Wood Beam Design 1/26

HW2 Wood Beam Design

Structure II
Section 004

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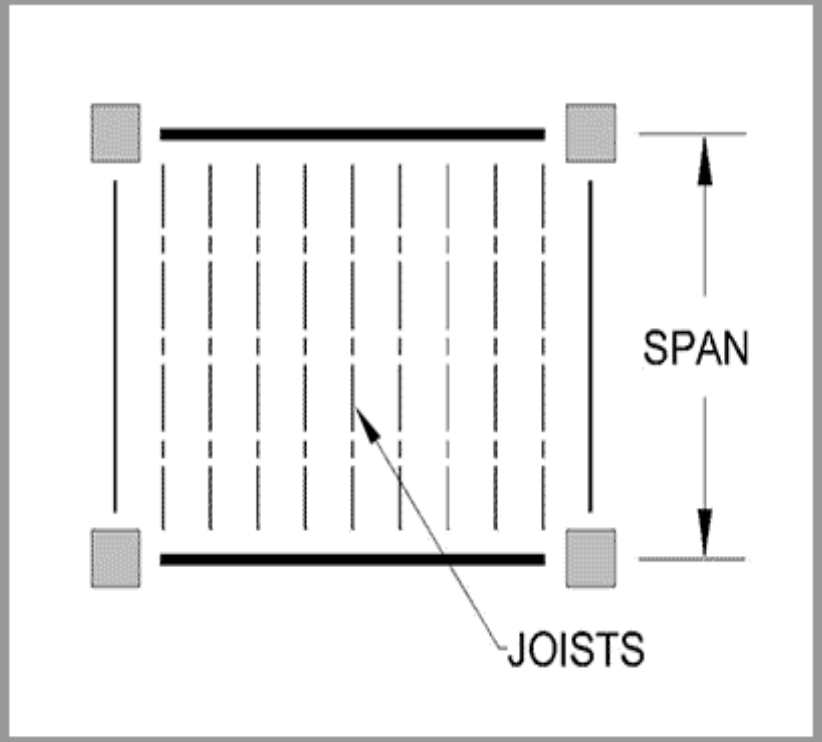
HW2 - Wood Beam Design

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



Given:
certain wood type
beam span
loading

Goal:
member size?
deflection?

Allowable Stress Design by NDS
Flexure

$F_b' \geq f_b$

Allowable Flexure Stress F_b'

F_b from NDS Supplement tables determined by species and grade

$\mathbf{F_b'} = F_b$ (usage factors)

usage factors for flexure:

- C_D Load Duration Factor
- C_M Moisture Factor
- C_t Temperature Factor
- C_L Beam Stability Factor
- C_F Size Factor
- C_{fu} Flat Use
- C_i Incising Factor
- C_r Repetitive Member Factor

$\geq$

Actual Flexure Stress f_b

$\mathbf{f_b} = Mc/I = M/S$

$S = I/c = bd^2/6$

Allowable Stress Design by NDS
Shear

$F_v' \geq f_v$

Allowable Shear Stress Fv'

F_v from tables determined by species and grade

$\mathbf{F_v'} = F_v$ (usage factors)

usage factors for shear:

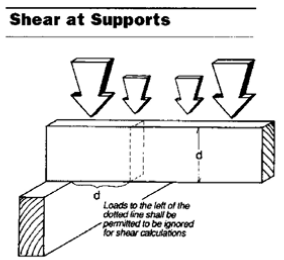
- C_D Load Duration Factor
- C_M Moisture Factor
- C_t Temperature Factor
- C_i Incising Factor

$\geq$

Actual Shear Stress fv

$\mathbf{f_v} = VQ / I\, b = 1.5\, V/A$

Can use V at d from support as maximum



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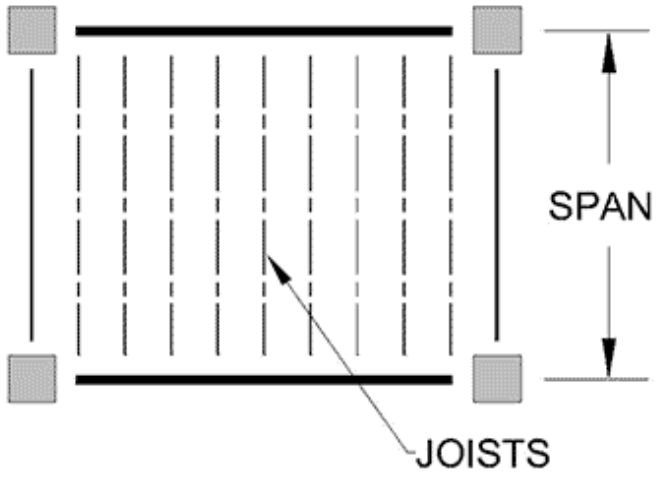

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1. Tabulated Allow. Bending Stress, Fb = 725 psi

2. Tabulated Allow. Shear Stress, Fv = 155 psi

3. Tabulated Modulus of Elasticity, E = 1000000 psi

NDS Supplement table 4A

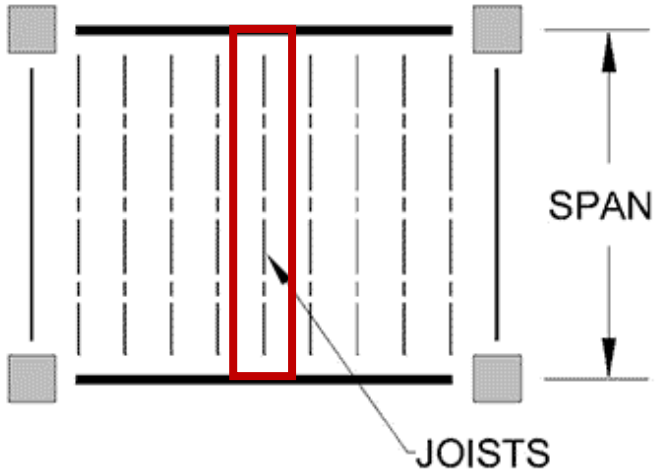
Table 4A (Cont.)

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 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	Modulus of Elasticity 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		



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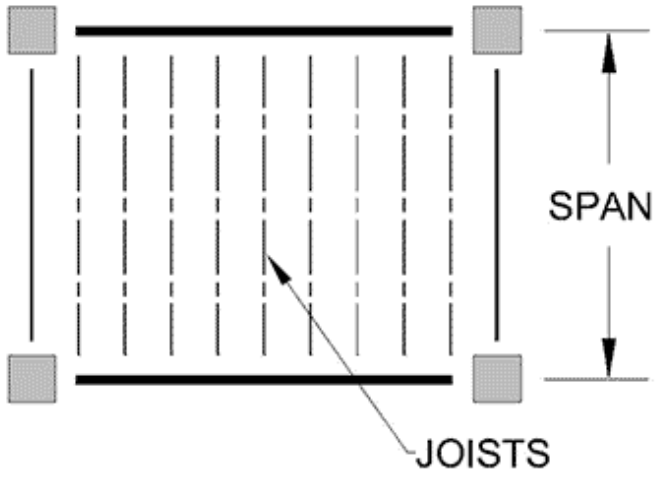
Joist Spacing, o.c.	16 IN
Moisture Content, m.c.	12 %
Floor DL	7 PSF
Floor LL	40 PSF

4. Total Applied Floor Load, (DL+LL)

7+40=47 PSF

5. Load on Joist, w

W=(DL+LL)*o.c.= 47*16/12 = 62.6 plf



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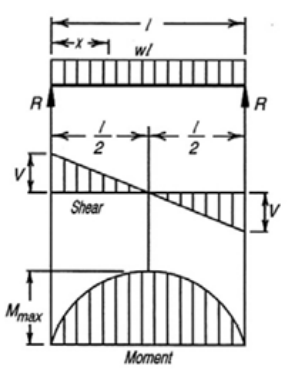
6. Actual Beam Bending Moment, M

1. SIMPLE BEAM—UNIFORMLY DISTRIBUTED LOAD

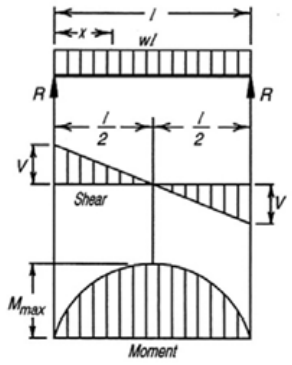


Total Equiv. Uniform Load	$= wl$
$R = V$	$= \frac{wl}{2}$
V_x	$= w\left(\frac{l}{2} - x\right)$
M_{max} (at center)	$= \frac{wl^2}{8}$
M_x	$= \frac{wx}{2}(l - x)$
Δ_{max} (at center)	$= \frac{5wl^4}{384EI}$
Δ_x	$= \frac{wx}{24EI}(l^3 - 2lx^2 + x^3)$

M = w*span²/8 = 62.66*16²/8 = 2005.12 lbs-ft

7. Actual Maximum Shear Force (at reaction), V

1. SIMPLE BEAM—UNIFORMLY DISTRIBUTED LOAD



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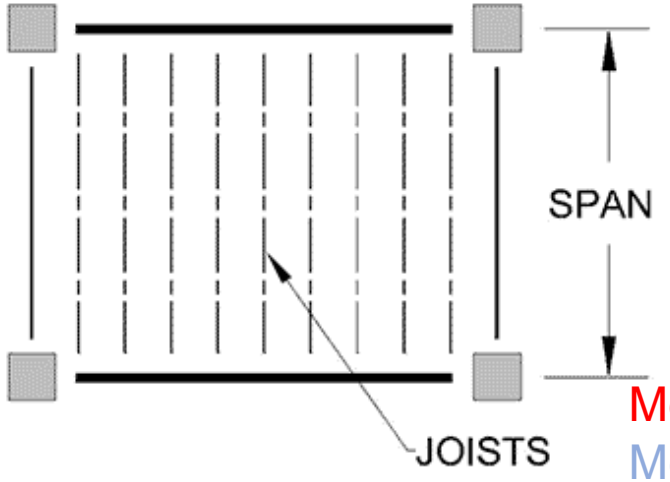
M_{max} (at center)	$= \frac{wl^2}{8}$
M_x	$= \frac{wx}{2}(l - x)$
Δ_{max} (at center)	$= \frac{5wl^4}{384EI}$
Δ_x	$= \frac{wx}{24EI}(l^3 - 2lx^2 + x^3)$

V = w*span/2 = 62.66*16/2 = 501.28 lbs

8. Nominal Depth of the Final Joist Used



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Floor DL	7 PSF
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M, V (actual load)

Fb, (based on the wood type)

F'=F*factor

Sx=M/Fb'

Rough Fb' (without size factor CF and CM)

Estimate Required Sx (rough)

Bigger size

Most efficient
Meet the estimated required Sx
Nominal

Choose member size

Fb'(with size factor CF and CM), Fv'

fb=M/Sx
fv=3V/2A

fb, fv

Fb'<fb?
Fv'<fv?

8. Nominal Depth of the Final Joist Used

table 4.3.1 from the MAIN NDS book

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
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_b	1.67	0.90	-
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	1.76	0.85	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	1.76	0.85	-

4 SAWN LUMBER

NDS Supplement table 4A

Wet Service Factor, C_M

1. 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:

Moisture Content = 12%,
12%<19%,
CM_b = CM_v = 1

Wet Service Factors, C_M

2.

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, $C_M = 1.0$

Tabulated Allow. Bending Stress

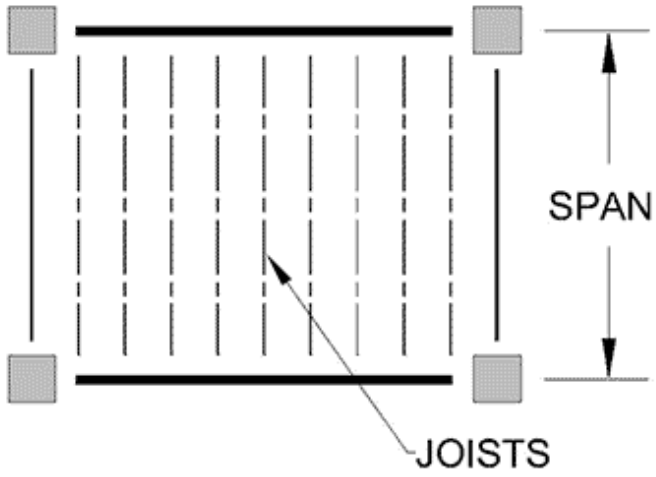
CF: size factor ?

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.

8. Nominal Depth of the Final Joist Used



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

Fb'_rough= Fb x(CD x CM_b x Ct x CL x ~~CF~~ x Cfu x Ci x Cr)
= 725*1*1.15 = 833.75 psi

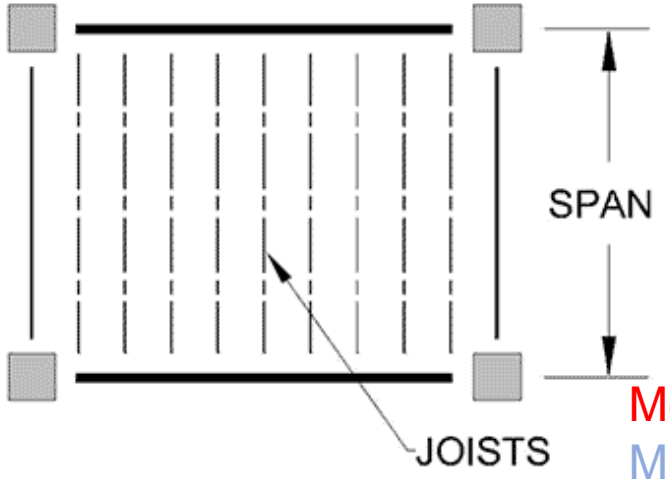
Sx_rough= M/Fb'_rough= 2005.12*12/833.75 = 28.86 in³

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

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/ft³	30 lbs/ft³	35 lbs/ft³	40 lbs/ft³	45 lbs/ft³	50 lbs/ft³
Boards[1]												
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

Choose 2" * 12" Sx = 31.64 in³ > 28.86 in³
A = 16.88 in²

8. Nominal Depth of the Final Joist Used



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Floor DL	7 PSF
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M, V (actual load)

Fb, (based on the wood type)

F'=F*factor

Sx=M/Fb'

Rough Fb' (without size factor CF and CM)

Estimate Required Sx (rough)

Bigger size

Most efficient
Meet the estimated required Sx
Nominal

Choose member size

Fb'(with size factor CF and CM), Fv'

fb=M/Sx
fv=3V/2A

fb, fv

Fb'<fb?
Fv'<fv?

8. Nominal Depth of the Final Joist Used

NDS Supplement table 4A

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

Wet Service Factor, C_M

1. 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}
2. 0.85*	1.0	0.97	0.67	0.8**	0.9

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

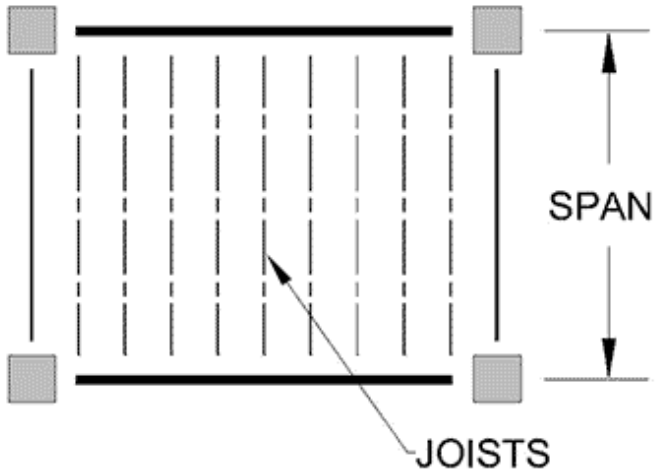
** when $(F_c)(C_F) \le 750$ psi, $C_M = 1.0$

Tabulated Allow. Bending Stress

CF: size factor

Moisture Content =12%,
12%<19%,
CM_b = CM_v = 1

8. Nominal Depth of the Final Joist Used



Fb' = Fb x(CD x CM_b x Ct x CL x CF x Cfu x Ci x Cr)
= 725*1*1*1.15 = 833.75 psi
fb = M/Sx = 2005.12*12/31.64 = 760.47 psi < 833.75 psi Pass

Fv' = Fvx (CD x CM_v x Ct x Ci)
= 155*1 = 155 psi
fv = 3V/2A = 3*501.28/(2*16.88) = 44.54 psi < 155 psi Pass

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Allowable Stress Design by NDS
Flexure

$F_b' \geq f_b$

Allowable Flexure Stress F_b'

F_b from NDS Supplement tables determined by species and grade

$F_b' = F_b$ (usage factors)

usage factors for flexure:
- C_D Load Duration Factor
- C_M Moisture Factor
- C_t Temperature Factor
- C_L Beam Stability Factor
- C_F Size Factor
- C_{fu} Flat Use
- C_i Incising Factor
- C_r Repetitive Member Factor

$\geq$

Actual Flexure Stress f_b

$f_b = Mc/I = M/S$

$S = I/c = bd^2/6$

Allowable Stress Design by NDS
Shear

$F_v' \geq f_v$

Allowable Shear Stress Fv'

F_v from tables determined by species and grade

$F_v' = F_v$ (usage factors)

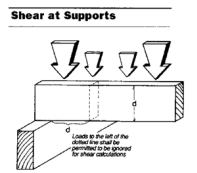
usage factors for shear:
- C_D Load Duration Factor
- C_M Moisture Factor
- C_t Temperature Factor
- C_i Incising Factor

$\geq$

Actual Shear Stress fv

$f_v = VQ / I\,b = 1.5\,V/A$

Can use V at d from support as maximum



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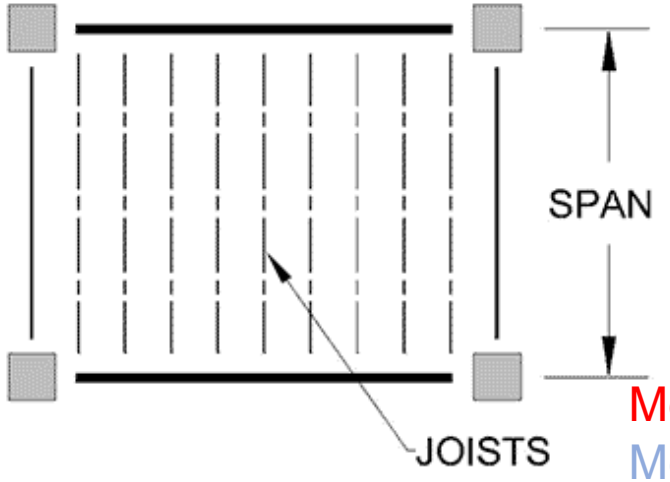

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M, V (actual load)

Fb, (based on the wood type)

F'=F*factor

Sx=M/Fb'

Rough Fb' (without size factor CF and CM)

Estimate Required Sx (rough)

Bigger size

Most efficient
Meet the estimated required Sx
Nominal

Choose member size

Fb'(with size factor CF and CM), Fv'

fb=M/Sx
fv=3V/2A

fb, fv

Fb'<fb?
Fv'<fv?

Input your answers to question 8-16

#	Question	Your Response	Correct Answer
1	Tabulated Allow. Bending Stress, Fb	725 PSI	725 PSI
2	Tabulated Allow. Shear Stress, Fv	155 PSI	155 PSI
3	Tabulated Modulus of Elasticity, E	1000000 PSI	1000000 PSI
4	Total Applied Floor Load, (DL+LL)	47 PSF	47 PSF
5	Load on Joist, w	62.66 PLF	62.66666667 PLF
6	Actual Beam Bending Moment, M	2005.12 FT-LB	2005.333333 FT-LB
7	Actual Maximum Shear Force (at reaction) , V	501.28 LBS	501.3333333 LBS
8	Nominal Depth of the Final Joist Used	12 IN	12 IN
9	Size Factor, CF	1	1
10	Repetetive Member Factor, Cr	1.15	1.15
11	Wet Service Factor for Fb, CM_b	1	1
12	Wet Service Factor for Fv, CM_v	1	1
13	Factored Allow. Bending Stress, F'b	833.75 PSI	833.75 PSI
14	Factored Allow. Shear Stress, F'v	155 PSI	155 PSI
15	Actual Bending Stress, fb_actual	760.47 PSI	760.5412346 PSI
16	Actual Shear Stress, fv_actual	44.54 PSI	44.56296296 PSI

17. Factored Allow. Modulus of Elasticity, E'(PSI)

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		

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
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	-	-	-	K_F	ϕ_b	λ
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	K_F	ϕ_t	λ
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	C_i	-	-	-	-	K_F	ϕ_v	λ
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_b	K_F	ϕ_c	λ
$F_c' = F_c$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	C_P	-	-	K_F	ϕ_c	λ
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	K_F	ϕ_s	-

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

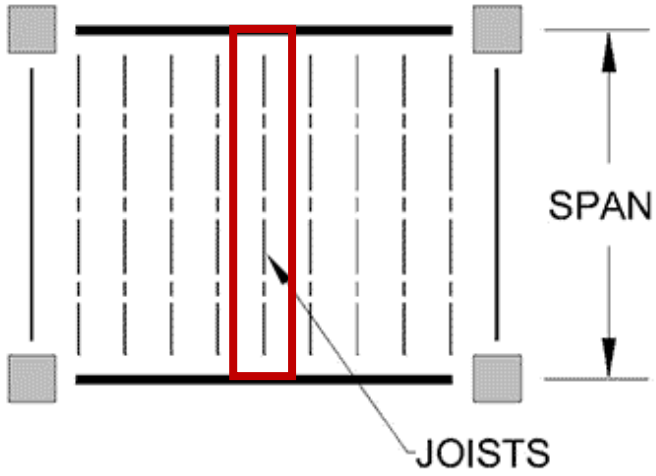
* when $(F_b)(C_F) \le 1{,}150$ psi, $C_M = 1.0$

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

Moisture Content =12%,
CM_E = 1

E' = E * (CM * Ct * Ci) = 1000000 x 1= 1000000 psi

18. Short Term Deflection for 100% LL



$$\Delta_{LL} = \frac{5 w_{LL} \ell^4}{384 E I}$$

w_LL = LL*o.c. = 40*16in/12 = 53.33 plf

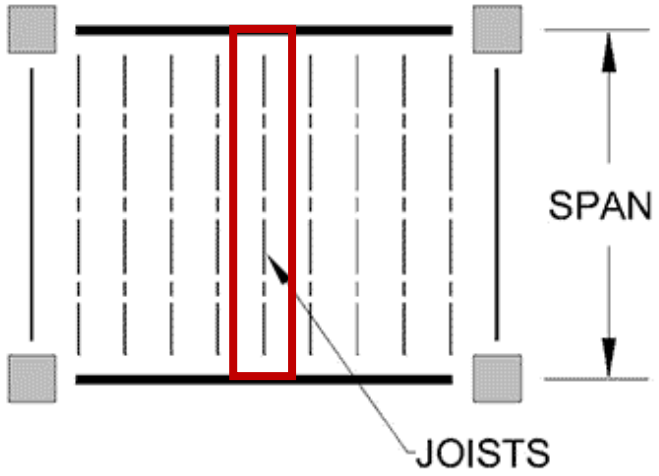
Deflection = 5 * w_LL * Span^4 / (384 * E' * I)

= 5 * (53.33 * $\frac{1}{12}$) * (16*12)^4 / (384 * 1000000 * 178) = 0.44 in

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

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

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
Boards[1]												
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



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

19. Short Term Deflection Limit for L/360

Deflection_limit = L/360 = Span/360 = 16*12/360 = 0.53 in

20. Deflection Passing, 1 for pass, 0 for fail

0.44 in < 0.53 in Pass!

Any Questions?

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Thank You!