6.5.3.2 Diaphragm Design

As noted, diaphragms are designed in accordance with simple beam equations. To determine the shear load on a simply supported diaphragm (i.e., diaphragm supported by shear walls at each side), the designer uses the following equation to calculate the unit shear force to be resisted by the diaphragm sheathing:

$$V_{max} = \frac{1}{2} wl \qquad \text{Eq. 6.5-10a}$$

$$v_{max} = \frac{V_{max}}{d} \qquad \text{Eq. 6.5-10b}$$

where,

V_{max} = the maximum shear load on the diaphragm (plf)
w = the tributary uniform load (plf) applied to the diaphragm resulting from seismic or wind loading
l = the length of the diaphragm perpendicular to the direction of the load (ft)
v_{max} = the unit shear across the diaphragm in the direction of the load (plf)
d = the depth or width of the diaphragm in the direction of the load (ft)

The following equations are used to determine the theoretical chord tension and compression forces on a simply supported diaphragm as described above:

$$M_{max} = \frac{1}{8} wl^2 \qquad \text{Eq. 6.5-11a}$$

$$T_{max} = C_{max} = \frac{M_{max}}{d} \qquad \text{Eq. 6.5-11b}$$

where,

M_{max} = the bending moment on the diaphragm (ft-lb)
w = the tributary uniform load (plf) applied to the diaphragm resulting from seismic or wind loading
l = the length of the diaphragm perpendicular to the direction of the load (ft)
T_{max} = the maximum chord tension force (lb)
C_{max} = the maximum chord compression force (lb)
d = the depth or width of the diaphragm in the direction of the load (ft)

If the diaphragm is not simply supported at its ends, the designer uses appropriate beam equations (see Appendix A) in a manner similar to that above to determine the shear and moment on the diaphragm. The calculations to determine the unit shear in the diaphragm and the tension and compression in the chords are also similar to those given above. It should be noted that the maximum chord forces occur at the location of the maximum moment. For a simply supported diaphragm, the maximum chord forces occur at mid-span between the perimeter shear walls. Thus, chord requirements may vary depending on location and magnitude of the bending moment on the diaphragm. Similarly, shear forces on a simply supported diaphragm are highest near the perimeter shear walls (i.e., reactions). Therefore, nailing requirements for diaphragms may be adjusted depending on the variation of the shear force in interior regions of the diaphragm. Generally, these variations are not critical in small residential structures such that fastening schedules can remain constant throughout the entire diaphragm. If there are openings in the horizontal diaphragm, the width of the opening dimension is usually discounted from the width *d* of the diaphragm when determining the unit shear load on the diaphragm.

6.5.3.3 Shear Transfer (Sliding)

The shear forces in the diaphragm must be adequately transferred to the supporting shear walls. For typical residential roof diaphragms, conventional roof framing connections are often sufficient to transfer the small sliding shear forces to the shear walls (unless heavy roof coverings are used in high-hazard seismic areas or steep roof slopes are used in high-hazard wind regions). The transfer of shear forces from floor diaphragms to shear walls may also be handled by conventional nailed connections between the floor boundary member (i.e., a band joist or end joist that is attached to the floor diaphragm sheathing) and the wall framing below. In heavily loaded conditions, metal shear plates may supplement the connections. The simple rule to follow for these connections is that the shear force in from the diaphragm must equal the shear force out to the supporting wall. Floors supported on a foundation wall are usually connected to a wood sill plate bolted to the foundation wall; however, the floor joist and/or the band joist may be directly connected to the foundation wall. Chapter 7 addresses the design of these shear connections.

6.5.3.4 Diaphragm Stiffness

Diaphragm stiffness may be calculated by using semi-empirical methods based on principles of mechanics. The equations are found in most modern building codes and industry guidelines (APA, 1997; ICBO, 1997; ICC, 1999). For typical residential construction, however, the calculation of diaphragm deflection is almost never necessary and rarely performed. Therefore, the equations and their empirical adjustment factors are not repeated here. Nonetheless, the designer who attempts diaphragm deflection or stiffness calculations is cautioned regarding the same accuracy concerns mentioned for shear wall drift calculations. The stiffness of floor and roof diaphragms is highly dependent on the final construction, including interior finishes (see Section 6.2 on whole-building tests).