

Arch324

STRUCTURES II

Winter 2026
Recitation

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Recitation Guidelines

Homework Problem

Lab (Groups of 1–3 students)

- Please complete the lab sheet during recitation and hand it in before leaving.
- Try to attend all sessions. Unexcused absences will **affect your grade** starting from the second missed class.

Analysis Example - HW3

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, L_1

11 FT

Weak Axis Length, L_2

3.66666667 FT

Narrow Width, d_2

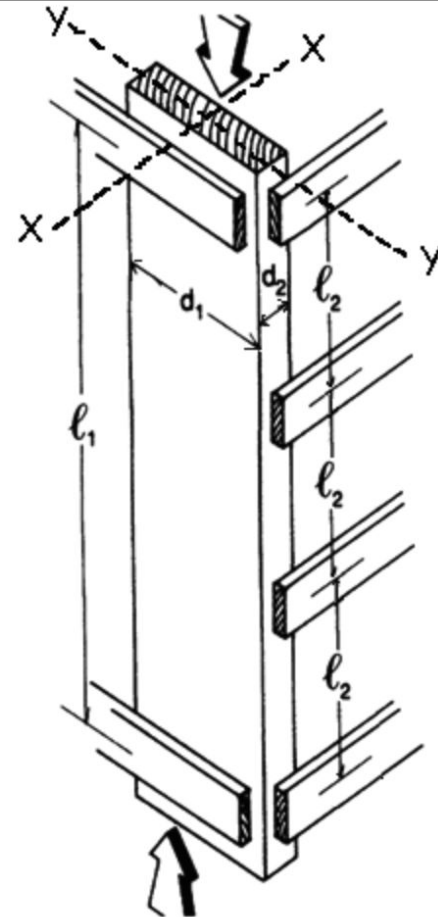
2 IN

Wide Width, d_1

8 IN

LoadType

Live Load



Analysis Example - HW3

15 Questions

#	Question	Your Response
1	Tabulated Allow. Compressive Stress, F_c	<input type="text"/> PSI
2	Tabulated Minimum Modulus of Elasticity, E_{min}	<input type="text"/> PSI
3	Load Duration Factor, CD	<input type="text"/>
4	Size Factor, CF	<input type="text"/>
5	Factored Allow. Modulus of Elasticity, E'_{min}	<input type="text"/> PSI
6	Strong Axis (x-x) Slenderness Ratio, l_{ex}/d_1	<input type="text"/>
7	Weak Axis (y-y) Slenderness Ratio, l_{ey}/d_2	<input type="text"/>
8	Controlling Slenderness Ratio, l_e/d	<input type="text"/>
9	Critical Buckling Design Value for Compression, F_{cE}	<input type="text"/> PSI
10	Reference Compression Design Value, F_c^*	<input type="text"/> PSI
11	Constant for Sawn Lumber, c	<input type="text"/>
12	Column Stability Factor, CP	<input type="text"/>
13	Factored Allow. Compressive Stress, F'_c	<input type="text"/> PSI
14	Column Area, A	<input type="text"/> IN ²
15	Maximum Allowable Axial Load Capacity, Pmax	<input type="text"/> LBS

Answer HW3

15 Questions

#	<u>Question</u>	<u>Correct Answer</u>
1	Tabulated Allow. Compressive Stress, F_c	1150 PSI
2	Tabulated Minimum Modulus of Elasticity, E_{min}	510000 PSI
3	Load Duration Factor, C_D	1
4	Size Factor, C_F	1.05
5	Factored Allow. Modulus of Elasticity, E'_{min}	510000 PSI
6	Strong Axis (x-x) Slenderness Ratio, l_{ex}/d_1	18.20689655
7	Weak Axis (y-y) Slenderness Ratio, l_{ey}/d_2	29.33333333
8	Controlling Slenderness Ratio, l_e/d	29.33333333
9	Critical Buckling Design Value for Compression, F_{cE}	487.2133264 PSI
10	Reference Compression Design Value, F_c^*	1207.5 PSI
11	Constant for Sawn Lumber, c	0.8
12	Column Stability Factor, C_P	0.362317185
13	Factored Allow. Compressive Stress, F'_c	437.4980008 PSI
14	Column Area, A	10.875 IN ²
15	Maximum Allowable Axial Load Capacity, P_{max}	4757.790759 LBS

Analysis Example - HW3

Q1-Q2

Wood Species: SPRUCE-PINE-FIR
 Wood Grade: No.1/No.2

- 1 Tabulated Allow. Compressive Stress, F_c
- 2 Tabulated Minimum Modulus of Elasticity, E_{min}

Q1 $F_c=1150$ PSI

Q2 $E_{min}=510000$ PSI

Table 4A 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 ^A G	Grading Rules Agency	
		Bending F_b	Tension parallel to grain F_t	Shear parallel to grain F_v	Compression perpendicular to grain $F_{c\perp}$	Compression parallel to grain F_c	Modulus of Elasticity			
							E			E_{min}
RED OAK										
Select Structural	2" & wider	1,150	675	170	820	1,000	1,400,000	510,000	0.67	NELMA
No. 1		825	500	170	820	825	1,300,000	470,000		
No. 2		800	475	170	820	625	1,200,000	440,000		
No. 3	2" & wider	475	275	170	820	375	1,100,000	400,000	0.67	NELMA
Stud		625	375	170	820	400	1,100,000	400,000		
Construction		925	550	170	820	850	1,200,000	440,000		
Standard	2" - 4" wide	525	300	170	820	650	1,100,000	400,000	0.67	NELMA
Utility		250	150	170	820	425	1,000,000	370,000		
REDWOOD										
Select Structural	2" & wider	1,100	625	160	425	1,100	1,100,000	400,000	0.37	RIS
No. 1		775	450	160	425	900	1,100,000	400,000		
No. 2		725	425	160	425	700	1,000,000	370,000		
No. 3	2" & wider	425	250	160	425	400	900,000	330,000	0.37	RIS
Stud		575	325	160	425	450	900,000	330,000		
Construction		825	475	160	425	925	900,000	330,000		
Standard	2" - 4" wide	450	275	160	425	725	900,000	330,000	0.37	RIS
Utility		225	125	160	425	475	800,000	290,000		
SPRUCE-PINE-FIR										
Select Structural	2" & wider	1,250	700	135	425	1,400	1,500,000	550,000	0.42	NLGA
No. 1/ No. 2		875	450	135	425	1,150	1,400,000	510,000		
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	0.42	NLGA
Construction		1,000	500	135	425	1,400	1,300,000	470,000		
Standard		2" - 4" wide	550	275	135	425	1,150	1,200,000		
Utility	275		125	135	425	750	1,100,000	400,000		

Analysis Example - HW3

Other wood species (Table 4A)

Table 4A 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)						Modulus of Elasticity	Specific Gravity ⁴	Grading Rules Agency
		Bending	Tension parallel to grain	Shear parallel to grain	Compression perpendicular to grain	Compression parallel to grain				
		F _b	F _t	F _v	F _{c⊥}	F _c	E	E _{min}	G	

Winter 2026

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Analysis Example - HW3

Q3-Q5

3	Load Duration Factor, CD	<input type="text"/>
4	Size Factor, CF	<input type="text"/>
5	Factored Allow. Modulus of Elasticity, E'min	<input type="text"/> PSI

Wide Width, **d1** **8 IN**

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

Grades	Width (depth)	F_b		F_t	F_c
		Thickness (breadth)			
		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
Stud	14" & wider	0.9	1.0	0.9	0.9
	2", 3", & 4"	1.1	1.1	1.1	1.05
	5" & 6"	1.0	1.0	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	1.0	1.0
Utility	4"	1.0	1.0	1.0	1.0
	2" & 3"	0.4	—	0.4	0.6

CF=1.05 **Q4**

Analysis Example - HW3

Q3-Q5

4.4.2 Wood Trusses

4.4.2.1 Increased chord stiffness relative to axial loads where a 2" x 4" or smaller sawn lumber truss compression chord is subjected to combined flexure and axial compression under dry service condition and has 3/8" or thicker wood structural panel sheathing nailed to the narrow face of the chord in accordance with code required roof sheathing fastener schedules (see References 32, 33, and 34), shall be permitted to be accounted for by multiplying the reference modulus of elasticity design value for beam and column stability, E_{min} , by the buckling stiffness factor, C_T , in column stability calculations (see 3.7 and Appendix H). When $\ell_e < 96"$, C_T shall be calculated as follows:

$$C_T = 1 + \frac{K_M \ell_e}{K_T E} \quad (4.4-1)$$

where:

ℓ_e = effective column length of truss compression chord (see 3.7), in.

K_M = 2300 for wood seasoned to 19% moisture content or less at the time of wood structural panel sheathing attachment.

= 1200 for unseasoned or partially seasoned wood at the time of wood structural panel sheathing attachment.

$K_T = 1 - 1.645(COV_E)$

= 0.59 for visually graded lumber

= 0.75 for machine evaluated lumber (MEL)

= 0.82 for products with $COV_E \leq 0.11$ (see Appendix F.2)

When $\ell_e > 96"$, C_T shall be calculated based on $\ell_e = 96"$.

Analysis Example - HW3

Q3-Q5

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

Given: $C_t=C_i=1.0$

$C_m=1.0$ (m.c.=15%)

$C_T=1.0$

Q3 $C_D=1.0$ (Live Load)

Q5 $E'_{min}=E_{min} \cdot C_m \cdot C_t \cdot C_i \cdot C_T=510000$ PSI

When m.c. $\leq 19\%$ $C_m=1.0$

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, $C_M = 1.0$

Analysis Example - HW3

Q6-Q8 and Q14

Narrow Width, d_2

2 IN

Wide Width, d_1

8 IN

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

Nominal Size $b \times d$	Standard Dressed Size (S4S) $b \times d$ in. x in.	Area of Section A in.^2	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_{xx} in.^3	Moment of Inertia I_{xx} in.^4	Section Modulus S_{yy} in.^3	Moment of Inertia I_{yy} in.^4	25 lbs/ft ³	30 lbs/ft ³	35 lbs/ft ³	40 lbs/ft ³	45 lbs/ft ³	50 lbs/ft ³
Boards¹												
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
Dimension Lumber (see NDS 4.1.3.2) and Decking (see NDS 4.1.3.5)												
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	3.906
3 x 6	2-1/2 x 5-1/2	13.75	12.60	34.66	5.729	7.161	2.387	2.865	3.342	3.819	4.297	4.774
3 x 8	2-1/2 x 7-1/4	18.13	21.90	79.39	7.552	9.440	3.147	3.776	4.405	5.035	5.664	6.293
3 x 10	2-1/2 x 9-1/4	23.13	35.65	164.9	9.635	12.04	4.015	4.818	5.621	6.424	7.227	8.030
3 x 12	2-1/2 x 11-1/4	28.13	52.73	296.6	11.72	14.65	4.883	5.859	6.836	7.813	8.789	9.766
3 x 14	2-1/2 x 13-1/4	33.13	73.15	484.6	13.80	17.25	5.751	6.901	8.051	9.201	10.35	11.50
3 x 16	2-1/2 x 15-1/4	38.13	96.90	738.9	15.89	19.86	6.619	7.943	9.266	10.59	11.91	13.24
4 x 4	3-1/2 x 3-1/2	12.25	7.15	12.51	7.146	12.51	2.127	2.552	2.977	3.403	3.828	4.253
4 x 5	3-1/2 x 4-1/2	15.75	11.81	26.58	9.188	16.08	2.734	3.281	3.828	4.375	4.922	5.469
4 x 6	3-1/2 x 5-1/2	19.25	17.65	48.53	11.23	19.65	3.342	4.010	4.679	5.347	6.016	6.684
4 x 8	3-1/2 x 7-1/4	25.38	30.66	111.1	14.80	25.90	4.405	5.286	6.168	7.049	7.930	8.811
4 x 10	3-1/2 x 9-1/4	32.38	49.91	230.8	18.89	33.05	5.621	6.745	7.869	8.993	10.12	11.24
4 x 12	3-1/2 x 11-1/4	39.38	73.83	415.3	22.97	40.20	6.836	8.203	9.570	10.94	12.30	13.67
4 x 14	3-1/2 x 13-1/4	46.38	102.41	678.5	27.05	47.34	8.051	9.661	11.27	12.88	14.49	16.10
4 x 16	3-1/2 x 15-1/4	53.38	135.66	1034	31.14	54.49	9.266	11.12	12.97	14.83	16.68	18.53

Given: $d_2=2''$ $d_1=8''$

From Table 1B:

2x8

$b \times d = 1.5'' \times 7.25''$

Q14 $A = 10.88 \text{ in}^2$

Analysis Example - HW3

Q6-Q8

End Support Conditions, K_e

K_e is a constant based on the end conditions

l is the actual length

l_e is the effective length (curved part)

$$l_e = K_e l$$

Table G1 Buckling Length Coefficients, K_e

Buckling modes						
Theoretical K_e value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design K_e when ideal conditions approximated	0.65	0.80	1.2	1.0	2.10	2.4
End condition code						
		Rotation fixed, translation fixed				
		Rotation free, translation fixed				
		Rotation fixed, translation free				
		Rotation free, translation free				

use these →

- 6 Strong Axis (x-x) Slenderness Ratio, l_{ex}/d_1
- 7 Weak Axis (y-y) Slenderness Ratio, l_{ey}/d_2
- 8 Controlling Slenderness Ratio, l_e/d

Strong Axis Length, L_1

11 FT

Weak Axis Length, L_2

3.666666667 FT

Transfer to inch

$K_e=1.0$
 $l_{ex}=L_1$
 $l_{ey}=L_2$

From Table 1B:
 2×8
 $b \times d = 1.5'' \times 7.25''$

Q6 $l_{ex}/d_1 = 11 \times 12 / 7.25 = 16.5 < 50$

Q7

$l_{ey}/d_2 = 3.666666667 \times 12 / 1.5 = 29.33 < 50$

Q8 $l_e/d = 29.33$ (max)

Analysis Example - HW3

Q9-Q15

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	Resistance Factor	Time Effect Factor	
													K_F	ϕ		
$F_b' = F_b$	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	
$F_{cL}' = F_{cL}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_b	1.67	0.90	-	
$E' = E$	x	-	C_M	C_t	-	-	C_{fu}^1	C_i	-	-	-	-	-	-	-	
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	C_{fu}^1	C_i	-	-	C_T	-	1.76	0.85	-	

¹ Where sawn lumber of Beam and Stringer grades is subject to loads causing flatwise bending or buckling, reference modulus of elasticity (E or E_{min}) shall be multiplied by the flat use factor, C_{fu} , specified in Table 4D of the NDS Supplement; otherwise, $C_{fu} = 1.0$.

Analysis Example - HW3

Q9-Q12

Given: $C_t=C_i=1.0$

$CF=1.05$

$CD=1.0$ (Live Load)

$C_m=1.0$ (m.c.=15%)

Q1 $F_c=1150$ PSI

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

where:

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

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

Q11 $c = 0.8$ for sawn lumber

$c = 0.85$ for round timber poles and piles

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

Q5

$$F_{cE} = \frac{0.822 (510000)}{(29.33)^2} = 487.32 \text{ psi} \quad \text{Q9}$$

Q8

$$F_c^* = F_c \cdot C_D \cdot C_M \cdot C_t \cdot C_F \cdot C_i$$
$$= 1150 \times 1.05 = 1207.5 \text{ psi} \quad \text{Q10}$$

$$C_p = \frac{1 + \left(\frac{487.32}{1207.5} \right)}{2(0.8)} - \sqrt{\left[\frac{1 + \left(\frac{487.32}{1207.5} \right)}{2(0.8)} \right]^2 - \frac{\left(\frac{487.32}{1207.5} \right)}{0.8}}$$
$$= 0.3623 \quad \text{Q12}$$

Analysis Example - HW3

Q13 Q15

13 Factored Allow. Compressive Stress, F'_c PSI

15 Maximum Allowable Axial Load Capacity, P_{max} LBS

Q13
$$F'_c = F_c \cdot C_D \cdot C_M \cdot C_t \cdot C_F \cdot C_i \cdot C_p$$
$$= 1150 \times 1.05 \times 0.3623$$
$$= 437.48 \text{ psi}$$

Q15
$$P_{max} = F'_c \cdot A = 437.48 \times 10.88 = 4759.78 \text{ LBS}$$

Q14 From Table 1B