1 WALL BRACING: WHY IT'S NEEDED AND HOW IT WORKS

All buildings, regardless of size or location, must be designed to safely resist the structural loads anticipated during their lifetime. These loads can be divided into two categories: *vertical loads* and *lateral loads*. Wood-frame construction makes it easy for building professionals to construct strong, attractive and durable structures that resist these loads, meet building code requirements and assure good performance.

VERTICAL LOADS

Vertical loads act in the "up" or "down" direction. In most cases the "down" loads are caused by gravity. These loads are the obvious ones: the weight of the building itself (dead load), the weight of everything and everybody in the building (live load), and environmental loads, such as those from snow, wind or earthquake. The "up" loads act in an upward direction. An example of an "up" load is wind uplift.

These loads are easy to understand and typical construction practice has evolved into an efficient system that does a good job of accommodating them. Generally speaking, builders in high wind areas are as comfortable installing uplift straps as they are placing headers on cripple studs.

CHAPTER 1

Summary

Because downward loads are always present (due to gravity), any deficiencies in the vertical load path are almost immediately apparent due to structural instability. For example, a beam with support at only one end will fall down during construction.

LATERAL LOADS

The real challenge lies not with the vertical loads, but rather with the "sideways" loads, or, as they are referred to in the design community, *lateral loads*. Lateral loads act in a direction parallel to the ground. Most often the result of wind or seismic (earthquake) forces, lateral loads can cause structures to bend and sway, collapse, or even – in cases where the structure is not well attached to the foundation – roll over.

A wood beam carrying an excessive vertical load may creak, groan, split or deflect over time, warning that repair may be necessary to prevent failure. Because the wind and seismic forces that result in lateral loads are sudden and infrequent, there are no such warning indicators of an impending failure.

In every region of the country, lateral load resistance – an essential part of which is wall bracing – has to be planned during design and built into the structure during construction. While this is especially important in regions susceptible to strong wind and seismic forces, the provisions or requirements of the *International Residential Code* (IRC) make lateral load resistance an important consideration in every part of the country. The IRC prescriptively requires specific building elements to resist lateral forces for all structures within its scope.

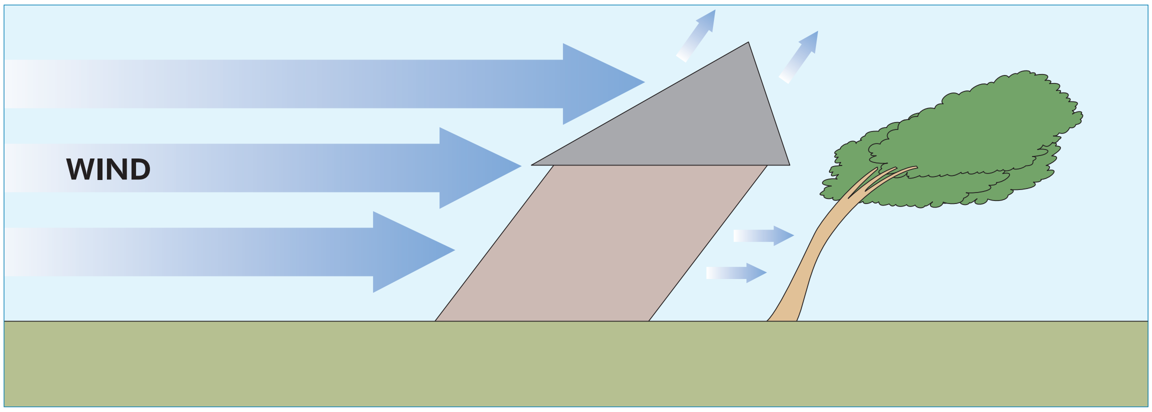
When designing a residence to meet the seismic or wind bracing requirements of the code, it is important to understand how lateral loads act on wood framing systems and how construction detailing and fasteners affect the ultimate lateral performance of the structure. Builders, designers and building officials can use the IRC wood wall bracing requirements to ensure strength, quality and safety in residential structures. Certainly, a better understanding of these requirements will ensure fewer mistakes in design and plan review, as well as in construction.

WIND FORCES

During a wind event, wind pushes against one wall while pulling on the opposite wall, as demonstrated in ***FIGURE 1.1***. Because the two walls receiving wind pressures – the receiving walls – push and pull the structure in the same direction as the wind, the walls on the sides of the structure – the bracing walls – must restrain the structure from moving. When the wind is in the perpendicular direction, the walls change roles: walls that previously restrained the structure now receive the wind pressures, and walls that previously received the wind pressures now must restrain the structure. Thus, all walls must be strong enough to resist the wind forces that push against the structure, regardless of whether they must act as a receiving wall or a restraining wall.

FIGURE 1.1

Wind forces acting on a structure



The 2015 IRC wall bracing provisions for wind apply only to residential structures located in areas where the ultimate design wind speed is less than 140 miles per hour. Ultimate design wind speeds are obtained from IRC Figure R301.2(4)A (***FIGURE 1.2***). However note that some regions of the U.S. that are subject to very high winds, as identified in IRC Figure R301.2(4) B (***FIGURE 1.3***), require the use of alternate engineering-based standards or engineered design and are not eligible for prescriptive bracing. If a specific location is defined by IRC Figure R301.2(4)B as a "wind design required" region, or the design wind speed is 140 mph or greater, the IRC wind design provisions do not apply and alternate standards or the IBC must be used. An area designated as a "special wind region" requires the designer to check with the local building official to determine the design wind speed for that location. IRC Section R301.2.1 and ***CHAPTER 2*** cover these requirements in detail. The wind speed values have changed in the 2015 IRC, as is clear in Figures 1.2 and 1.3. Explanation of these values is found in ***CHAPTER 2***, in the discussion of Section R301.2.1.1.

FIGURE 1.2

Map of basic wind speeds

Adapted from IRC Figure R301.2(4)A

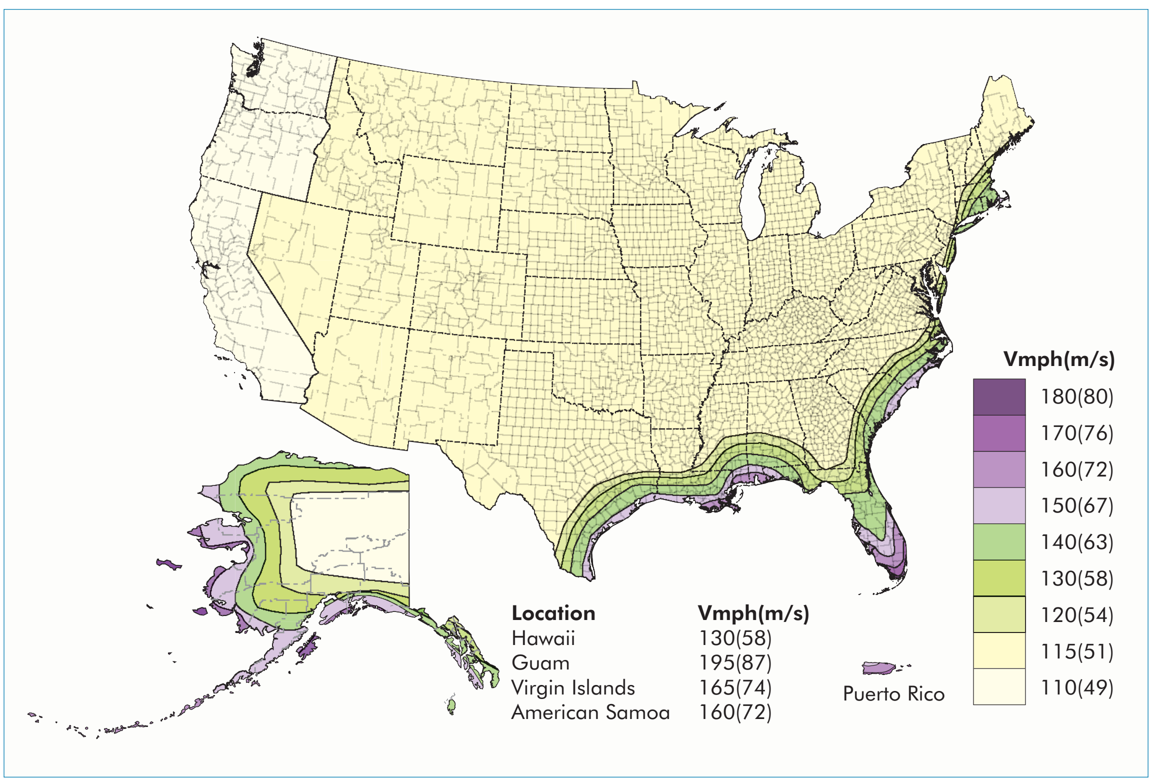
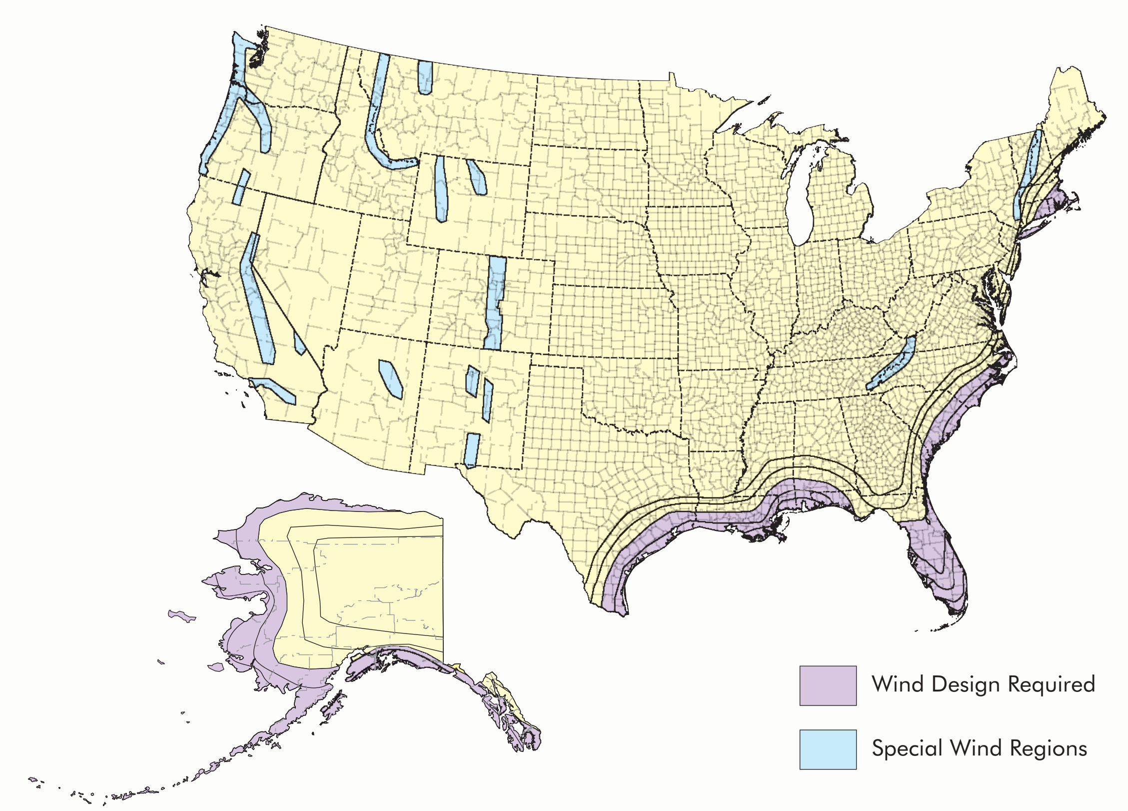


FIGURE 1.3

Map of regions that require wind design

Adapted from IRC Figure R301.2(4)B



In addition to the ultimate design wind speed, the IRC requires identification of the building site's wind exposure category. As explained in IRC Section R301.2.1.4 and ***CHAPTER 2*** of this guide, wind exposure category is determined by evaluation of the site characteristics that affect the building's exposure to wind from any direction. The evaluation considers variations in topography, vegetation and nearby structures. Historically, the four wind exposure categories were: A, B, C and D; for engineered structures, however, the design community has merged A and B into a single exposure under Exposure B. The IRC has deleted Exposure Category A in the 2015 edition as well.

The wind bracing requirements of IRC Table R602.10.3(1) (***TABLE 3.3***) are based on Exposure Category B. For Exposure Categories C and D, bracing requirements increase up to 70 percent in accordance with the adjustment factors found in IRC Table R602.10.3(2) (***TABLE 3.4***).

The wind exposure category is also used to determine the IRC Section R301.2.1 design load performance requirements for components and cladding. The proper selection of wall sheathing products and the correct amount of such products is essential to ensure the exterior wall assembly has the capacity to resist component and cladding wind pressure and suction forces when acting as the receiving wall. For example, IRC Table R602.3(3) addresses the proper selection and installation of wood structural panel sheathing based on the design wind speed and exposure category. See ***CHAPTER 2***.

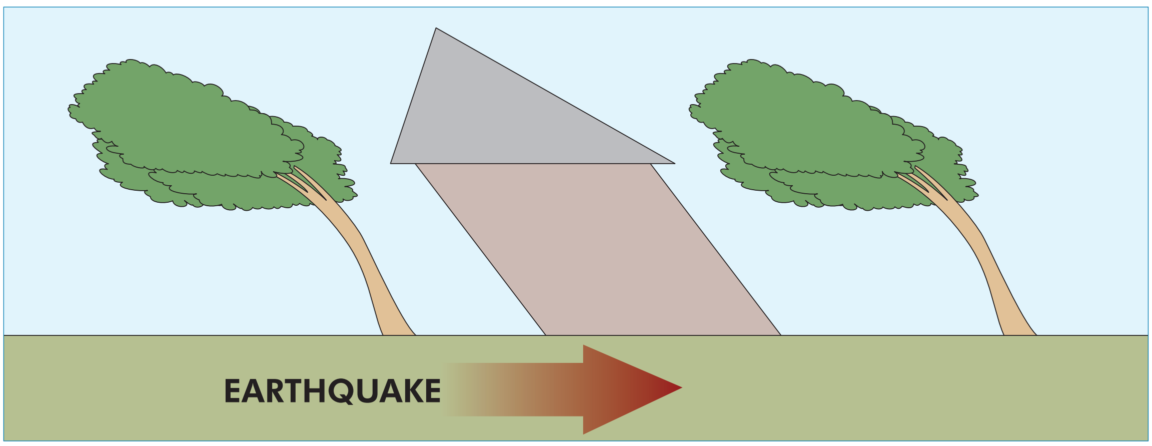
SEISMIC FORCES

Seismic forces are generated by ground motions during an earthquake event, as shown in ***FIGURE 1.4***. The ground motion causes the structure's mass to accelerate back and forth, up and down. This acceleration causes forces to develop within the structure in locations where the structure's mass is concentrated (Newton's Second Law: Force = Mass x Acceleration). Essentially, the seismic ground motion moves the foundation (*acceleration*), while inertia (*mass* of the structure) attempts to resist this motion. Instead of mass, building codes use seismic weight to determine seismic forces. The seismic weight multiplied by an acceleration expressed as a fraction of the earth's gravity produces the seismic force. Because seismic forces are directly proportional to the weight (mass) of the structure, IRC Section R301.2.2.2.1 (see ***CHAPTER 2***) imposes limits on the weights of materials used to construct the building. The seismic weight of the structure is generally concentrated at the floors and roof of the structure.

FIGURE 1.4

Earthquake forces acting on a structure

Vertical (upward) forces not shown for clarity



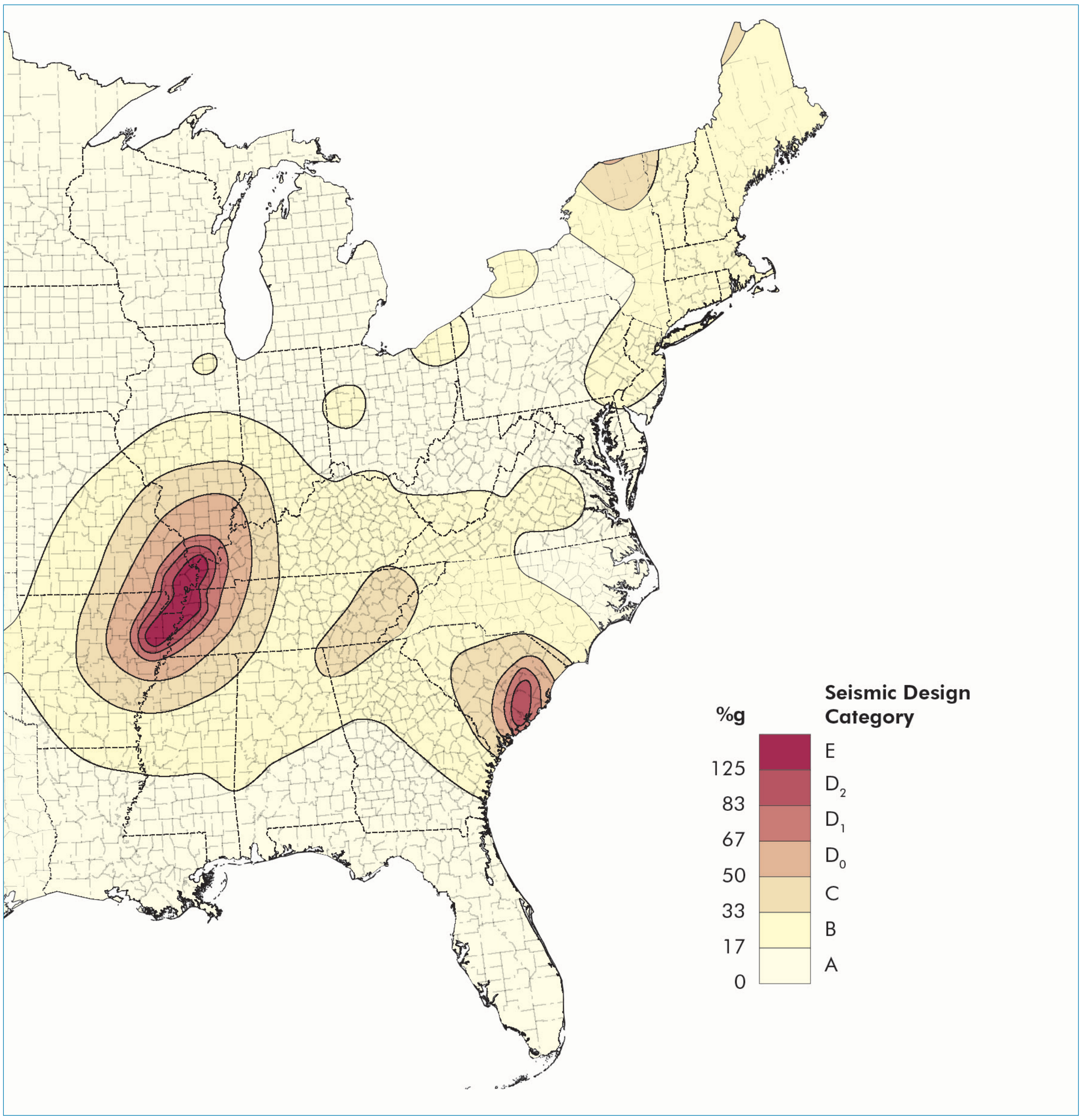
Similar to the wind maps discussed previously, the IRC provides an earthquake map (IRC Figure R301.2(2)) that displays the various Seismic Design Categories for regions of the country. The portion of the map showing the eastern half of the continental United States is excerpted in ***FIGURE 1.5*** of this guide.

FIGURE 1.5

Portion of Seismic Design Categories – Site Class D map

Adapted from IRC Figure R301.2(2)

Eastern U.S. shown (all of U.S. not shown for clarity)



The use of Seismic Design Categories is a simplified means of determining the potential hazard of an earthquake in a region. For residential structures, these categories range from Seismic Design Category (SDC) A to E, with A being the lowest hazard and D_2 the highest covered by the IRC.

For SDC E, the IRC contains provisions for reclassification of structures from SDC E to D_2 (see IRC Section R301.2.2.1.2, excerpted in ***CHAPTER 2***) under certain circumstances.

For SDC E structures that cannot be reclassified, the prescriptive structural requirements of the IRC cannot be used and the *International Building Code* (IBC) or other referenced standards must be used to engineer the structure.

The wind and seismic maps in IRC Figures R301.2(4) and R301.2(2) respectively (copied and excerpted in ***FIGURES 1.2, 1.3*** and ***1.5***) are used to determine the bracing requirements for a given structure in a particular location. In those regions of the country where the lateral loads for the design-level event (wind or seismic) are lower, minimal bracing is required for residential-type structures. Other areas are considered high wind regions, seismic regions, or both. In these regions, additional wall bracing is required to accommodate the potentially larger lateral loads.

DETERMINING WIND AND SEISMIC REQUIREMENTS

Your local building officials have already determined the wind or seismic design criteria (and other design criteria, including snow load, frost depth, termite danger, flood hazard, etc.) for your location. When a local jurisdiction adopts the IRC, they identify the information required in IRC Table R301.2(1) *Climatic and Geographic Design Criteria* (***TABLE 2.1***). Contact your local building official and ask for a copy of this information. Note that some building departments post this information on their website. See ***CHAPTER 2*** for further information.

IMPORTANT TERMINOLOGY

When discussing the lateral load path, it is helpful to be familiar with commonly used terminology, such as diaphragms, braced wall panels and shear walls. Section R202 of the IRC defines these terms as follows:

Braced wall line: A straight line through the building plan that represents the location of the lateral resistance provided by the wall bracing.

Braced wall panel: A full-height section of wall constructed to resist in-plane shear loads through interaction of framing members, sheathing material and anchors. The panel's length meets the requirements of its particular bracing method, and contributes toward the total amount of bracing required along its braced wall line in accordance with Section R602.10.1.

Diaphragm: A horizontal or nearly horizontal system acting to transmit lateral forces to the vertical resisting elements. When the term "diaphragm" is used, it includes horizontal bracing systems.

Shear wall: A general term for walls that are designed and constructed to resist racking from seismic and wind by use of masonry, concrete, cold-formed steel or wood framing in accordance with Chapter 6 of this code and the associated limitations in Section R301.2 of this code. *(Editorial note: this term is most often used in engineered design in accordance with the IBC or other appropriate referenced standards.)*

In the IRC, diaphragms are simply the roof and floor systems. Due to the prescriptive nature of the IRC, the diaphragm is “defined” by the minimum thicknesses of roof and floor sheathing (as provided in IRC Table R503.2.1.1(1)) along with the minimum nailing required by IRC Table R602.3(1), Items 30-32. Roof and floor diaphragms built to these specifications are deemed to provide sufficient capacity for the loads and exposures covered by the IRC for residential-type structures.

Shear walls and braced wall panels each serve the same purpose: to transfer the shear (lateral loads) from the diaphragm above to the structure below while resisting racking from the lateral loads. In this guide, the term “shear wall” refers to an engineered wall segment designed in accordance with the IBC or referenced standards, and “braced wall” or “braced wall panel” refers to a wall segment constructed in accordance with the prescriptive bracing provisions of the IRC. Further discussion about the differences between shear walls and braced wall panels is presented later in this chapter.

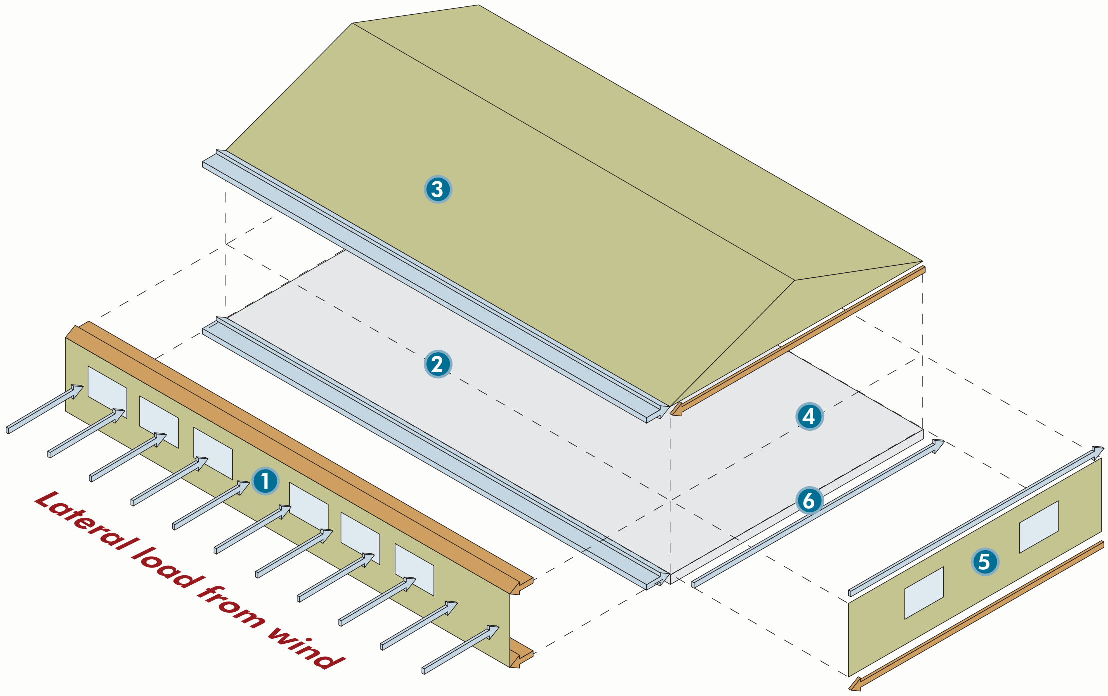
WHAT IS THE LATERAL LOAD PATH?

It is very important to understand the concept of a lateral load path because it helps make sense of the IRC prescriptive wall bracing requirements. In short, the lateral load path is simply the path that the lateral or horizontal load takes as it passes through the structure, including components and connections, on its way to the supporting foundation and ultimately the ground. ***FIGURE 1.6*** shows the critical parts of the lateral load path. Vertical loads (gravity and uplift) follow a similar load path, moving through other structural components on their way to the foundation and ground.

The lateral load path for wind loads is simpler to visualize than the load path for seismic loads. ***FIGURE 1.6*** provides a basic example of the lateral load path resulting from wind loading of a wall. The load is shown acting on a windward receiving wall with its subsequent load path through the building. For simplicity, the suction pressure on the leeward receiving wall and wind pressures on the roof are not included in this illustration.

FIGURE 1.6

Critical parts and flow of the load path



1 Windward receiving wall carries load to foundation at bottom of wall and roof diaphragm at top of wall

2 Connections at bottom and top of wall transfer these loads into the foundation and diaphragm

3 Roof or floor diaphragm carries load to bracing walls

4 Connections between roof/floor and wall transfers load from diaphragm to bracing walls

5 Bracing wall carries load from diaphragm to foundation

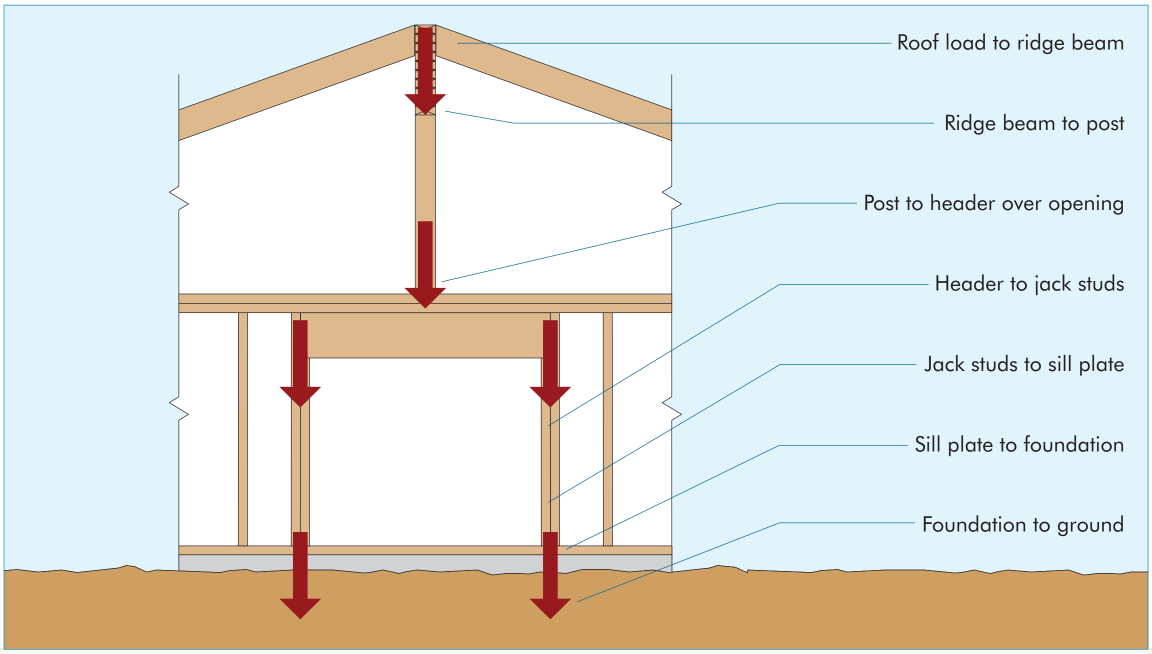
6 Transfer of loads from the bracing walls to the foundation

WHAT IS THE VERTICAL LOAD PATH?

In the downward vertical load path, all structural members carrying gravity load (for example, rafters, trusses and joists) must bear on members below (for example, posts, cripple walls, beams and headers) designed to carry that load. Each of these members must bear on others until the load is transferred through the foundation and into the ground. The downward load path is fairly easy to understand. Just like a child's first set of building blocks, one block is stacked on another. Due to the force of gravity, vertical loads are always present and it is relatively easy to identify the load path, as shown in ***FIGURE 1.7***.

FIGURE 1.7

Example of vertical load path



The upward load path is the same as the downward load path except the load is acting in the "up" direction. Upward (wind uplift) loads must be resisted by uplift straps and/or structural wall sheathing, connectors and anchors that keep the structure intact and attached to the foundation.

While the objective of the lateral load path (to get the applied loads into the ground) is exactly the same as the vertical load path, the actual path it takes is not always obvious. Another key difference is that connections are even more important in the lateral load path. Unlike the downward vertical load path, in which gravity causes many members to bear on each other, there is nothing holding the different components together in the upward vertical or lateral load paths unless the builder makes a connection using nails, straps or framing anchors. The location and requirement for these connections is not always obvious.

Also, unlike downward vertical loads, upward vertical loads and lateral loads are intermittent as high winds and/or earthquakes are relatively uncommon occurrences. When these intermittent load events do occur, the lateral and upward load paths must be in place with each element and connection properly sized and constructed to resist these transient loads. Buildings missing connections in these critical load paths are subject to failure.