for light-frame structures. In essence, a designer's compliance with accepted seismic design provisions may not necessarily be a good indication of actual performance in a major seismic event. This statement may be somewhat unsettling but is worthy of mention. For wind design, the problem is not as severe in that the lateral load can be more easily treated as a static load, with system response primarily a matter of determining lateral capacity without complicating inertial effects, at least for small light-frame buildings.

In conclusion, the designer should have a reasonable knowledge of the underpinnings of current LFRS design approaches (including their uncertainties and limitations). However, many designers do not have the opportunity to become familiar with the experience gained from testing whole buildings or assemblies. Design provisions are generally based on an "element-based" approach to engineering and usually provide little guidance on the performance of the various elements as assembled in a real building. Therefore, the next section presents a brief overview of several whole-house lateral load tests.

6.2 Overview of Whole-Building Tests

A growing number of full-scale tests of houses have been conducted to gain insight into actual system strength and structural behavior. Several researchers have recently summarized the body of research; the highlights follow (Thurston, 1994; NIST, 1998).

One whole-house test program investigated the lateral stiffness and natural frequency of a production-built home (Yokel, Hsi, and Somes, 1973). The study applied a design load simulating a uniform wind pressure of 25 psf to a conventionally built home: a two-story, split-foyer dwelling with a fairly typical floor plan. The maximum deflection of the building was only 0.04 inches and the residual deflection about 0.003 inches. The natural frequency and dampening of the building were 9 hz (0.11 s natural period) and 6 percent, respectively. The testing was nondestructive such that the investigation yielded no information on "postyielding" behavior; however, the performance was good for the nominal lateral design loads under consideration.

Another whole-house test applied transverse loads without uplift to a wood-framed house. Failure did not occur until the lateral load reached the "equivalent" of a 220 mph wind event without inclusion of uplift loads (Tuomi and McCutcheon, 1974). The house was fully sheathed with 3/8-inch plywood panels, and the number of openings was somewhat fewer than would be expected for a typical home (at least on the street-facing side). The failure took the form of slippage at the floor connection to the foundation sill plate (i.e., there was only one 16d toenail at the end of each joist, and the band joist was not connected to the sill). The connection was somewhat less than what is now required in the United States for conventional residential construction (ICC, 1998). The racking stiffness of the walls nearly doubled from that experienced before the addition of the roof framing. In addition, the simple 2x4 wood trusses were able to carry a gravity load of 135 psf–more than three times the design load of 40 psf. However, it is important to note that combined uplift and lateral load, as would be expected in high-wind conditions, was not tested. Further, the test house was relatively small and "boxy" in comparison to modern homes.

Many whole-house tests have been conducted in Australia. In one series of whole-house tests, destructive testing has shown that conventional residential construction (only slightly different from that in the United States) was able to withstand 2.4 times its intended design wind load (corresponding to a 115 mph wind speed) without failure of the structure (Reardon and Henderson, 1996). The test house had typical openings for a garage, doors, and windows, and no special wind-resistant detailing. The tests applied a simultaneous roof uplift load of 1.2 times the total lateral load. The drift in the two-story section was 3 mm at the maximum applied load while the drift in the open one-story section (i.e., no interior walls) was 3 mm at the design load and 20 mm at the maximum applied load.

Again in Australia, a house with fiber cement exterior cladding and plasterboard interior finishes was tested to 4.75 times its "design" lateral load capacity (Boughton and Reardon, 1984). The walls were restrained with tie rods to resist wind uplift loads as required in Australia's typhoon-prone regions. The roof and ceiling diaphragm was found to be stiff; in fact, the diaphragm rigidly distributed the lateral loads to the walls. The tests suggested that the house had sufficient capacity to resist a design wind speed of 65 m/s (145 mph).

Yet another Australian test of a whole house found that the addition of interior ceiling finishes reduced the deflection (i.e., drift) of one wall line by 75 percent (Reardon, 1988; Reardon, 1989). When cornice trim was added to cover or dress the wall-ceiling joint, the deflection of the same wall was reduced by another 60 percent (roughly 16 percent of the original deflection). The tests were conducted at relatively low load levels to determine the impact of various nonstructural components on load distribution and stiffness.

Recently, several whole-building and assembly tests in the United States have been conducted to develop and validate sophisticated finite-element computer models (Kasal, Leichti, and Itani, 1994). Despite some advances in developing computer models as research tools, the formulation of a simplified methodology for application by designers lags behind. Moreover, the computer models tend to be time-intensive to operate and require detailed input for material and connection parameters that would not normally be available to typical designers. Given the complexity of system behavior, the models are often not generally applicable and require "recalibration" whenever new systems or materials are specified.

In England, researchers have taken a somewhat different approach by moving directly from empirical system data to a simplified design methodology, at least for shear walls (Griffiths and Wickens, 1996). This approach applies various "system factors" to basic shear wall design values to obtain a value for a specific application. System factors account for material effects in various wall assemblies, wall configuration effects (i.e., number of openings in the wall), and interaction effects with the whole building. One factor even accounts for the fact that shear loads on wood-framed shear walls in a full brick-veneered building are reduced by as much as 45 percent for wind loads, assuming, of course, that the brick veneer is properly installed and detailed to resist wind pressures.

More recently, whole-building tests have been conducted in Japan (and to a lesser degree in the United States) by using large-scale shake tables to study the inertial response of whole, light-frame buildings (Yasumura, 1999). The tests have demonstrated whole-building stiffness of about twice that experienced by