grain, and modulus of elasticity. In particular, the 1997 edition of the NDS includes the most up-to-date design values based on test results from an eight-year full-scale testing program that uses lumber samples from mills across the United States and Canada.

Characteristic structural properties for use in allowable stress design (ASTM D1990) and load and resistance factor design (ASTM D5457) are used to establish design values (ASTM, 1998a; ASTM, 1998b). Test data collected in accordance with the applicable standards determine a characteristic strength value for each grade and species of lumber. The value is usually the mean (average) or fifth percentile test value. The fifth percentile represents the value that 95 percent of the sampled members exceeded. In ASD, characteristic structural values are multiplied by the reduction factors in Table 5.1. The reduction factors are implicit in the allowable values published in the NDS-S for standardized conditions. The reduction factor normalizes the lumber properties to a standard set of conditions related to load duration, moisture content, and other factors. It also includes a safety adjustment if applicable to the particular limit state (i.e., ultimate capacity). Therefore, for specific design conditions that differ from the standard basis, design property values should be adjusted as described in Section 5.2.4.

The reduction factors in Table 5.1 are derived as follows as reported in ASTM D2915 (ASTM, 1997):

- $F_b$ reduction factor = (10/16 load duration factor)(10/13 safety factor);
- $F_t$ reduction factor = (10/16 load duration factor)(10/13 safety factor);
- $F_v$ reduction factor = (10/16 load duration factor)(4/9 stress concentration factor) (8/9 safety factor);
- $F_c$ reduction factor = (2/3 load duration factor)(4/5 safety factor); and
- $F_{c\perp}$ reduction factor = (2/3 end position factor)

## 5.2.4 Adjustment Factors

The allowable values published in the NDS-S are determined for a standard set of conditions. Yet, given the many variations in the characteristics of wood that affect the material's structural properties, several adjustment factors are available to modify the published values. For efficient design, it is important to use the appropriate adjustments for conditions that vary from those used to derive the standard design values. Table 5.2 presents adjustment factors that apply to different structural properties of wood. The following sections briefly discuss the adjustment factors most commonly used in residential applications. For information on other adjustment factors, refer to the NDS, NDS-S, and the NDS commentary.

## TABLE 5.1 *Design Properties and Associated Reduction Factors for ASD*

| Stress Property | Reduction Factor | Basis of Estimated Characteristic Value from Test Data | Limit State | ASTM Designation |
|---|---|---|---|---|
| Extreme fiber stress in bending, $F_b$ | $\frac{1}{2.1}$ | Fifth percentile | Ultimate capacity | D1990 |
| Tension parallel to grain, $F_t$ | $\frac{1}{2.1}$ | Fifth percentile | Ultimate capacity | D1990 |
| Shear parallel to grain, $F_v$ | $\frac{1}{4.1}$ | Fifth percentile | Ultimate capacity | D245 |
| Compression parallel to grain, $F_c$ | $\frac{1}{1.9}$ | Fifth percentile | Ultimate capacity | D1990 |
| Compression perpendicular to grain, $F_{c\perp}$ | $\frac{1}{1.5}$ | Mean | 0.04" deflection[1] | D245 |
| Modulus of elasticity, $E$ | $\frac{1}{1.0}$ | Mean | Proportional limit[2] | D1990 |

*Sources: ASTM, 1998a; ASTM, 1998c.*
Notes:
[1]The characteristic design value for $F_{c\perp}$ is controlled by a deformation limit state. In fact, the lumber will densify and carry an increasing load as it is compressed.
[2]The proportional limit of wood load-deformation behavior is not clearly defined because it is nonlinear. Therefore, designation of a proportional limit is subject to variations in interpretation of test data.

## TABLE 5.2 *Adjustment Factor Applicability to Design Values for Wood*

| Design Properties[1] | Adjustment Factor[2] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $C_D$ | $C_r$ | $C_H$ | $C_F$ | $C_P$ | $C_L$ | $C_M$ | $C_{fu}$ | $C_b$ | $C_T$ | $C_V$ | $C_t$ | $C_i$ | $C_c$ | $C_f$ |
| $F_b$ | ✔ | ✔ | | ✔ | | ✔ | ✔ | ✔ | | | ✔ | ✔ | ✔ | ✔ | ✔ |
| $F_t$ | ✔ | | | ✔ | | | ✔ | | | | | ✔ | ✔ | | |
| $F_v$ | ✔ | | ✔ | | | | ✔ | | | | | ✔ | ✔ | | |
| $F_{c\perp}$ | | | | | | | ✔ | | ✔ | | | ✔ | ✔ | | |
| $F_c$ | ✔ | | | ✔ | ✔ | | ✔ | | | | | ✔ | ✔ | | |
| $E$ | | | | | | | ✔ | | | ✔ | | ✔ | ✔ | | |

*Source: Based on NDS•2.3 (AF&PA, 1997).*
Notes:
[1]Basic or unadjusted values for design properties of wood are found in NDS-S. See Table 5.1 for definitions of design properties.
[2]Shaded cells represent factors most commonly used in residential applications; other factors may apply to special conditions.

Key to Adjustment Factors:

- $C_D$, Load Duration Factor. Applies when loads are other than "normal" 10-year duration (see Section 5.2.4.1 and NDS•2.3.2).

- $C_r$, Repetitive Member Factor. Applies to bending members in assemblies with multiple members spaced at maximum 24 inches on center (see Section 5.2.4.2 and NDS•4.3.4).