S.E. Exam Review: Timber Design

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ASCE | KNOWLEDGE & LEARNING

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NCEES Guide

1. Vertical Forces Exam – Friday Breadth
   - Wood, 4 out of 40 questions: **sawn beams**, **glue-laminated beams**, **columns**, engineered lumber, bearing walls trusses, bolted, nailed, and screwed connection
2. Vertical Forces Exam – Friday Depth
   - 4 - 1 hour problems, will include a wood structure.
3. Lateral Forces Exam – Saturday Breadth
   - Wood, 3 out of 40 questions: **shear walls**, **plywood diaphragms** and sub-diaphragms
4. Lateral Forces Exam – Saturday Depth
   - 4 - 1 hour problems, may include a timber structure.

Focus on the bold topics. Use ASD.

Any timber design experience? – Courses or Design

Timber experience – feedback via chat

How many at site have

A. Little or none

B. A short course and/or a little design

C. Design simple buildings/elements

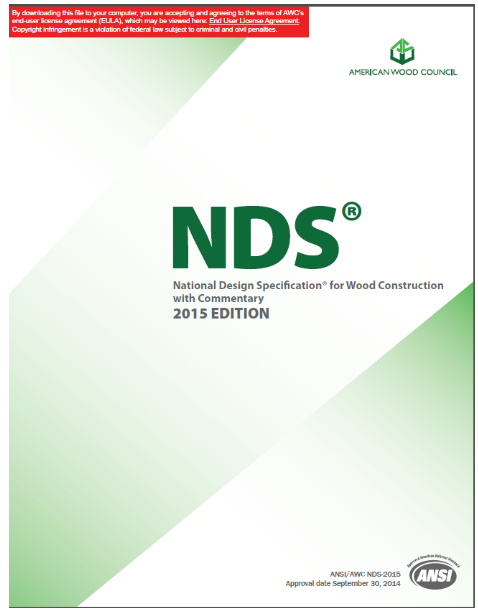
D. Design timber routinely

E. Design timber in sleep – a timber wiz, etc.

As per NCEES, Use the NDS-2015 ASD/LRFD Standard

Assume you have access to NDS and Commentary

Newer Edition

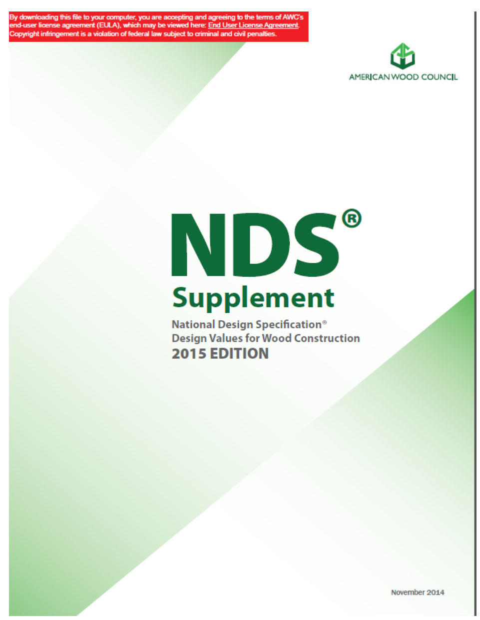


As per NCEES, Use the NDS-2015 ASD/LRFD Standard

Assume you have access to NDS Supplement

By the way, there are addendums to the Supplement

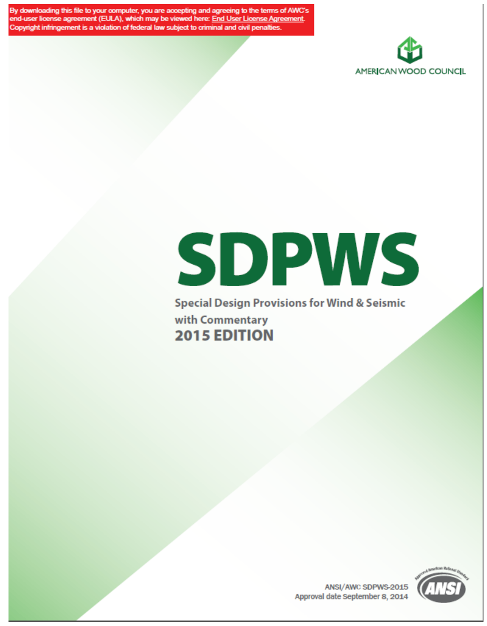
Newer Edition



As per NCEES, Use the AWC-SDPWS 2015 Standard

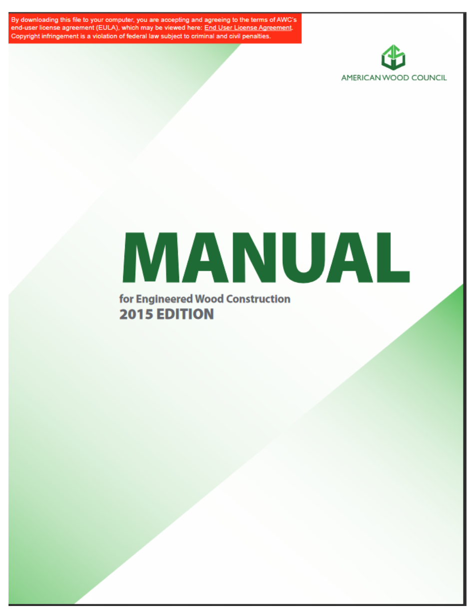
Assume you have access to AWC-SDPWS

Newer Edition



As per NCEES, Use the NDS-2015 ASD/LRFD Standard

Also recommend manual



Wood Design Methods -

- Generally 3 methods used
- Prescriptive – for conventional construction, limited to typical residential construction, span and height tables, not addressed
- Allowable Stress Design (ASD) – engineered, most common historically, [f ≤ adjusted F], in NDS (National Design Standard)
- Load Resistance Factor Design (LRFD) – newer. What I normally teach, but to keep it simple I am presenting ASD.

ASD Load Combinations – IBC 2015/ASCE 7-10 VERT. & LATERAL

- $D + F$
- $D + H + F + L$
- $D + H + F + (L_r \text{ or } S \text{ or } R)$
- $D + H + F + 0.75(L) + 0.75(L_r \text{ or } S \text{ or } R)$
- $D + H + F + (0.6W \text{ or } 0.7E)$
- $D + H + F + 0.75(0.6W) + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
- $D + H + F + 0.75(0.7E) + 0.75L + 0.75(S)$
- $0.6D + 0.6W + H$
- $0.6(D + F) + H + 0.7E$

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber VERT. & LATERAL

		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	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	1.76	0.85	-

Table 5.3.1 Applicability of Adjustment Factors for Structural Glued Laminated Timber VERT. & LATERAL

		ASD only	ASD and LRFD										LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor[1]	Volume Factor[1]	Flat Use Factor	Curvature Factor	Stress Interaction Factor	Shear Reduction Factor	Column Stability 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_V	C_{fu}	C_c	C_I	-	-	-	2.54	0.85	λ
$F_t' = F_t$	x	C_D	C_M	C_t	-	-	-	-	-	-	-	-	2.70	0.80	λ
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	-	-	C_{vr}	-	-	2.88	0.75	λ
$F_{rt}' = F_{rt}$	x	C_D	C_M	C_t	-	-	-	-	-	-	-	-	2.88	0.75	λ
$F_c' = F_c$	x	C_D	C_M	C_t	-	-	-	-	-	-	C_P	-	2.40	0.90	-
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	-	-	-	-	C_b	1.67	0.90	-
$E' = E$	x	-	C_M	C_t	-	-	-	-	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	-	-	-	-	-	1.76	0.85	-

1. The beam stability factor, C_L, shall not apply simultaneously with the volume factor, C_V, for structural glued laminated timber bending members (see 5.3.6). Therefore, the lesser of these adjustment factors shall apply.

Table 7.3.1 Applicability of Adjustment Factors for Prefabricated Wood I-Joists - VERT.

		ASD only	ASD and LRFD				LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Repetitive Member Factor	Format Conversion Factor	Resistance Factor	Time Effect Factor
							K_F	ϕ	
$M_r' = M_r$	x	C_D	C_M	C_t	C_L	C_r	K_F	0.85	λ
$V_r' = V_r$	x	C_D	C_M	C_t	-	-	K_F	0.75	λ
$R_r' = R_r$	x	C_D	C_M	C_t	-	-	K_F	0.75	λ
$EI' = EI$	x	-	C_M	C_t	-	-	-	-	-
$(EI)_{min}' = (EI)_{min}$	x	-	C_M	C_t	-	-	K_F	0.85	-
$K' = K$	x	-	C_M	C_t	-	-	-	-	-

Wood Systems and Elements VERT. & LATERAL

Two Basic Types of Systems

Light Timber Systems

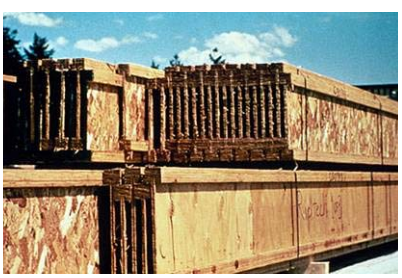
- Plywood
- Joists – sawn timber or EWP (Eng. Wood Products)
- Beams – sawn timber or EWP
- Stud Walls
- Posts – columns, pipe columns

Light Timber Systems VERT. & LATERAL

Sawn Timber
Floor Joists

Sawn Timber
Stud Walls

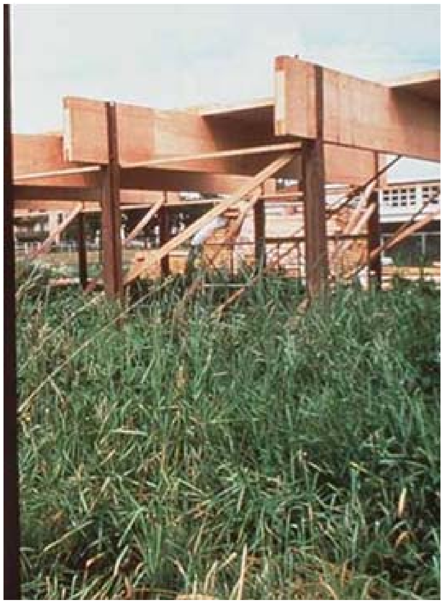
Light Timber Systems VERT. & LATERAL



Sawn timber trusses and other engineered products substituted for roof/floor joists and beams , usually design using load tables

Also heavy –

Wood Systems and Elements VERT. & LATERAL



Heavy Timber System ("Post and Beams")

- Planks
- Glu-laminated beams and girders (sometimes sawn timber)
- Glu-laminated columns or posts

Wood Beams – Flexural Design VERT. & LATERAL

General – under flexure only

- Check bending capacity ($f_b \leq F'_{bASD}$)

  Under service level loads

- Check shear sapacity ($f_v \leq F'_{vASD}$)

  Under service level loads

- Check deflections ($\Delta_{\max} \leq \Delta_{\text{max allowed}}$)

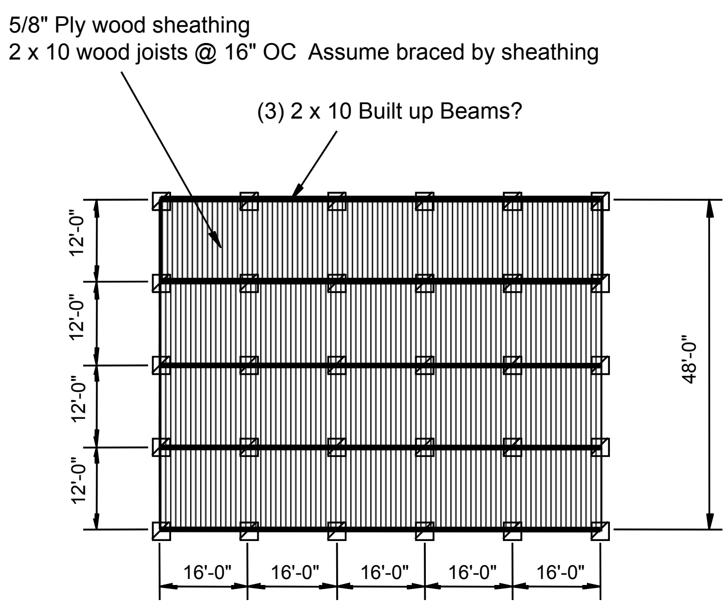
  Under service level live loads

Wood Design "Guess and Check" VERT.

Get basic layout, then

1. Determine span and spacing
2. Determine load – max unfactored shear and moment.
3. Select size/species to ensure f_{bmax} and $f_{vmax} \leq F'_{bASD}$ and F'_{vASD}. (adjusted allowables)
4. Check deflect. Resize or reduce spacing or span if needed.

Examples for Sawn Timber VERT.



From calculations - Dead load including joist weight and partitions = 12 psf
Live load = 40 psf

Example Sawn Timber Beam VERT.

Design joists – max span 12 ft

Live load $= 40 \times 16/12 = 53.3 \text{ lb/ft}$

Dead load $= 12 \times 16/12 = 16 \text{ lb/ft}$

Max moment $= 69.3\,(12)^2/8 = 1{,}247.4 \text{ lb} \cdot \text{ft}$

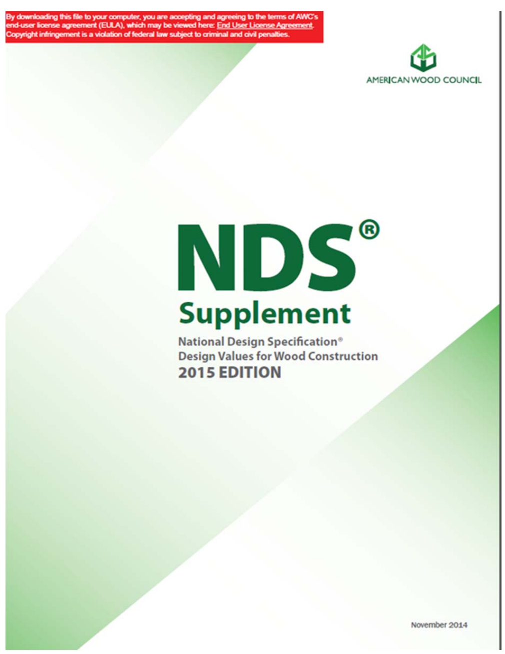
Now either guess at size of joist or wood species and grade

Try a 2x10 $S = 1.5\,(9.25)^2/6 = 21.4 \text{ in}^3$

$A = 1.5 \times 9.25 = 13.9 \text{ in}^2$

See tables in NDS Supplement

Look at the NDS Supplement VERT. & LATERAL



Section Tables Sawn Timber VERT. & LATERAL

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
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
				88.99	1.055	0.396	1.465	1.758	2.051	2.344	2.637	2.930
Decking (see NDS 4.1.3.5)												
				1.953	0.938	0.703	0.651	0.781	0.911	1.042	1.172	1.302
				5.359	1.313	0.984	0.911	1.094	1.276	1.458	1.641	1.823
				11.39	1.688	1.266	1.172	1.406	1.641	1.875	2.109	2.344
				20.80	2.063	1.547	1.432	1.719	2.005	2.292	2.578	2.865
				47.63	2.719	2.039	1.888	2.266	2.643	3.021	3.398	3.776
				98.93	3.469	2.602	2.409	2.891	3.372	3.854	4.336	4.818
				178.0	4.219	3.164	2.930	3.516	4.102	4.688	5.273	5.859
				290.8	4.969	3.727	3.451	4.141	4.831	5.521	6.211	6.901
				8.932	3.646	4.557	1.519	1.823	2.127	2.431	2.734	3.038
				18.98	4.688	5.859	1.953	2.344	2.734	3.125	3.516	3.906
				34.66	5.729	7.161	2.387	2.865	3.342	3.819	4.297	4.774
				79.39	7.552	9.440	3.147	3.776	4.405	5.035	5.664	6.293
				164.9	9.635	12.04	4.015	4.818	5.621	6.424	7.227	8.030
				296.6	11.72	14.65	4.883	5.859	6.836	7.813	8.789	9.766
				484.6	13.80	17.25	5.751	6.901	8.051	9.201	10.35	11.50
				738.9	15.89	19.86	6.619	7.943	9.266	10.59	11.91	13.24
				12.51	7.146	12.51	2.127	2.552	2.977	3.403	3.828	4.253
				26.58	9.188	16.08	2.734	3.281	3.828	4.375	4.922	5.469
				48.53	11.23	19.65	3.342	4.010	4.679	5.347	6.016	6.684
				111.1	14.80	25.90	4.405	5.286	6.168	7.049	7.930	8.811
				230.8	18.89	33.05	5.621	6.745	7.869	8.993	10.12	11.24
				415.3	22.97	40.20	6.836	8.203	9.570	10.94	12.30	13.67
				678.5	27.05	47.34	8.051	9.661	11.27	12.88	14.49	16.10
				1034	31.14	54.49	9.266	11.12	12.97	14.83	16.68	18.53
5.3)												
				34.17	15.19	34.17	3.516	4.219	4.922	5.625	6.328	7.031
				76.26	27.73	76.26	5.252	6.302	7.352	8.403	9.453	10.50
				193.4	37.81	104.0	7.161	8.594	10.03	11.46	12.89	14.32
				263.7	70.31	263.7	9.766	11.72	13.67	15.63	17.58	19.53
				535.9	89.06	334.0	12.37	14.84	17.32	19.79	22.27	24.74
				678.8	142.9	678.8	15.67	18.80	21.94	25.07	28.20	31.34
				1204	173.0	821.7	18.97	22.76	26.55	30.35	34.14	37.93
				1458	253.5	1458	22.96	27.55	32.14	36.74	41.33	45.92
				2358	297.6	1711	26.95	32.34	37.73	43.13	48.52	53.91
				2768	410.1	2768	31.64	37.97	44.30	50.63	56.95	63.28
				4189	470.8	3178	36.33	43.59	50.86	58.13	65.39	72.66
				4810	620.6	4810	41.71	50.05	58.39	66.74	75.08	83.42
				6923	700.7	5431	47.09	56.51	65.93	75.35	84.77	94.18
				7816	893.2	7816	53.17	63.80	74.44	85.07	95.70	106.3
				10813	995.3	8709	59.24	71.09	82.94	94.79	106.6	118.5
				12049	1236	12049	66.02	79.22	92.4	105.6	118.8	132.0
				16150	1363	13285	72.79	87.34	101.9	116.5	131.0	145.6
				17806	1656	17806	80.25	96.30	112.4	128.4	144.5	160.5
				23252	1810	19463	87.72	105.3	122.8	140.3	157.9	175.4
				25415	2163	25415	95.88	115.1	134.2	153.4	172.6	191.8

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}
Boards[1]						
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

Check Bending – ASD VERT. & LATERAL

Sawn Timber Design Equation

$$f_{bmax} = M_{max}/S \leq F_b'$$

$$F_b' = F_b C_D C_M C_t C_L C_F C_{fu} C_i C_r$$

F_b is from the tables depending on species, grades, size, grading rules etc. See Supplement.

Bending VERT. & LATERAL

C_M = Tables (4 A, B, C, D, E, F) – See Supplement

= 0.85 or 1.0 for visually graded sawn timber

4A (2 or 4) or 4D (5x5 or larger) when EMC > 19% for extended time

Note $C_M = 1.0$ if $(F_b C_F) \leq 1{,}150$ psi

$C_t = 1.0$ for $T \leq 100°$ F (2.3.3 in code)

Table 2.3.3 Temperature Factor, C_t

Reference Design Values	In-Service Moisture Conditions[1]	C_t		
		$T \leq 100°F$	$100°F < T \leq 125°F$	$125°F < T \leq 150°F$
F_t, E, E_{min}	Wet or Dry	1.0	0.9	0.9
F_b, F_v, F_c, and $F_{c\perp}$	Dry	1.0	0.8	0.7
	Wet	1.0	0.7	0.5

1. Wet and dry service conditions for sawn lumber, structural glued laminated timber, prefabricated wood I-joists, structural composite lumber, and wood structural panels are specified in 4.1.4, 5.1.4, 7.1.4, 8.1.4, and 9.3.3, respectively.

Adjustment Factors VERT. & LATERAL

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.

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, $C_M = 1.0$

Flat Use Factor, C_{fu}

Bending design values adjusted by size factors are based on edgewise use (load applied to narrow face). When dimension lumber is used flatwise (load applied to wide face), the bending design value, F_b, shall also be multiplied by the following flat use factors:

Flat Use Factors, C_{fu}

Width (depth)	Thickness (breadth)	
	2" & 3"	4"
2" & 3"	1.0	—
4"	1.1	1.0
5"	1.1	1.05
6"	1.15	1.05
8"	1.15	1.05
10" & wider	1.2	1.1

NOTE
To facilitate the use of Table 4A, shading has been employed to distinguish design values based on a 4" nominal width (Construction, Standard, and Utility grades) or a 6" nominal width (Stud grade) from design values based on a 12" nominal width (Select Structural, No.1 & Btr, No.1, No.2, and No.3 grades).

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

F'_b VERT. & LATERAL

C_F = for sawn timber

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
Grades	Width (depth)	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
	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

F'_b VERT. & LATERAL

C_{fu} = flat use factor – when lumber is turned flat

Flat Use Factors, C_{fu}		
	Thickness (breadth)	
Width (depth)	2" & 3"	4"
2" & 3"	1.0	-
4"	1.1	1.0
5"	1.1	1.05
6"	1.15	1.05
8"	1.15	1.05
10" & wider	1.2	1.1

C_i = Incising factor – when dimension lumber is grooved > 0.4" & up to 3/8" long – density 1,100/ft^2

Then C_i = 0.8 For F_b, F_t, F_c, F_v

For E and E_{min} C_i = 0.95. For all other cond. C_i = 1

F'_b VERT. & LATERAL

C_r = repetitive member factor – must have at least three members, 2-4 thick, spaced up 2' apart and joined by other members such as floors then = 1.15, otherwise = 1.0.

C_D = Duration Factor – see Appendix B – Use shortest for a given load combo.

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

1. Load duration factors shall not apply to reference modulus of elasticity, E, reference modulus of elasticity for beam and column stability, E_{min}, nor to reference compression perpendicular to grain design values, $F_{c\perp}$, based on a deformation limit.

Bending VERT. & LATERAL

C_L = Stability factor (braced vs. unbraced beams)

See Spec 3.3.3 – C_L = 1.0 if braced, blocked, or near square. See requirements of Section 4.4.1 for sawn timber only.

$$F_{bE} = \frac{1.2E'_{min}}{R_B^2}$$

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

$$R_B = \sqrt{\frac{\ell_e d}{b^2}} \qquad (3.3\text{-}5)$$

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:

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

Table 3.3.3 Effective Length, ℓ_e, for Bending Members
VERT. & LATERAL

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

1. For single span or cantilever bending members with loading conditions not specified in Table 3.3.3:
   $\ell_e = 2.06\ \ell_u$ where $\ell_u/d < 7$
   $\ell_e = 1.63\ \ell_u + 3d$ where $7 \leq \ell_u/d < 14.3$
   $\ell_e = 1.84\ \ell_u$ where $\ell_u/d > 14.3$
2. Multiple span applications shall be based on table values or engineering analysis.

F_b
VERT. & LATERAL

F_b Values listed in Supplement for varies species and grades of lumber

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	
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		475	275	170	820	375	1,100,000	400,000		
Stud	2" & wider	625	375	170	820	400	1,100,000	400,000		
Construction	2" - 4" wide	925	550	170	820	850	1,200,000	440,000		
Standard		525	300	170	820	650	1,100,000	400,000		
Utility		250	150	170	820	425	1,000,000	370,000		
REDWOOD										
Clear Structural	2" & wider	1,750	1,000	160	650	1,850	1,400,000	510,000	0.44	RIS
Select Structural		1,350	800	160	650	1,500	1,400,000	510,000	0.44	
Select Structural, open grain		1,100	625	160	425	1,100	1,100,000	400,000	0.37	
No. 1		975	575	160	650	1,200	1,300,000	470,000	0.44	
No. 1, open grain		775	450	160	425	900	1,100,000	400,000	0.37	
No. 2		925	525	160	650	950	1,200,000	440,000	0.44	
No. 2, open grain		725	425	160	425	700	1,000,000	370,000	0.37	
No. 3		525	300	160	650	550	1,100,000	400,000	0.44	
No. 3, open grain		425	250	160	425	400	900,000	330,000	0.37	
Stud	2" & wider	575	325	160	425	450	900,000	330,000	0.44	
Construction	2" - 4" wide	825	475	160	425	925	900,000	330,000	0.44	
Standard		450	275	160	425	725	900,000	330,000	0.44	
Utility		225	125	160	425	475	800,000	290,000	0.44	
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		
Construction	2" - 4" wide	1,000	500	135	425	1,400	1,300,000	470,000		
Standard		550	275	135	425	1,150	1,200,000	440,000		
Utility		275	125	135	425	750	1,100,000	400,000		
SPRUCE-PINE-FIR (SOUTH)										
Select Structural	2" & wider	1,300	575	135	335	1,200	1,300,000	470,000	0.36	NELMA NSLB WCLIB WWPA
No. 1		875	400	135	335	1,050	1,200,000	440,000		
No. 2		775	350	135	335	1,000	1,100,000	400,000		
No. 3		450	200	135	335	575	1,000,000	370,000		
Stud	2" & wider	600	275	135	335	625	1,000,000	370,000		
Construction	2" - 4" wide	875	400	135	335	1,200	1,000,000	370,000		
Standard		500	225	135	335	1,000	900,000	330,000		
Utility		225	100	135	335	675	900,000	330,000		
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		

F_b – Choose from Table   VERT. & LATERAL

Species and commercial grade	Size classification	Bending F_b	Tension parallel to grain F_t
REDWOOD			
Clear Structural	2" & wider	1,750	
Select Structural		1,350	
Select Structural, open grain		1,100	
No. 1		975	
No. 1, open grain		775	
No. 2		925	
No. 2, open grain		725	
No. 3		525	
No. 3, open grain		425	
Stud	2" & wider	575	
Construction	2" - 4" wide	825	
Standard		450	
Utility		225	
SPRUCE-PINE-FIR			
Select Structural	2" & wider	1,250	
No. 1/ No. 2		875	
No. 3		500	
Stud	2" & wider	675	
Construction	2" - 4" wide	1,000	
Standard		550	
Utility		275	
SPRUCE-PINE-FIR (SOUTH)			
Select Structural		1,300	

For the Sawn Timber Beam (Joist) Example VERT.

$F_{b'req} = M/S = (1{,}247.1/21.4\ \text{in}^3)12 = 699\ \text{psi}$

$F_b' = C_D C_M C_t C_L C_F C_{fu} C_i C_r F_b$

Dry service, normal temps, no incisions $C_t = C_M = C_i = 1.0$
Braced by sheathing & bridging so $C_L = 1.0$,
on edge $C_{fu} = 1.0$,
(D+L) load $C_D = 1.0$
Multiple member so $C_r = 1.15$,
$C_F = 1.1$ for #1-3 for 2” width
So F_b must be $\geq 699/1.15(1.1)$
$= 553$ psi
Choose a species and grade with
$F_b \geq 553$ psi

Size Factor, C_F
Tabulated bending, tension, and compression parallel to grain design values fo
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"
Select Structural, No.1 & Btr, No.1, No.2, No.3	2", 3", & 4"	1.5	1.5
	5"	1.4	1.4
	6"	1.3	1.3
	8"	1.2	1.3
	10"	1.1	1.2
	12"	1.0	1.1
	14" & wider	0.9	1.0
Stud	2", 3", & 4"	1.1	1.1
	5" & 6"	1.0	1.0
	8" & wider	Use No.3 Grade tabulated design	
Construction, Standard	2", 3", & 4"	1.0	1.0
Utility	4"	1.0	1.0
	2" & 3"	0.4	—

F_b – Choose from Table 4A VERT. & LATERAL

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)						
		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}
RED OAK								
Select Structural	2" & wider	1,150	675	170	820	1,000	1,400,000	510,000
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		475	275	170	820	375	1,100,000	400,000
Stud	2" & wider	625	375	170	820	400	1,100,000	400,000
Construction	2" - 4" wide	925	550	170	820	850	1,200,000	440,000
Standard		525	300	170	820	650	1,100,000	400,000
Utility		250	150	170	820	425	1,000,000	370,000
REDWOOD								
Clear Structural	2" & wider	1,750	1,000	160	650	1,850	1,400,000	510,000
Select Structural		1,350	800	160	650	1,500	1,400,000	510,000
Select Structural, open grain		1,100	625	160	425	1,100	1,100,000	400,000
No. 1		975	575	160	650	1,200	1,300,000	470,000
No. 1, open grain		775	450	160	425	900	1,100,000	400,000
No. 2		925	525	160	650	950	1,200,000	440,000
No. 2, open grain		725	425	160	425	700	1,000,000	370,000
No. 3		525	300	160	650	550	1,100,000	400,000
No. 3, open grain		425	250	160	425	400	900,000	330,000
Stud	2" & wider	575	325	160	425	450	900,000	330,000
Construction	2" - 4" wide	825	475	160	425	925	900,000	330,000
Standard		450	275	160	425	725	900,000	330,000
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
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
Construction	2" - 4" wide	1,000	500	135	425	1,400	1,300,000	470,000
Standard		550	275	135	425	1,150	1,200,000	440,000
Utility		275	125	135	425	750	1,100,000	400,000

Example Sawn Timber Beam VERT.

A No 1 or 2 SPF 2 x 10 would work

$F_b = 875\, psi > 553$ (F_b required)

Look at shear design for sawn timber beams

Shear Design – Sawn Timber VERT. & LATERAL

$f_v \leq F_v'$

$f_v = VQ/Ib$ & for rectangular cross sections

$f_{vmax} = 1.5(V/A)$

$F'_{vASD} = C_D C_M C_t C_i F_v$

$C_M = 0.97$ for shear wet service

= 1.0 for dry service

The rest is the same

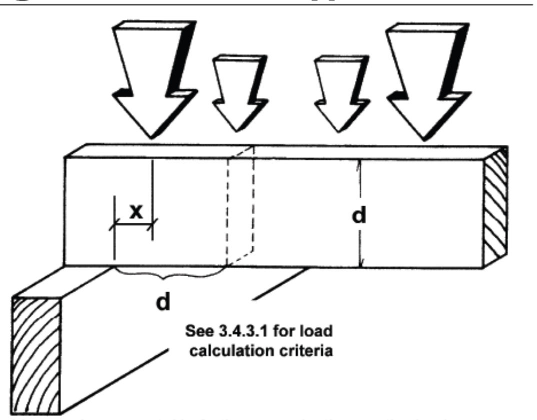
for bending.

		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	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	C_i	-	-	C_T	-	1.76	0.85	-

Shear Design - VERT. & LATERAL

Can reduce shear and design for shear at d from supports

Figure 3C Shear at Supports



If notched - look to Section 3.4.3 for certain conditions or use mechanics

For Sawn Timber Beam (Joist) Example VERT.

$f_{vmax} = 1.5\,V/A = (1.5(69.3)(12)/2)(1/13.9) = 44.9 \text{ psi}$

Only C_D, C_m and C_t – all = 1.0

SPF (any grade) has a $F_{vASD} = 135 \text{ psi}$

$F'_{vASD} = C_D C_M C_t C_i F_v = 1(1)1(1)(135) = 135$ psi

OK in Shear – 135 psi > 44.9 psi

Note should add the weight of the joist and re-check stresses – by inspection OK

Deflections VERT.

Service Level Loads Deflection

Limit live load deflections to L/360 or L/240

Long term effects – creep

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

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, 5.1.5, 7.1.4, and 8.1.4, respectively.

= 2.0 for structural glued laminated timber used in wet service conditions as defined in 5.1.5.

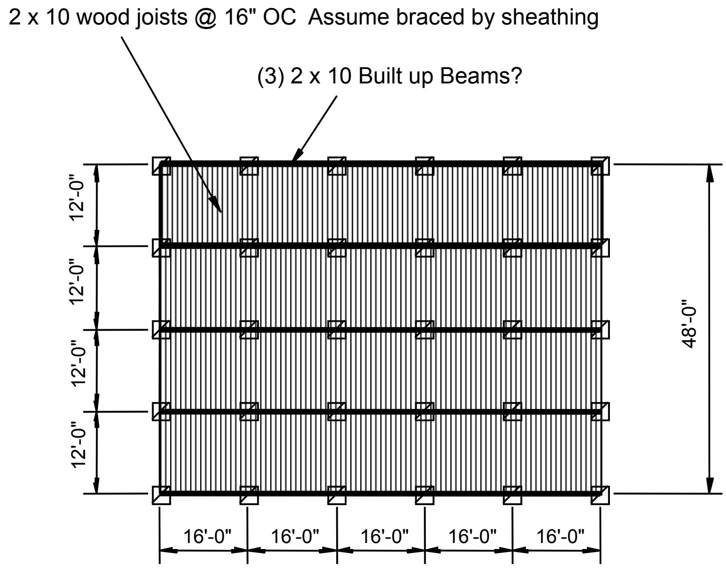
= 2.0 for wood structural panels used in dry service conditions as defined in 4.1.4.

= 2.0 for unseasoned lumber or for seasoned lumber used in wet service conditions as defined in 4.1.4.

Δ_{LT} = immediate deflection due to the long-term component of the design load

Δ_{ST} = deflection due to the short-term or normal component of the design load

Sawn Timber Joist Example VERT.



From calculations - Dead load including joist weight and partitions = 12 psf
Live load = 40 psf

Example Sawn Timber Joist - VERT.

Check deflections – only short term (2x10)

$I = 1.5\,(9.25)^3/12 = 98.9\ \text{in}^4$ $\quad W_L = 1.33(40) = 53.3\ \text{lb/ft}$

$\Delta_{max} = 5(53.3)(12)^4(12)^3/[384(510{,}000)98.9] = 0.49\ in.$

$= L/292$ **What's wrong with this?**

Use 2x10 x 16" OC – SPF No. 2 or better

E from Table 4A for Light Members VERT. & LATERAL

Species and commercial grade	Size classification	Design values in pounds per square inch (psi)						
		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}
RED OAK								
Select Structural	2" & wider	1,150	675	170	820	1,000	1,400,000	510,000
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		475	275	170	820	375	1,100,000	400,000
Stud	2" & wider	625	375	170	820	400	1,100,000	400,000
Construction	2" - 4" wide	925	550	170	820	850	1,200,000	440,000
Standard		525	300	170	820	650	1,100,000	400,000
Utility		250	150	170	820	425	1,000,000	370,000
REDWOOD								
Clear Structural	2" & wider	1,750	1,000	160	650	1,850	1,400,000	510,000
Select Structural		1,350	800	160	650	1,500	1,400,000	510,000
Select Structural, open grain		1,100	625	160	425	1,100	1,100,000	400,000
No. 1		975	575	160	650	1,200	1,300,000	470,000
No. 1, open grain		775	450	160	425	900	1,100,000	400,000
No. 2		925	525	160	650	950	1,200,000	440,000
No. 2, open grain		725	425	160	425	700	1,000,000	370,000
No. 3		525	300	160	650	550	1,100,000	400,000
No. 3, open grain		425	250	160	425	400	900,000	330,000
Stud	2" & wider	575	325	160	425	450	900,000	330,000
Construction	2" - 4" wide	825	475	160	425	925	900,000	330,000
Standard		450	275	160	425	725	900,000	330,000
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
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
Construction	2" - 4" wide	1,000	500	135	425	1,400	1,300,000	470,000
Standard		550	275	135	425	1,150	1,200,000	440,000
Utility		275	125	135	425	750	1,100,000	400,000

Example Sawn Timber Joist VERT. & LATERAL

Check deflections – only short term

$I = 1.5\,(9.25)^3/12 = 98.9\text{ in}^4$

$\Delta_{max} = 5(53.3)(12)^4(12)^3/[384(\mathbf{1,400,000})98.9] = 0.17\ in.$

$= L/801$ Less than L/360 or L/480 OK

Use 2x10 x 16” OC – SPF No. 2 or better

Heavy Timber Beam Design -VERT. & LATERAL

- The same design procedures as before for sawn timber, but use Table 4D for heavy timbers to get some factors and reference stresses (F_b, F_v, etc.)
- Heavy Timbers are usually glulams – glulam beams designed essentially the same, but again, some adjustment factors are different from sawn timber
- Also, reference stresses and sections are different Tables 5A, B, C, D

Glued Laminated Timbers - VERT. & LATERAL

- Glued-laminated timbers are made up of wood laminations, or "lams" that are face bonded (glued) together with waterproof adhesives.
- The grain of all laminations run parallel with the length of the member. Lams are typically less than 2" inches thick.
- Glulam range in net widths from 2 1/2 to 10 3/4 inches, although nearly any member width can be produced.

Table 5.3.1 Applicability of Adjustment Factors for Structural Glued Laminated Timber - VERT. & LATERAL

		ASD only	ASD and LRFD										LRFD only		
		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor[1]	Volume Factor[1]	Flat Use Factor	Curvature Factor	Stress Interaction Factor	Shear Reduction Factor	Column Stability 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_V	C_{fu}	C_c	C_I	-	-	-	2.54	0.85	λ
$F_t' = F_t$	x	C_D	C_M	C_t	-	-	-	-	-	-	-	-	2.70	0.80	λ
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	-	-	C_{vr}	-	-	2.88	0.75	λ
$F_{rt}' = F_{rt}$	x	C_D	C_M	C_t	-	-	-	-	-	-	-	-	2.88	0.75	λ
$F_c' = F_c$	x	C_D	C_M	C_t	-	-	-	-	-	-	C_P	-	2.40	0.90	-
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	-	-	-	-	C_b	1.67	0.90	-
$E' = E$	x	-	C_M	C_t	-	-	-	-	-	-	-	-	-	-	-
$E_{min}' = E_{min}$	x	-	C_M	C_t	-	-	-	-	-	-	-	-	1.76	0.85	-

1. The beam stability factor, C_L, shall not apply simultaneously with the volume factor, C_V, for structural glued laminated timber bending members (see 5.3.6). Therefore, the lesser of these adjustment factors shall apply.

Design Properties of Glulam - VERT. & LATERAL

- Bending members are specified w.r.t. maximum allowable bending stress.
- For example, a 24F has allowable bending stress of 2,400 psi., and 26F an allowable bending stress of 2,600 psi.
- Various layups are used. An unbalanced 24F layup using visually graded Douglas-fir lumber is a 24F-V4. The "V" indicates visually graded lumber. A 24F-E4 indicates mechanical graded lumber.

Glulam Sizes for Western Species and Southern Pine (1d) Shown in Supplement - VERT. & LATERAL

Table 1C Section Properties of Wester Species Structural Glued Laminated Timber (cont.)

Depth	Area	X-X Axis			Y-Y Axis	
d (in)	A (in^2)	I_x (in^4)	S_x (in^3)	r_x (in)	I_y (in^4)	S_y (in^3)
3-1/2 in. Width					$(r_y = 1.010 \text{ in})$	
6	21.00	63.00	21.00	1.732	21.44	12.25
7-1/2	26.25	123.0	32.81	2.165	26.80	15.31
9	31.50	212.6	47.25	2.598	32.16	18.38
9-1/4	32.38	230.8	49.91	2.670	33.05	18.89
9-1/2	33.25	250.1	52.65	2.742	33.94	19.40
10-1/2	36.75	337.6	64.31	3.031	37.52	21.44
11-1/4	39.38	415.3	73.83	3.248	40.20	22.97
11-7/8	41.56	488.4	82.26	3.428	42.43	24.24
12	42.00	504.0	84.00	3.464	42.88	24.50
13-1/2	47.25	717.6	106.3	3.897	48.23	27.56
14	49.00	800.3	114.3	4.041	50.02	28.58
15	52.50	984.4	131.3	4.330	53.59	30.63
16	56.00	1195	149.3	4.619	57.17	32.67
16-1/2	57.75	1310	158.8	4.763	58.95	33.69
18	63.00	1701	189.0	5.196	64.31	36.75
19-1.2	68.25	2163	221.8	5.629	69.67	39.81
20	70.00	2333	233.3	5.774	71.46	40.83
21	73.50	2701	257.3	6.062	75.03	42.88
22	77.00	3106	282.3	6.351	78.60	44.92
22-1.2	78.75	3322	295.3	6.495	80.39	45.94
24	84.00	4032	336.0	6.928	85.75	49.00

5.3.8 Curvature Factor, C_c - VERT.

For curved portions of bending members, the reference bending design value shall be multiplied by the following curvature factor:

$$C_c = 1 - (2{,}000)(t/R)^2 \qquad (5.3\text{-}3)$$

Where:

t = thickness of laminations, in.

R = radius of curvature of inside face of member, in.

$t/R \leq 1/100$ for hardwoods and Southern Pine

$t/R \leq 1/125$ for other softwoods

C_v = Volume Factor - VERT. & LATERAL

$$C_v = \left(\frac{21}{L}\right)^{1/x}\left(\frac{12}{d}\right)^{1/x}\left(\frac{5.125}{b}\right)^{1/x} \leq 1.0 \qquad (5.3\text{-}1)$$

Where:

L = length of bending member between points of zero moment, ft

d = depth of bending member, in.

b = width (breadth) of bending member. For multiple piece width layups, b = width of widest piece used in the layup. Thus, $b \leq 10.75$ in.

x = 20 for Southern Pine

x = 10 for all other species

Table 5A - VERT. & LATERAL

Table 5A **Expanded - Reference Design Values for Structural Glued Laminated Softwood Timber Combinations**[1]
(Members stressed primarily in bending) (Tabulated design values are for normal load duration and dry service conditions. See NDS 5.3 for a comprehensive description of design value adjustment factors.)

Use with Table 5A Adjustment Factors

Combination Symbol	Species Outer/ Core	Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations): Bending, Bottom of Beam Stressed in Tension (Positive Bending) F_{bx}^{+} (psi)	Bending, Top of Beam Stressed in Tension (Negative Bending) F_{bx}^{-} (psi)	Compression Perpendicular to Grain, Tension Face $F_{c\perp x}$ (psi)	Compression Perpendicular to Grain, Compression Face $F_{c\perp x}$ (psi)	Shear Parallel to Grain F_{vx} (2) (psi)	Modulus of Elasticity, For Deflection Calculations E_x (10^6 psi)	Modulus of Elasticity, For Stability Calculations $E_{x\,min}$ (10^6 psi)	Bending About Y-Y Axis (Loaded Parallel to Wide Faces of Laminations): Bending F_{by} (psi)	Compression Perpendicular to Grain $F_{c\perp y}$ (psi)	Shear Parallel to Grain F_{vy} (2)(3) (psi)	Modulus of Elasticity, For Deflection Calculations E_y (10^6 psi)	Modulus of Elasticity, For Stability Calculations $E_{y\,min}$ (10^6 psi)	Axially Loaded: Tension Parallel to Grain F_t (psi)	Axially Loaded: Compression Parallel to Grain F_c (psi)	Fasteners: Specific Gravity for Fastener Design, Top or Bottom Face G	Fasteners: Specific Gravity for Fastener Design, Side Face G
16F-1.3E		**1600**	**925**	**315**		**195**	**1.3**	**0.69**	**800**	**315**	**170**	**1.1**	**0.58**	**675**	**925**	**0.41**	
16F-V3	DF/DF	1600	1250	560	560	265	1.5	0.79	1450	560	230	1.5	0.79	975	1500	0.50	0.50
16F-V6	DF/DF	1600	1600	560	560	265	1.6	0.85	1450	560	230	1.5	0.79	1000	1600	0.50	0.50
16F-E2	HF/HF	1600	1050	375	375	215	1.4	0.74	1200	375	190	1.3	0.69	825	1150	0.43	0.43
16F-E3	DF/DF	1600	1200	560	560	265	1.6	0.85	1400	560	230	1.5	0.79	975	1600	0.50	0.50
16F-E6	DF/DF	1600	1600	560	560	265	1.6	0.85	1550	560	230	1.5	0.79	1000	1600	0.50	0.50
16F-E7	HF/HF	1600	1600	375	375	215	1.4	0.74	1350	375	190	1.3	0.74	875	1250	0.43	0.43
16F-V2	SP/SP	1600	1400	740	650	300	1.5	0.79	1450	650	260	1.4	0.74	1000	1300	0.55	0.55
16F-V3	SP/SP	1600	1450	740	740	300	1.4	0.74	1450	650	260	1.4	0.74	975	1400	0.55	0.55
16F-V5	SP/SP	1600	1600	650	650	300	1.6	0.85	1600	650	260	1.5	0.79	1000	1550	0.55	0.55
16F-E1	SP/SP	1600	1250	650	650	300	1.6	0.85	1400	650	260	1.6	0.85	1050	1550	0.55	0.55
16F-E3	SP/SP	1600	1600	650	650	300	1.7	0.90	1650	650	260	1.6	0.85	1100	1550	0.55	0.55
20F-1.5E		**2000**	**1100**	**425**		**195**	**1.5**	**0.79**	**800**	**315**	**170**	**1.2**	**0.63**	**725**	**925**	**0.41**	
20F-V3	DF/DF	2000	1450	650	560	265	1.6	0.85	1450	560	230	1.5	0.79	1000	1550	0.50	0.50
20F-V7	DF/DF	2000	2000	650	650	265	1.6	0.85	1450	560	230	1.6	0.85	1050	1600	0.50	0.50
20F-V12	AC/AC	2000	1400	560	560	265	1.5	0.79	1250	470	230	1.4	0.74	925	1500	0.46	0.46
20F-V13	AC/AC	2000	2000	560	560	265	1.5	0.79	1250	470	230	1.4	0.74	950	1550	0.46	0.46
20F-V14	POC/POC	2000	1450	560	560	265	1.5	0.79	1300	470	230	1.4	0.74	900	1600	0.46	0.46
20F-V15	POC/POC	2000	2000	560	560	265	1.5	0.79	1300	470	230	1.4	0.74	900	1600	0.46	0.46
20F-E2	HF/HF	2000	1400	500	500	215	1.6	0.85	1200	375	190	1.4	0.74	925	1350	0.43	0.43
20F-E3	DF/DF	2000	1200	560	560	265	1.7	0.90	1400	560	230	1.6	0.85	1050	1600	0.50	0.50
20F-E6	DF/DF	2000	2000	560	560	265	1.7	0.90	1550	560	230	1.6	0.85	1150	1650	0.50	0.50
20F-E7	HF/HF	2000	2000	500	500	215	1.6	0.85	1450	375	190	1.4	0.74	1050	1450	0.43	0.43
20F-E8	ES/ES	2000	1300	450	450	200	1.5	0.79	1000	315	175	1.4	0.74	825	1100	0.41	0.41
24F-E/SPF1	SPF/SPF	2400	2400	560	560	215	1.6	0.85	1150	470	190	1.6	0.85	1150	2000	0.42	0.42
24F-E/SPF3	SPF/SPF	2400	1550	560	650	215	1.6	0.85	1200	470	195	1.5	0.79	900	1750	0.42	0.42
20F-V2	SP/SP	2000	1550	740	650	300	1.5	0.79	1450	650	260	1.4	0.74	1000	1400	0.55	0.55
20F-V3	SP/SP	2000	1450	650	650	300	1.5	0.79	1600	650	260	1.5	0.79	1000	1400	0.55	0.55
20F-V5	SP/SP	2000	2000	740	740	300	1.6	0.85	1450	650	260	1.4	0.74	1050	1500	0.55	0.55
20F-E1	SP/SP	2000	1300	650	650	300	1.7	0.90	1400	650	260	1.6	0.85	1050	1550	0.55	0.55
20F-E3	SP/SP	2000	2000	650	650	300	1.7	0.90	1700	650	260	1.6	0.85	1150	1600	0.55	0.55
24F-1.7E		**2400**	**1450**	**500**		**210**	**1.7**	**0.90**	**1050**	**315**	**185**	**1.3**	**0.69**	**775**	**1000**	**0.42**	
24F-V5	DF/HF	2400	1600	650	650	215	1.7	0.90	1350	375	200	1.5	0.79	1100	1450	0.50	0.43
24F-V10	DF/HF	2400	2400	650	650	215	1.8	0.95	1450	375	200	1.5	0.79	1150	1550	0.50	0.43
24F-E11	HF/HF	2400	2400	500	500	215	1.8	0.95	1550	375	190	1.5	0.79	1150	1550	0.43	0.43
24F-E15	HF/HF	2400	1600	500	500	215	1.7	0.95	1200	375	190	1.5	0.79	975	1500	0.43	0.43
24F-V1	SP/SP	2400	1750	740	650	300	1.7	0.90	1450	650	260	1.5	0.79	1100	1500	0.55	0.55
24F-V4 (4)	SP/SP	2400	1650	740	650	210	1.7	0.90	1350	470	230	1.5	0.79	975	1350	0.55	0.43
24F-V5	SP/SP	2400	2400	740	740	300	1.7	0.90	1700	650	260	1.6	0.85	1150	1600	0.55	0.55

Table 5A - VERT. & LATERAL

Combination Symbol	Species Outer/ Core	Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations): Bending, Bottom of Beam Stressed in Tension (Positive Bending) F_{bx}^{+} (psi)	Bending, Top of Beam Stressed in Tension (Negative Bending) F_{bx}^{-} (psi)	Compression Perpendicular to Grain, Tension Face $F_{c\perp x}$ (psi)	Compression Perpendicular to Grain, Compression Face $F_{c\perp x}$ (psi)	Shear Parallel to Grain F_{vx} (2) (psi)	Modulus of Elasticity, For Deflection Calculations E_x (10^6 psi)	Modulus of Elasticity, For Stability Calculations $E_{x\,min}$ (10^6 psi)	Bending F_{by} (psi)
16F-1.3E		**1600**	**925**	**315**		**195**	**1.3**	**0.69**	**800**
16F-V3	DF/DF	1600	1250	560	560	265	1.5	0.79	1450
16F-V6	DF/DF	1600	1600	560	560	265	1.6	0.85	1450
16F-E2	HF/HF	1600	1050	375	375	215	1.4	0.74	1200
16F-E3	DF/DF	1600	1200	560	560	265	1.6	0.85	1400
16F-E6	DF/DF	1600	1600	560	560	265	1.6	0.85	1550
16F-E7	HF/HF	1600	1600	375	375	215	1.4	0.74	1350
16F-V2	SP/SP	1600	1400	740	650	300	1.5	0.79	1450
16F-V3	SP/SP	1600	1450	740	740	300	1.4	0.74	1450
16F-V5	SP/SP	1600	1600	650	650	300	1.6	0.85	1600
16F-E1	SP/SP	1600	1250	650	650	300	1.6	0.85	1400
16F-E3	SP/SP	1600	1600	650	650	300	1.7	0.90	1650
20F-1.5E		**2000**	**1100**	**425**		**195**	**1.5**	**0.79**	**800**
20F-V3	DF/DF	2000	1450	650	560	265	1.6	0.85	1450
20F-V7	DF/DF	2000	2000	650	650	265	1.6	0.85	1450
20F-V12	AC/AC	2000	1400	560	560	265	1.5	0.79	1250

Table 5B - VERT. & LATERAL

Table 5B Reference Design Values for Structural Glued Laminated Softwood Timber

(Members stressed primarily in axial tension or compression) (Tabulated design values are for normal load duration and dry service conditions. See NDS 5.3 for a comprehensive description of design value adjustment factors.)

Use with Table 5B Adjustment Factors

Combination Symbol	Species	Grade	All Loading: Modulus of Elasticity, For Deflection Calculations E (10^6 psi)	All Loading: Modulus of Elasticity, For Stability Calculations E_{min} (10^6 psi)	All Loading: Compression Perpendicular to Grain $F_{c\perp}$ (psi)	Axially Loaded: Tension Parallel to Grain, 2 or More Laminations F_t (psi)	Axially Loaded: Compression Parallel to Grain, 4 or More Laminations F_c (psi)	Axially Loaded: Compression Parallel to Grain, 2 or 3 Laminations F_c (psi)	Bending about Y-Y Axis (Loaded Parallel to Wide Faces of Laminations): Bending, 4 or More Laminations F_{by} (psi)	Bending about Y-Y Axis: Bending, 3 Laminations F_{by} (psi)	Bending about Y-Y Axis: Bending, 2 Laminations F_{by} (psi)	Bending about Y-Y Axis: Shear Parallel to Grain(1)(2)(3) F_{vy} (psi)	Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations): Bending, 2 Laminations to 15 in. Deep(4) F_{bx} (psi)	Bending About X-X Axis: Shear Parallel to Grain(3) F_{vx} (psi)	Fasteners: Specific Gravity for Fastener Design G
Visually Graded Western Species															
1	DF	L3	1.5	0.79	560	950	1550	1250	1450	1250	1000	230	1250	265	0.50
2	DF	L2	1.6	0.85	560	1250	1950	1600	1800	1600	1300	230	1700	265	0.50
3	DF	L2D	1.9	1.00	650	1450	2300	1900	2100	1850	1550	230	2000	265	0.50
4	DF	L1CL	1.9	1.00	590	1400	2100	1950	2200	2000	1650	230	2100	265	0.50
5	DF	L1	2.0	1.06	650	1650	2400	2100	2400	2100	1800	230	2200	265	0.50
14	HF	L3	1.3	0.69	375	800	1100	1050	1200	1050	850	190	1100	215	0.43
15	HF	L2	1.4	0.74	375	1050	1350	1350	1500	1350	1100	190	1450	215	0.43
16	HF	L1	1.6	0.85	375	1200	1500	1500	1750	1550	1300	190	1600	215	0.43
17	HF	L1D	1.7	0.90	500	1400	1750	1750	2000	1850	1550	190	1900	215	0.43
22(5)	SW	L3	1.0	0.53	315	525	850	725	800	700	575	170	725	195	0.35
69	AC	L3	1.2	0.63	470	725	1150	1100	1100	975	775	230	1000	265	0.46
70	AC	L2	1.3	0.69	470	975	1450	1450	1400	1250	1000	230	1350	265	0.46
71	AC	L1D	1.6	0.85	560	1250	1900	1900	1850	1650	1400	230	1750	265	0.46
72	AC	L1S	1.6	0.85	560	1250	1900	1900	1850	1650	1400	230	1900	265	0.46
73	POC	L3	1.3	0.69	470	775	1500	1200	1200	1050	825	230	1050	265	0.46
74	POC	L2	1.4	0.74	470	1050	1900	1550	1450	1300	1100	230	1400	265	0.46
75	POC	L1D	1.7	0.90	560	1350	2300	2050	1950	1750	1500	230	1850	265	0.46
Visually Graded Southern Pine															
47	SP	N2M12	1.4	0.74	650	1200	1900	1150	1750	1550	1300	260	1400	300	0.55
47 1:10	SP	N2M10	1.4	0.74	650	1150	1700	1150	1750	1550	1300	260	1400	300	0.55
47 1:8	SP	N2M	1.4	0.74	650	1000	1500	1150	1600	1550	1300	260	1400	300	0.55
48	SP	N2D12	1.7	0.90	740	1400	2200	1350	2000	1800	1500	260	1600	300	0.55
48 1:10	SP	N2D10	1.7	0.90	740	1350	2000	1350	2000	1800	1500	260	1600	300	0.55
48 1:8	SP	N2D	1.7	0.90	740	1150	1750	1350	1850	1800	1500	260	1600	300	0.55
49	SP	N1M16	1.7	0.90	650	1350	2100	1450	1950	1750	1500	260	1800	300	0.55
49 1:14	SP	N1M14	1.7	0.90	650	1350	2000	1450	1950	1750	1500	260	1800	300	0.55
49 1:12	SP	N1M12	1.7	0.90	650	1300	1900	1450	1950	1750	1500	260	1800	300	0.55
49 1:10	SP	N1M	1.7	0.90	650	1150	1700	1450	1850	1750	1500	260	1800	300	0.55
50	SP	N1D14	1.9	1.00	740	1550	2300	1700	2300	2100	1750	260	2100	300	0.55
50 1:12	SP	N1D12	1.9	1.00	740	1500	2200	1700	2300	2100	1750	260	2100	300	0.55
50 1:10	SP	N1D	1.9	1.00	740	1350	2000	1700	2100	2100	1750	260	2100	300	0.55

1. For members with 2 or 3 laminations, the reference shear design value for transverse loads parallel to the wide faces of the laminations, F_{vy}, shall be reduced by multiplying by a factor of 0.84 or 0.95, respectively.
2. The reference shear design value for transverse loads applied parallel to the wide faces of the laminations, F_{vy}, shall be multiplied by 0.4 for members with 5, 7, or 9 laminations manufactured from multiple piece laminations (across width) that are not edge bonded. The reference shear design value, F_{vy}, shall be multiplied by 0.5 for all other members manufactured from multiple piece laminations with unbonded edge joints. This reduction shall be cumulative with the adjustments in footnotes 1 and 3.
3. The reference design values for shear, F_{vx} and F_{vy}, shall be multiplied by the shear reduction factor, C_{vr}, for the conditions defined in NDS 5.3.10.
4. For members greater than 15 in. deep, the reference bending design value, F_{bx}, shall be reduced by multiplying by a factor of 0.88.
5. When Western Cedars, Western Cedars (North), Western Woods, and Redwood (open grain) are used in combinations for Softwood Species (SW), the reference design value for modulus of elasticity, E, shall be reduced by 100,000 psi and E_{min} shall be reduced by 52,800 psi. When Coast Sitka Spruce, Coast Species, Western White Pine, and Eastern White Pine are used in combinations for Softwood Species (SW) reference design values for shear parallel to grain, F_{vx} and F_{vy}, shall be reduced by 10 psi, before applying any other adjustments.

Table 5B

Table 5B Reference Design Values for Structural Glu

(Members stressed primarily in axial tension or compression) (Ta
NDS 5.3 for a comprehensive description of design value adjustment fa

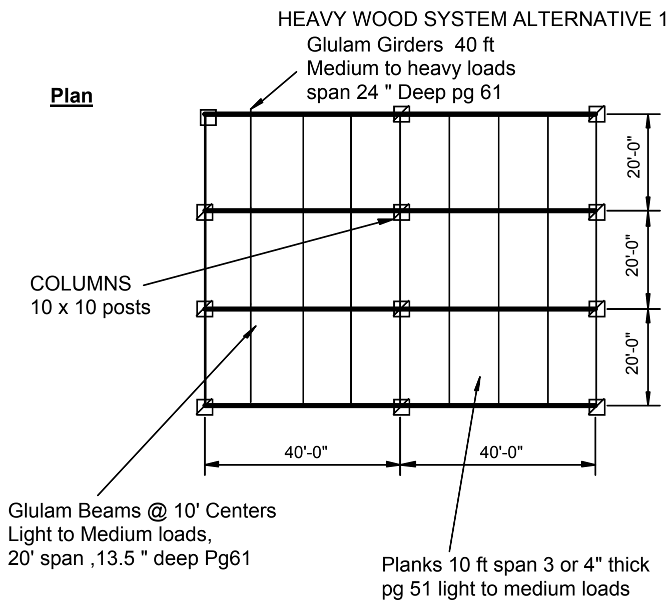
Use with Table 5B Adj

Combination Symbol	Species	Grade	All Loading: Modulus of Elasticity, For Deflection Calculations, E (10^6 psi)	All Loading: Modulus of Elasticity, For Stability Calculations, E_{min} (10^6 psi)	All Loading: Compression Perpendicular to Grain, $F_{c\perp}$ (psi)	Axially Loaded: Tension Parallel to Grain, 2 or More Laminations, F_t (psi)	Axially Loaded: Compression Parallel to Grain, 4 or More Laminations, F_c (psi)	Axially Loaded: Compression Parallel to Grain, 2 or 3 Laminations, F_c (psi)
Visually Graded Western Species								
1	DF	L3	1.5	0.79	560	950	1550	1250
2	DF	L2	1.6	0.85	560	1250	1950	1600
3	DF	L2D	1.9	1.00	650	1450	2300	1900
4	DF	L1CL	1.9	1.00	590	1400	2100	1950
5	DF	L1	2.0	1.06	650	1650	2400	2100
14	HF	L3	1.3	0.69	375	800	1100	1050
15	HF	L2	1.4	0.74	375	1050	1350	1350
16	HF	L1	1.6	0.85	375	1200	1500	1500
17	HF	L1D	1.7	0.90	500	1400	1750	1750
22[6]	SW	L3	1.0	0.53	315	525	850	725
69	AC	L3	1.2	0.63	470	725	1150	1100
70	AC	L2	1.3	0.69	470	975	1450	1450
71	AC	L1D	1.6	0.85	560	1250	1900	1900
72	AC	L1S	1.6	0.85	560	1250	1900	1900
73	POC	L3	1.3	0.69	470	775	1500	1200
74	POC	L2	1.4	0.74	470	1050	1900	1550
75	POC	L1D	1.7	0.90	560	1350	2300	2050

Glulams - VERT. & LATERAL

- Table 5C is for hardwood glulams loaded primarily in bending
- Table 5D is for hardwood glulams loaded primarily in axial tension or compression

Wood Design Example 2 – Previous Prelim. Design VERT.



Design Load = 40 live load psf and 20 psf dead (not including girder wts.)

Example Exterior Glulam Girder - VERT.

Use trib. width and uniform load analysis

Live load $= 40 \times 10 = 400\ \text{lb/ft}$

Dead load $= 20 \times 10 = 200\ \text{lb/ft}$

Max moment $= 600\,(40)^2/8 = 120{,}000\ \text{lb} \cdot \text{ft}$

Now either guess at size of girder or wood species and grade

Try a 6.75 x 39 glulam $\quad S = 1{,}711\ \text{in}^3$

$A = 263.3\ \text{in}^2$ weight ~ 65 lb/ft

Example Exterior Glulam Girder - VERT.

$F_{b'ASD\ req} = M/S = (133{,}000/1{,}711\ \text{in}^3)12 = 932\ \text{psi}$

$F'_{bASD} = C_D C_M C_t C_L(\text{or } C_V) C_{fu} C_C C_I F_b$

Dry service, normal temps, no curvature not on flat

$C_I = C_{fu} = C_t = C_M = C_C = 1.0$

Unbraced length Table 3.3.3

Simple span beam – $L_e = 1.54 \times (L_u = 10') = 15.4$ –

concentrated loads and bracing at ¼ points or = 2.06 L_u

$L_e = 10(2.06) = 20.6$ for uniform loads braces at supports

Use $L_e = 20.6$ – check slenderness ratio = $R_B = [L_e d/b^2]^{1/2}$

$R_B = [20.6(12)39/6.75^2]^{1/2} = 14.55 < 50$ (limit)

Example Exterior Glulam Beam VERT.

$F_{bE} = 1.2E'_{min}/R_B^2$

Guess $16F - 1.3E(16F - V6)$ - from Table 5A $E_{min} = 850{,}000$

$F_{bx} = 1{,}600$ so $F_b^* = 1{,}600\ \text{psi}$

$F_{bE} = 1.2\,(850{,}000)/(14.55)^2 = 4{,}818\ \text{psi}$

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

$= 0.977$

Check $C_v = (21/L)^{1/x}(12/d)^{1/x}(5.125/b)^{1/x} < 1.0$

$X = 10$ for all but southern pine

L in feet and d and b in inches

$C_v = (21/40)^{1/10}(12/39)^{1/10}(5.125/6.75)^{1/10} = 0.811 < C_L$ Gov.

Table 5A - VERT. & LATERAL

Combination Symbol	Species Outer/ Core	Bending About X-X Axis (Loaded Perpendicular to Wide Faces of Laminations): Bending, Bottom of Beam Stressed in Tension (Positive Bending) F_{bx}^{+} (psi)	Bending, Top of Beam Stressed in Tension (Negative Bending) F_{bx}^{-} (psi)	Compression Perpendicular to Grain, Tension Face $F_{c\perp x}$ (psi)	Compression Perpendicular to Grain, Compression Face $F_{c\perp x}$ (psi)	Shear Parallel to Grain F_{vx} (2) (psi)	Modulus of Elasticity, For Deflection Calculations E_x (10^6 psi)	Modulus of Elasticity, For Stability Calculations $E_{x\,min}$ (10^6 psi)	Bending F_{by} (psi)
16F-1.3E		**1600**	**925**	**315**		**195**	**1.3**	**0.69**	**800**
16F-V3	DF/DF	1600	1250	560	560	265	1.5	0.79	1450
16F-V6	DF/DF	1600	1600	560	560	265	1.6	0.85	1450
16F-E2	HF/HF	1600	1050	375	375	215	1.4	0.74	1200
16F-E3	DF/DF	1600	1200	560	560	265	1.6	0.85	1400
16F-E6	DF/DF	1600	1600	560	560	265	1.6	0.85	1550
16F-E7	HF/HF	1600	1600	375	375	215	1.4	0.74	1350
16F-V2	SP/SP	1600	1400	740	650	300	1.5	0.79	1450
16F-V3	SP/SP	1600	1450	740	740	300	1.4	0.74	1450
16F-V5	SP/SP	1600	1600	650	650	300	1.6	0.85	1600
16F-E1	SP/SP	1600	1250	650	650	300	1.6	0.85	1400
16F-E3	SP/SP	1600	1600	650	650	300	1.7	0.90	1650
20F-1.5E		**2000**	**1100**	**425**		**195**	**1.5**	**0.79**	**800**
20F-V3	DF/DF	2000	1450	650	560	265	1.6	0.85	1450
20F-V7	DF/DF	2000	2000	650	650	265	1.6	0.85	1450
20F-V12	AC/AC	2000	1400	560	560	265	1.5	0.79	1250
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Example Glulam Girder VERT.

$F'_{bASD} = 0.811 \times 1{,}600 = 1{,}297 > 932$ psi

OK in bending

Check shear

$f_{vmax} = 1.5(V/A) = (1.5)\,(665(40)/2)/263.3 = 75.8$ psi

F'_{vASD} = only C_D, C_M and $C_t = 1.0$ all

$16F - 1.3E(16FV6),\ F'_v = 265(1 \times 1 \times 1) = 265 \text{ psi} > 75.8$

OK in shear

Example Glulam Girder VERT. & LATERAL

Check deflections – only short term

$I = 33{,}370\ \text{in}^4$ (Table 1C)

$\Delta_{max} = 5(400)(40)^4(12)^3/[384(\mathbf{1,600,000})33{,}370] = 0.43\ in.$

$= L/1{,}112$ OK for $L/360$

<u>Use 6.75 x 39" 16F-1.3 E (16FV6) glulam</u>

What would change in the girder design if the deck was assumed to fully brace the girder? VERT.

Possible Answers

A. The C_L factor would change and the girder capacity would increase.

B. The C_L factor would change and the girder capacity would decrease.

C. The C_V factor would change and the girder capacity would decrease.

D. The C_L factor would change and the girder capacity would not change.

Possible Breadth Exam Problems - VERT.

a) Given a loading and span, select grade of lumber of a given size (or given grade, select size) to resist load. **Beam Ex 1 or 2, just use size given**.

b) Given a beam, what is the maximum load that can be applied – smaller of that given by moment, shear or deflection check. **Beam Ex 1 or 2, just use size given and check flexure, etc**.

c) Given a beam, find max. moment capacity or shear capacity, etc. **Beam Ex 1 or 2, just use size given and check flexure, etc**.

Compression Loading VERT. & LATERAL

- Compression parallel to grain – usually columns
- Compression perpendicular to the grain – usually bearing

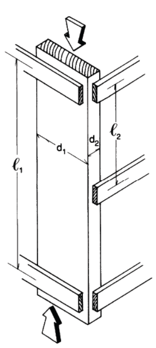
Compression Parallel to Grain - VERT. & LATERAL

- $f_c = P_{cap}/A_n \leq F'_{cASD}$
- $F'_{cASD} = F_c \times C_D \times C_m \times C_t \times C_p \times$*
- C_D, C_M, C_t as with bending
- * C_i, and C_F are also applied for sawn timber – as with bending

Compression Parallel to Grain - VERT. & LATERAL

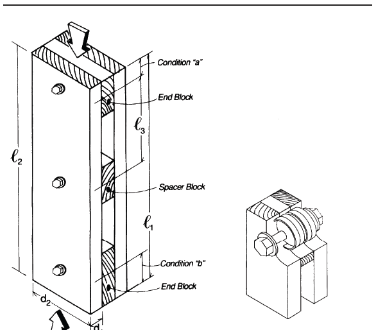
- Code classifies three column types – solid, spaced or built-up

Figure 3F Simple Solid Column



3.6.4 Compression Members Bearing End to End

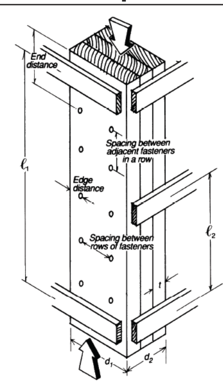
Figure 15A Spaced Column Joined by Split Ring or Shear Plate Connectors



Spaced column

Typical shear plate connection in end block of spaced column

Figure 15B Mechanically Laminated Built-Up Columns



Compression Parallel to Grain - VERT. & LATERAL

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

$F_c^* =$ adjusted allowable except C_p

$F_{cE} = \frac{0.822E'_{min}}{(l_e/d)^2}$ $\qquad c = 0.8$ sawn timber, 0.9 for glulams

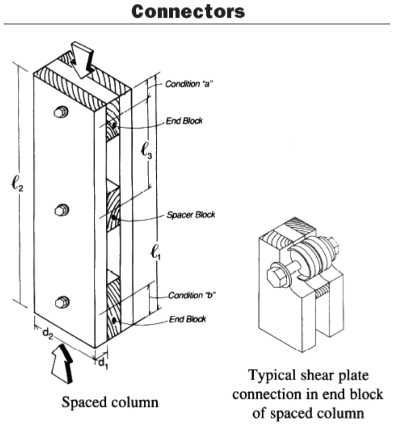
Largest l_e/d governs and must not exceed 50, $l_e = K_e l$

App G suggests

$K_{e_{pin\_pin}} = 1.0$ and $K_{e_{fixed\_fixed}} = 0.65$

Spaced Columns - VERT. & LATERAL

Figure 15A Spaced Column Joined by Split Ring or Shear Plate Connectors



Condition "a": end distance ≤ $\ell_1/20$

ℓ_1 and ℓ_2 = distances between points of lateral support in planes 1 and 2, measured from center to center of lateral supports for continuous spaced columns, and measured from end to end for simple spaced columns, inches.

ℓ_3 = Distance from center of spacer block to centroid of the group of split ring or shear plate connectors in end blocks, inches.

d_1 and d_2 = cross-sectional dimensions of individual rectangular compression members in planes of lateral support, inches.

Condition "b": $\ell_1/20$ < end distance ≤ $\ell_1/10$

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

$c = 0.8$ sawn timber, 0.9 for glulams

Largest l/d governs and must not exceed 50 or 40 (see Section 15.2)

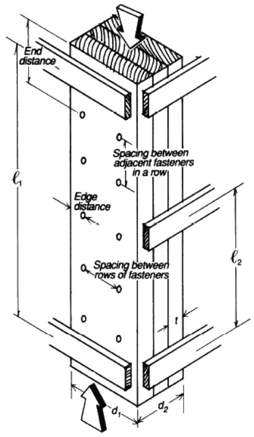
$k_x = 2.5$ for condition a and 3.0 for condition b

$l_e = Kl$

Note that split ring systems must provide capacity as defined in 15.2

Built-up Columns - VERT. & LATERAL

Figure 15B Mechanically Laminated Built-Up Columns



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

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

$K_f = 0.6$ for built-up columns where ℓ_{e2}/d_2 is used to calculate F_{cE} and the built-up columns are nailed in accordance with 15.3.3

$K_f = 0.75$ for built-up columns where ℓ_{e2}/d_2 is used to calculate F_{cE} and the built-up columns are bolted in accordance with 15.3.4

$K_f = 1.0$ for built-up columns where ℓ_{e1}/d_1 is used to calculate F_{cE} and the built-up columns are either nailed or bolted in accordance with 15.3.3 or 15.3.4, respectively

$c = 0.8$ for sawn lumber

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

Example Sawn Timber Column - VERT.

Assume Column as Shown – Pin–Pin supports

P = 5,760 lb dead + 24,000 lb live = 29,760 lb

Dry service, normal temps, no incising

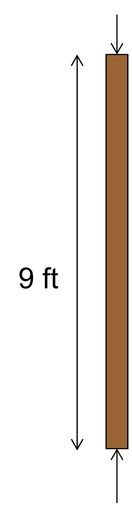
$C_m = C_t = C_D = 1.0$ – guess $C_p = 0.8$

Guess larger than 2-4" use Table 4D post and timber SPF#1

$F_c = 700\,psi = F_c^*$ since factors except C_p are = 1.0 (including C_F)

Then area required $= 29{,}760/700 \times 0.8 = 53.1\ in^2$

Try an 8 x 8 in – area $= (7.5)^2 = 56.25\ in^2$



Example Sawn Timber Column - VERT.

Table 4D (Cont.) **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	$F_{c\perp}$	F_c	E	E_{min}	G	
SPRUCE-PINE-FIR										
Select Structural	Beams and Stringers	1,100	650	125	425	775	1,300,000	470,000	0.42	NLGA
No.1		900	450	125	425	625	1,300,000	470,000		
No.2		600	300	125	425	425	1,000,000	370,000		
Select Structural	Posts and Timbers	1,050	700	125	425	800	1,300,000	470,000		
No.1		850	550	125	425	700	1,300,000	470,000		
No.2		500	325	125	425	500	1,000,000	370,000		
SPRUCE-PINE-FIR (SOUTH)										
Select Structural	Beams and Stringers	1,050	625	125	335	675	1,200,000	440,000	0.36	NELMA NSLB WWPA WCLIB
No.1		900	450	125	335	550	1,200,000	440,000		
No.2		575	300	125	335	375	1,000,000	370,000		
Select Structural	Posts and Timbers	1,000	675	125	335	700	1,200,000	440,000		
No.1		800	550	125	335	625	1,200,000	440,000		
No.2		475	325	125	335	425	1,000,000	370,000		
WESTERN CEDARS										
Select Structural	Beams and Stringers	1,150	675	140	425	875	1,000,000	370,000		
No.1		975	475	140	425	725	1,000,000	370,000		

Example Sawn Timber Column VERT.

$$F_{cE} = 0.822(E_{min})/(L_e/d)^2 = 0.822\,(470{,}000)/(9 \times 12/7.5)^2 = 1{,}863 \text{ psi}$$

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

$= 0.906$ (note $c = 0.8$ for sawn timber and $C_F = 1$)

$$F_c' = 700 \times 1 \times 1 \times 1 \times 0.906 = 634 \text{ psi}$$

$f_c = 29{,}760/56.25 = 529 \text{ psi} < 634$ OK

Use a 8x8 SPF #1 Post

Example Built-up Sawn Timber Column VERT.

Similar to previous example – pinned-pinned supports. Find capacity of the column.

Assume (5) 2 x 6, SPF #2 Built-up Column

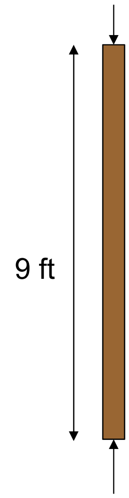
Dry service, normal temps, no incising

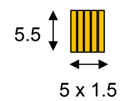
$C_m = C_t = C_D = 1.0$

Use Table 4A , $C_F = 1.1$, & (SPF #1&2) $F_c = 1{,}150$ psi

Assume nailed to meet 15.3.3. $K_{f2} = 0.6$ for buckling about nailed axis and $K_{f1} = 1.0$ for buckling about solid axis

Area $= 5 \times 1.5 \times 5.5 = 7.5 \times 5.5 = 41.25\ \text{in}^2$





Example Built-up Timber Column - VERT.

$F_{cE1} = 0.822(E_{min})/(L_{e1}/d_1)^2 = 0.822\,(510{,}000)/(9 \times 12/5.5)^2 = 1{,}087$ psi

$F_{cE2} = 0.822(E_{min})/(L_{e2}/d_2)^2 = 0.822\,(510{,}000)/(9 \times 12/7.5)^2 = 2{,}022$ psi

$F_c^* = 1.1 \times 1{,}150 = 1{,}265$ psi

$$C_{p1} = K_{f1}\left(1 + (F_{cE1}/F_c^*)\right)/2c - \left[\left[\left(1 + (F_{cE1}/F_c^*)\right)/2c\right]^2 - (F_{cE1}/F_c^*)/c\right]^{1/2})$$

$= 0.636$ for $K_{f1} = 1.0$

$$C_p = K_{f2}\left(1 + (F_{cE2}/F_c^*)\right)/2c - \left[\left[\left(1 + (F_{cE2}/F_c^*)\right)/2c\right]^2 - (F_{cE2}/F_c^*)/c\right]^{1/2})$$

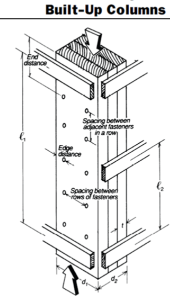
$= 0.495$ for $K_{f2} = 0.6$ governs

(note $c = 0.8$ for sawn timber)

$F_c' = 1{,}265 \times 0.495 = 626$ psi

Capacity $= 41.25 \times 626 = 25{,}830$ lb

Figure 15B Mechanically Laminated Built-Up Columns



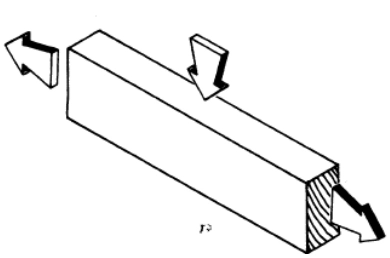
Possible Breadth Exam Problems - VERT.

a) Given a loading and height, select grade of lumber of a given size (or given grade, select size) to resist load. **Column Ex 1 or 2, just use size given**.

b) Given a column, what is the maximum load that can be applied. **Column Ex 1 or 2, just use size given and back calculate load from stress**.

c) Truss compression members – **design as a column after load is determined. Usually pin-pin supports**.

Combined Axial Load and Bending - VERT. & LATERAL



For truss tension members, no bending, just limit $f_t = T/A_n \leq F_t'$

3.9.1 Bending and Axial Tension

Members subjected to a combination of bending and axial tension (see Figure 3G) shall be so proportioned that:

$$\frac{f_t}{F_t'} + \frac{f_b}{F_b^*} \leq 1.0 \quad (3.9\text{-}1)$$

and

$$\frac{f_b - f_t}{F_b^{**}} \leq 1.0 \quad (3.9\text{-}2)$$

Where

F_b^* = reference bending design value multiplied by all applicable adjustment factors except C_L

F_b^{**} = reference bending design value multiplied by all applicable adjustment factors except C_v

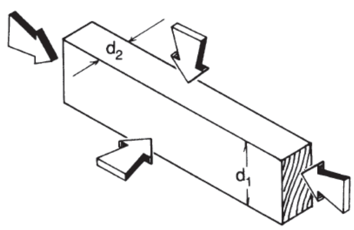
Combined Axial Load and Bending - VERT. & LATERAL

3.9.2 Bending and Axial Compression

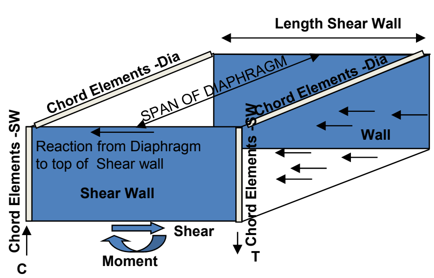
Members subjected to a combination of bending about one or both principal axes and axial compression (see Figure 3H) shall be so proportioned that:

$$\left[\frac{f_c}{F_c'}\right]^2 + \frac{f_{b1}}{F_{b1}'[1-(f_c/F_{cE1})]} + \frac{f_{b2}}{F_{b2}'[1-(f_c/F_{cE2})-(f_{b1}/F_{bE})^2]} \leq 1.0 \qquad (3.9\text{-}3)$$

Ch. 15.4 NDS – Columns with eccentric axial loads and/or side loads, slightly different formula



Diaphragms & Load Distribution - LATERAL



- Design sheathing and framing to take shear and
- End/edge elements to take cord forces (columns - tension members)
- Chord force = M/d
- Design chord elements for extra axial force – beam column. Be careful with bearing on plates at base of shear walls and anchors.
- d – distance between centerline of chords

Wood diaphragms are almost always flexible –

Lat. Load distribution w.r.t. trib. width

Shear Walls and Diaphragms - LATERAL

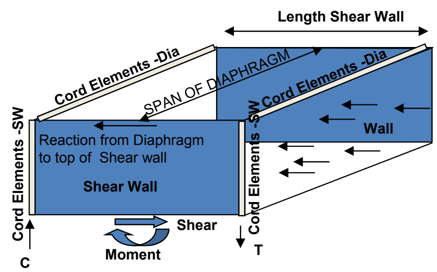


Table 4.2.4 Maximum Diaphragm Aspect Ratios (Horizontal or Sloped Diaphragms)	
Diaphragm Sheathing Type	Maximum L/W Ratio
Wood structural panel, unblocked	3:1
Wood structural panel, blocked	4:1
Single-layer straight lumber sheathing	2:1
Single-layer diagonal lumber sheathing	3:1
Double-layer diagonal lumber sheathing	4:1

- Get shear per unit length = shear/net length of shear wall or depth of diaphragm from:
- AWC SDPW&S – I will use this since it is specifically referenced by the NCEES Materials.
- IBC Section 2305 can also be used.
- Aspect ratios of diaphragm limited to 3:1 (no blocking) or 4:1 in NDS SDPW&S for structural panels

Shear Walls and Diaphragms - LATERAL

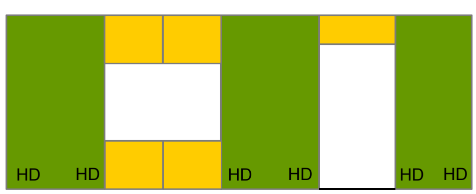


Table 4.3.4 Maximum Shear Wall Aspect Ratios	
Shear Wall Sheathing Type	Maximum h/b_s Ratio
Wood structural panels, unblocked	2:1
Wood structural panels, blocked	3.5:1
Particleboard, blocked	2:1
Diagonal sheathing, conventional	2:1
Gypsum wallboard	2:1[1]
Portland cement plaster	2:1[1]
Structural Fiberboard	3.5:1
1. Walls having aspect ratios exceeding 1.5:1 shall be blocked shear walls.	

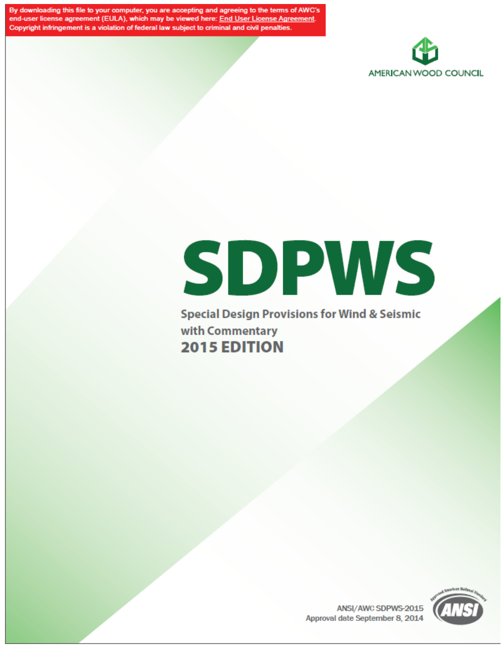
For segmented shear walls, three methods of design are used –

The simplest is to design full height segments to have a sum of resistances that is greater that the total diaphragm reaction. OK as long as same materials.

Must have chord elements at edge of each segment.

Segments must meet SDPWS Section 4.3.4 aspect ratios & shear walls 3.5:1 to 1.5:1

Use the AWC-SDPWS 2015 Standard LATERAL



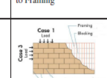
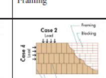
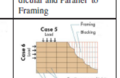
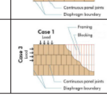
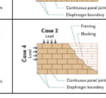
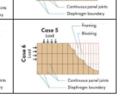
Diaphragm Capacities - LATERAL

Table 4.2A Nominal Unit Shear Capacities for Wood-Frame Diaphragms

Blocked Wood Structural Panel Diaphragms[1,2,3,4,5]

					A SEISMIC												B WIND			
					Nail Spacing (in.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 & 4), and at all panel edges (Cases 5 & 6)												Nail Spacing (in.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 & 4), and at all panel edges (Cases 5 & 6)			
					6			4			2-1/2			2			6	4	2-1/2	2
					Nail Spacing (in.) at other panel edges (Cases 1, 2, 3, & 4)												Nail Spacing (in.) at other panel edges (Cases 1, 2, 3, & 4)			
Sheathing Grade	Common Nail Size	Minimum Fastener Penetration in Framing Member or Blocking (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Adjoining Panel Edges and Boundaries (in.)	6			6			4			3			6	6	4	3
					v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_w (plf)	v_w (plf)	v_w (plf)	v_w (plf)
						OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY				
Structural I	6d	1-1/4	5/16	2	370	15	12	500	8.5	7.5	750	12	10	840	20	15	520	700	1050	1175
				3	420	12	9.5	560	7.0	6.0	840	9.5	8.5	950	17	13	590	785	1175	1330
	8d	1-3/8	3/8	2	540	14	11	720	9.0	7.5	1060	13	10	1200	21	15	755	1010	1485	1680
				3	600	12	10	800	7.5	6.5	1200	10	9.0	1350	18	13	840	1120	1680	1890
	10d	1-1/2	15/32	2	640	24	17	850	15	12	1280	20	15	1460	31	21	895	1190	1790	2045
				3	720	20	15	960	12	9.5	1440	16	13	1640	26	18	1010	1345	2015	2295
Sheathing and Single-Floor	6d	1-1/4	5/16	2	340	15	10	450	9.0	7.0	670	13	9.5	760	21	13	475	630	940	1065
				3	380	12	9.0	500	7.0	6.0	760	10	8.0	860	17	12	530	700	1065	1205
			3/8	2	370	13	9.5	500	7.0	6.0	750	10	8.0	840	18	12	520	700	1050	1175
				3	420	10	8.0	560	5.5	5.0	840	8.5	7.0	950	14	10	590	785	1175	1330
	8d	1-3/8	3/8	2	480	15	11	640	9.5	7.5	960	13	9.5	1090	21	13	670	895	1345	1525
				3	540	12	9.5	720	7.5	6.0	1080	11	8.5	1220	18	12	755	1010	1510	1710
			7/16	2	510	14	10	680	8.5	7.0	1010	12	9.5	1150	20	13	715	950	1415	1610
				3	570	11	9.0	760	7.0	6.0	1140	10	8.0	1290	17	12	800	1065	1595	1805
			15/32	2	540	13	9.5	720	7.5	6.5	1060	11	8.5	1200	19	13	755	1010	1485	1680
				3	600	10	8.5	800	6.0	5.5	1200	9.0	7.5	1350	15	11	840	1120	1680	1890
	10d	1-1/2	15/32	2	580	25	15	770	15	11	1150	21	14	1310	33	18	810	1080	1610	1835
				3	650	21	14	860	12	9.5	1300	17	12	1470	28	16	910	1205	1820	2060
			19/32	2	640	21	14	850	13	9.5	1280	18	12	1460	28	17	895	1190	1790	2045
				3	720	17	12	960	10	8.0	1440	14	11	1640	24	15	1010	1345	2015	2295

1. Nominal unit shear capacities shall be adjusted in accordance with 4.2.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.2.6. For specific requirements, see 4.2.7.1 for wood structural panel diaphragms. See Appendix A for common nail dimensions.
2. For species and grades of framing other than Douglas-Fir-Larch or Southern Pine, reduced nominal unit shear capacities shall be determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor = [1-(0.5-G)], where G = Specific Gravity of the framing lumber from the *NDS* (Table 12.3.3A). The Specific Gravity Adjustment Factor shall not be greater than 1.
3. Apparent shear stiffness values, G_a, are based on nail slip in framing with moisture content less than or equal to 19% at time of fabrication and panel stiffness values for diaphragms constructed with either OSB or 3-ply plywood panels. When 4-ply or 5-ply plywood panels or composite panels are used, G_a values shall be permitted to be multiplied by 1.2.
4. Where moisture content of the framing is greater than 19% at time of fabrication, G_a values shall be multiplied by 0.5.
5. Diaphragm resistance depends on the direction of continuous panel joints with respect to the loading direction and direction of framing members, and is independent of the panel orientation.

	Cases 1&3: Continuous Panel Joints Perpendicular to Framing	**Cases 2&4**: Continuous Panel Joints Parallel to Framing	**Cases 5&6**: Continuous Panel Joints Perpendicular and Parallel to Framing
Long Panel Direction Perpendicular to Supports			
Long Panel Direction Parallel to Supports[a]			

(a) Panel span rating for out-of-plane loads may be lower than the span rating with the long panel direction perpendicular to supports (See Section 3.2.2 and Section 3.2.3)

Diaphragm Capacities - LATERAL

Table 4.2C Nominal Unit Shear Capacities for Wood-Frame Diaphragms

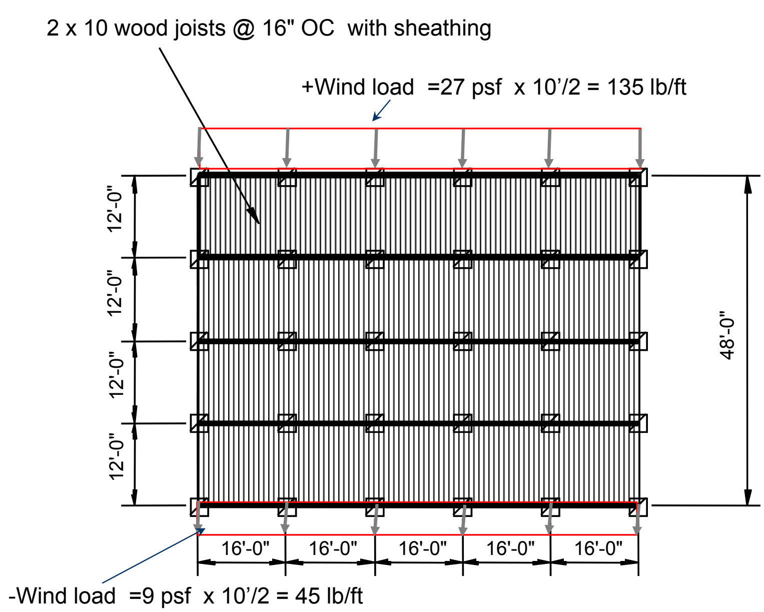
Unblocked Wood Structural Panel Diaphragms[1,2,3,4]

Sheathing Grade	Common Nail Size	Minimum Fastener Penetration in Framing (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Supported Edges and Boundaries (in.)	A SEISMIC – 6 in. Nail Spacing at diaphragm boundaries and supporting members – Case 1 – v_s (plf)	Case 1 – G_a (kips/in.) OSB	Case 1 – G_a (kips/in.) PLY	Cases 2,3,4,5,6 – v_s (plf)	Cases 2,3,4,5,6 – G_a (kips/in.) OSB	Cases 2,3,4,5,6 – G_a (kips/in.) PLY	B WIND – 6 in. Nail Spacing at diaphragm boundaries and supporting members – Case 1 – v_w (plf)	Cases 2,3,4,5,6 – v_w (plf)
Structural I	6d	1-1/4	5/16	2	330	9.0	7.0	250	6.0	4.5	460	350
				3	370	7.0	6.0	280	4.5	4.0	520	390
	8d	1-3/8	3/8	2	480	8.5	7.0	360	6.0	4.5	670	505
				3	530	7.5	6.0	400	5.0	4.0	740	560
	10d	1-1/2	15/32	2	570	14	10	430	9.5	7.0	800	600
				3	640	12	9.0	480	8.0	6.0	895	670
Sheathing and Single-Floor	6d	1-1/4	5/16	2	300	9.0	6.5	220	6.0	4.0	420	310
				3	340	7.0	5.5	250	5.0	3.5	475	350
			3/8	2	330	7.5	5.5	250	5.0	4.0	460	350
				3	370	6.0	4.5	280	4.0	3.0	520	390
	8d	1-3/8	3/8	2	430	9.0	6.5	320	6.0	4.5	600	450
				3	480	7.5	5.5	360	5.0	3.5	670	505
			7/16	2	460	8.5	6.0	340	5.5	4.0	645	475
				3	510	7.0	5.5	380	4.5	3.5	715	530
			15/32	2	480	7.5	5.5	360	5.0	4.0	670	505
				3	530	6.5	5.0	400	4.0	3.5	740	560
	10d	1-1/2	15/32	2	510	15	9.0	380	10	6.0	715	530
				3	580	12	8.0	430	8.0	5.5	810	600
			19/32	2	570	13	8.5	430	8.5	5.5	800	600
				3	640	10	7.5	480	7.0	5.0	895	670

Also have tables of high load diaphragms and lumber diaphragms

Allowable values = nominal resistance/2

Simple Diaphragm Example LATERAL



Simple Diaphragm Example LATERAL

Determine the shear flow, q

Critical diaphragm shear = (135 + 45) lb/ft x (5)(16’) x 1/2 = 7,200 lb

0.6W = 7,200 x 0.6 = 4,320 lb

$$q = \frac{4,320}{4x12} = 90 \text{ lb/ft}$$

Use Table 42C Unblocked – Assume Case 1 (But any will work)

Unblocked – 2 inch members, 6d nails @ 6 inch OC, single floor sheathing .

q_{allow} = ½ x 420 = 210 lb/ft > 90 lb/ft Therefore OK

Note for all other cases , q_{allow} = ½ x 310 = 155 lb/ft > 90 lb/ft

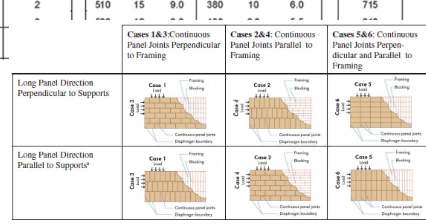
Diaphragm Capacities - LATERAL

Allowable values = nominal resistance/2

Table 4.2C Nominal Unit Shear Capacities for Wood-Frame Diaphragms

Unblocked Wood Structural Panel Diaphragms[1,2,3,4]

Sheathing Grade	Common Nail Size	Minimum Fastener Penetration in Framing (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Supported Edges and Boundaries (in.)	A SEISMIC – 6 in. Nail Spacing at diaphragm boundaries and supporting members – Case 1 – v_s (plf)	Case 1 – G_a (kips/in.) OSB	Case 1 – G_a (kips/in.) PLY	Cases 2,3,4,5,6 – v_s (plf)	Cases 2,3,4,5,6 – G_a (kips/in.) OSB	Cases 2,3,4,5,6 – G_a (kips/in.) PLY	B WIND – 6 in. Nail Spacing at diaphragm boundaries and supporting members – Case 1 – v_w (plf)	Cases 2,3,4,5,6 – v_w (plf)
Structural I	6d	1-1/4	5/16	2	330	9.0	7.0	250	6.0	4.5	460	350
				3	370	7.0	6.0	280	4.5	4.0	520	390
	8d	1-3/8	3/8	2	480	8.5	7.0	360	6.0	4.5	670	505
				3	530	7.5	6.0	400	5.0	4.0	740	560
	10d	1-1/2	15/32	2	570	14	10	430	9.5	7.0	800	600
				3	640	12	9.0	480	8.0	6.0	895	670
Sheathing and Single-Floor	6d	1-1/4	5/16	2	300	9.0	6.5	220	6.0	4.0	420	310
				3	340	7.0	5.5	250	5.0	3.5	475	350
			3/8	2	330	7.5	5.5	250	5.0	4.0	460	350
				3	370	6.0	4.5	280	4.0	3.0	520	390
	8d	1-3/8	3/8	2	430	9.0	6.5	320	6.0	4.5	600	450
				3	480	7.5	5.5	360	5.0	3.5	670	505
			7/16	2	460	8.5	6.0	340	5.5	4.0	645	475
				3	510	7.0	5.5	380	4.5	3.5	715	530
			15/32	2	480	7.5	5.5	360	5.0	4.0	670	505
				3	530	6.5	5.0	400	4.0	3.5	740	560
	10d	1-1/2	15/32	2	510	15	9.0	380	10	6.0	715	530
				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			19/32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



(a) Panel span rating for out-of-plane loads may be lower than the span rating with the long panel direction perpendicular to supports (See Section 3.2.2 and Section 3.2.3)

Shear Walls – Also Have Tables for Gyp. Board LATERAL

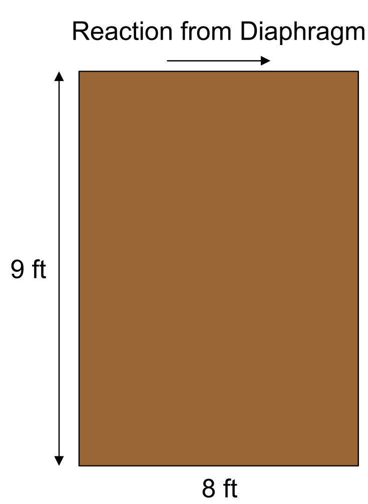
Table 4.3A Nominal Unit Shear Capacities for Wood-Frame Shear Walls[1,3,6,7]

Wood-based Panels[4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimun Fastener Penetration in Framing Member or Blocking (in.)	Fastener Type & Size	A SEISMIC – Panel Edge Fastener Spacing (in.) 6 – v_s (plf)	6 – G_a (kips/in.) OSB	6 – G_a PLY	4 – v_s (plf)	4 – G_a (kips/in.) OSB	4 – G_a PLY	3 – v_s (plf)	3 – G_a (kips/in.) OSB	3 – G_a PLY	2 – v_s (plf)	2 – G_a (kips/in.) OSB	2 – G_a PLY	B WIND – Panel Edge Fastener Spacing (in.) 6 – v_w (plf)	4 – v_w (plf)	3 – v_w (plf)	2 – v_w (plf)
			Nail (common or galvanized box)		OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY				
Wood Structural Panels - Structural I[4,5]	5/16	1-1/4	6d	400	13	10	600	18	13	780	23	16	1020	35	22	560	840	1090	1430
	3/8[2]	1-3/8	8d	460	19	14	720	24	17	920	30	20	1220	43	24	645	1010	1290	1710
	7/16[2]			510	16	13	790	21	16	1010	27	19	1340	40	24	715	1105	1415	1875
	15/32			560	14	11	860	18	14	1100	24	17	1460	37	23	785	1205	1540	2045
	15/32	1-1/2	10d	680	22	16	1020	29	20	1330	36	22	1740	51	28	950	1430	1860	2435
Wood Structural Panels – Sheathing[4,5]	5/16	1-1/4	6d	360	13	9.5	540	18	12	700	24	14	900	37	18	505	755	980	1260
	3/8			400	11	8.5	600	15	11	780	20	13	1020	32	17	560	840	1090	1430
	3/8[2]	1-3/8	8d	440	17	12	640	25	15	820	31	17	1060	45	20	615	895	1150	1485
	7/16[2]			480	15	11	700	22	14	900	28	17	1170	42	21	670	980	1260	1640
	15/32			520	13	10	760	19	13	980	25	15	1280	39	20	730	1065	1370	1790
	15/32	1-1/2	10d	620	22	14	920	30	17	1200	37	19	1540	52	23	870	1290	1680	2155
	19/32			680	19	13	1020	26	16	1330	33	18	1740	48	22	950	1430	1860	2435
			Nail (galvanized casing)																
Plywood Siding	5/16	1-1/4	6d	280	13		420	16		550	17		720	21		390	590	770	1010
	3/8	1-3/8	8d	320	16		480	18		620	20		820	22		450	670	870	1150
			Nail (common or galvanized box)																
Particleboard ~~Sheathing -~~ (M-S "Exterior Glue" and M-2 "Exterior Glue")	3/8		6d	240	15		360	17		460	19		600	22		335	505	645	840
	3/8		8d	260	18		380	20		480	21		630	23		365	530	670	880
	1/2			280	18		420	20		540	22		700	24		390	590	755	980
	1/2		10d	370	21		550	23		720	24		920	25		520	770	1010	1290
	5/8			400	21		610	23		790	24		1040	26		560	855	1105	1455
Structural Fiberboard Sheathing	1/2		Nail (galvanized roofing) 11 ga. galv. roofing nail (0.120" x 1-1/2" long x 7/16" head)				340	4.0		460	5.0		520	5.5			475	645	730
	25/32		*11 ga. galv. roofing nail (0.120"* x 1-3/4" long x 3/8" head)				340	4.0		460	5.0		520	5.5			475	645	730

1. Nominal unit shear values shall be adjusted in accordance with 4.3.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.3.6. For specific requirements, see 4.3.7.1 for wood structural panel shear walls, 4.3.7.2 for particleboard shear walls, and 4.3.7.3 for fiberboard shear walls. See Appendix A for common and box nail dimensions.
2. Shears are permitted to be increased to values shown for 15/32 inch sheathing with same nailing provided (a) studs are spaced a maximum of 16 inches on center, or (b) panels are applied with long dimension across studs.
3. For species and grades of framing other than Douglas-Fir-Larch or Southern Pine, reduced nominal unit shear capacities shall be determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor = [1-(0.5-G)], where G = Specific Gravity of the framing lumber from the *NDS* (Table 11.3.2A). The Specific Gravity Adjustment Factor shall not be greater than 1.
4. Apparent shear stiffness values G_a, are based on nail slip in framing with moisture content less than or equal to 19% at time of fabrication and panel stiffness values for shear walls constructed with either OSB or 3-ply plywood panels. When 4-ply or 5-ply plywood panels or composite panels are used, G_a values shall be permitted to be increased by 1.2.
5. Where moisture content of the framing is greater than 19% at time of fabrication, G_a values shall be multiplied by 0.5.
6. Where panels are applied on both faces of a shear wall and nail spacing is less than 6" on center on either side, panel joints shall be offset to fall on different framing members. Alternatively, the width of the nailed face of framing members shall be 3" nominal or greater at adjoining panel edges and nails at all panel edges shall be staggered.
7. Galvanized nails shall be hot-dipped or tumbled.

Example Shear Wall - LATERAL



A stud shear wall – assume 2x4 SPF #2 Studs, 16" OC, with 7/16" Structural I sheathing and 8d nails at 6" O.C. at panel on edges and 12" OC intermediate fasteners.

What is the shear (seismic) diaphragm reaction allowed and the chord forces on the wall?

Example Shear Wall - LATERAL

The aspect ratio $= h/l = 9/8 - 1.125 < 2$ allowed for structural sheathing and seismic (slide 84)

Check max shear allowed in Table 4.3A

= nominal shear/2

Shear Walls – Also Have Tables for Gyp. Board -LATERAL

Table 4.3A Nominal Unit Shear Capacities for Wood-Frame Shear Walls[1,3,6,7]

Wood-based Panels[4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimun Fastener Penetration in Framing Member or Blocking (in.)	Fastener Type & Size	A SEISMIC – Panel Edge Fastener Spacing (in.) 6 – v_s (plf)	6 – G_a (kips/in.) OSB	6 – G_a PLY	4 – v_s (plf)	4 – G_a (kips/in.) OSB	4 – G_a PLY	3 – v_s (plf)	3 – G_a (kips/in.) OSB	3 – G_a PLY	2 – v_s (plf)	2 – G_a (kips/in.) OSB	2 – G_a PLY	B WIND – Panel Edge Fastener Spacing (in.) 6 – v_w (plf)	4 – v_w (plf)	3 – v_w (plf)	2 – v_w (plf)
			Nail (common or galvanized box)		OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY				
Wood Structural Panels - Structural I[4,5]	5/16	1-1/4	6d	400	13	10	600	18	13	780	23	16	1020	35	22	560	840	1090	1430
	3/8[2]			460	19	14	720	24	17	920	30	20	1220	43	24	645	1010	1290	1710
	7/16[2]	1-3/8	8d	510	16	13	790	21	16	1010	27	19	1340	40	24	715	1105	1415	1875
	15/32			560	14	11	860	18	14	1100	24	17	1460	37	23	785	1205	1540	2045
	15/32	1-1/2	10d	680	22	16	1020	29	20	1330	36	22	1740	51	28	950	1430	1860	2435
Wood Structural Panels – Sheathing[4,5]	5/16	1-1/4	6d	360	13	9.5	540	18	12	700	24	14	900	37	18	505	755	980	1260
	3/8			400	11	8.5	600	15	11	780	20	13	1020	32	17	560	840	1090	1430
	3/8[2]	1-3/8	8d	440	17	12	640	25	15	820	31	17	1060	45	20	615	895	1150	1485
	7/16[2]			480	15	11	700	22	14	900	28	17	1170	42	21	670	980	1260	1640
	15/32			520	13	10	760	19									1065	1370	1790
	15/32	1-1/2	10d	620	22	14	920	30									1290	1680	2155
	19/32			680	19	13	1020	26									1430	1860	2435
Plywood Siding			Nail (galvanized casing)																
	5/16	1-1/4	6d	280	13		420										590	770	1010
	3/8	1-3/8	8d	320	16		480										670	870	1150
Particleboard Sheathing - (M-S "Exterior Glue" and M-2 "Exterior Glue")			Nail (common or galvanized box)																
	3/8		6d	240	15		360										505	645	840
	3/8		8d	260	18		380										530	670	880
	1/2			280	18		420	20		540	22		700	24		390	590	755	980
	1/2		10d	370	21		550	23		720	24		920	25		520	770	1010	1290
	5/8			400	21		610	23		790	24		1040	26		560	855	1105	1455
Structural Fiberboard Sheathing	1/2		Nail (galvanized roofing) 11 ga. galv. roofing nail (0.120" x 1-1/2" long x 7/16" head)				340	4.0		460	5.0		520	5.5			475	645	730
	25/32		*11 ga. galv. roofing nail (0.120" x 1-3/4" long x 3/8" head)*				340	4.0		460	5.0		520	5.5			475	645	730

Note 2 states that if 16" OC studs, use 15/32 values

1. Nominal unit shear values shall be adjusted in accordance with 4.3.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.3.6. For specific requirements, see 4.3.7.1 for wood structural panel shear walls, 4.3.7.2 for particleboard shear walls, and 4.3.7.3 for fiberboard shear walls. See Appendix A for common and box nail dimensions.
2. Shears are permitted to be increased to values shown for 15/32 inch sheathing with same nailing provided (a) studs are spaced a maximum of 16 inches on center, or (b) panels are applied with long dimension across studs.
3. For species and grades of framing other than Douglas-Fir-Larch or Southern Pine, reduced nominal unit shear capacities shall be determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor = [1-(0.5-G)], where G = Specific Gravity of the framing lumber from the *NDS* (Table 11.3.2A). The Specific Gravity Adjustment Factor shall not be greater than 1.
4. Apparent shear stiffness values G_a, are based on nail slip in framing with moisture content less than or equal to 19% at time of fabrication and panel stiffness values for shear walls constructed with either OSB or 3-ply plywood panels. When 4-ply or 5-ply plywood panels or composite panels are used, G_a values shall be permitted to be increased by 1.2.
5. Where moisture content of the framing is greater than 19% at time of fabrication, G_a values shall be multiplied by 0.5.
6. Where panels are applied on both faces of a shear wall and nail spacing is less than 6" on center on either side, panel joints shall be offset to fall on different framing members. Alternatively, the width of the nailed face of framing members shall be 3" nominal or greater at adjoining panel edges and nails at all panel edges shall be staggered.
7. Galvanized nails shall be hot-dipped or tumbled.

Example Shear Wall - LATERAL

Nominal shear per unit length = 560 lb/ft (seismic)

Allowable shear per unit length $= 560/2 = 280\ \text{lb/ft}$

Adjust for specific gravity adjustment factor $= [1 - (0.5 - SG)]$

Table 11.3.2A – NDS – SG SPF = 0.42

Allowable diaphragm reaction $= 280 \times 8 \times [1 - (0.5 - 0.42)] = 2{,}061\ \text{lb}$

For this reaction, the chord forces are:

Assume (2) 2x4 on each edge $d = 96 - 3 = 93'' = 7.75'$

Chord forces $= 2{,}061 \times 9/7.75 = \pm 2{,}400\ \text{lb}$

Table 11.3.1 Applicability of Adjustment Factors for Connections - VERT. & LATERAL

			ASD only	ASD and LRFD										LRFD only		
			Load Duration Factor[1]	Wet Service Factor	Temperature Factor	Group Action Factor	Geometry Factor[3]	Penetration Depth Factor[3]	End Grain Factor[3]	Metal Side Plate Factor[3]	Diaphragm Factor[3]	Toe-Nail Factor[3]	Format Conversion Factor K_F	Resistance Factor ϕ	Time Effect Factor
Lateral Loads																
Dowel-type Fasteners (e.g. bolts, lag screws, wood screws, nails, spikes, drift bolts, & drift pins)	$Z' = Z$	x	C_D	C_M	C_t	C_g	C_Δ	-	C_{eg}	-	C_{di}	C_{tn}	3.32	0.65	λ
Split Ring and Shear Plate Connectors	$P' = P$ $Q' = Q$	x	C_D C_D	C_M C_M	C_t C_t	C_g C_g	C_Δ C_Δ	C_d C_d	- -	C_{st} -	- -	- -	3.32	0.65	λ
Timber Rivets	$P' = P$ $Q' = Q$	x	C_D C_D	C_M C_M	C_t C_t	- -	- C_Δ[5]	- -	- -	C_{st}[4] C_{st}[4]	- -	- -	3.32	0.65	λ
Spike Grids	$Z' = Z$	x	C_D	C_M	C_t	-	C_Δ	-	-	-	-	-	3.32	0.65	λ
Withdrawal Loads																
Nails, spikes, lag screws, wood screws, & drift pins	$W' = W$	x	C_D	C_M[2]	C_t	-	-	-	C_{eg}	-	-	C_{tn}	3.32	0.65	λ

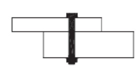
Get Cg, W, Z and Other Values from Tables
VERT. & LATERAL

Table 12.2A Lag Screw Reference Withdrawal Design Values, W[1]											
Tabulated withdrawal design values (W) are in pounds per inch of thread penetration into side grain of wood member. Length of thread penetration in main member shall not include the length of the tapered tip.											
Specific Gravity, G[2]	Lag Screw Diameter, D										
	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"	3/4"	7/8"	1"	1-1/8"	1-1/4"
0.73	397	469	538	604	668	789	905	1016	1123	1226	1327
0.71	381	450	516	579	640	757	868	974	1077	1176	1273
0.68	357	422	484	543	600	709	813	913	1009	1103	1193
0.67	349	413	473	531	587	694	796	893	987	1078	1167
0.58	281	332	381	428	473	559	641	719	795	869	940
0.55	260	307	352	395	437	516	592	664	734	802	868
0.51	232	274	314	353	390	461	528	593	656	716	775
0.50	225	266	305	342	378	447	513	576	636	695	752
0.49	218	258	296	332	367	434	498	559	617	674	730
0.47	205	242	278	312	345	408	467	525	580	634	686
0.46	199	235	269	302	334	395	453	508	562	613	664
0.44	186	220	252	283	312	369	423	475	525	574	621
0.43	179	212	243	273	302	237	409	459	508	554	600
0.42	173	205	235	264	291	344	395	443	490	535	579
0.41	167	198	226	254	281	332	381	428	473	516	559
0.40	161	190	218	245	271	320	367	412	455	497	538
0.39	155	183	210	236	261	308	353	397	438	479	518
0.38	149	176	202	227	251	296	340	381	422	461	498
0.37	143	169	194	218	241	285	326	367	405	443	479
0.36	137	163	186	209	231	273	313	352	389	425	460
0.35	132	156	179	200	222	262	300	337	373	407	441
0.31	110	130	149	167	185	218	250	281	311	339	367

Get Cg, W, Z and Other Values from Tables
VERT. & LATERAL

Table 12A **BOLTS: Reference Lateral Design Values, Z, for Single Shear (two member) Connections[1,2]**

for sawn lumber or SCL with both members of identical specific gravity



Thickness: Main Member	Thickness: Side Member	Bolt Diameter	G=0.67 Red Oak				G=0.55 Mixed Maple Southern Pine				G=0.50 Douglas Fir-Larch				G=0.49 Douglas Fir-Larch(N)				G=0.46 Douglas Fir(S) Hem-Fir(N)			
t_m in.	t_s in.	D in.	$Z_{\parallel}$ lbs.	$Z_{s\perp}$ lbs.	$Z_{m\perp}$ lbs.	$Z_{\perp}$ lbs.	$Z_{\parallel}$ lbs.	$Z_{s\perp}$ lbs.	$Z_{m\perp}$ lbs.	$Z_{\perp}$ lbs.	$Z_{\parallel}$ lbs.	$Z_{s\perp}$ lbs.	$Z_{m\perp}$ lbs.	$Z_{\perp}$ lbs.	$Z_{\parallel}$ lbs.	$Z_{s\perp}$ lbs.	$Z_{m\perp}$ lbs.	$Z_{\perp}$ lbs.	$Z_{\parallel}$ lbs.	$Z_{s\perp}$ lbs.	$Z_{m\perp}$ lbs.	$Z_{\perp}$ lbs.
		1/2	650	420	420	330	530	330	330	250	480	300	300	220	470	290	290	210	440	270	270	190
		5/8	810	500	500	370	660	400	400	280	600	360	360	240	590	350	350	240	560	320	320	220
1-1/2	1-1/2	3/4	970	580	580	410	800	460	460	310	720	420	420	270	710	400	400	260	670	380	380	240
		7/8	1130	660	660	440	930	520	520	330	850	470	470	290	830	460	460	280	780	420	420	250
		1	1290	740	740	470	1060	580	580	350	970	530	530	310	950	510	510	300	890	480	480	280
		1/2	760	490	490	390	620	390	390	290	560	350	350	250	550	340	340	250	520	320	320	230
		5/8	940	590	590	430	770	470	470	330	700	420	420	280	690	410	410	280	650	380	380	250
1-3/4	1-3/4	3/4	1130	680	680	480	930	540	540	360	850	480	480	310	830	470	470	300	780	440	440	280
		7/8	1320	770	770	510	1080	610	610	390	990	550	550	340	970	530	530	320	910	500	500	300
		1	1510	860	860	550	1240	680	680	410	1130	610	610	360	1110	600	600	350	1040	560	560	320
		1/2	770	480	540	440	660	400	420	350	610	370	370	310	610	360	360	300	580	340	330	270
		5/8	1070	660	630	520	930	560	490	390	850	520	430	340	830	520	420	330	780	470	390	300
2-1/2	1-1/2	3/4	1360	890	720	570	1120	660	560	430	1020	590	500	380	1000	560	480	360	940	520	450	330
		7/8	1590	960	800	620	1300	720	620	470	1190	630	550	410	1170	600	540	390	1090	550	500	360
		1	1820	1020	870	660	1490	770	680	490	1360	680	610	440	1330	650	590	420	1250	600	550	390
		1/2	770	480	560	440	660	400	470	360	610	370	430	330	610	360	420	320	580	340	400	310
		5/8	1070	660	760	590	940	560	620	500	880	520	540	460	870	520	530	450	830	470	490	410
	1-1/2	3/4	1450	890	900	770	1270	660	690	580	1200	590	610	510	1190	560	590	490	1140	520	550	450
		7/8	1890	960	990	830	1680	720	770	630	1590	630	680	550	1570	600	650	530	1470	550	600	480
		1	2410	1020	1080	890	2010	770	830	670	1830	680	740	590	1790	650	710	560	1680	600	660	520
		1/2	830	510	590	480	720	420	510	390	670	380	470	350	660	380	460	340	620	360	440	320
		5/8	1160	680	820	620	1000	580	640	520	930	530	560	460	920	530	550	450	880	500	510	410
3-1/2	1-3/4	3/4	1530	900	940	780	1330	770	720	580	1250	680	640	520	1240	660	620	500	1190	600	580	460
		7/8	1970	1120	1040	840	1730	840	810	640	1620	740	710	550	1590	700	690	530	1490	640	640	490
		1	2480	1190	1130	900	2030	890	880	670	1850	790	780	590	1820	750	760	570	1700	700	700	530
		1/2	830	590	590	530	750	520	520	460	720	490	490	430	710	480	480	420	690	460	460	410
		5/8	1290	880	880	780	1170	780	780	650	1120	700	700	560	1110	690	690	550	1070	650	650	500
	3-1/2	3/4	1860	1190	1190	950	1690	960	960	710	1610	870	870	630	1600	850	850	600	1540	800	800	560
		7/8	2540	1410	1410	1030	2170	1160	1160	780	1970	1060	1060	680	1940	1040	1040	650	1810	980	980	590
		1	3020	1670	1670	1100	2480	1360	1360	820	2260	1230	1230	720	2210	1190	1190	690	2070	1110	1110	640
		5/8	1070	660	760	590	940	560	640	500	880	520	590	460	870	520	590	450	830	470	560	430

Conclusion

Thank you for your attention!

Any questions?

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