Arch 324 Structures II

Winter 2026 Recitation 004

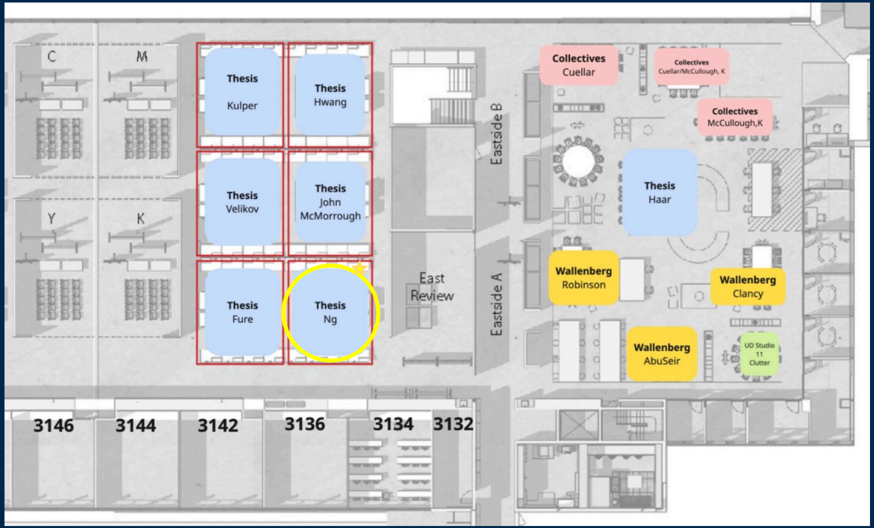
Peter von Bülow
Amely Wackerbauer

TAUBMAN COLLEGE

GSI Info :)

Amely Wackerbauer awackerb@umich.edu

Office Hours: By Appointment
Studio Location: TN (Ng)'s Thesis Studio + Research Room



TAUBMAN
COLLEGE

Recitation 004

Welcome to session 2!

- Quick Lecture Recap
- Homework #2 Wood Beam Design
- No lab today

Feel free to ask questions anytime

TAUBMAN COLLEGE

Lecture: Wood Beam Design (1/14)

Analysis Procedure (capacity)

Given: member size, material and span.
Req'd: Max. Safe Load (**capacity**)

1. Determine F_b and F'_b
2. Assume $f_b = F'_b$
   - Maximum actual = allowable stress
3. Solve stress equations for force
   - $M = f_b S$
   - $V = 0.66 f_v A$
4. Use maximum moment to find loads
   - Back calculate a load from moment
   - Assumes moment controls
5. Check Shear
   - Use load found is step 4 to check shear stress.
   - If it fails ($f_v > F'_v$), then find load based on shear.
6. Check deflection
7. Check bearing

Design Procedure

Given: load, wood and grade, span, other usage conditions
Req'd: member size

1. **Find Max Shear & Moment**
   - Simple case – equations
   - Complex case - diagrams
2. **Determine allowable stresses, F_b**
   - Apply usage factors to get F'_b
3. **Solve $S = M/F_b'$**
4. **Choose a section from Table 1B**
   - Revise DL and F_b'
   - Check step 3 and revise.
5. **Check shear stress**
   - First for V max (easier)
   - If that fails, try V at d distance from support.
   - If the section still fails, choose a new section with $A=1.5V/F_v'$
6. **Check deflection**
7. **Check bearing**

TAUBMAN COLLEGE

Lecture: Wood Column Analysis (1/21)

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	-

TAUBMAN COLLEGE

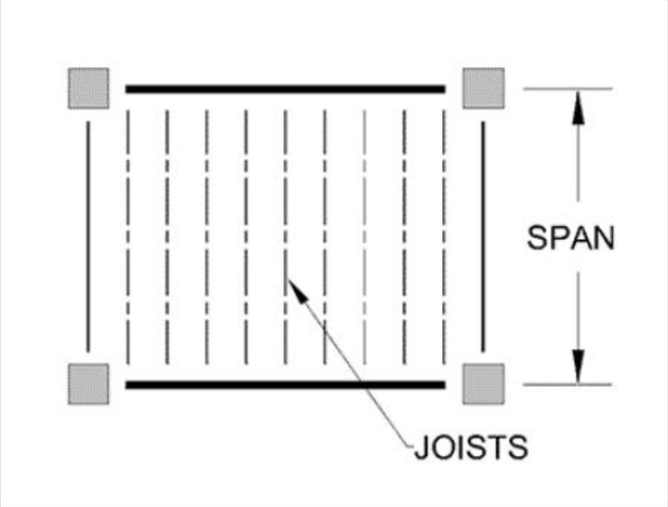
HW #2: Wood Beam Design

2. Wood Beam Design

Design a 2x dimensioned lumber floor joist to carry the given dead + live floor load (neglect joist selfweight). Assume the floor meets conditions of 4.4.1 so CL=1.0. Also Ct", Cfu," and Ci = 1.0. Find the short term deflection of your chosen beam under live load only (100% LL is short term). Compare your LL deflection with the code limit of L/360.

DATASET: 1 -2- -3-

Wood Species	WESTERN CEDARS
Wood Grade	No.1
Span	16 FT
Joist Spacing, o.c.	16 IN
Moisture Content, m.c.	12 %
Floor DL	7 PSF
Floor LL	40 PSF



HW #2: Wood Beam 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.)

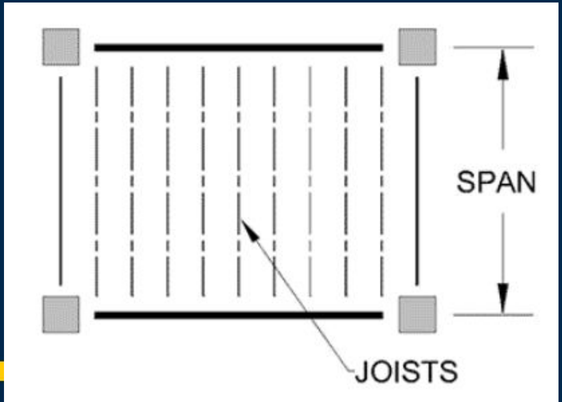
USE WITH TABLE 4A ADJUSTMENT FACTORS

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		

TAUBMAN COLLEGE

HW #2: Wood Beam Design

DATASET: 1	-2- -3-
Wood Species	WESTERN CEDARS
Wood Grade	No.1
Span	16 FT
Joist Spacing, o.c.	16 IN
Moisture Content, m.c.	12 %
Floor DL	7 PSF
Floor LL	40 PSF



m.c. = 12%
DL = 7 PSF
LL = 40 PSF
joist spacing = 16in
neglect joist selfweight

$w = DL + LL$
$= 7 + 40 = $ **47 PSF** → Answer to #4

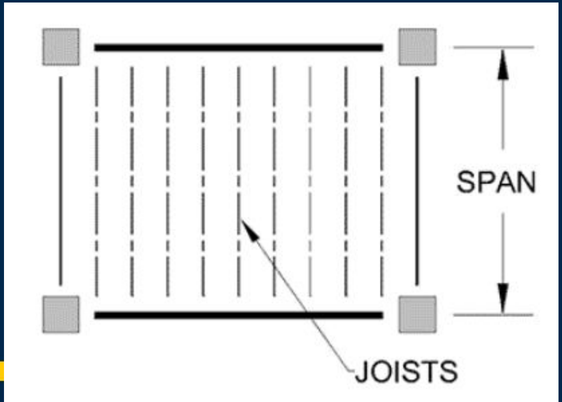
joist spacing = 16in

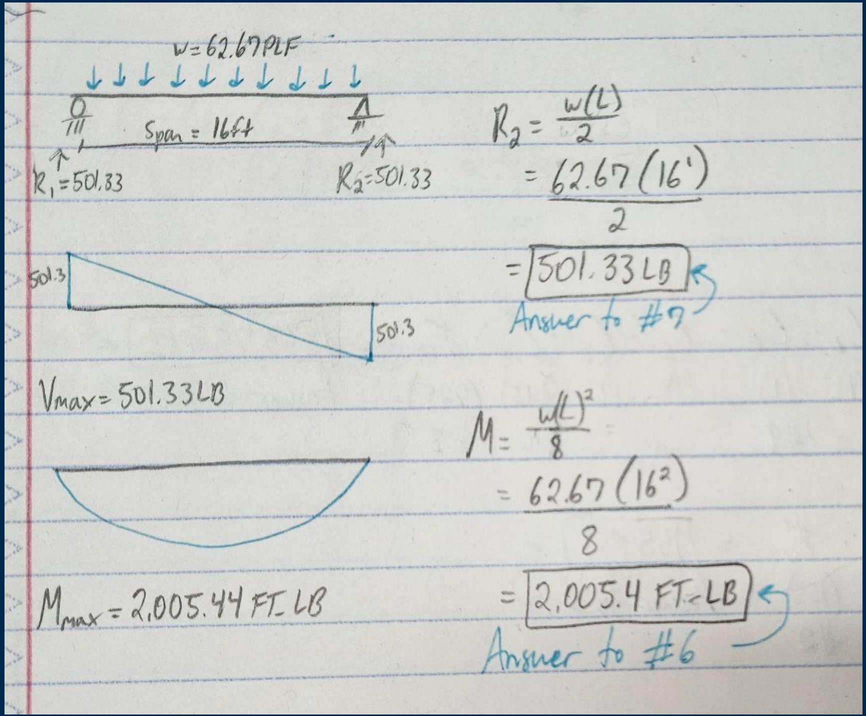
$w = 47 \times \frac{16}{12} = $ **62.67 PLF** → Answer to #5

convert!

HW #2: Wood Beam Design

DATASET: 1	-2- -3-
Wood Species	WESTERN CEDARS
Wood Grade	No.1
Span	16 FT
Joist Spacing, o.c.	16 IN
Moisture Content, m.c.	12 %
Floor DL	7 PSF
Floor LL	40 PSF





HW #2: Wood Beam Design

The following formula shall be used to determine the density in lbs/ft^3 of wood:

$$\text{density} = 62.4\left[\frac{G}{1 + G(0.009)(\text{m.c.})}\right]\left[1 + \frac{\text{m.c.}}{100}\right]$$

where:

G = specific gravity of wood

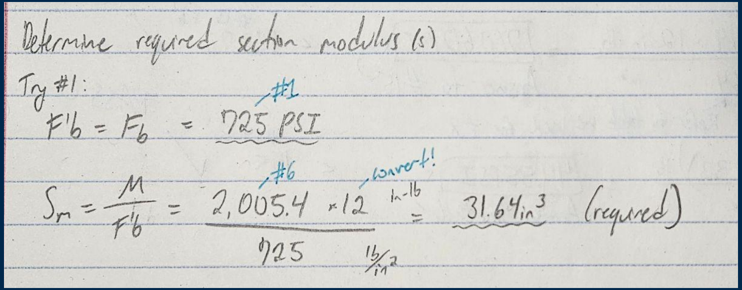
m.c. = moisture content of wood, %

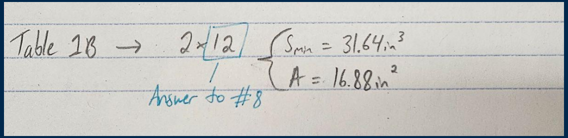
TAUBMAN COLLEGE

HW #2: Wood Beam Design

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

Nominal Size b x d	Standard Dressed Size (S4S) b x d in. x in.	Area of Section A in.^{2}	X-X AXIS Section Modulus S_{xx} in.^{3}	X-X AXIS Moment of Inertia I_{xx} in.^{4}	Y-Y AXIS Section Modulus S_{yy} in.^{3}	Y-Y AXIS Moment of Inertia I_{yy} in.^{4}	Approximate weight in pounds per linear foot (lbs/ft) of piece when density of wood equals: 25 lbs/ft^3	30 lbs/ft^3	35 lbs/ft^3	40 lbs/ft^3	45 lbs/ft^3	50 lbs/ft^3
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





TAUBMAN COLLEGE

HW #2: Wood Beam 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

Grades	Width (depth)	F_b Thickness (breadth) 2" & 3"	F_b Thickness (breadth) 4"	F_t	F_c
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

TAUBMAN COLLEGE

HW #2: Wood Beam Design

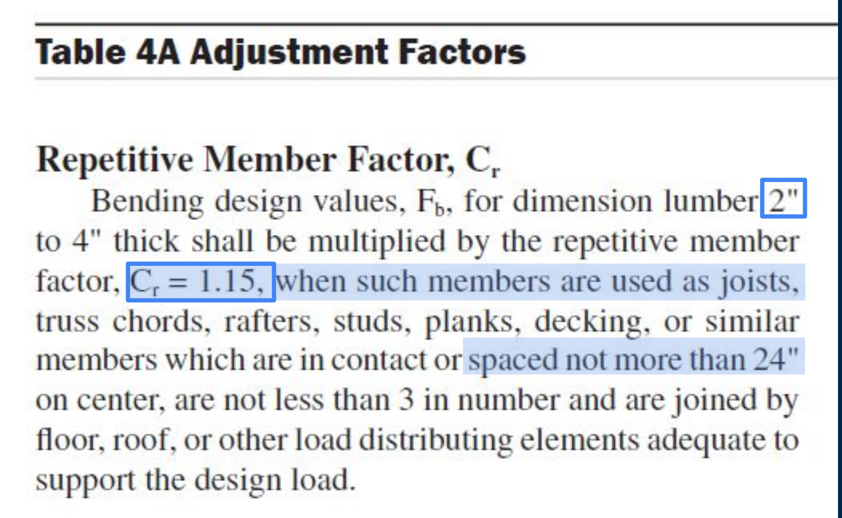


Table 4A Adjustment Factors

Repetitive Member Factor, C_r

Bending design values, F_b, for dimension lumber 2" to 4" thick shall be multiplied by the repetitive member factor, $C_r = 1.15$, when such members are used as joists, truss chords, rafters, studs, planks, decking, or similar members which are in contact or spaced not more than 24" on center, are not less than 3 in number and are joined by floor, roof, or other load distributing elements adequate to support the design load.

HW #2: Wood Beam Design

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 $(F_b)(C_F) \le 1{,}150$ psi, $C_M = 1.0$

** when $(F_c)(C_F) \le 750$ psi, $C_M = 1.0$

if $(F_b)(C_F) \le 1{,}150 \rightarrow C_M = 1.0$

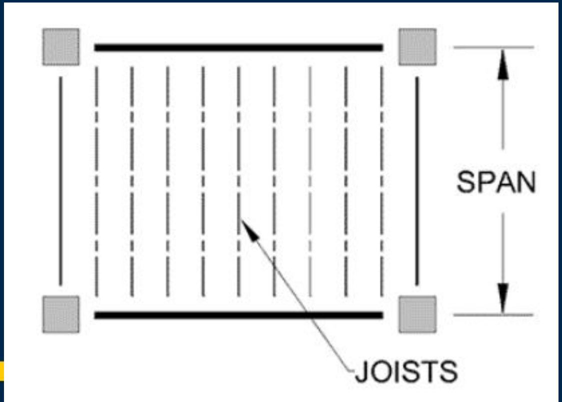
$> 1{,}150 \rightarrow C_M = 0.85$

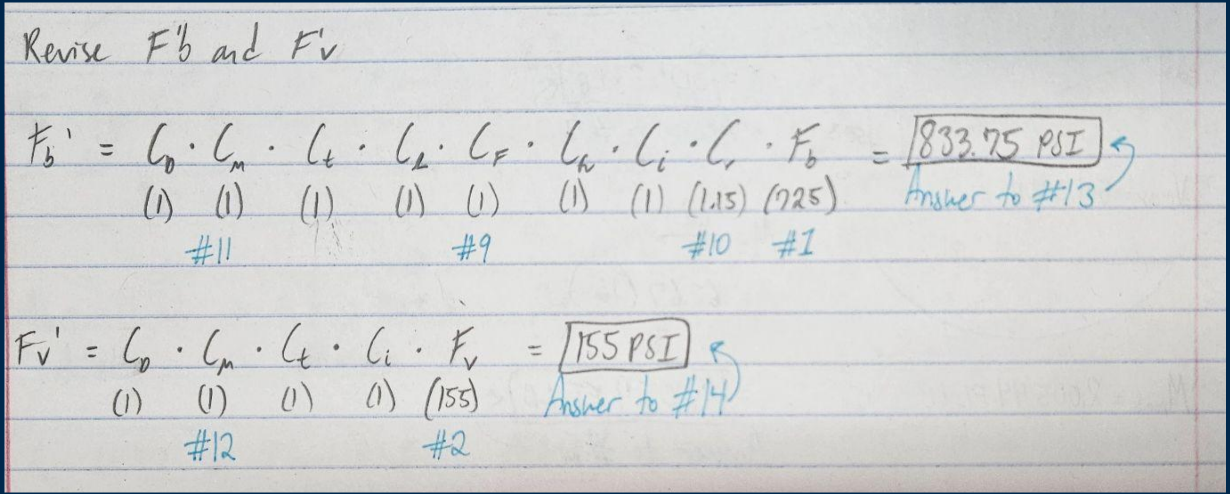
#1, #9

$725(1) \le 1{,}150$!

HW #2: Wood Beam Design

DATASET: 1	-2- -3-
Wood Species	WESTERN CEDARS
Wood Grade	No.1
Span	16 FT
Joist Spacing, o.c.	16 IN
Moisture Content, m.c.	12 %
Floor DL	7 PSF
Floor LL	40 PSF

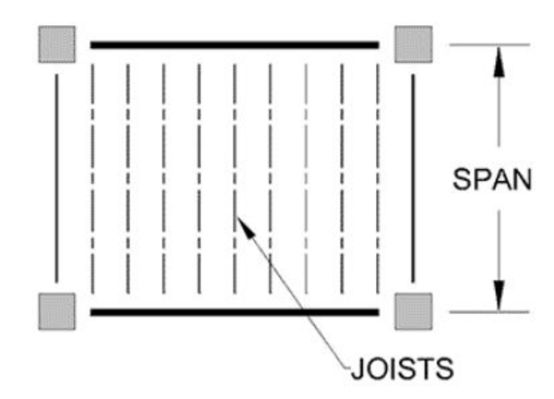


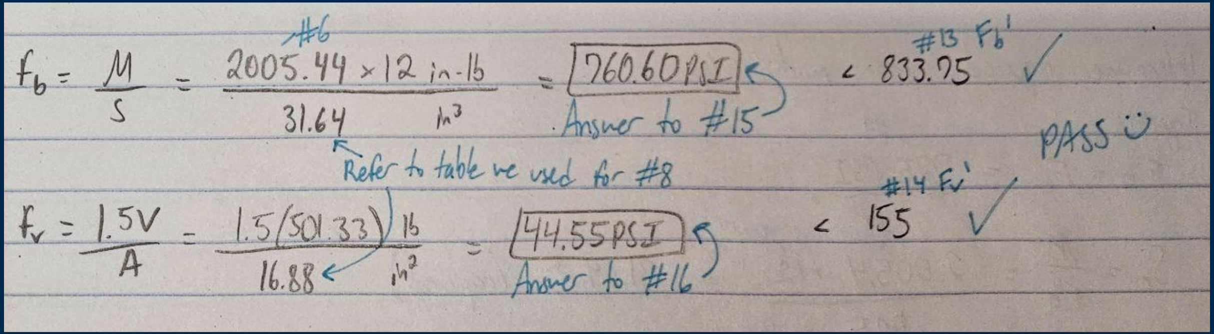


TAUBMAN
COLLEGE

HW #2: Wood Beam Design

DATASET: 1	-2- -3-
Wood Species	WESTERN CEDARS
Wood Grade	No.1
Span	16 FT
Joist Spacing, o.c.	16 IN
Moisture Content, m.c.	12 %
Floor DL	7 PSF
Floor LL	40 PSF





TAUBMAN COLLEGE

HW #2: Wood Beam Design

3.5 Bending Members – Deflection

3.5.1 Deflection Calculations

If deflection is a factor in design, it shall be calculated by standard methods of engineering mechanics considering bending deflections and, when applicable, shear deflections. Consideration for shear deflection is required when the reference modulus of elasticity has not been adjusted to include the effects of shear deflection (see Appendix F).

3.5.2 Long-Term Loading

Where total deflection under long-term loading must be limited, increasing member size is one way to provide extra stiffness to allow for this time dependent deformation (see Appendix F). Total deflection, Δ_T, shall be calculated as follows:

$$\Delta_T = K_{cr}\,\Delta_{LT} + \Delta_{ST} \qquad (3.5\text{-}1)$$

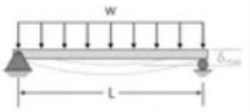
where:

K_{cr} = time dependent deformation (creep) factor

= 1.5 for seasoned lumber, structural glued laminated timber, prefabricated wood I-joists, or structural composite lumber used in dry service conditions as defined in 4.1.4, 5.1.4, 7.1.4, and 8.1.4, respectively.

TABLE 1604.3 DEFLECTION LIMITS[a, b, c, h, i]

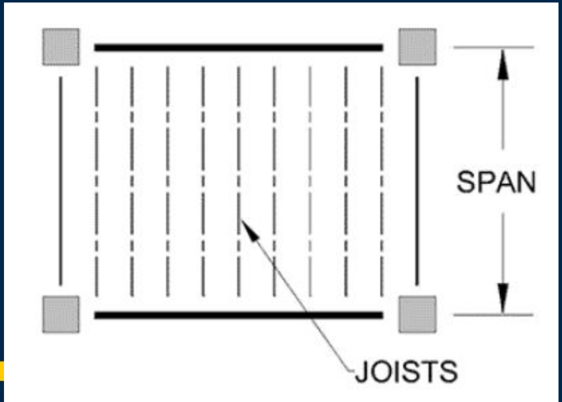
CONSTRUCTION	L	S or W^f	$D + L^{d,g}$
Roof members:[e]			
Supporting plaster or stucco ceiling	l/360	l/360	l/240
Supporting nonplaster ceiling	l/240	l/240	l/180
Not supporting ceiling	l/180	l/180	l/120
Floor members	l/360	—	l/240
Exterior walls:			
With plaster or stucco finishes	—	l/360	—
With other brittle finishes	—	l/240	—
With flexible finishes	—	l/120	—
Interior partitions:[b]			
With plaster or stucco finishes	l/360	—	—
With other brittle finishes	l/240	—	—
With flexible finishes	l/120	—	—
Farm buildings	—	—	l/180
Greenhouses	—	—	l/120

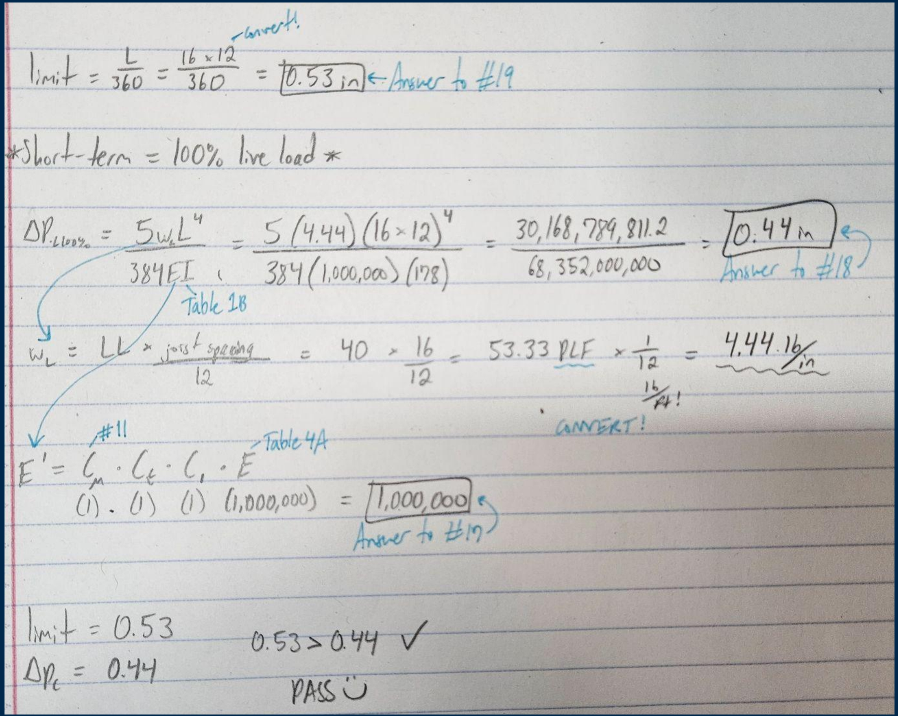


$$\delta_{max} = \frac{5wL^4}{384EI}$$

HW #2: Wood Beam Design

DATASET: 1	-2- -3-
Wood Species	WESTERN CEDARS
Wood Grade	No.1
Span	16 FT
Joist Spacing, o.c.	16 IN
Moisture Content, m.c.	12 %
Floor DL	7 PSF
Floor LL	40 PSF

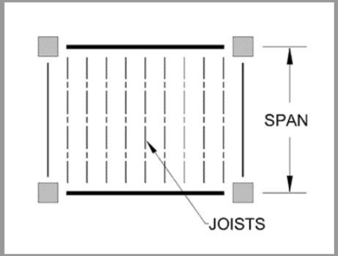




HW #2: Wood Beam Design

2. Wood Beam Design

Design a 2x dimensioned lumber floor joist to carry the given dead + live floor load (neglect joist selfweight). Assume the floor meets conditions of 4.4.1 so CL=1.0. Also Ct", Cfu," and Ci = 1.0. Find the short term deflection of your chosen beam under live load only (100% LL is short term). Compare your LL deflection with the code limit of L/360.



DATASET: 1 -2- -3-

Wood Species	WESTERN CEDARS
Wood Grade	No.1
Span	16 FT
Joist Spacing, o.c.	16 IN
Moisture Content, m.c.	12 %
Floor DL	7 PSF
Floor LL	40 PSF

Your answer was correct.
You scored 5 points.

#	Question	Your Response	Correct Answer	Score
1	Tabulated Allow. Bending Stress, Fb	725 PSI	725 PSI	5
2	Tabulated Allow. Shear Stress, Fv	155 PSI	155 PSI	5
3	Tabulated Modulus of Elasticity, E	1000000 PSI	1000000 PSI	5
4	Total Applied Floor Load, (DL+LL)	47 PSF	47 PSF	5
5	Load on Joist, w	62.67 PLF	62.66666667 PLF	5
6	Actual Beam Bending Moment, M	2005.44 FT-LB	2005.333333 FT-LB	5
7	Actual Maximum Shear Force (at reaction) , V	501.33 LBS	501.3333333 LBS	5
8	Nominal Depth of the Final Joist Used	12 IN	12 IN	5
9	Size Factor, CF	1	1	5
10	Repetetive Member Factor, Cr	1.15	1.15	5
11	Wet Service Factor for Fb, CM_b	1	1	5
12	Wet Service Factor for Fv, CM_v	1	1	5
13	Factored Allow. Bending Stress, F'b	833.75 PSI	833.75 PSI	5
14	Factored Allow. Shear Stress, F'v	155 PSI	155 PSI	5
15	Actual Bending Stress, fb_actual	760.6 PSI	760.5412346 PSI	5
16	Actual Shear Stress, fv_actual	44.55 PSI	44.56296296 PSI	5
17	Factored Allow. Modulus of Elasticity, E'	1000000 PSI	1000000 PSI	5
18	Short Term Deflection for 100% LL	0.44 IN	0.441869063 IN	5
19	Short Term Deflection Limit for L/360	0.53 IN	0.533333333 IN	5
20	Deflection Passing: enter "1" for pass or "0" for fail	1 (1 or 0)	1 (1 or 0)	5

TAUBMAN COLLEGE

GSI Info :)

Amely Wackerbauer awackerb@umich.edu

Office Hours: By Appointment
Studio Location: TN (Ng)'s Thesis Studio + Research Room

TAUBMAN COLLEGE