Chapter

1

Wood Buildings and Design Criteria

1.1 Introduction

There are probably more buildings constructed with wood than any other structural material. Many of these buildings are single-family residences, but many larger apartment buildings as well as commercial and industrial buildings also use wood framing. Wood is currently moving into mid-rise construction, with buildings of four to six stories being increasingly common. In addition, while the majority of wood-frame construction has in the past been light-frame systems, cross-laminated timber (CLT) systems are now emerging.

The widespread use of wood in the construction of buildings has both an economic and an aesthetic basis. The ability to construct wood buildings with a minimal amount of specialized equipment has kept the cost of wood-frame buildings competitive with other types of construction. On the other hand, where architectural considerations are important, the beauty and the warmth of exposed wood are difficult to match with other materials.

Wood-frame construction has evolved from a method used in primitive shelters into a major field of structural design. However, in comparison with the time devoted to steel and reinforced concrete design, timber design is not given sufficient attention in most colleges and universities.

This book is designed to introduce the subject of timber design as applied to wood light-frame building construction. Although the discussion centers on building design, the concepts also apply to the design of other types of wood-frame structures. Final responsibility for the design of a building rests with the structural engineer. However, this book is written to introduce the subject to a broad audience. This includes engineers, engineering technologists, architects, and others concerned with building design. A background in statics and strength of materials is required to adequately follow the text. Most wood-frame buildings are highly redundant structures, but for design simplicity are assumed to be made up of statically determinate members. The ability to analyze simple trusses, beams, and frames is also necessary.

1.2 Types of Buildings

There are various types of framing systems that can be used in wood buildings. The most common type of wood-frame construction uses a system of horizontal diaphragms and vertical shearwalls to resist lateral forces, and this book deals specifically with the design of this basic type of building. At one time building codes classified a shearwall building as a *box system*, which was a good physical description of the way in which the structure resists lateral forces. However, building codes have dropped this terminology, and most wood-frame shearwall buildings are now classified as *bearing wall systems*. The distinction between the shearwall and diaphragm system and other systems is explained in Chap. 3.

Other types of wood building systems, such as glulam arches, post-frame (or pole) buildings, and cross-laminated timber buildings, are beyond the specific scope of this book. It is felt that the designer should first have a firm understanding of the behavior of basic shearwall buildings and the design procedures that are applied to them. With a background of this nature, the designer can acquire from currently available sources (e.g., Refs. 1.2, 1.8, and 1.12) the design techniques for other systems.

The basic bearing wall system can be constructed entirely from wood components. See Fig. 1.1. Here the *roof, floors, and walls* use wood framing. The calculations necessary to design these structural elements are illustrated throughout the text in comprehensive examples.

In addition to buildings that use only wood components, other common types of construction make use of wood components in combination with some other type or types of structural material. Perhaps the most common mix of structural materials is in buildings that use *wood roof and floor systems* and *concrete tilt-up* or *masonry (concrete block or brick) shearwalls*. See Fig. 1.2. This type of construction is common, especially in one-story commercial and industrial buildings. This construction is economical for small buildings, but its economy improves as the size of the building increases. Trained crews can erect large areas of *panelized* roof systems in short periods of time. See Fig. 1.3.

Design procedures for the wood components used in buildings with concrete or masonry walls are also illustrated throughout this book. The connections between wood and concrete or masonry elements are particularly important and are treated in considerable detail.

This book covers the *complete* design of wood-frame *box*-type buildings from the roof level down to the foundation. In a complete building design, *vertical loads and lateral forces* must be considered, and the design procedures for both are covered in detail.

Wind and seismic (earthquake) are the two lateral forces that are normally taken into account in the design of a building. In recent years, design for lateral forces has become a significant portion of the design effort. The reason

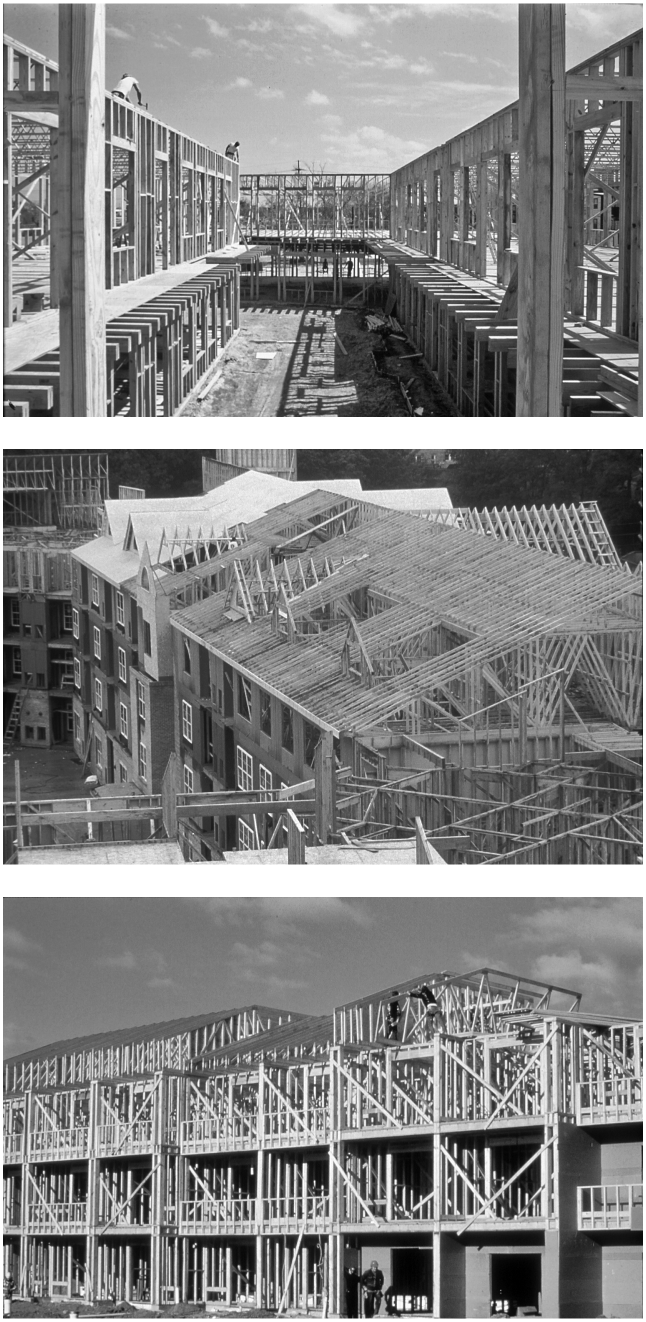

Figure 1.1 Multistory wood-frame buildings. (*Photo courtesy of Southern Pine Council.*)

Figure 1.2*a* *Foreground:* Office portion of wood-frame construction. *Background:* Warehouse with concrete tilt-up walls and wood roof system. (*Photo courtesy of Mike Hausmann.*)

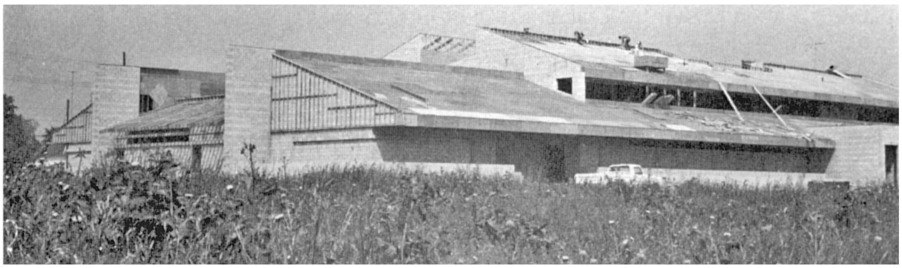

Figure 1.2*b* Building with reinforced-masonry block walls and a wood roof system with plywood sheathing. (*Photo courtesy of Mark Williams*.)

for this is an increased awareness of the effects of lateral forces. In addition, the building codes have substantially revised the design requirements for both wind and seismic forces. These changes are the result of extensive research in wind engineering and earthquake-resistant design.

1.3 Required and Recommended References

The seventh edition of this book was prompted by primarily the publication of the 2012 edition of the *National Design Specification for Wood Construction* (NDS) (Ref. 1.4), as well as by *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-10) (Ref. 1.3) and the 2012 *International Building Code* (IBC) (Ref. 1.9). The 2012 NDS, like the previous 2005 edition, is in a *dual format*, including both *allowable stress design* (ASD) and *load and resistance factor design* (LRFD) provisions. Previous editions of the NDS had been in ASD only.

Figure 1.3 Interior of a building with a panelized roof system. (*Photo courtesy of Southern Pine Council.*)

The NDS is published by the American Wood Council (AWC) of the American Forest and Paper Association (AF&PA) and represents the latest structural design recommendations by the wood industry. In addition to basic design provisions for both ASD and LRFD, the 2012 NDS contains chapters specific to sawn lumber, glued-laminated timber, poles and piles, wood I-joists, structural composite lumber, wood structural panels, mechanical connections, dowel-type fasteners, split ring and shear plate connectors, timber rivets, shearwalls and diaphragms, special loading conditions, and fire design.

The NDS is actually the formal design section of what is a series of interrelated design documents. There are two primary companion documents that support and complete the dual-format *National Design Specification for Wood Construction*. The first companion document is the *NDS Supplement: Design Values for Wood Construction*, which is often referred to simply as the *Supplement* or the *NDS Supplement* as this was the original and for many years the only supplement to the NDS. The NDS Supplement contains all the reference design values for various species groupings of structural lumber and glued-laminated timber. The NDS Supplement is updated at the same time as the NDS, so the current Supplement edition is 2012.

The second companion design document to the NDS is the *Special Design Provisions for Wind and Seismic* (Ref. 1.6), also called the *Wind and Seismic Supplement* or *SDPWS*. The Wind and Seismic Supplement is the newest supplement and is maintained as a separate document due to the unique requirements related to wind- and seismic-resistant design. Included in the SDPWS are reference design values for shearwalls and diaphragms, which comprise the primary lateral-force-resisting system (LFRS) in most wood structures. SDPWS is updated on a different cycle than the NDS, and the current edition is 2008. A new edition will be published in 2015.

The NDS along with both the NDS Supplement and the SDPWS comprise the core of what is needed to design engineered wood structures. Because of the subject matter, the reader must have a copy of the NDS to properly follow this book. Additionally, the numerous tables of member properties, design values, fastener capacities, and unit shears for shearwalls and diaphragms are lengthy. Rather than reproducing these tables in this book, the reader is better served to have copies of both supplements as well. Having a copy of the *NDS*, the *NDS Supplement: Design Values for Wood Construction*, and the *NDS Supplement: Special Design Provisions for Wind and Seismic* is analogous to having a copy of the AISC Steel Manual (Ref. 1.1) in order to be familiar with structural steel design.

Commentary on the NDS provisions is provided in the NDS document. This commentary provides additional guidance and other supporting information for the design provisions included in the NDS.

In addition to the NDS and its two supplements, another associated document is available from the AF&PA American Wood Council. This document is the *ASD/LRFD Manual for Engineered Wood Construction.* The ASD/LRFD Manual for Engineered Wood Construction was first introduced for ASD in 1999 for the 1997 NDS, and for the first time brought together all necessary information required for the design of wood structures. Prior to this, the designer referred to the NDS for the design of solid sawn lumber and glulam members, as well as the design of many connection details. For the design of other wood components and systems, the designer was required to look elsewhere. For example, the design of shearwalls and diaphragms was not covered in the NDS, but through various other sources including publications by APA—The Engineered Wood Association. 2012 Manual contains supporting information for both LRFD and ASD, including nonmandatory design information such as span tables, load tables, and fire assemblies. The Manual is organized to parallel the NDS.

All or part of the design recommendations in the NDS will eventually be incorporated into the wood design portions of most building codes. With recent codes, this adoption has typically occurred through adopting by reference (citing as adopted) a particular edition of the NDS, NDS Supplement, and SDPWS. However, the code change process can take considerable time. This book deals specifically with the design provisions of the 2012 NDS, and the designer should verify local building code acceptance before basing the design of a particular wood structure on these criteria.

This book also concentrates heavily on understanding the loads and forces required in the design of a structure. Emphasis is placed on both gravity loads and lateral forces. Toward this goal, the design loads and forces in this book are taken from the 2012 *International Building Code* (IBC) (Ref. 1.9). The IBC is published by the International Codes Council (ICC), and it is highly desirable for the reader to have a copy of the IBC to follow the discussion in this book.

Frequent references are made in this book to the NDS, the NDS Supplements, SDPWS, the ASD/LRFD Manual for Engineered Wood Construction, and the IBC. In addition, a number of cross references are made to discussions or examples in this book that may be directly related to a particular subject. The reader should clearly understand the meaning of the following references: