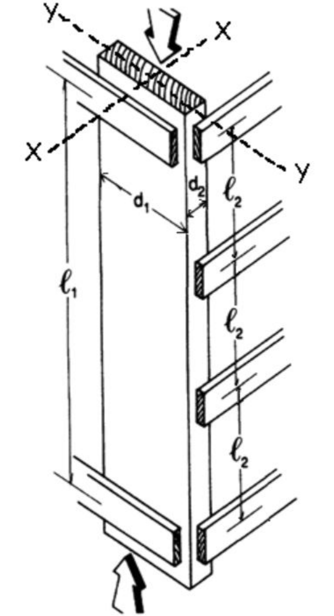
y - y

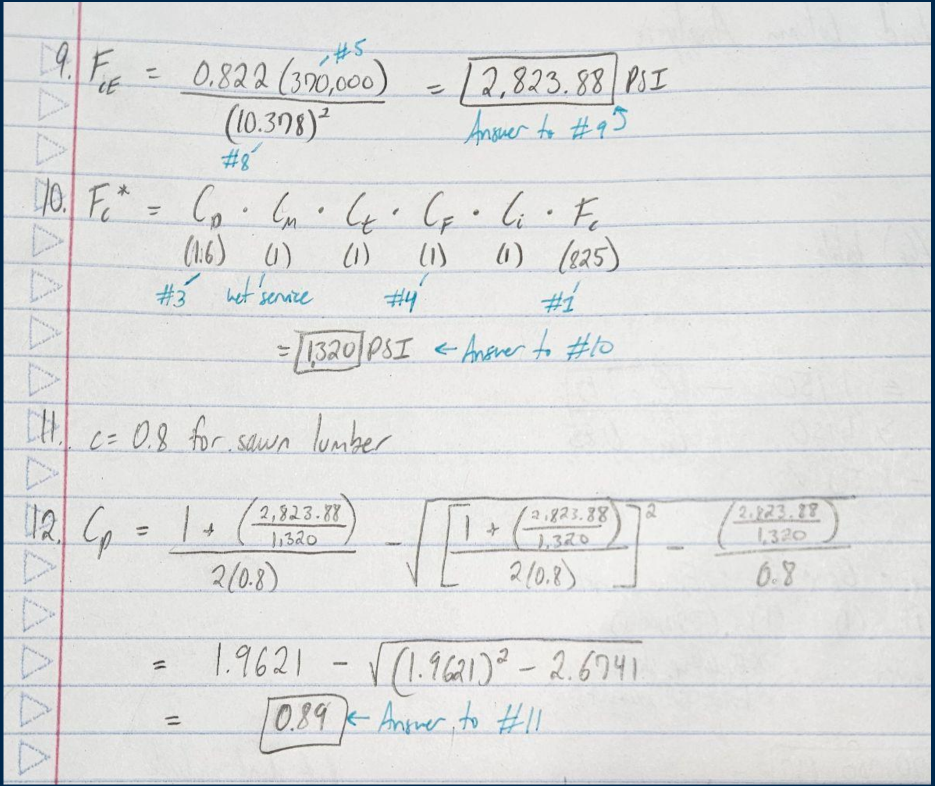
$l_{ey} = 2.67' \times 12 = 32''$

$\frac{l_{ey}}{d_2} = \frac{32}{3.5} = \boxed{9.15} < 50$ ✓

Answer to #7

HW #3: Wood Column Design





9. $$F_{cE} = \frac{0.822(\overset{\#5}{370{,}000})}{(\underset{\#8}{10.378})^2} = \underset{\text{Answer to \#9}}{\boxed{2{,}823.88}}\ \text{PSI}$$

10. $$F_c^* = \underset{\underset{\#3}{(1.6)}}{C_D} \cdot \underset{\underset{\text{wet service}}{(1)}}{C_M} \cdot \underset{(1)}{C_t} \cdot \underset{\underset{\#4}{(1)}}{C_F} \cdot \underset{(1)}{C_i} \cdot \underset{\underset{\#1}{(825)}}{F_c}$$

$$= \boxed{1{,}320}\ \text{PSI} \leftarrow \text{Answer to \#10}$$

11. $c = 0.8$ for sawn lumber

12. $$C_p = \frac{1 + \left(\frac{2{,}823.88}{1{,}320}\right)}{2(0.8)} - \sqrt{\left[\frac{1 + \left(\frac{2{,}823.88}{1{,}320}\right)}{2(0.8)}\right]^2 - \frac{\left(\frac{2{,}823.88}{1{,}320}\right)}{0.8}}$$

$$= 1.9621 - \sqrt{(1.9621)^2 - 2.6741}$$

$$= \boxed{0.89} \leftarrow \text{Answer to \#11}$$

HW #3: Wood Column Design

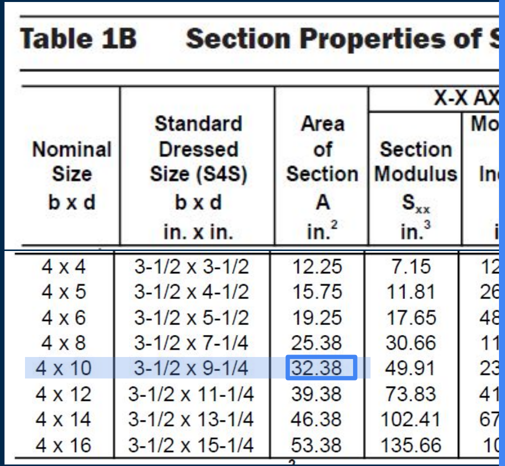
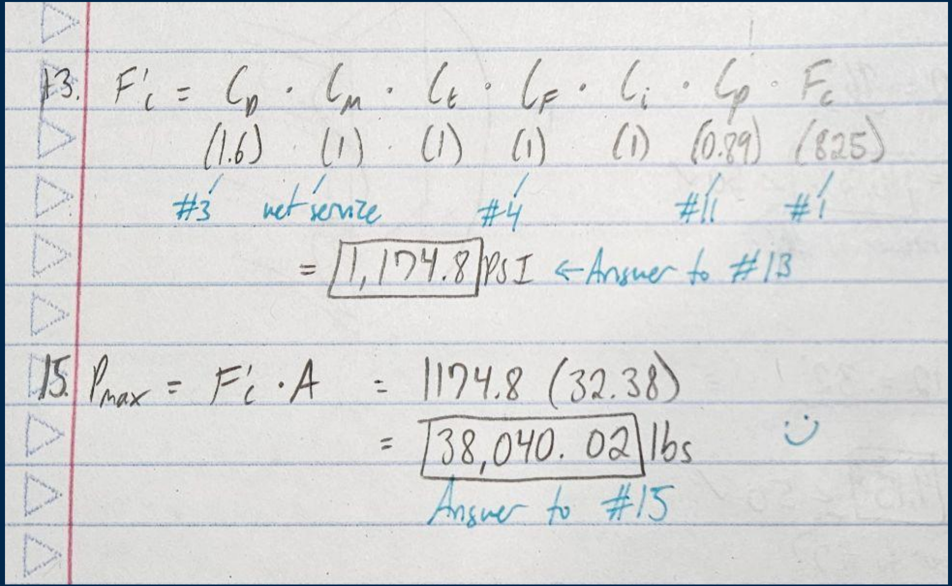


Table 1B Section Properties of S

Nominal Size b x d	Standard Dressed Size (S4S) b x d in. x in.	Area of Section A in.^{2}	X-X AX Section Modulus S_{xx} in.^{3}	Mo In i
4 x 4	3-1/2 x 3-1/2	12.25	7.15	12
4 x 5	3-1/2 x 4-1/2	15.75	11.81	26
4 x 6	3-1/2 x 5-1/2	19.25	17.65	48
4 x 8	3-1/2 x 7-1/4	25.38	30.66	11
4 x 10	3-1/2 x 9-1/4	32.38	49.91	23
4 x 12	3-1/2 x 11-1/4	39.38	73.83	41
4 x 14	3-1/2 x 13-1/4	46.38	102.41	67
4 x 16	3-1/2 x 15-1/4	53.38	135.66	10

Q14



13. $F'_c = C_D \cdot C_M \cdot C_t \cdot C_F \cdot C_i \cdot C_p \cdot F_c$

$(1.6) \cdot (1) \cdot (1) \quad (1) \quad (1) \quad (0.89) \quad (825)$

#3 wet service #4 #11 #1

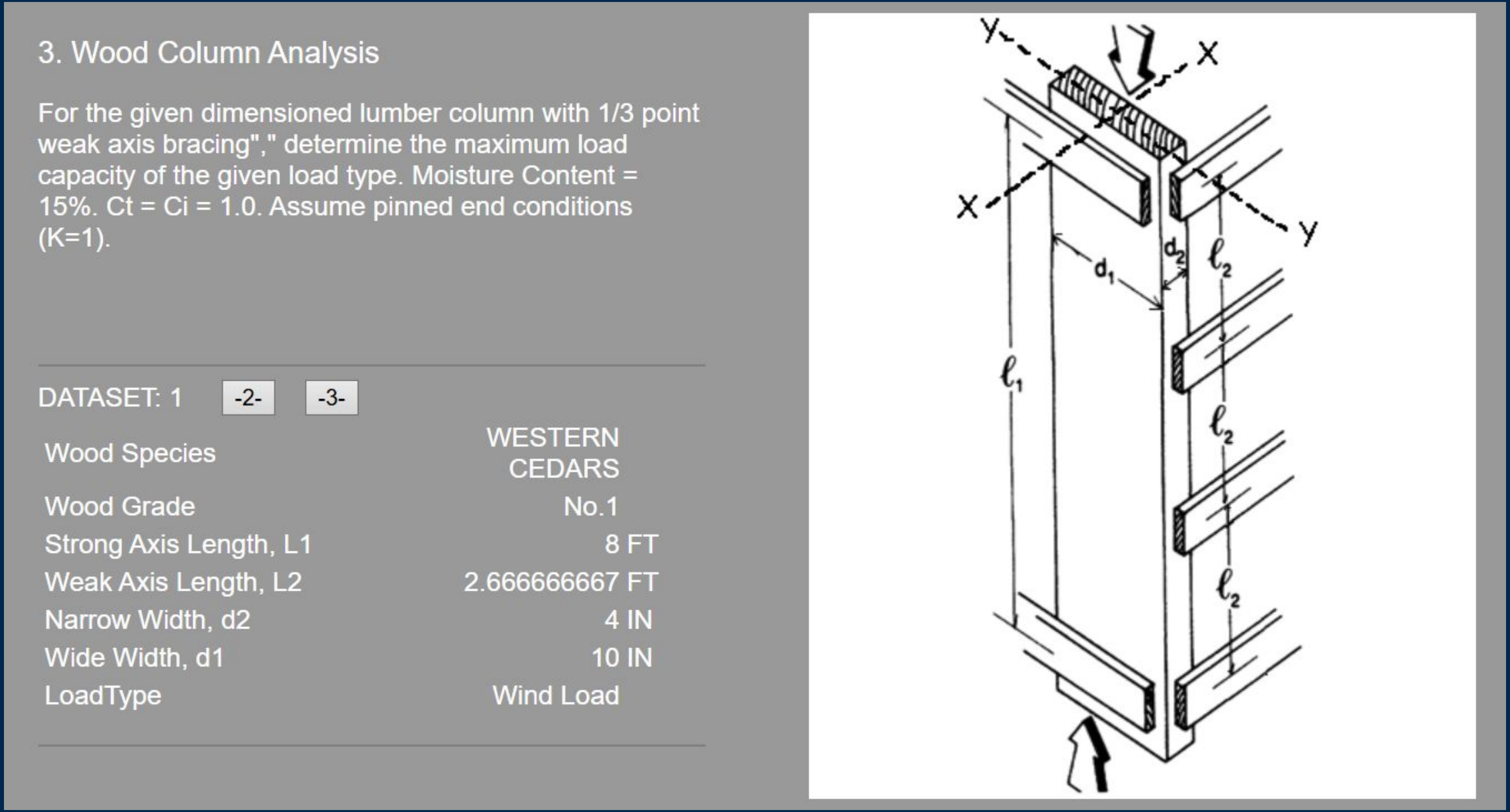
$= \boxed{1,174.8}$ PSI ← Answer to #13

15. $P_{max} = F'_c \cdot A = 1174.8\ (32.38)$

$= \boxed{38,040.02}$ lbs ☺

Answer to #15

HW #3: Wood Column Design



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Wide Width, d1	10 IN
LoadType	Wind Load

LAB!