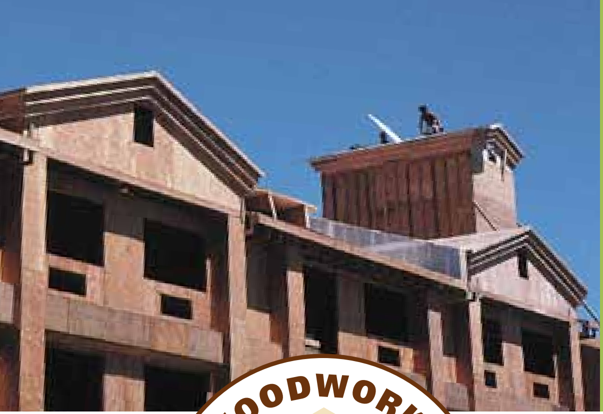

Designing for Wind Resistance

WOODWORKS FOR NON-RESIDENTIAL CONSTRUCTION

Wood Design & Building Series

When designing a wood-frame building to resist high winds and other lateral loads, design engineers use sheathing products such as wood structural panels, structural fiberboard, particleboard and board sheathing to create diaphragms and shear walls that transfer the loads into the foundation. Or, they use rigid frame construction to transfer the lateral loads. Regardless of the option chosen, wood-frame construction makes it easy to design strong, durable buildings that meet code requirements and ensure reliable performance under high winds.

Earn one AIA/CES LU (HSW) by reading this document and taking a short online quiz. For details and learning objectives, visit the Online Training Library at *woodworks.org*. WoodWorks is an approved AIA provider.

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Wood's Advantage Under Wind Loads

Wood has a number of inherent characteristics that make it ideal for non-residential buildings in areas prone to high wind:

- When structural wood panels such as plywood and oriented strand board (OSB) are properly attached to lumber framing members, they form some of the most solid and stable roof, floor and wall systems available. These materials are also used to form the diaphragms and shear walls necessary to resist high wind loads.
- Wood is able to resist higher stresses when the load is applied for a short time; this feature enhances its performance in high wind events, which are typically of short duration.
- Wood diaphragm design enables designers to create durable structures that can resist high wind and seismic loads for little or no extra cost.
- Panelized wood roof systems are ideal for large, low-slope non-residential buildings because they can be erected quickly and improve the quality of construction.

Design Standards for Wind Loading

Section 2305 of the *International Building Code (IBC), General Design Requirements for Lateral-force Resisting Systems* covers code requirements for structures using wood shear walls and diaphragms to resist wind and other lateral loads.

The Conventional Light-Frame Construction provisions in Chapter 23 (Section 2308) of the IBC govern buildings under both wind and seismic loading. Provisions apply if the building meets all requirements of Section 2308.2.

When wind speeds or limitations exceed those permitted by Section 2308, the shear wall and diaphragm design must conform to Section 1609 of the IBC, which specifies wind loads as set forth in the American Society of Civil Engineers' (ASCE) *Minimum Design Loads for Buildings and Other Structures* (ASCE-7).

In addition to ASCE-7, *ANSI/AF&PA Special Design Provisions for Wind and Seismic Standard with Commentary (Wind and Seismic)* is a referenced standard. *Wind and Seismic* covers materials, design and construction of wood members, fasteners and assemblies to resist wind and seismic forces.

Engineering design of wood structures to resist wind or seismic forces can use either Allowable Stress Design (ASD) or Load and Resistance Factor Design (LRFD) methodologies. *Wind and Seismic* contains criteria for proportioning, design and detailing of engineered wood systems, members, and connections in lateral force resisting systems. The standard also provides nominal shear capacities of diaphragms and shear walls for reference assemblies.

Provisions contained in *Wind and Seismic* are generally consistent with provisions of the IBC and the *NEHRP (National Earthquakes Hazard Reduction Program) Recommended Provisions for Seismic Regulations for New Buildings* (FEMA 368), as well as recommendations in current design standards or guidelines such as ASCE-7.

Design Basics

All buildings, regardless of their size or location, must be designed to resist the structural loads anticipated during the building's lifetime. To do this, designers must first consider two types of loads:

VERTICAL LOADS

Vertical loads are loads acting in the "up and down" direction. These loads are the obvious ones; the weight of the building itself (dead load), the weight of everything in the building (live load) and variable loads such as those from snow. Because vertical loads are easy to understand, typical wood-frame construction practice has evolved into an efficient system that does a good job of accommodating them.

LATERAL LOADS

Lateral loads are those that act in a horizontal direction or parallel to the ground. Because wind can act in any direction, the building professional must design the building to withstand forces acting along both the length and width (major axes) of the structure. In addition to these two lateral forces, wind events can cause an uplift vertical force. Therefore, there are three forces—all at 90 degrees to each other—acting on every element and every connection between elements. Designers must calculate the load capacity of all major building elements and *every* connection between each element to make sure they have the capacity to resist all three loads and transfer lateral forces between them to provide continuity throughout the structure.

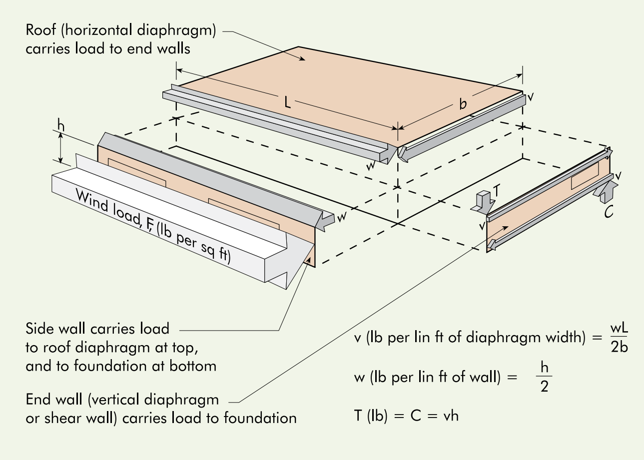
In order for the lateral-load resisting system to work, the wall receiving the wind force must transfer this load into the roof and floor diaphragms, the roof and floor diaphragms must transfer the lateral loads to the shear walls, and the shear walls must transfer this load into the foundation *(Figure 1).* The effectiveness of the load transfer system is only as good as the quality and quantity of the connections. Therefore, use of proper fasteners and detailing is critical.

Wood construction systems rely on correct design and installation of all components, including framing, sheathing and inter-element fastening details. When properly connected and tied to the foundation, shear walls and diaphragm elements give wood-frame buildings tremendous resistance to lateral forces.

LOAD PATH AND LOAD TRANSFER PRINCIPLES

The means by which loads and forces acting on the building are transferred through the structure into the diaphragm, from the roof and floor diaphragms to the shear walls, and into the foundation, is referred to as the load path.

Distribution of Lateral Loads on Building



Source: APA – The Engineered Wood Association

Understanding a vertical load path is straightforward. Vertical loads act upwards or downwards on the horizontal elements of the structure—i.e., the roof and floors. The roof and floors transfer these forces to the load-bearing walls and into the foundation. From the foundation, the load transfers into the ground. Vertical load transfer is simple because of the way elements are "stacked" on top of each other in conventional framing.

The lateral load path is less intuitive but the rules remain the same. The elements of a wood-frame building that enable it to withstand lateral forces are shear walls and diaphragms. These elements must resist the lateral loads applied, and connections between elements must be strong enough to transfer the loads between elements.

The load path is the basically same for all lateral loads, regardless of whether the load is caused by a wind or seismic event. The lateral load is either transferred *into* the roof element (when wind pushes against the walls perpendicular to the wind), or it originates directly *in* the roof element (as would happen during an earthquake).

Therefore, the general lateral load path is from the roof or floor into the walls parallel to the force, to the foundation and into the ground. This load path then repeats itself with the force applied at 90 degrees to the first one.

Interconnection of all framing elements is critical to performance of a wind-resistive structure. The building should have a continuous load path of interconnected framing elements, from footings and foundation walls to floors, walls and roof framing. Every structure in a high seismic or hurricane region is subject to loads in three orthogonal directions: vertical loads (both down and up), as well as loads along both the major horizontal axes of the structure (loads parallel and perpendicular to the plane of the wall). This means forces will try to pull every inter-element connection apart in all three directions. This is an important concept for designers to consider when designing connections.

Shear Walls and Diaphragms

When designing a wind-resistant building, engineers can choose various structural components and combine them into what the building code calls a main wind-force resisting system. These structural components include diaphragms and shear walls. Installation of wood structural panels or board sheathing over roof or floor supports creates a diaphragm, a flat structural unit that acts like a deep, thin I-beam or girder to resist lateral forces.

The diaphragm's panels act as the web of the beam to resist shear, while the edge members act as flanges, resisting bending stresses. These edge members, commonly called chords in diaphragm design, may be joists, ledgers, trusses, top plates or other wood components. Diaphragms vary considerably in load-carrying capacity, depending on whether they are blocked or unblocked.

Wood structural panels, structural fiberboard, particleboard or board sheathing fastened over wall framing can be used to create shear walls *(Figure 2)*. Shear walls receive reactions from the roof and floor diaphragms, and transmit these forces into the foundation. Shear walls resist lateral forces parallel to the plane of the wall. A shear wall is simply a cantilevered diaphragm; load applied at the top of the wall transfers out along the bottom of the wall to the foundation.

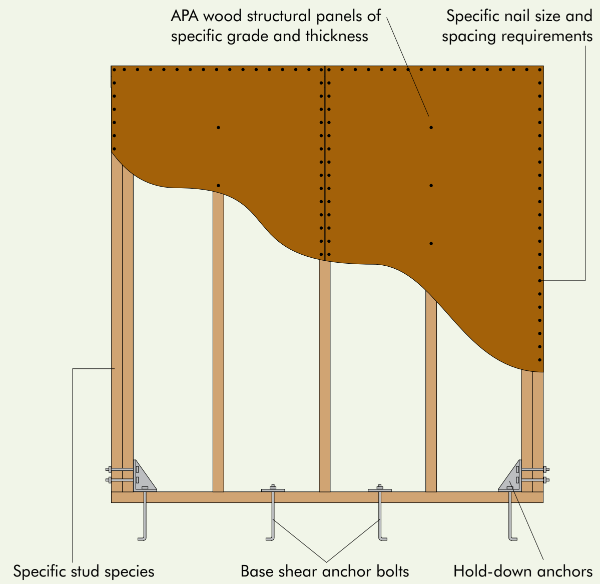
System Design

Structural design of the main wind-force resisting system is a relatively simple process if the designer keeps the overall concept of load path in mind. Any sheathed element in a building adds strength and stiffness to the structure. So, if walls, floors and roofs are sheathed with structural wood panels or boards over lumber framing and adequately tied (together and to the foundation) with approved connectors, they meet many of the requirements of a main wind-force resisting system.

In non-residential buildings with tilt-up concrete or masonry walls, most damage during a high wind event occurs if the roof-to-wall connections around the perimeter of the roof diaphragm are overstressed. To prevent this type of damage, properly connect roof framing to exterior walls and install continuous ties across the roof between walls.

When designing walls, building professionals often use framing anchors in lieu of or to augment traditional fastening connectors such as bolts and nails, particularly in applications where the lateral forces are high. Examples are shear wall hold-down anchors and rods. Framing anchors are also used at roof truss to wall top plate connections, where the connector must accommodate forces in three different directions during high wind events.

Engineered Shear Walls



Source: APA – The Engineered Wood Association *Figure 2*

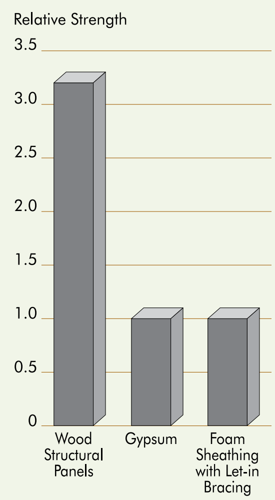
Wind Loads and Wall Design

Wind exerts pressures (inward or outward) on all exterior building surfaces. Minimum required wall design wind pressures are of similar magnitude to typical roof and floor vertical design pressures due to gravity loading. If a building's exterior cladding does not have the capacity to resist these pressures, the sheathing behind it must. Section 1609.1.3 of the 2003 IBC states that structural members and systems and components and cladding in a building or structure must be anchored to resist wind-induced overturning, uplift and sliding, and to provide continuous load paths for these forces to the foundation.

Comparative Tests of Wall Sheathing Products Under Cyclic Loading

In tests by APA, walls fully sheathed with plywood or OSB were three times stronger than walls constructed with gypsum wall sheathing or let-in bracing.

The comparative wall sheathing tests, part of an ongoing research program by APA, were designed to simulate the dynamic effects of seismic events. The tests involved 8 x 8 ft walls constructed according to the bracing provisions and nail schedules of the major model building codes.



Structural wood members must be designed as a main wind-force resisting system element, a components and cladding element, or both. Some elements, such as load-bearing studs and structural sheathing, fit both systems.

One suggested approach is to separately design the wood member as an element of each system. This approach requires at least two checks, but separate verification of both cases is necessary and beneficial.

An example would be to design studs using both main wind-force resisting system pressures (to account for combined interactions of axial and bending stresses) and components and cladding pressures (which consider axial or bending stresses individually).

- For main wind-force resisting system pressures, the fact that maximum loads do not occur in every place at exactly the same time is taken into consideration, and the "average" load is used.
- Components and cladding loads address "worst case" loading on a particular element during the wind event, so these loads are not intended for use when considering load interaction from multiple surfaces.

Stud design is often limited by the components and cladding load case. In most instances, components and cladding can be considered the controlling limit in wind design of load-bearing and non-load-bearing exterior studs.

The failure of structurally inadequate wall coverings can be a real problem in high wind events. The initial failure or breaching of the wall envelope exposes the interior of the building to significant amounts of wind-driven rain, which frequently results in further damage. Once wind and rain enter the structural wall envelope, the building begins losing its structural integrity. In addition, the building may become subject to even higher loads due to internal pressurization acting along with external wind pressures. The combination of lower strength and higher loads can be problematic, so it is important to protect the integrity of a building's exterior cladding.

Insurance

A structure's wind resistance largely determines its Extended Coverage Endorsement (ECE) and is an important factor in determining total insurance costs. Underwriters Laboratories (UL) and FM Approvals (Factory Mutual) are two agencies that research, test and assign wind uplift classifications that buildings must often meet in order to be insurable. UL assigns systems a semi-wind-resistive classification (Class 30 or 60) or a fully-wind-resistive classification (Class 90). FM assigns uplift ratings based on the wind uplift pressure in pounds per square foot that the system was able to resist during testing (90 or 105, for example).

SOURCES AND OTHER MATERIALS

American Wood Council / American Forest & Paper Association, www.awc.org

- *ANSI/AF&PA NDS-2005 – National Design Specification® for Wood Construction (NDS®)*
- *ANSI/AF&PA SDPWS-2005 – Special Design Provisions for Wind and Seismic Standard with Commentary*
- *Considerations in Wind Design of Wood Structures*
- *Wood Frame Construction Manual, Guide to Wood Construction in High Wind Areas*

APA – The Engineered Wood Association, www.apawood.org

- *Building in High Wind and Seismic Zones*
- *Diaphragms and Shear Walls Design/Construction Guide*
- *Engineered Wood Construction Guide*
- *Introduction to Lateral Design*
- *Lateral Load Connections for Low-Slope Roof Diaphragms*
- *Nonresidential Roof Systems Design/Construction Guide*
- *Collector Design for Bracing in Conventional Construction*
- *Understanding the Importance of Structural Wall Sheathing as a Wall Covering*
- *Wind-Rated Roofs, Designing Commercial Roofs to Withstand Wind Uplift Forces*

Western Wood Products Association, www.wwpa.org

- *Tech Note – Design Load Tables for Wood Studwalls Subjected to Wind Pressure*

Materials are also available via the WoodWorks Web site, in the section on *Key Issues/Wind Design,* www.woodworks.org