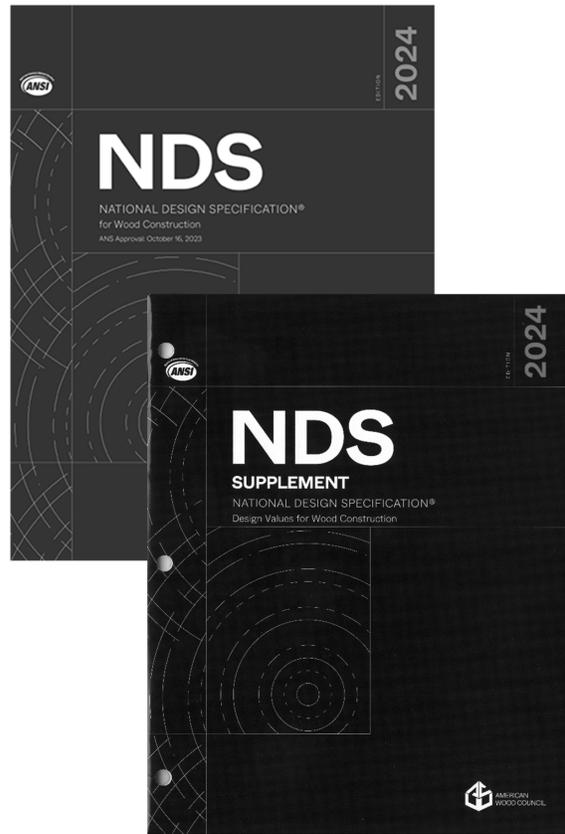


Wood Beam Design

- Wood Beam Capacity Analysis
- Wood Beam Design



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 in 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

Table 4A (Cont.) Reference Design Values for Visual (2" - 4" thick)^{1,2,3}

(All species except Southern Pine— see duration and dry service conditions. See NDS adjustment factors.)

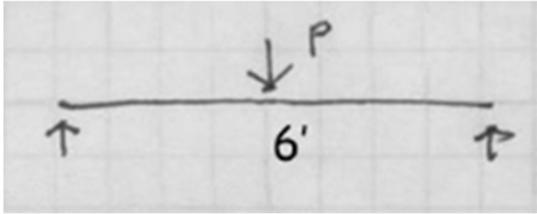
		USE WITH TABLE 4A A1		
Species and commercial grade	Size classification	Design val		
		Bending F_b	Tension parallel to grain F_t	Shear parallel to grain F_v
SPRUCE-PINE-FIR				
Select Structural		1,250	700	135
No. 1/ No. 2	2" & wider	875	450	135
No. 3		500	250	135
Stud	2" & wider	675	350	135
Construction Standard		1,000	500	135
Utility	2" - 4" wide	550	275	135
		275	125	135

from NDS 2012

Analysis Example (capacity)

Given: member size, material and span.

Req'd: Max. Safe Load (capacity)



using SPF No.2 and 10 min load

1. Determine F_b and F'_b
2. Assume $f_b = F'_b$
 - Maximum actual = allowable stress
3. Solve stress equations for force
 - $M = f_b S$ (i.e. moment capacity)

GIVEN : SPAN = 6' P@C
SECTION = 2x4 (1.5x3.5)
NDS Table 4A $F_b = 875 \text{ psi}$ $F_v = 135 \text{ psi}$
REQ'D : MAXIMUM LOAD P

$$f_b = F'_b = F_b C_D C_F$$
$$F'_b = 2100 \text{ psi}$$

NDS Sup. Table 1B

$$S_x = 3.063 \text{ in}^3$$

$$M_t = F'_b S_x = 2100 (3.063)$$
$$= 6432.3 \text{ in} \cdot \text{lb}$$
$$= 536 \text{ ft} \cdot \text{lb}$$

Analysis Example (capacity)

3. Use maximum forces to find loads
 - Back calculate a maximum load from moment capacity

$$M_t = PL/4$$
$$P = M_t 4/L$$
$$P = 536 (4)/6$$
$$P = 357 \text{ lb}$$

4. Check shear

- Check shear for load capacity from step 3.
- Use P from moment to find V_{max}
- Check that $f_v < F'_v$

$$V_{max} = P/2 = 357/2 = 178.5 \text{ lb}$$
$$f_v = \frac{3}{2} \frac{V}{A} = 1.5 \frac{178.5}{5.25} = 51 \text{ psi}$$

4. Check deflection (serviceability)

5. Check bearing (serviceability)

$$51 \text{ psi} < 216 \text{ psi} \checkmark \text{OK}$$

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

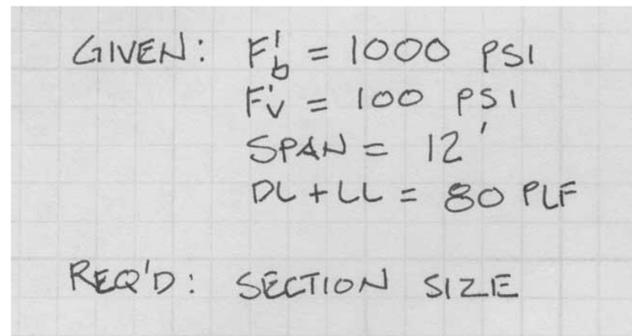
7. Check bearing

Nominal Size b x d	Standard Dressed Size (S4S) b x d in. x in.	Area of Section A in. ²	X-X AXIS		Y-Y AXIS	
			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
Boards¹						
1 x 3	3/4 x 2-1/2	1.875	0.781	0.977	0.234	0.088
1 x 4	3/4 x 3-1/2	2.625	1.531	2.680	0.328	0.123
1 x 6	3/4 x 5-1/2	4.125	3.781	10.40	0.516	0.193
1 x 8	3/4 x 7-1/4	5.438	6.570	23.82	0.680	0.255
1 x 10	3/4 x 9-1/4	6.938	10.70	49.47	0.867	0.325
1 x 12	3/4 x 11-1/4	8.438	15.82	88.99	1.055	0.396
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
2 x 4	1-1/2 x 3-1/2	5.250	3.06	5.359	1.313	0.984
2 x 5	1-1/2 x 4-1/2	6.750	5.06	11.39	1.688	1.266
2 x 6	1-1/2 x 5-1/2	8.250	7.56	20.80	2.063	1.547
2 x 8	1-1/2 x 7-1/4	10.88	13.14	47.63	2.719	2.039
2 x 10	1-1/2 x 9-1/4	13.88	21.39	98.93	3.469	2.602
2 x 12	1-1/2 x 11-1/4	16.88	31.64	178.0	4.219	3.164
2 x 14	1-1/2 x 13-1/4	19.88	43.89	290.8	4.969	3.727
3 x 4	2-1/2 x 3-1/2	8.75	5.10	8.932	3.646	4.557
3 x 5	2-1/2 x 4-1/2	11.25	8.44	18.98	4.688	5.859
3 x 6	2-1/2 x 5-1/2	13.75	12.60	34.66	5.729	7.161
3 x 8	2-1/2 x 7-1/4	18.13	21.90	79.39	7.552	9.440
3 x 10	2-1/2 x 9-1/4	23.13	35.65	164.9	9.635	12.04
3 x 12	2-1/2 x 11-1/4	28.13	52.73	296.6	11.72	14.65
3 x 14	2-1/2 x 13-1/4	33.13	73.15	484.6	13.80	17.25
3 x 16	2-1/2 x 15-1/4	38.13	96.90	738.9	15.89	19.86
4 x 4	3-1/2 x 3-1/2	12.25	7.15	12.51	7.146	12.51
4 x 5	3-1/2 x 4-1/2	15.75	11.81	26.58	9.188	16.08
4 x 6	3-1/2 x 5-1/2	19.25	17.65	48.53	11.23	19.65
4 x 8	3-1/2 x 7-1/4	25.38	30.66	111.1	14.80	25.90
4 x 10	3-1/2 x 9-1/4	32.38	49.91	230.8	18.89	33.05
4 x 12	3-1/2 x 11-1/4	39.38	73.83	415.3	22.97	40.20
4 x 14	3-1/2 x 13-1/4	46.38	102.41	678.5	27.05	47.34
4 x 16	3-1/2 x 15-1/4	53.38	135.66	1034	31.14	54.49

Design Example

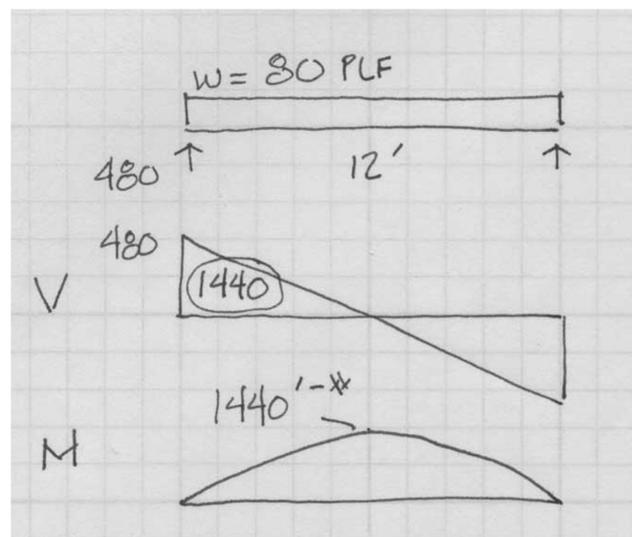
Given: load, wood and grade, span,
other usage conditions (F'_b)

Req'd: member size



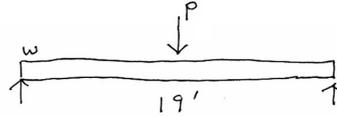
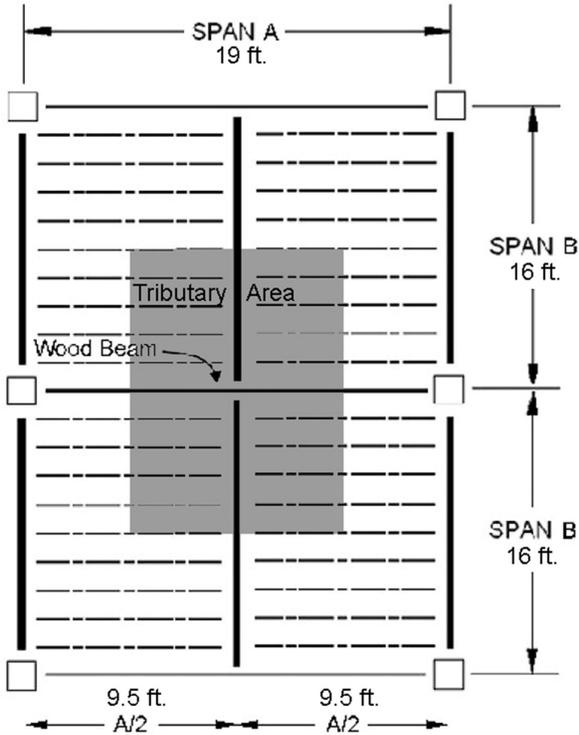
1. Find Max Shear & Moment

- Simple case – equations
- Complex case - diagrams



Timber Beam Design

Find applied load and force



GIVEN:
 COAST SITKA SPRUCE No.2 15% M.C.
 $G = 0.43$ DENSITY ≈ 30 PCF

Trial 1:

ESTIMATE SIZE (RULE OF THUMB)
 $d' \approx L/15 \approx 19/15 = 1.3' = 15.6'' \approx 16''$
 $b:d = 1:2 \quad b = 8''$
 \therefore ESTIMATE 8×16

DL = 19 PSF LL = 55 PSF

$P_{DL} = (19 + 55)(\text{TRIBUTARY AREA})$
 $= 74(152) = 11248$ LBS

$w = 24.22$ PLF (TAB 1B)

$M_p = \frac{P \cdot l}{4} = \frac{11248(19)}{4} = 53428$ ft-lb

$M_w = \frac{w \cdot l^2}{8} = \frac{24.22(19)^2}{8} = 1093$ ft-lb
 \uparrow
 54521 ft-lb

Timber Beam Design

Find allowable stress

$F_b = 625$ PSI
 $F_v = 115$ PSI
 $E = 1200000$ PSI
 $E_{min} = 440000$ PSI

From NDS Supplement:
 Coast Sitka Spruce No.2

The following formula shall be used to determine the density in lbs/ft³ 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, %

$\text{m.c.} = 15\%$ $G = 0.43$
 $\text{density} = 29.2$ pcf use 30

Table 4D Reference Design Values for Visually Graded Timbers (5" x 5" and larger)^{1,3}

(Tabulated design values are for normal load duration and dry service conditions, unless specified otherwise. See NDS 4.3 for a comprehensive description of design value adjustment factors.)

USE WITH TABLE 4D 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	E				
		F _b	F _t	F _v	F _{cL}	F _c					
COAST SITKA SPRUCE											
Select Structural	Beams and Stringers	1,150	675	115	455	775	1,500,000	550,000	0.43	NLGA	
No.1		950	475	115	455	650	1,500,000	550,000			
No.2		625	325	115	455	425	1,200,000	440,000			
Select Structural	Posts and Timbers	1,100	725	115	455	825	1,500,000	550,000	0.43	NLGA	
No.1		875	575	115	455	725	1,500,000	550,000			
No.2		525	350	115	455	500	1,200,000	440,000			

Timber Beam Design

TRY 1

$$F'_b \approx F_b = 625 \text{ PSI}$$

$$S_x = \frac{M}{F'_b} = \frac{54521 \text{ ft-lb}}{625 \text{ PSI}} (12)$$

Trial 1:
choose S_x and size

$$S_x = 1047 \text{ in}^3 \text{ (REQUIRED)}$$

$$S_x = M / F'_b$$

$$\therefore 8 \times 16 \text{ } S_x = 300.3 \text{ in}^3 \text{ FAILS}$$

$$\text{TRY } 12 \times 24 \text{ } S_x = 1058 \text{ in}^3$$

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

Nominal Size b x d	Standard Dressed Size (S4S) b x 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
Beams & Stringers (see NDS 4.1.3.3 and NDS 4.1.5.3)												
10 x 14	9-1/2 x 13-1/2	128.3	288.6	1948	203.1	964.5	22.27	26.72	31.17	35.63	40.08	44.53
10 x 16	9-1/2 x 15-1/2	147.3	380.4	2948	233.1	1107	25.56	30.68	35.79	40.90	46.02	51.13
10 x 18	9-1/2 x 17-1/2	166.3	484.9	4243	263.2	1250	28.86	34.64	40.41	46.18	51.95	57.73
10 x 20	9-1/2 x 19-1/2	185.3	602.1	5870	293.3	1393	32.16	38.59	45.03	51.46	57.89	64.32
10 x 22	9-1/2 x 21-1/2	204.3	731.9	7868	323.4	1536	35.46	42.55	49.64	56.74	63.83	70.92
10 x 24	9-1/2 x 23-1/2	223.3	874.4	10274	353.5	1679	38.76	46.51	54.26	62.01	69.77	77.52
12 x 16	11-1/2 x 15-1/2	178.3	460.5	3569	341.6	1964	30.95	37.14	43.32	49.51	55.70	61.89
12 x 18	11-1/2 x 17-1/2	201.3	587.0	5136	385.7	2218	34.94	41.93	48.91	55.90	62.89	69.88
12 x 20	11-1/2 x 19-1/2	224.3	728.8	7106	429.8	2471	38.93	46.72	54.51	62.29	70.08	77.86
12 x 22	11-1/2 x 21-1/2	247.3	886.0	9524	473.9	2725	42.93	51.51	60.10	68.68	77.27	85.85
12 x 24	11-1/2 x 23-1/2	270.3	1058	12437	518.0	2978	46.92	56.30	65.69	75.07	84.45	93.84
14 x 18	13-1/2 x 17-1/2	236.3	689.1	6029	531.6	3588	41.02	49.22	57.42	65.63	73.83	82.03
14 x 20	13-1/2 x 19-1/2	263.3	855.6	8342	592.3	3998	45.70	54.84	63.98	73.13	82.27	91.41
14 x 22	13-1/2 x 21-1/2	290.3	1040	11181	653.1	4408	50.39	60.47	70.55	80.63	90.70	100.8
14 x 24	13-1/2 x 23-1/2	317.3	1243	14600	713.8	4818	55.08	66.09	77.11	88.13	99.14	110.2

Timber Beam Design

Trial 2: 12 x 24 LL + DL m.c. < 19% not flat use

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 λ	
$F'_b = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	-	-	-	2.54	0.85	λ

Timber Beam Design

Trial 2: 12 x 24 LL + DL m.c. < 19% not flat use

Table 4D Adjustment Factors

Size Factor, C_F

When visually graded timbers are subjected to loads applied to the narrow face, tabulated design values shall be multiplied by the following size factors:

Size Factors, C_F			
Depth	F_b	F_t	F_c
$d > 12''$	$(12/d)^{1/9}$	1.0	1.0
$d \leq 12''$	1.0	1.0	1.0

Flat Use Factor, C_{fu}

When members classified as Beams and Stringers* in Table 4D are subjected to loads applied to the wide face, tabulated design values shall be multiplied by the following flat use factors:

Flat Use Factor, C_{fu}			
Grade	F_b	E and E_{min}	Other Properties
Select Structural	0.86	1.00	1.00
No.1	0.74	0.90	1.00
No.2	1.00	1.00	1.00

*"Beams and Stringers" are defined in NDS 4.1.3 (also see Table 1B).

Wet Service Factor, C_M

When timbers are 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 (for Southern Pine and Mixed Southern Pine, use tabulated design values without further adjustment):

Wet Service Factors, C_M					
F_b	F_t	F_v	$F_{c\perp}$	F_c	E and E_{min}
1.00	1.00	1.00	0.67	0.91	1.00

$$C_F = (12/23.5)^{1/9} = 0.928$$

Timber Beam Design Trial 2: 12 x 24

C_L

Table 3.3.3

"Concentrated load at center with lateral support at center"

$$l_e = 1.11 l_u$$

$$C_L: \\ l_u = 9.5' \\ = 114''$$

$$l_e = 1.11(l_u) \\ = 1.11(114) = 126.5''$$

$$R_B = \sqrt{\frac{l_e d}{b^2}} = 4.74$$

$$F_{bE} = \frac{1.2 E_{min}}{R_B^2} = \frac{1.2(440000)}{4.74^2} = 23482 \text{ psi}$$

$$F_b^* = F_b(C_F) = 65(0.928) = 580$$

$$\frac{F_{bE}}{F_b^*} = 40.5$$

$$C_L = 0.999$$

3.3.3.6 The slenderness ratio, R_B , for bending members shall be calculated as follows:

$$R_B = \sqrt{\frac{l_e d}{b^2}} \quad (3.3-5)$$

3.3.3.7 The slenderness ratio for bending members, R_B , shall not exceed 50.

3.3.3.8 The beam stability factor shall be calculated as follows:

$$C_L = \frac{1 + (F_{bE}/F_b^*)}{1.9} - \sqrt{\left[\frac{1 + (F_{bE}/F_b^*)}{1.9} \right]^2 - \frac{F_{bE}/F_b^*}{0.95}} \quad (3.3-6)$$

where:

F_b^* = reference bending design value multiplied by all applicable adjustment factors except C_{fu} , C_v , and C_L (see 2.3)

$$F_{bE} = \frac{1.20 E_{min}'}{R_B^2}$$

Timber Beam Design Trial 2: 12 x 24

C_L Table 3.3.3

"Concentrated load at center with lateral support at center"

$$l_e = 1.11 l_u$$

Table 3.3.3 Effective Length, l_e , for Bending Members

Cantilever ¹	where $l_u/d < 7$	where $l_u/d \geq 7$
Uniformly distributed load	$l_e = 1.33 l_u$	$l_e = 0.90 l_u + 3d$
Concentrated load at unsupported end	$l_e = 1.87 l_u$	$l_e = 1.44 l_u + 3d$
Single Span Beam ^{1,2}	where $l_u/d < 7$	where $l_u/d \geq 7$
Uniformly distributed load	$l_e = 2.06 l_u$	$l_e = 1.63 l_u + 3d$
Concentrated load at center with no intermediate lateral support	$l_e = 1.80 l_u$	$l_e = 1.37 l_u + 3d$
Concentrated load at center with lateral support at center	$l_e = 1.11 l_u$	
Two equal concentrated loads at 1/3 points with lateral support at 1/3 points	$l_e = 1.68 l_u$	
Three equal concentrated loads at 1/4 points with lateral support at 1/4 points	$l_e = 1.54 l_u$	
Four equal concentrated loads at 1/5 points with lateral support at 1/5 points	$l_e = 1.68 l_u$	
Five equal concentrated loads at 1/6 points with lateral support at 1/6 points	$l_e = 1.73 l_u$	
Six equal concentrated loads at 1/7 points with lateral support at 1/7 points	$l_e = 1.78 l_u$	
Seven or more equal concentrated loads, evenly spaced, with lateral support at points of load application	$l_e = 1.84 l_u$	
Equal end moments	$l_e = 1.84 l_u$	

1. For single span or cantilever bending members with loading conditions not specified in Table 3.3.3:

$$l_e = 2.06 l_u \quad \text{where } l_u/d < 7$$

$$l_e = 1.63 l_u + 3d \quad \text{where } 7 \leq l_u/d \leq 14.3$$

$$l_e = 1.84 l_u \quad \text{where } l_u/d > 14.3$$

2. Multiple span applications shall be based on table values or engineering analysis.

Timber Beam Design

Trial 2: 12 x 24 $S_x = 1058 \text{ in}^3$ $A = 270 \text{ in}^2$

TRY 2 CONT.

$$12 \times 24 \quad C_F = 0.928 \quad C_L = 0.999 \quad C_D = 1.0$$

$$F'_b = F_b (C_D C_F C_L) = 625 (1.0 \cdot 0.928 \cdot 0.999) = 579.3 \text{ psi}$$

$$w_{\text{SELF}} = D \frac{\text{AREA}}{144} = 30 \frac{270 \text{ in}^2}{144} = 56.25 \text{ PLF}$$

$$M_w = \frac{w l^2}{8} = \frac{56.25 (19)^2}{8} = 2538 \text{ FT-LB}$$

$$M_{\text{TOTAL}} = M_p + M_w = 53428 + 2538 = 55969 \text{ FT-LB}$$

$$S'_{\text{REQ}} = \frac{M}{F} = \frac{55969 (12)}{579.3} = 1159.4 \text{ in}^3$$

1159.4 > 1058 so 12 x 24 is too small

Timber Beam Design

Trial 3: S_x req'd = 1159 in³

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

Nominal Size b x d	Standard Dressed Size (S4S) b x 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
Beams & Stringers (see NDS 4.1.3.3 and NDS 4.1.5.3)												
10 x 14	9-1/2 x 13-1/2	128.3	288.6	1948	203.1	964.5	22.27	26.72	31.17	35.63	40.08	44.53
10 x 16	9-1/2 x 15-1/2	147.3	380.4	2948	233.1	1107	25.56	30.68	35.79	40.90	46.02	51.13
10 x 18	9-1/2 x 17-1/2	166.3	484.9	4243	263.2	1250	28.86	34.64	40.41	46.18	51.95	57.73
10 x 20	9-1/2 x 19-1/2	185.3	602.1	5870	293.3	1393	32.16	38.59	45.03	51.46	57.89	64.32
10 x 22	9-1/2 x 21-1/2	204.3	731.9	7868	323.4	1536	35.46	42.55	49.64	56.74	63.83	70.92
10 x 24	9-1/2 x 23-1/2	223.3	874.4	10274	353.5	1679	38.76	46.51	54.26	62.01	69.77	77.52
12 x 16	11-1/2 x 15-1/2	178.3	460.5	3569	341.6	1964	30.95	37.14	43.32	49.51	55.70	61.89
12 x 18	11-1/2 x 17-1/2	201.3	587.0	5136	385.7	2218	34.94	41.93	48.91	55.90	62.89	69.88
12 x 20	11-1/2 x 19-1/2	224.3	728.8	7106	429.8	2471	38.93	46.72	54.51	62.29	70.08	77.86
12 x 22	11-1/2 x 21-1/2	247.3	886.0	9524	473.9	2725	42.93	51.51	60.10	68.68	77.27	85.85
12 x 24	11-1/2 x 23-1/2	270.3	1058	12437	518.0	2978	46.92	56.30	65.69	75.07	84.45	93.84
14 x 18	13-1/2 x 17-1/2	236.3	689.1	6029	531.6	3588	41.02	49.22	57.42	65.63	73.83	82.03
14 x 20	13-1/2 x 19-1/2	263.3	855.6	8342	592.3	3998	45.70	54.84	63.98	73.13	82.27	91.41
14 x 22	13-1/2 x 21-1/2	290.3	1040	11181	653.1	4408	50.39	60.47	70.55	80.63	90.70	100.8
14 x 24	13-1/2 x 23-1/2	317.3	1243	14600	713.8	4818	55.08	66.09	77.11	88.13	99.14	110.2
16 x 20	15-1/2 x 19-1/2	302.3	982.3	9578	780.8	6051	52.47	62.97	73.46	83.96	94.45	104.9
16 x 22	15-1/2 x 21-1/2	333.3	1194	12837	860.9	6672	57.86	69.43	81.00	92.57	104.1	115.7
16 x 24	15-1/2 x 23-1/2	364.3	1427	16763	941.0	7293	63.24	75.89	88.53	101.2	113.8	126.5

try 14 x 24 $S_x = 1243$ in³

Timber Beam Design

Trial 3: 14 x 24 (13 1/2 x 23 1/2) $S_x = 1243$ in³

revise adjustment factors:

$$C_F = \left(\frac{12}{23.5}\right)^{1/4} = 0.928$$

$$C_L \quad l_e = 126.5''$$

$$R_B = \sqrt{\frac{l_e d'}{b^2}} = \sqrt{\frac{126.5(23.5)}{13.5^2}} = 4.039$$

$$F_{0E} = \frac{1.2(440000)}{4.039^2} = 32359.8 \text{ psi}$$

$$F^* = 625(0.928) = 580.0 \text{ psi}$$

$$F_{0E}/F^* = \frac{32359.8}{580} = 55.79$$

$$C_L = 0.999$$

Timber Beam Design

Trial 3: 14 x 24 A = 317.3 in² S_x = 1243 in³ w_{DL} = 66.1 PLF

check stresses:

TRY 3

$$14 \times 24 \quad A = 317.3 \text{ in}^2 \quad S_x = 1242.6 \text{ in}^3$$

$$F'_b = 625 (1.0 \cdot 0.928 \cdot 0.999) = 579.5 \text{ psi}$$

$$\text{CHECK } f_b = \frac{M}{S_x} = \frac{56410}{1242.6} = 45.4 \text{ psi} < 579.5 = F'_b$$

← REVISE M_w = 944.8 FT-LB

$$\text{CHECK SHEAR: } V_{\max} = \frac{w l}{2} + \frac{P}{2} = \frac{66.1(19)}{2} + \frac{11248}{2} = 6251.9 \text{ LB}$$

$$f_v = \frac{3}{2} \frac{V}{A} = \frac{3}{2} \frac{6251.9}{317.3} = 29.56 \text{ psi} < 115 = F'_v \quad \checkmark$$

∴ USE 14x24

Timber Beam Design

Trial 3: 14 x 24 I_x = 14600 in⁴

check deflection: assume 30% of LL is sustained

see NDS 3.5 K_{cr} = 1.5 "seasoned lumber"

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:

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

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.

Timber Beam Design

Trial 3: 14 x 24 $I_x = 14600 \text{ in}^4$

check deflection:
assume 30% of LL is sustained

see NDS 3.5

$K_{cr} = 1.5$ "seasoned lumber"

DEFLECTION

LONG-TERM: w_D P_D 30% P_L

$$\Delta_{w_D} = \frac{5w_D l^4}{384EI} = \frac{5(66.1)(19)^4(1728)}{384(1200000)(14600)} = 0.011''$$

$$\Delta_{P_D} = \frac{P_D l^3}{48EI} = \frac{2888(19)^3(1728)}{48(1200000)(14600)} = 0.0407''$$

$$\Delta_{P_{L30\%}} = \frac{0.3(P_L) l^3}{48EI} = \frac{0.3(8360)(19)^3(1728)}{48(1200000)(14600)} = 0.035''$$

$$\Delta_{LT} = 0.0867''$$

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	//360	//360	//240
Supporting nonplaster ceiling	//240	//240	//180
Not supporting ceiling	//180	//180	//120
Floor members	//360	—	//240
Exterior walls:			
With plaster or stucco finishes	—	//360	—
With other brittle finishes	—	//240	—
With flexible finishes	—	//120	—
Interior partitions: ^b			
With plaster or stucco finishes	//360	—	—
With other brittle finishes	//240	—	—
With flexible finishes	//120	—	—
Farm buildings	—	—	//180
Greenhouses	—	—	//120

SHORT-TERM: 70% P_L

$$\Delta_{P_{L70\%}} = \frac{0.7(P_L) l^3}{48EI} = \frac{0.7(8360)(19)^3(1728)}{48(1200000)(14600)} = 0.0825''$$

TOTAL DEFLECTION:

$$\Delta_T = K_{cr} \Delta_{LT} + \Delta_{ST}$$

$$= 1.5(0.0867) + 0.0825 = \underline{0.213''}$$

$$L/240 = 19(12)/240 = 0.95''$$

Timber Beam Design

Find allowable stress

$$F_b = 625 \text{ PSI}$$

$$F_v = 115 \text{ PSI}$$

$$E = 1200000 \text{ PSI}$$

$$E_{min} = 440000 \text{ PSI}$$

From NDS Supplement:
Coast Sitka Spruce No2

The following formula shall be used to determine the density in lbs/ft³ 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, %

$$\text{m.c} = 15\% \quad G = 0.43$$

$$\text{density} = 29.2 \text{ pcf} \quad \text{use } 30$$

Table 4D Reference Design Values for Visually Graded Timbers (5" x 5" and larger)^{1,3}

(Tabulated design values are for normal load duration and dry service conditions, unless specified otherwise. See NDS 4.3 for a comprehensive description of design value adjustment factors.)

USE WITH TABLE 4D 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_{cL}	F_c	E	E_{min}		
COAST SITKA SPRUCE										
Select Structural	Beams and Stringers	1,150	675	115	455	775	1,500,000	550,000	0.43	NLGA
No.1		950	475	115	455	650	1,500,000	550,000		
No.2		625	325	115	455	425	1,200,000	440,000		
Select Structural	Posts and Timbers	1,100	725	115	455	825	1,500,000	550,000	0.43	NLGA
No.1		875	575	115	455	725	1,500,000	550,000		
No.2		525	350	115	455	500	1,200,000	440,000		

Timber Beam Design Trial 2: 14 x 24 b = 13.5"

check support bearing:

$$C_b = 1.0 \text{ (end support)}$$

3.10.4 Bearing Area Factor, C_b

Reference compression design values perpendicular to grain, $F_{c\perp}$, apply to bearings of any length at the ends of a member, and to all bearings 6" or more in length at any other location. For bearings less than 6" in length and not nearer than 3" to the end of a member, the reference compression design value perpendicular to grain, $F_{c\perp}$, shall be permitted to be multiplied by the following bearing area factor, C_b :

$$C_b = \frac{\ell_b + 0.375}{\ell_b} \quad (3.10-2)$$

where:

ℓ_b = bearing length measured parallel to grain, in.

Equation 3.10-2 gives the following bearing area factors, C_b , for the indicated bearing length on such small areas as plates and washers:

Table 3.10.4 Bearing Area Factors, C_b

ℓ_b	0.5"	1"	1.5"	2"	3"	4"	6" or more
C_b	1.75	1.38	1.25	1.19	1.13	1.10	1.00

For round bearing areas such as washers, the bearing length, ℓ_b , shall be equal to the diameter.

FIND MINIMUM ℓ_b :

$$F_{c\perp} = 455 \text{ PSI}$$

$$F'_{c\perp} = F_{c\perp} (C_M C_t C_i C_b) = 455 (1.0 \ 1.0 \ 1.0 \ 1.0) = 455 \text{ PSI}$$

$$R = \text{END REACTION} = \frac{P}{2} + \frac{wL}{2} = 6251.9 \text{ LBS}$$

$$F'_{c\perp} = f_{c\perp} = \frac{R}{A_b} = \frac{6251.9}{b \ell_b} = 455 \text{ PSI}$$

$$\ell_b = \frac{6251.9 \text{ LB}}{13.5" \ 455 \text{ PSI}} = 1.02" \text{ (MINIMUM)}$$