addition, other parts of the diaphragm boundary (i.e., walls) that also resist the bending tension and compressive forces are not considered. Certainly, a vast majority of residential roof diaphragms that are not considered "engineered" by current diaphragm design standards have exhibited ample capacity in major design events. Thus, the beam analogy used to develop an analytic model for the design of wood-framed horizontal diaphragms has room for improvement that has yet to be explored from an analytic standpoint.

As with shear walls, openings in the diaphragm affect the diaphragm's capacity. However, no empirical design approach accounts for the effect of openings in a horizontal diaphragm as for shear walls (i.e., the PSW method). Therefore, if openings are present, the effective depth of the diaphragm in resisting shear forces must either discount the depth of the opening or be designed for shear transfer around the opening. If it is necessary to transfer shear forces around a large opening in a diaphragm, it is common to perform a mechanics-based analysis of the shear transfer around the opening. The analysis is similar to the previously described method that uses free-body diagrams for the design of shear walls. The reader is referred to other sources for further study of diaphragm design (Ambrose and Vergun, 1987; APA, 1997; Diekmann, 1986).

6.5 Design Guidelines

6.5.1 General Approach

This section outlines methods for designing shear walls (Section 6.5.2) and diaphragms (Section 6.5.3). The two methods of shear wall design are the segmented shear wall (SSW) method and the perforated shear wall (PSW) method. The selection of a method depends on shear loading demand, wall configuration, and the desired simplicity of the final construction. Regardless of design method and resulting LFRS, the first consideration is the amount of lateral load to be resisted by the arrangement of shear walls and diaphragms in a given building. The design loads and basic load combinations in Chapter 3, Table 3.1, are as follows:

- 0.6D + (W or 0.7E) ASD
- 0.9D + (1.5W or 1.0E) LRFD

Earthquake load and wind load are considered separately, with shear walls designed in accordance with more stringent loading conditions.

Lateral building loads should be distributed to the shear walls on a given story by using one of the following methods as deemed appropriate by the designer:

- tributary area approach;
- total shear approach; or
- relative stiffness approach.

These methods were described earlier (see Section 6.4). In the case of the tributary area method, the loads can be immediately assigned to the various shear wall lines based on tributary building areas (exterior surface area for wind loads and building plan area for seismic loads) for the two orthogonal directions of loading (assuming rectangular-shaped buildings and relatively uniform mass distribution for seismic design). In the case of the total shear approach, the load is considered as a "lump sum" for each story for both orthogonal directions of loading. The shear wall construction and total amount of shear wall for each direction of loading and each shear wall line are then determined in accordance with this section to meet the required load as determined by either the tributary area or total shear approach. The designer must be reasonably confident that the distribution of the shear walls and their resistance is reasonably "balanced" with respect to building geometry and the center of the total resultant shear load on each story. As mentioned, both the tributary and total shear approaches have produced many serviceable designs for typical residential buildings, provided that the designer exercises sound judgment.

In the case of the relative stiffness method, the assignment of loads must be based on an assumed relationship describing the relative stiffness of various shear wall lines. Generally, the stiffness of a wood-framed shear wall is assumed to be directly related to the length of the shear wall segments and the unit shear value of the wall construction. For the perforated shear wall method, the relative stiffness of various perforated shear wall lines may be assumed to be directly related to the design strength of the various perforated shear wall lines. Using the principle of moments and a representation of wall racking stiffness, the designer can then identify the center of shear resistance for each story and determine each story's torsional load (due to the offset of the load center from the center of resistance). Finally, the designer superimposes direct shear loads and torsional shear loads to determine the estimated shear loads on each of the shear wall lines.

It is common practice (and required by some building codes) for the torsional load distribution to be used only to add to the direct shear load on one side of the building but not to subtract from the direct shear load on the other side, even though the restriction is not conceptually accurate. Moreover, most seismic design codes require evaluations of the lateral resistance to seismic loads with "artificial" or "accidental" offsets of the estimated center of mass of the building (i.e., imposition of an "accidental" torsional load imbalance). These provisions, when required, are intended to conservatively address uncertainties in the design process that may otherwise go undetected in any given analysis (i.e., building mass is assumed uniform when it actually is not). As an alternative, uncertainties may be more easily accommodated by increasing the shear load by an equivalent amount in effect (i.e., say 10 percent). Indeed, the seismic shear load using the simplified method (see Equation 3.8-1 in Chapter 3) includes a factor that increases the design load by 20 percent and may be considered adequate to address uncertainties in torsional load distribution. However, the simple "20 percent" approach to addressing accidental torsion loads is not explicitly permitted in any current building code. But, for housing, where many redundancies also exist, the "20 percent" rule seems to be a reasonable substitute for a more "exact" analysis of accidental torsion. Of course, it is not a substitute for evaluating and designing for torsion that is expected to occur.