CHAPTER 6

Lateral Resistance to Wind and Earthquake

6.1 General

The objectives in designing a building's lateral resistance to wind and earthquake forces are

- to provide a system of shear walls, diaphragms, and interconnections to transfer lateral loads and overturning forces to the foundation;
- to prevent building collapse in extreme wind and seismic events; and
- to provide adequate stiffness to the structure for service loads experienced in moderate wind and seismic events.

In light-frame construction, the lateral force-resisting system (LFRS) comprises shear walls, diaphragms, and their interconnections to form a whole-building system that may behave differently than the sum of its individual parts. In fact, shear walls and diaphragms are themselves subassemblies of many parts and connections. Thus, designing an efficient LFRS system is perhaps the greatest challenge in the structural design of light-frame buildings. In part, the challenge results from the lack of any single design methodology or theory that provides reasonable predictions of complex, large-scale system behavior in conventionally built or engineered light-frame buildings.

Designer judgment is a crucial factor that comes into play when the designer selects how the building is to be analyzed and to what extent the analysis should be assumed to be a correct representation of the true design problem. Designer judgment is essential in the early stages of design because the analytic methods and assumptions used to evaluate the lateral resistance of light-frame buildings are not in themselves correct representations of the problem. They are analogies that are sometimes reasonable but at other times depart significantly from reason and actual system testing or field experience.

This chapter focuses on methods for evaluating the lateral resistance of individual subassemblies of the LFRS (i.e., shear walls and diaphragms) and the response of the whole building to lateral loads (i.e., load distribution). Traditional design approaches as well as innovative methods, such as the *perforated shear wall design method*, are integrated into the designer's "tool box." While the code-approved methods have generally "worked," there is considerable opportunity for improvement and optimization. Therefore, the information and design examples presented in this chapter provide a useful guide and resource that supplement existing building code provisions. More important, the chapter is aimed at fostering a better understanding of the role of analysis versus judgment and promoting more efficient design in the form of alternative methods.

The lateral design of light-frame buildings is not a simple endeavor that provides "exact" solutions. By the very nature of the LFRS, the real behavior of light-frame buildings is highly dependent on the performance of building systems, including the interactions of structural and nonstructural components. For example, the nonstructural components in conventional housing (i.e., sidings, interior finishes, interior partition walls, and even windows and trim) can account for more than 50 percent of a building's lateral resistance. Yet, the contribution of these components is not considered as part of the "designed" LFRS for lack of appropriate design tools and building code provisions that may prohibit such considerations. In addition, the need for simplified design methods inevitably leads to a trade-off–analytical simplicity for design efficiency.

In seismic design, factors that translate into better performance may not always be obvious. The designer should become accustomed to thinking in terms of the relative stiffness of components that make up the whole building. Important, too, is an understanding of the inelastic (nonlinear), nonrigid body behavior of wood-framed systems that affect the optimization of strength, stiffness, dampening, and ductility. In this context, the concept that more strength is better is insupportable without considering the impact on other important factors. Many factors relate to a structural system's deformation capability and ability to absorb and safely dissipate energy from abusive cyclic motion in a seismic event. The intricate interrelationship of these several factors is difficult to predict with available seismic design approaches.

For example, the basis for the seismic response modifier R is a subjective representation of the behavior of a given structure or structural system in a seismic event (refer to Chapter 3). In a sense, it bears evidence of the inclusion of "fudge factors" in engineering science for reason of necessity (not of preference) in attempting to mimic reality. It is not necessarily surprising, then, that the amount of wall bracing in conventional homes shows no apparent correlation with the damage levels experienced in seismic events (HUD, 1999). Similarly, the near-field damage to conventional homes in the Northridge Earthquake did not correlate with the magnitude of response spectral ground accelerations in the short period range (HUD, 1999). The short-period spectral response acceleration, it will be recalled, is the primary ground motion parameter used in the design of most low-rise and light-frame buildings (refer to Chapter 3).

The apparent lack of correlation between design theory and actual outcome points to the tremendous uncertainty in existing seismic design methods