Conclusion

The serviceability limit states used for deflection and floor vibration limit the maximum span. The deflection limited span is 13 ft-10 in and the vibration limited span is 12 ft-6 in. Span selection based on deflection or vibration is an issue of designer judgment. The maximum span limited by the structural safety checks was 14 ft-11 in due to bending. Therefore, the serviceability limit will provide a notable safety margin above that required. Thus, No. 2 grade lumber should be considered for economy in that it will have only a small effect on the serviceability limits. Conversely, if floor stiffness is not an expected issue with the owner or occupant, the span may be increased beyond the serviceability limits if needed to "make it work." Many serviceable homes have been built with 2x8 floor joists spanning as much as 15 feet; however, if occupants have a low tolerance for floor vibration, a lesser span should be considered.

For instructional reasons, shrinkage across the depth of the floor joist or floor system may be estimated as follows based on the equations in Section 5.3.2:

d_1 = 7.25 in $\quad$ M_1 = 19% maximum (S-dry lumber)
d_2 = ? $\quad$ M_2 = 10% (estimated equilibrium MC)

$$d_2 = d_1 \left(\frac{1 - \frac{a - 0.2M_2}{100}}{1 - \frac{a - 0.2M_1}{100}} \right) = 7.25 \text{ in} \left(\frac{1 - \frac{6.031 - 0.2(10)}{100}}{1 - \frac{6.031 - 0.2(19)}{100}} \right) = 7.1 \text{ in}$$

Shrinkage ≅ 7.25 ft-7.08 in = 0.15 in (almost 3/16 in)

In a typical wood-framed house, shrinkage should not be a problem, provided that it is uniform throughout the floor system. In multistory platform frame construction, the same amount of shrinkage across each floor can add up to become a problem, and mechanical systems and structural details should allow for such movement. Kiln-dried lumber may be specified to limit shrinkage and building movement after construction.

EXAMPLE 5.2 *Simple Span Floor Joist Design (Optimize Lumber)*

Given

Live load (L) = 40 psf
Dead load (D) = 10 psf
Clear span = 14 ft-2 in
Joist size = 2x10

Find Optimum lumber species and grade

Solution

1. Calculate the applied load

W = (joist spacing)(D+L) = (2 ft)(40 psf +10 psf) = 100 plf

2. Determine bending stress

$$M_{max} = \frac{w\ell^2}{8} = \frac{(100\text{ plf})(14.17\text{ ft})^2}{8} = 2{,}510\text{ ft-lb}$$

$$F_b = \frac{M}{S} = \frac{(2{,}510\text{ ft}-\text{lb})(12\text{ in/ft})}{21.39\text{ in}^3} = 1{,}408\text{ psi}$$

3. Determine horizontal shear stress

$$V_{max} = \frac{w\ell}{2} = \frac{(100\text{ plf})(14.17\text{ ft})}{2} = 709\text{ lb}$$

$$f_v = \frac{3V}{2A} = \frac{3(709\text{ lb})}{2(1.5\text{ in})(9.25\text{ in})} = 77\text{ psi}$$

4. Determine bearing stress:

$$R_1 = R_2 = V_{max} = 709\text{ lb}$$

$$f_{c\perp} = \frac{R}{A_b} = \frac{709\text{ lb}}{(2\text{ in})(1.5\text{ in})} = 236\text{ psi}$$

Wall and roof loads, if any, are carried through rim/band joist

5. Determine minimum modulus of elasticity due to selected deflection criteria

$$\rho_{max} = \frac{5w\ell^4}{384EI} = \frac{5(80\text{ plf})*(14.17\text{ ft})^4(1{,}728\text{ in}^3/\text{ft}^3)}{384E\ (98.93\text{ in}^4)} = 733{,}540/E$$

*includes live load of 40 psf only

$$\rho_{all} \leq \ell/360$$

$$\rho_{max} \leq \rho_{all}$$

$$\frac{733{,}540}{E} = \frac{(14.17\text{ ft})(12\text{ in/ft})}{360}$$

$$E_{min} = 1.55 \times 10^6\text{ psi}$$