Horizontal Shear

Because shear parallel to grain (i.e., horizontal shear) is induced by bending action, it is also known as bending shear and is greatest at the neutral axis. Bending shear is not transverse shear; lumber will always fail in other modes before failing in transverse or cross-grain shear owing to the longitudinal orientation of the wood fibers in structural members.

The horizontal shear force is calculated for solid sawn lumber by including the component of all loads (uniform and concentrated) that act perpendicular to the bearing surface of the solid member in accordance with NDS•3.4.3. Loads within a distance, *d*, from the bearing point are not included in the horizontal shear calculation; *d* is the depth of the member for solid rectangular members. Transverse shear is not a required design check, although it is used to determine the magnitude of horizontal shear by using basic concepts of engineering mechanics as discussed below.

The following equations from NDS•3.4 for horizontal shear analysis are limited to solid flexural members such as solid sawn lumber, glulam, or mechanically laminated beams. Notches in beams can reduce shear capacity and should be considered in accordance with NDS•3.4.4. Also, bolted connections influence the shear capacity of a beam; refer to NDS•3.4.5. If required, greater horizontal shear capacity may be obtained by increasing member depth or width, decreasing the clear span or spacing of the member, or selecting another species with a higher allowable shear capacity. The general equation for horizontal shear stress is discussed in the NDS and in mechanics of materials text books. Because dimension lumber is solid and rectangular, the simple equation for f_v is most commonly used.

[NDS•3.4]

$f_v \le F'_v$ basic design check for horizontal shear

$F'_v = F_v$ x (applicable adjustment factors per Section 5.2.4)

$f_v = \frac{VQ}{Ib}$ horizontal shear stress (general equation)

$f_v = \frac{3V}{2A}$ for maximum horizontal shear stress at the neutral axis of solid rectangular members

Compression Perpendicular to Grain (Bearing)

For bending members bearing on wood or metal, a minimum bearing of 1.5 inches is typically recommended. For bending members bearing on masonry, a minimum bearing of 3 inches is typically advised. The resulting bearing areas may not, however, be adequate in the case of heavily loaded members. On the other hand, they may be too conservative in the case of lightly loaded members. The minimum bearing lengths are considered to represent good practice.

The following equations from the NDS are based on net bearing area. Note that the provisions of the NDS acknowledge that the inner bearing edge experiences added pressure as the member bends. As a practical matter, the added pressure does not pose a problem because the compressive capacity, $F'_{c\perp}$, of wood increases as the material is compressed. Further, the design value is based on a deformation limit, not on failure by crushing. Thus, the NDS recommends the added pressure at bearing edges not be considered. The designer is also alerted to the use of the bearing area factor, C_b, which accounts for the ability of wood to distribute large stresses originating from a small bearing area not located near the end of a member. Examples include interior bearing supports and compressive loads on washers in bolted connections.

[NDS•3.10]

$f_{c\perp} \leq F'_{c\perp}$ basic design check for compression perpendicular to grain

$F'_{c\perp} = F_{c\perp}$ x (applicable adjustment factors per Section 5.2.4)

$f_{c\perp} = \frac{P}{A_b}$ stress perpendicular to grain due to load, P, on net bearing area, A_b.

The above equations pertain to bearing that is perpendicular to grain; for bearing at an angle to grain, refer to NDS•3.10. The later condition would apply to sloped bending members (i.e., rafters) notched at an angle for bearing. For light-frame construction, bearing stress is rarely a limiting factor.

Combined Bending and Axial Loading

Depending on the application and the combination of loads considered, some members such as wall studs and roof truss members, experience bending stress in addition to axial loading. The designer should evaluate combined bending and axial stresses as appropriate. If additional capacity is required, the selection of a higher grade of lumber is not always an efficient solution for overstressed compression members under combined axial and bending loads because the design may be limited by stability rather than by a stress failure mode. Efficiency issues will become evident when the designer calculates the components of the combined stress interaction equations that are given below and found in the NDS.

[NDS•3.9]

Combined bending and axial tension design check

$$\frac{f_t}{F'_t} + \frac{f_b}{F_b^*} \leq 1$$

$$\frac{f_b - f_t}{F_b^{**}} \leq 1$$

Combined bending and axial compression design check

$$\left(\frac{f_c}{F'_c}\right)^2 + \frac{f_{b1}}{F'_{b1}\left(1 - {f_c}/{F_{cE1}}\right)} + \frac{f_{b2}}{F'_{b2}\left(1 - \left({f_c}/{F_{cE2}}\right) - \left({f_{b1}}/{F_{bE}}\right)^2\right)} \leq 1$$

Compression and Column Stability

For framing members that support axial loads only (i.e., columns), the designer must consider whether the framing member can withstand the axial compressive forces on it without buckling or compressive failure. If additional