Introduction:
Sizes of Structural Lumber and Use
Text Chapter 4

Design Approach:

The design of structural wood is carried on the basis of allowable stresses at service load levels. Structural calculations are based on the standard net size of a piece of lumber. Most structural lumber is dressed lumber.

1) Dressed Lumber: Lumber that has been surfaced to the standard net size, which is less than the nominal size (stated)(Textbook Section 4.11 and NDS 01 Supplement).

   i.e. 8 x12 member (nominal size = 8 x 12 in.) actually is 7 ½ x 11 ½ in. (Standard net size) NDS Table 1A Sec. 3 Supplement 2001. Lumber is dressed on a planning machine for the purpose of obtaining smooth surfaces and uniform sizes. Typically lumber will be S4S (surfaced on 4 sides).

Table 1A Nominal and Minimum Dressed Sizes of Sawn Lumber

Item	Thickness (inches)			Face Widths (inches)		
		Minimum dressed			Minimum dressed	
	Nominal	Dry	Green	Nominal	Dry	Green
Boards	3/4	5/8	11/16	2	1-1/2	1-9/16
	1	3/4	25/32	3	2-1/2	2-9/16
	1-1/4	1	1-1/32	4	3-1/2	3-9/16
	1-1/2	1-1/4	1-9/32	5	4-1/2	4-5/8
				6	5-1/2	5-5/8
				7	6-1/2	6-5/8
				8	7-1/4	7-1/2
				9	8-1/4	8-1/2
				10	9-1/4	9-1/2
				11	10-1/4	10-1/2
				12	11-1/4	11-1/2
				14	13-1/4	13-1/2
				16	15-1/4	15-1/2
Dimension Lumber	2	1-1/2	1-9/16	2	1-1/2	1-9/16
	2-1/2	2	2-1/16	3	2-1/2	2-9/16
	3	2-1/2	2-9/16	4	3-1/2	3-9/16
	3-1/2	3	3-1/16	5	4-1/2	4-5/8
	4	3-1/2	3-9/16	6	5-1/2	5-5/8
	4-1/2	4	4-1/16	8	7-1/4	7-1/2
				10	9-1/4	9-1/2
				12	11-1/4	11-1/2
				14	13-1/4	13-1/2
				16	15-1/4	15-1/2

3 SECTION PROPERTIES

2) Rough Sawn: Large timbers are usually rough sawn to dimensions that are close to standard net sizes, roughly 1/8" larger than the standard dressed size. Rough surface is usually ordered specially for architectural purposes in smaller sizes.

3) Full Sawn: In this case a rough surface is obtained with actual size equal to the nominal size.

Wood Rating

The majority of sawn lumber is graded by visual inspection, and material graded in this way (visually) is known as visually graded structural lumber. As the lumber comes out of the mill, a person familiar with lumber grading rules examines each piece and assigns and stamps a grade. There are two broad size classifications of sawn lumber:

- Dimension Lumber: smaller (thinner) sizes of structural lumber. Dimension lumber usually ranges in the size from 2x2 through 4x16. In other words, dimension lumber is any material with a thickness (smaller dimension of a piece of wood, and width is the larger dimension) of 2 to 4 inches.
- Timbers: are the larger pieces and have a minimum nominal dimension of 5 inches. Thus, the smallest practical size timber is a 6x6 inch.

The design properties given in the NDS supplement are based on two different sets of ASTM Standards (Textbook Sections 4.3 and 4.4):

- In-grade procedures applied to Dimension lumber
- Clear wood procedures applied to timbers

The lumber grading rules which establish the allowable stresses for use in structural design have been developed over the years. The relative size of the wood was used as a guide in anticipating its use. Although most lumber is visually graded, a small % of lumber is MACHINE STRESS' RATED by subjecting each piece of wood to a non-distructive test. This process is highly automated. As lumber comes out of the mill, it passes through a series of rollers. In this process, a bending load is applied about the minor axis of the cross section, and the modulus of elasticity of each piece measured. In addition the piece is visually inspected. The material graded using MSR is limited to a thickness of 2" or less. MSR has less variability in mechanical properties than visually graded lumber. Consequently, is often used to fabricate engineered wood products.

- Glulam beams
- Wood I joists and light frame

However, stress rated boards are not commonly used for structural framing because they are very thin. So we will focus on dimension lumber. It must be remarked that the allowable stress depends on the species and on the **size of the member.**

Species (Sec. 4.5 Textbook):

A large number of species can be used to produce structural lumber. The 2001 NDS supplement (Sec. 4, Page 29) contains allowable stresses for a large number of species. The choice of species for use in design is a matter of economics typically. For a given location only a few species groups may be available and it is prudent to check with local distributors as well as a wood products agency. The species of tress used for structural lumber are classified as hardwoods and softwoods owing not necessarily to a description of the wood properties. For example evergreens aka conifers are a large majority of the structural lumber. This will be either Douglas-Fir or Southern Pine.

Table 4A Base Design Values for Visually Graded Dimension Lumber (2"-4" thick)[1,2]

(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)						Grading Rules Agency
		Bending F_b	Tension parallel to grain F_t	Shear parallel to grain F_v	Compression perpendicular to grain $F_{c\perp}$	Compression parallel to grain F_c	Modulus of Elasticity E	
ASPEN								
Select Structural		875	500	120	265	725	1,100,000	NELMA NSLB WWPA
No.1		625	375	120	265	600	1,100,000	
No.2	2" & wider	600	350	120	265	450	1,000,000	
No.3		350	200	120	265	275	900,000	
Stud	2" & wider	475	275	120	265	300	900,000	
Construction		700	400	120	265	625	900,000	
Standard	2"-4" wide	375	225	120	265	475	900,000	
Utility		175	100	120	265	300	800,000	
BEECH-BIRCH-HICKORY								
Select Structural		1450	850	195	715	1200	1,700,000	NELMA
No.1		1050	600	195	715	950	1,600,000	
No.2	2" & wider	1000	600	195	715	750	1,500,000	
No.3		575	350	195	715	425	1,300,000	
Stud	2" & wider	775	450	195	715	475	1,300,000	
Construction		1150	675	195	715	1000	1,400,000	
Standard	2"-4" wide	650	375	195	715	775	1,300,000	
Utility		300	175	195	715	500	1,200,000	

4 DESIGN VALUES

Allowable Stresses/Design Values (NDS Tabulated values in the NDS Supplement 01): Are determined by multiplying the tabulated (stresses) by the appropriate adjustment factors (Textbook, Sections 4.13-4.22, and design example in Section 4.23). Thus becoming allowable design value (*F'*). For example for tension parallel to the grain:

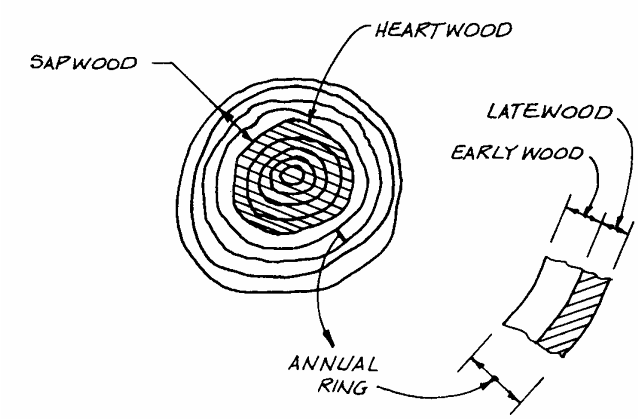


Figure 4.4 Cross section of a log.

$$F_t' = F_t \ x \left(\text{adjustment factors}\right) = Design\ value$$

For an acceptable design, the axial tensile stress due to loads, f_t, should not exceed the allowable (adjusted) stress:

$$f_t \le F_t'$$

Design Value (stress)	Tabulated Stress	Allowable (adjusted) Stress
Bending	F_b	F_b'
Tension parallel to grain	F_t	F_t'
Shear parallel to grain	P_u	F_v'
Compression perpendicular to grain	F_{c1}	F_{cI}'
Compression parallel to grain	F_c	F_c'
Modulus of elasticity	E	E'

<u>Adjustment Factors</u>: Some decrease other increase tabulated value (Textbook, Sections 4.13-4.22, and design example in Section 4.23, and NDS 2001 Sections 2 and 4)

Examples:

C_D = load duration factor

C_M = web service factor (moisture content)

C_F = size factor

C_{fu} = flat use factor

C_f = form factor

<u>Stresses and adjustment factors:</u>

<u>Stresses due to known loads</u> :(NDS 2001, Section 3))

$$f_t = \frac{P}{A},\ f_b = \frac{M}{S},\ etc.$$

Tabulated Values (Stresses): Tabulated design values listed in the NDS Supplement 2001 ED. These values include reduction for safety (F) and are for normal load duration under the specified moisture service condition. Modulus of elasticity (E) does not include reduction for safety and represent average values.

Dimension Lumber Page 29 NDS Supp. 2001

Table 4A, page 30, 31: Base design value for visually graded dimension lumber (except southern pine)
Table 4B, page 36,37: Base design value for visually graded southern pine
Table 4C, page 39-42: Design values for mechanically graded dimension lumber (MSR)

Timbers (5x5 and larger)

Table 4D, page 43-49: Design values for visually graded timbers (all species)

Adjustment Factors (Sec 4.3 NDS 01 and Suplement to NDS Tables):

A. Wet Serviced Factor: C_M

EMC = Equilibrium moisture content = the average moisture content that lumber assumes in service.

Moisture designation in grade stamp
S-Grn (surface green) MC = 19% (in service)

S-Dry (surfaced dry) MC = 15% (in service)

These values can vary depending on environmental conditions (in most buildings ranges from 7-14% EMC). Special conditions must be analyzed individually.

Tabulated values in NDS supplement apply to members with EMC of 19% or less (regardless of S-GRN or S-Dry). If EMC exceeds 19%for an extended period of time, table values should be multiplied by C_M (see Page 30 and others for values in Table 4 NDS-Supp 01)

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
0.85*	1.0	0.97	0.67	0.8**	0.9

* when $(F_b)(C_F) \le 1150$ psi, $C_M = 1.0$
** when $(F_c)(C_F) \le 750$ psi, $C_M = 1.0$

B. Load Duration Factor: C_D

Wood can handle higher stresses if loads are applied for a short period of time. All tabulated values apply to normal duration loading (10 years) The term "duration of load" refers to the total accumulated length of time that a load is applied during the life of a structure.

Table 2.3.2 in NDS 01 provides C_D to be used in the one associated with the shortest-duration of time. Whichever combination of loads, together with the appropriate load duration factor produces the largest member size is the one that must be used in design.

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 modulus of elasticity, E, nor to compression perpendicular to grain design values, $F_{c\perp}$, based on a deformation limit.
2. Load duration factors greater than 1.6 shall not apply to structural members pressure-treated with water-borne preservatives (see Reference 30), or fire retardant chemicals. The impact load duration factor shall not apply to connections.

C. <u>Size Factor:</u> C_F

The size of the member has an effect on its unit stress.

- See Supplement 01 Tables: 4A, 4B, 4C, 4D and 4E

Size Factor, C_F

Tabulated bending, tension and compression parallel to grain design values for dimension lumber 2" to 4" thick shall be multiplied by the following size factors:

Size Factors, C_F

		F_b		F_t	F_c
		Thickness (breadth)			
Grades	Width (depth)	2" & 3"	4"		
Select Structural, No.1 & Btr., No.1, No.2, No.3	2", 3" & 4"	1.5	1.5	1.5	1.15
	5"	1.4	1.4	1.4	1.1
	6"	1.3	1.3	1.3	1.1
	8"	1.2	1.3	1.2	1.05
	10"	1.1	1.2	1.1	1.0
	12"	1.0	1.1	1.0	1.0
	14" & wider	0.9	1.0	0.9	0.9
Stud	2", 3" & 4"	1.1	1.1	1.1	1.05
	5" & 6"	1.0	1.0	1.0	1.0
	8" & wider	Use No.3 Grade tabulated design values and size factors			
Construction, Standard	2", 3" & 4"	1.0	1.0	1.0	1.0
Utility	4"	1.0	1.0	1.0	1.0
	2" & 3"	0.4	—	0.4	0.6

D. <u>Repetitive Member Factor:</u> C_r only "F_b"!!

The system performance of a series of small closely spaced wood members, where failure of one member is not fatal (see Supplement 01)

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 centers, are not less than 3 in number and are joined by floor, roof or other load distributing elements adequate to support the design load.

E. <u>Flat use Factor:</u> C_{fu}

Except for decking, tabulated stress for dimension lumber apply to wood members that are stressed in flexure about the strong axis – “edgewise or load applied to narrow face”. If however load is a applied to the wide face – the stresses may be increased by C_{fu}.

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}

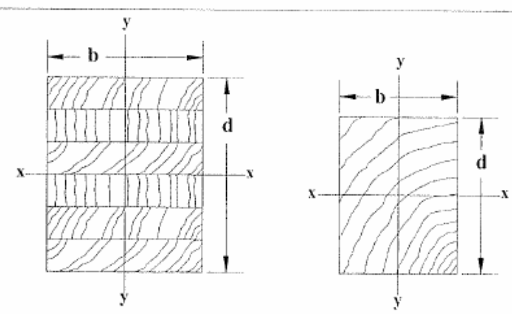
Width (depth)	Thickness (breadth)	
	2" & 3"	4"
2" & 3"	1.0	—
4"	1.1	1.0
5"	1.1	1.05
6"	1.15	1.05
8"	1.15	1.05
10" & wider	1.2	1.1

Tabulated bending stresses also for timber Beams & stringers apply for bending about x-axis. NDS does not provide C_{fu} for these cases.

3.1.3 Definitions

NEUTRAL AXIS, in the cross section of a beam, is the line on which there is neither tension nor compression stress.

Figure 1A Dimensions for Rectangular Cross Section



Glued Laminated Timber   Sawn Lumber

F. Temperature Factor: C_t

The strength of the wood in service is increased as the temperature cools below the normal temp in most buildings. On the other hand, the strength decreases as temperatures are increased. The factor C_t is the multiplier that is used to reduce tabulated stresses if higher than normal temperatures are encountered in a design situation. Values of C_t are given in NDS Sec. 2.3.4 for T > 100°F. Important to note that strength will be regained when temperature returns to normal values! Thus this factor applies for sustained conditions.

Table 2.3.3 Temperature Factor, C_t

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

1. Wet and dry service conditions for sawn lumber, glued laminated timber, prefabricated wood I-joists, structural composite lumber, and wood structural panels are specified in 4.1.4, 5.1.5, 7.1.4, 8.1.4, and 9.3.3, respectively.

G. Form Factor: C_f

The purpose of this factor is to adjust tabulated bending stress F_b for non-rectangular sections (see Section 3.3.4 in NDS 01).

3.3.4 Form Factor, C_f

Tabulated bending design values, F_b, for bending members with either a circular cross section or a square cross section loaded in the plane of the diagonal (diamond section) shall be multiplied by the following form factors, C_f:

Table 3.3.4 Form Factors, C_f

	C_f
Round Section	1.18
Diamond Section	1.414

These form factors insure that a circular or diamond shaped bending member has the same moment capacity as a square bending member having the same cross-sectional area. If a circular member is tapered, it shall be considered a beam of variable cross section.

Example:

Determine the tabulated and allowable design values for the following member and loading condition.

- No. 2 Hem-Fir (bending about strong axis)
- Floor beams 4x6 in @ 4' on centers. Loads are (D+L). High-humidity conditions exist, and moisture content may exceed 19%.

Stresses

Bending (NDS Supp 01)

Table 4A (Cont.) Base Design Values for Visually Graded Dimension Lumber (2"-4" thick)[1,2]

(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): Bending F_b	Tension parallel to grain F_t	Shear parallel to grain F_v	Compression perpendicular to grain $F_{c\perp}$	Compression parallel to grain F_c	Modulus of Elasticity E	Grading Rules Agency
HEM-FIR								
Select Structural		1400	925	150	405	1500	1,600,000	
No.1 & Btr		1100	725	150	405	1350	1,500,000	
No.1		975	625	150	405	1350	1,500,000	
No.2	2" & wider	850	525	150	405	1300	1,300,000	WCLIB WWPA
No.3		500	300	150	405	725	1,200,000	
Stud	2" & wider	675	400	150	405	800	1,200,000	
Construction		975	600	150	405	1550	1,300,000	
Standard	2"-4" wide	550	325	150	405	1300	1,200,000	
Utility		250	150	150	405	850	1,100,000	

Tabulated value, F_b = 850 psi (Tab. 4A Supp. NDS 01)

Factors (NDS 01 Sec. 4.3)

(Table 4.3.1, NDS 01 Page 27)

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Form Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	C_f	-	-	-
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	-
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	C_i	-	-	-	-	-
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	C_b
$F_c' = F_c$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	C_P	-	-
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_T	-

In many practical situations, a number of adjustment factors may have a value of 1.0. A comprehensive summary of the modification factors for wood members is given in NDS Table 4.3.1

C_D = load duration factors (Sec. 2.3.2 NDS)

$C_D = 1.0$ (Table 2.3.2 controlled by live load)

C_M = Wet service (Sec. 4.3.3 NDS 01, Supp Ch 4, Table 4A)

$C_M = 0.85$ since $M_C > 19\%$ or 1.0 if $F_b\ C_F \leq 1150\ psi$

C_F = size factor (Sec. 4.3, NDS 01 and Table 4A)

$C_F = 1.3$

since $F_b x C_F = 850\ x\ 1.3 = 1105$ psi < 1150 psi

$C_M = 1.0$

C_t = Temperature factor (Sec. 4.3.4 NDS) $T \leq 100^{o} F$

$C_t = 1.0$

C_L = Beam Stability Factor (Sec. 4.3.5 and 3.3.3 NSD 01)

(Sec. 4.4.1.2) $d / b = \frac{6}{4} = 1.5 < 2.0$; no lateral support is required

(Sec. 3.3.3.2) $C_L = 1.0$ (Also 3.3.3.3 could be invoked if needed)

$C_{fu} = 1.0$ (Element is not loaded on its flat side)

C_i = Incising Factor (Sec. 4.3.8) done to increase treatment penetrations

$C_i = 1.0$

C_r = Repetitive Member Factor (Sec. 4.3.9 NDS)

$C_r = 1.0$

C_f = Form factor (Sec. 4.3.10 &3.3.4)

$\therefore C_f = 1.0$

Finally calculate allowable stress for bending

$$F_b' = 850\ x\ 1\ x \ldots x\ 1.3\ x \ldots = 1105\ psi$$

Tension II to Grain

F_T = Tension parallel to grain (Table 4A Supp)

$F_T = 525\ psi$

Factors (NDS 01, Sec. 4.3 & Table 4.3.1)

$C_D = 1.0$

$C_M = 1.0$ (Table 4A, Supp Adj. Factors)

$C_t = 1.0$

$C_F = 1.3$

$C_i = 1.0$

$F_T' = 525\ x\ 1.3 = 683\ psi$

Shear II to Grain, F_V

$F_V = 150\ psi$

Factors (NDS 4.3)

$C_D = 1.0$
$C_M = 0.97$ Table 4A Supp Adj. Factor
$C_t = 1.0$
$C_i = 1.0$

$F_V^{'} = 150\ psi\ x\ 0.97 = 146\ psi$

<u>Compression ⊥to grain</u>

$F_{C\perp} = 405\ psi$

<u>Factors</u> (NDS 4.3) Table 4.3.1

(Sec. 4.3.3) and Table 4A

$C_M = 0.67$
$C_t = 1.0$
$C_i = 1.0$
$C_b =$ Bearing area factor (Sec. 4.3.13)
Assume $\ell_b \geq 6"$
$C_b = 1.0$
$F_{C_\perp} = 405\ x\ 0.67 = 271\ psi$

<u>Compression II to grain</u>

$F_c = 1300\ psi$
<u>Factors</u> (NDS 4.3 @ Table 4.3.1)

$C_D = 1.0$ (Table 4A, Supp)
$C_M = 0.8$ or 1.0 when $(F_c)(C_F) \leq 750\ psi$
$C_F = 1.1$ (Table 4A, Supp)
$\therefore C_M = 0.8$ since $1300 \times 1.1 > 750$
$C_t = 1.0$
$C_i = 1.0$
$C_p = 1.0$ (This is a beam!)
$F_c^{'} = 1300\ x\ 0.8\ x\ 1.1\ x \ldots 1.0 = 1144\ psi$

Modulus of Elasticity, MOE

From Table 4A

$$E = 1{,}300{,}000 \ psi$$

$$C_M = 0.9 \ (Factors \ in \ Table \ 4A, Supp)$$

$$C_t = 1.0$$

$$C_i = 1.0$$

$$C_T = Buckling \ Stiffness \ factor \ for \ wood \ tresses \ (4.4.2)$$

$$N.A.$$

$$\therefore$$

$$E' = 1{,}300{,}000 \ x \ 0.9 = 1{,}170{,}000 \ psi$$

$$C_t = temperature \ factor$$

$$C_r = repetitive \ factor$$

Design Summary – Beams (Chapter 6 Text)

1. Determine trial beam size based on bending stress considerations (long. Bending stress, II to grain – see Fig. 6.1a). For sawn lumber loaded-edgewise only are given tabulated values.

$$(S)_{reqd} = \frac{M}{F_b^{'}}$$

Select trial member with (use Table for dressed S4S)

$$(S)_{prov} \geq (S)_{reqd}$$

recheck for appropriate size factor, C_F, since initially is unknown (beam size) so that

$$f_b = \frac{M}{(S_{act})} \leq F_b^{'} \text{ (with actual } C_F \text{)}$$

2. Check shear (Sec. 3.4 NDS)

$$f_v = 1.5\frac{V}{A} \leq F_v^{'} \text{ supp. with app. factors}$$

$$f_v = \frac{V}{t_d w}$$

In this calculation a reduced shear (d- away from support face, d = overall depth) can be used V' (Sec. 3.4.31)(a)

$$f_v^{'} = 1.5\frac{V'}{A}$$

If this check shows the beam size selected to be inadequate, the size is revised to provide sufficient A.

Deflection Criteria (IBC 2003 Sec. 3.5 NDS 01)

Limits are established for deflections for beams, trusses, and similar members that are not to be exceeded under certain gravity loads. Table 1604.3 in the IBC 2003 gives the necessary limits and other information necessary to ensure user comfort and to prevent excessive cracking of plaster ceilings.

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

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

For SI: 1 foot = 304.8 mm.

a. For structural roofing and siding made of formed metal sheets, the total load deflection shall not exceed $l/60$. For secondary roof structural members supporting formed metal roofing, the live load deflection shall not exceed $l/150$. For secondary wall members supporting formed metal siding, the design wind load deflection shall not exceed $l/90$. For roofs, this exception only applies when the metal sheets have no roof covering.

b. Interior partitions not exceeding 6 feet in height and flexible, folding and portable partitions are not governed by the provisions of this section. The deflection criterion for interior partitions is based on the horizontal load defined in Section 1607.13.

c. See Section 2403 for glass supports.

d. For wood structural members having a moisture content of less than 16 percent at time of installation and used under dry conditions, the deflection resulting from $L + 0.5D$ is permitted to be substituted for the deflection resulting from $L + D$.

e. The above deflections do not ensure against ponding. Roofs that do not have sufficient slope or camber to assure adequate drainage shall be investigated for ponding. See Section 1611 for rain and ponding requirements and Section 1503.4 for roof drainage requirements.

For Green Lumber (MC > 19%)

$$\Delta_{TOTAL} = 2.0\,(\Delta_{long\ term}) + \Delta_{short\ term} < L/180$$

$$\Delta_{Live} < L/240$$

For Seasoned Lumber (MC < 19%)

$$\Delta_{TOTAL} = 1.5(\Delta_{Long\ Term}) + \Delta_{Short\ Term} < L/180$$

$$\Delta_{Live} < L/240$$

where

$\Delta_{Long\ Term}$ = immediate deflection due to the long term portion of the design load (usually dead load)

$\Delta_{Short\ Term}$ = immediate deflection due to short term component of the design load (usually live load)

Bearing - Sec. 3.10 NDS 01

3.10.2 Bearing Perpendicular to Grain

The actual compression stress perpendicular to grain shall be based on the net bearing area and shall not exceed the allowable compression design value perpendicular to grain, $f_{c\perp} \leq F_{c\perp}'$. When calculating bearing area at the ends of bending members, no allowance shall be made for the fact that as the member bends, pressure upon the inner edge of the bearing is greater than at the member end.

3.10.4 Bearing Area Factor, C_b

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

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

where:

ℓ_b = bearing length measured parallel to grain, in.

This equation gives the following bearing area factors, C_b, for the indicated bearing length on such small areas as plates and washers:

Table 3.10.4 Bearing Area Factors, C_b

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

Example: Sawn Beam Design (Dimension Lumber)

- Beams are spaced 16 inches on center (roof beam)
- Buckling of the compression zone is prevented by the plywood roof sheathing
- Material is No. 1 Douglas Fir – larch
- Loads

$w_D = 19\ lb/ft$ (Dead load per lineal ft.)
$w_L = 27\ lb/ft$ (Live load per lineal ft.)
$\text{TOTAL} = 46\ lb/ft$

Required load combination (Sect. 2.3.2 NDS 01 and Table 2.3.2) and Duration Factors

$D_{alone} \Rightarrow C_D = 0.9$
$D + L = C_D = 1.15$ $(snow\ load)$

Determine trial size based on bending and then check other criteria.

(Sec. 4.3.9, NDS 01 and Table 4A of the supplement, Spacing < 24") $C_r = 1.15$

(Table 4A Supp to NDS01) $C_F = 1.20$

(MC < 19%, normal temperature conditions, compression edge of bending member supported throughout in accordance with 4.4.1.2 and no incision)

C_M, C_T, C_L and $C_i = 1.0$

$F_b = 1000\,(1.15)\,(1.2)\,(1.15) = 1587\ psi$

$$\text{Reqd } S = \frac{M_{\max}}{F_b'} = \frac{12{,}515}{1587} = 7.9\ in^3$$

Try 2x6 S = 7.56 in^3 (From Table 1B Supp).

From NDS Supplement Table 4A

$$C_F = 1.3 \qquad F_b' = 1587\ x\ \frac{1.3}{1.2} = 1719\ psi$$

$$S_{reqd} = \frac{1255}{1719} = 7.32\ in^3 < 7.56\ \therefore o.k.$$

<u>Check for Shear</u> (NDS Sec. 3.4)

$$f_v = \frac{3}{2}\frac{V}{b_d}\ (Rect.)$$

$$C_M, C_t = 1.0 \quad A = 8.25\ in^2 \quad (Table\ 1B\ Supp)$$

Conservative to use $V = V_{MAX} = 46.0\,(13.5) = 3110$

$$f_V = \frac{3}{2}\frac{(311)}{(8.25)} = 56.5\ psi$$

$$F_V' = F_V\,(C_D)\,(C_M)\,(C_t)\,(C_i)$$
$$= 180\,(1.15) = 207\ psi > 56.5\ psi \quad \therefore ok$$

<u>Check Deflections</u>

$$E' = E\,(C_M)\,(C_T)\,(C_i)(C_t) = E$$
$$= 1{,}7000\ Ksi\ (Table\ 4A\ Supp\ NDS01)$$
$$\Delta_L = \frac{5\,w_L\,L^4}{384E'I} = \frac{5(27.0)(13.5)^4(1728)}{(384)\,(1{,}700{,}000)(20.8)} = 0.57''$$
$$\Delta_L = \frac{L}{240} = \frac{13.5\ x\ 12}{240} = 0.67'' > 0.57'' \quad \therefore ok$$

Also check for long term effects by calculating dead plus live deflection does not exceed L/180 (**Do in-class**).

Use 2x6 No. 1 DF-L MC ≤ 19%

<u>Bearing Stress Check</u> (Sec. 3.10 NDS01)

$$F_{C_\perp}' = F_{C_\perp}\,(C_M)\,(C_t)\,(C_b) = 625\ psi$$
$$\operatorname{Re}qd.\,\Delta = \frac{R}{F_{C_\perp}'} = \frac{311}{625} = 0.49\ in^2$$
$$\operatorname{Re}qd.\,\ell_b > \frac{A}{b} = \frac{0.99}{1.5} = 0.33 : < 6'' \quad \therefore ok$$