- Allowable bending and allowable shear stress vary with different wood species, grades, and the design code used.
- Wood does not act the same in all directions.

Mechanical Properties of a Piece of Wood

Subjected to normal stresses, wood is stronger if the load is parallel to the grain rather than perpendicular It's shear resistance, is much weaker in the direction parallel to the grain.

Steps for Timber Beam Design

Step 1: Determine the beam span, support conditions, allowable stresses, and other design limitations. Identify or compute the loads.

Step 2: Determine the maximum shear force and the maximum bending moment along the beam. For simple loadings, use the formulas from Table 13-1.

Step 3: Using the largest value of the bending moment, regardless of the sign, compute the minimum required section modulus from the flexure formula:

$$S_{req} = \frac{M_{max}}{\sigma_{allow}}$$

Step 4: Timber beams are usually available in rectangular sections for which the maximum shear stress is 1.5 times the average shear stress (Equation 14-11). In view of the weak shear stress resistance parallel to the grain, the minimum rectangular cross-sectional area required must be calculated from

$$A_{req} = \frac{1.5\ V_{max}}{\tau_{allow}}$$

Step 5: Scan Table A-6 in the appendix and select the lightest rectangular timber section that has a section modulus (about the strong axis) slightly greater than the required value computed in step 3 and an area slightly greater than the required area computed in step 4. Compute the percentage of the extra section modulus provided and the percentage of extra cross-sectional area provided, and make sure that these percentages are greater than the percentage of the ratio of the weight of the beam selected to the total design load.

In general, the preferred aspect ratio (depth/width) is between 1.5 - 3
Narrow and deep is more effective against bending moments.

Remember,
Nominal Dimension = true or named, i.e 2x4 → 2" x 4"
Dressed Dimension = actual, i.e. Table A-6 2x4 → 1½" x 3½"

TABLE 15–2 Allowable Stresses for Timber

Species	Extreme Fiber in Bending psi (kPa)	Tension Parallel to Grain psi (kPa)	Longi-tudinal Shear psi (kPa)	Compression: Perpen-dicular to Grain psi (kPa)	Compression: Parallel to Grain psi (kPa)
Douglas fir	1450 (10 000)	625 (4310)	95 (660)	385 (2650)	1050 (7240)
Eastern hemlock	1350 (9310)	925 (6380)	80 (550)	360 (2480)	950 (6550)
Southern pine	1600 (11 000)	825 (5690)	90 (620)	410 (2830)	1250 (8620)
Ponderosa pine	1100 (7580)	725 (5000)	65 (450)	235 (1620)	750 (5170)
California redwood	1350 (9310)	650 (4480)	100 (690)	270 (1860)	1050 (7240)

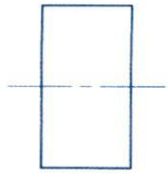


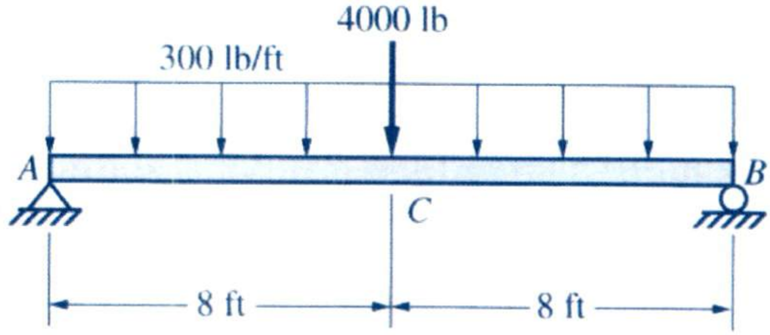
TABLE A–6(a) Properties of Structural Timber: U.S. Customary Units

Nominal Size (in.)	Standard Dressed Size (in.)	Area of Section A (in.^{2})	Moment of Inertia I (in.^{4})	Section Modulus S (in.^{3})	Weight per ft w (lb/ft)
2 × 4	1½ × 3½	5.25	5.36	3.06	1.46
× 6	× 5½	8.25	20.8	7.56	2.29
× 8	× 7¼	10.9	47.6	13.14	3.02
× 10	× 9¼	13.9	98.9	21.4	3.85
3 × 4	2½ × 3½	8.75	8.93	5.10	2.43
× 6	× 5½	13.8	34.7	12.6	3.82
× 8	× 7¼	18.1	79.4	21.9	5.04
× 10	× 9¼	23.1	165	35.7	6.42
× 12	× 11¼	28.1	297	52.7	7.81
4 × 4	3½ × 3½	12.3	12.5	7.15	3.40
× 6	× 5½	19.3	48.5	17.6	5.35
× 8	× 7¼	25.4	111	30.7	7.05
× 10	× 9¼	32.4	231	49.9	8.93
× 12	× 11¼	39.4	415	73.8	10.9
× 14	× 13¼	46.4	678	102	12.9
6 × 6	5½ × 5½	30.3	76.3	27.7	8.40
× 8	× 7½	41.3	193	51.6	11.5
× 10	× 9½	52.3	393	82.7	14.5
× 12	× 11½	63.3	697	121	17.6
× 14	× 13½	74.3	1128	167	20.6
× 16	× 15½	85.3	1707	220	23.7
× 18	× 17½	96.3	2456	281	26.7
8 × 8	7½ × 7½	56.3	264	70.3	15.6
× 10	× 9½	71.3	536	113	19.8
× 12	× 11½	86.3	951	165	24.0
× 14	× 13½	101	1538	228	28.1
× 16	× 15½	116	2327	300	32.3
× 18	× 17½	131	3350	383	36.5
× 20	× 19½	146	4634	475	40.6
10 × 10	9½ × 9½	90.3	679	143	25.1
× 12	× 11½	109	1204	209	30.3
× 14	× 13½	128	1948	289	35.6
× 16	× 15½	147	2948	380	40.9
× 18	× 17½	166	4243	485	46.2
× 20	× 19½	185	5870	602	51.5
× 22	× 21½	204	7868	732	56.7

Note: Properties and weights are for dressed sizes. Weight per unit foot is based on an assumed average weight of 40 lb/ft^3. Moment of inertia and section modulus are about the strong axis.

Example P15-16

Select the lightest, rectangular Southern pine section for the simply supported girder subjected to the loading shown in Fig. P15-16.



Solution.

Step 1. List the knowns

$P = 4000$ lb

$w = 300$ lb/ft

$L = 16$ ft

$a = 8$ ft

Table 15-2 – Allowable stresses for Southern Pine

$\sigma_{allow} = 1600$ psi

$\tau_{allow} = 90$ psi

Step 2. Calculate V_{MAX} & M_{MAX}

Table 13-1, case 1 and Case 4 (By Superpositio)

$$V_{MAX} = \frac{P}{2} + \frac{wL}{2} = \frac{4000 \text{ lb}}{2} + \frac{300 \frac{\text{lb}}{\text{ft}} (16 \text{ ft})}{2} = 4400 \text{ lb}$$

$$M_{MAX} = \frac{PL}{4} + \frac{wL^2}{8} = \frac{4000 \text{ lb} (16 \text{ ft})}{4} + \frac{300 \frac{\text{lb}}{\text{ft}} (16 \text{ ft})^2}{8} = 25{,}600 \text{ lb} \cdot \text{ft}$$

Step 3.

$$S_{req} = \frac{M_{MAX}}{\sigma_{allow}} = \frac{25{,}600 \text{ lb} \cdot \text{ft} \left(\frac{12 \text{ in}}{\text{ft}}\right)}{1600 \text{ psi}} = 192 \text{ in.}^3$$

Step 4.

$$A_{req} = \frac{1.5 V_{MAX}}{\tau_{allow}} = \frac{1.5 (4400 \text{ lb})}{90 \text{ psi}} = 73.3 \text{ in.}^2$$

Step 5. Table A-6(a)

Lightest Timber that meets both S_{req} & A_{req}

6 x 16	23.7 lb/ft
8 x 14	28.1 lb/ft
10 x 12	30.3 lb/ft

Lightest timber is 6 x 16

$A = 85.3 \text{ in.}^2$

$S = 220 \text{ in.}^3$

$wt = 23.7 \text{ lb/ft}$

Check

Compute percentage of the extra section modulus and the percentage of extra cross-sectional area provided

Must be $> \dfrac{\text{Weight of the beam}}{\text{total design load}}$

moment Due to the Beam Weight

$$M_{wt} = \frac{(23.7 \text{ lb/ft})(16 \text{ ft})^2}{8} = 758 \text{ lb}\cdot\text{ft} \quad \text{(Table 13-1, case 4)}$$

$$\frac{M_{wt}}{M_{MAX}} = \frac{758 \text{ lb}\cdot\text{ft}}{25600 \text{ lb}\cdot\text{ft}} = 0.03 = 3\%$$

$$\frac{\text{Extra } S}{S_{req}} = \frac{220 \text{ in.}^3 - 192 \text{ in.}^3}{192 \text{ in.}^3} = 0.146 = 14.6\% > 3\% \quad \checkmark \text{ ok, bending}$$

$$\frac{\text{Extra } A}{A_{req}} = \frac{85.3 \text{ in.}^2 - 73.3 \text{ in.}^2}{73.3 \text{ in.}^2} = 0.164 = 16.4\% \quad \checkmark \text{ Shear, ok}$$

Use, 6 x 16 rectangular Section