

Part 1: Basic Components for Code Compliant Bracing



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Introduction

Residential structures must resist two important types of loads: (1) gravity load and (2) lateral load. Gravity acts in a vertical (downward) direction and, therefore, gravity load comes from the weight of the building as well as the weight of things, like people or snow that may be supported by the building over the course of time. Traditionally, gravity loads have been the focus of attention in housing design to ensure the proper sizing of studs, joists, and rafters for example. As a result, homes rarely have problems with gravity load resistance. Lateral loads act in a horizontal direction on a building, but comparatively little attention to lateral loads has been given to housing until recent years. As newer homes have tended toward larger plans with increased open interior space and greater use of windows in exterior walls, proper bracing of homes has necessarily become more important to consider than it was in the past. As a result, newer codes such as the International Residential Code have given greater attention to requirements for proper bracing of homes to resist lateral loads. Another load not considered in this brief is uplift load that occurs as a result of wind uplift pressure acting on the surface of a roof. Uplift load acts vertically, but in the opposite direction from gravity load.

The International Residential Code (IRC) and past experience dictate that conventional wood frame dwellings must be adequately braced against lateral (racking) forces due to wind and earthquakes. To achieve this structural safety objective, several wall bracing options and requirements are provided in IRC Section R602.10 Wall Bracing. While necessary to address many typical bracing conditions and materials, the sheer number of options and requirements creates confusion. Therefore, a sound understanding and application of the IRC bracing provisions is needed to help designers, code officials, and builders work together toward code-compliant dwellings with maximum value for a diverse housing market. The IRC bracing provisions are based on rudimentary

approach in estimating the shear forces in the building.

This document is the first of a series of three briefs and it answers the following four questions:

1. What causes lateral loads?
2. What parts of a structure resist lateral loads?
3. How does wall bracing work in the IRC?
4. When should I consider wall bracing?

More experienced readers with specific needs may skip to any of the documents in this series to obtain the level of detail and information required. The three parts of this series are as follows:

- PART 1: Basic Concepts for Code-Compliant Bracing
- PART 2: IRC Wall Bracing Requirements
- PART 3: “Beyond Code” Bracing Solutions

What Causes Lateral Loads?

Lateral loads result from wind or earthquake actions and both can cause a collapse of improperly braced building. The way that wind or earthquake loads act on a building is completely different, but they have the same general effect. These two sources of lateral load are discussed below.

Wind Loads

Wind load is really the result of wind pressures acting on the building surfaces during a wind event. This wind pressure is primarily a function of the wind speed because the pressure or load increases with the square of the wind velocity (i.e., doubling of wind speed results in a four-fold increase in wind load or pressure). Wind load during a hurricane can last hours and a building experiences sustained wind load and short wind impacts (gusts). While the wind pressures are treated as a “static” (do not vary with time) or constant load for purposes of design, the real loads actually fluctuate dramatically with gustiness of wind as well as wind direction. Two fundamental wind effects are of a concern: (1)

localized “spikes” in wind pressure that act on small areas of a building to cause damage to items such as roof panels or siding (known as components and cladding wind loads in engineering terms) and (2) averaged wind loads that act on larger areas of the building which the entire structure must resist (known in engineering terms as main wind force resisting system loads). The latter is a subject of bracing provisions specified in the International Residential Code and discussed in this series of three briefs. It is a simple matter to realize that as a building gets larger or taller the surface area upon which wind loads act increases. Therefore, the lateral force that must be resisted by the bracing system increases.

Earthquake Loads

Earthquake forces experienced by a building result from ground motions (accelerations) which are also fluctuating or dynamic in nature, in fact they reverse direction somewhat chaotically. The magnitude of an earthquake force depends on the magnitude of an earthquake, distance from the earthquake source (epicenter), local ground conditions that may amplify ground shaking (or dampen it), the weight (or mass) of the structure, and the type of structural system and its ability to withstand abusive cyclic loading. In theory and practice, the lateral force that a building experiences from an earthquake increases in direct proportion with the acceleration of ground motion at the building site and the mass of the building (i.e., a doubling in ground motion acceleration or building mass will double the load). This theory rests on the simplicity and validity of Newton’s law of physics: $F = m \times a$, where ‘F’ represents force, ‘m’ represents mass or weight, and ‘a’ represents acceleration. For example, as a car accelerates forward, a force is imparted to the driver through the seat to push him forward with the car (this force is equivalent to the weight of the driver multiplied by the acceleration or rate of change in speed of the car). As the brake is applied, the car is decelerated and a force is imparted to the driver by the seat-belt to push him back toward the seat. Similarly, as the ground accelerates back and forth during an earthquake it imparts back-and-forth (cyclic) forces to a building through its foundation which is forced to move with the ground. One can imagine a very light structure such as fabric tent that will be undamaged in almost any earthquake but it will not survive high wind. The reason is the low

mass (weight) of the tent. Over 90% of all residential buildings in the US are built as light-frame wood structures that are very light compared to masonry or reinforced concrete buildings. Therefore, residential buildings generally perform reasonably well in earthquakes but are more vulnerable in high-wind load prone areas. Regardless, the proper amount of bracing is required in both cases.

What parts of a structure resist lateral loads?

The lateral resistance of the residential structure is almost entirely provided by a system of shear walls and diaphragms. These two parts of the lateral force resisting system (bracing system) of a home are discussed below.

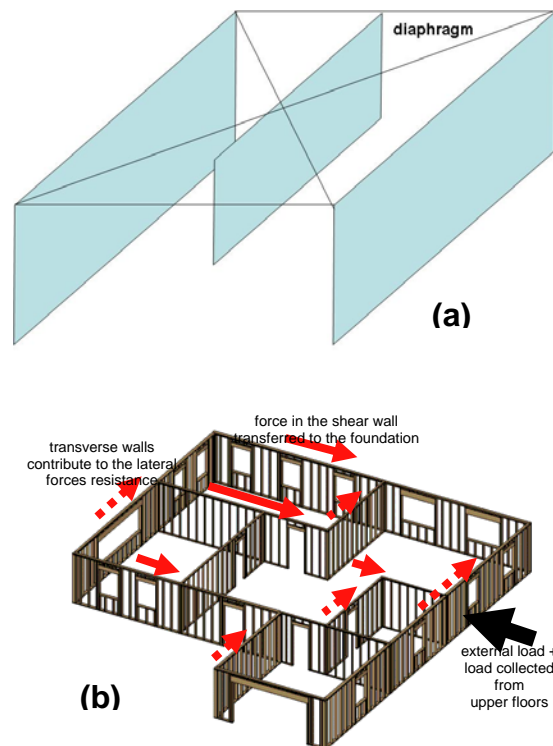


Figure 1: Concept of shear walls and diaphragms. All walls contribute to the house stiffness.

(a) Schematic, (b) Wall participation is the force transfer

Diaphragm

A diaphragm is a structural term that simply refers to a horizontal plate-like system (i.e., a sheathed floor, ceiling or a roof assembly) that distributes lateral loads acting on the building to shear walls (or braced

wall lines) that support a floor or roof diaphragm and prevent it from excessive sideways movement leading to potential collapse. Thus, a floor or roof diaphragm serves an important role of tying the light-frame building together (Figure 1).

The basic concept is to collect all the loads and transfer them to the foundation. In the IRC, construction of floor and roof systems (diaphragms) is addressed in separate chapters of the code (Chapters 5 and 8).

Shear Wall

A shear wall is a structural term for a wall or portion of a wall line (i.e., braced wall panel) that is specifically braced to prevent racking of the studs in domino fashion as the floor or roof diaphragm above transfers shear (racking) forces into the plane (length direction) of a braced wall line (braced wall line is explained latter in the text). In general, only braced wall lines parallel to a given lateral load direction are considered in providing racking resistance. However, even the interior and transverse walls (Figure 1b) participate in load transfer and overall stiffness providing that they too are adequately connected to the floor or roof diaphragm system above. This three-dimensional action is not explicitly considered in the current IRC bracing provisions and requires the services of a design professional to implement. In addition, the portion of the lateral load imparted to each shear wall or braced wall line by a floor or roof diaphragm depends on various factors but, in general, a stiffer wall (stronger and more rigid bracing) will attract a larger portion of the total lateral load as compared to the less stiff wall (3). Unlike water, structural loads tend to follow the path of greatest resistance or stiffness until that path is “broken” or weakened. This means, for example, that a wall with large opening will attract less load compared to a wall of the same size and construction with small or no opening.

As discussed above, “wall bracing” is an important part of the bracing system but will not, by itself, be sufficient in providing lateral resistance of the building. An entire system and load path must be established (e.g., diaphragms connected to shear walls, shear walls connected to floors/foundation, etc.). Consequently, the IRC provides basic connection requirements for framing (floor, wall, and roof construction) to provide such a system for

the limited design wind and earthquake conditions addressed directly in the code. For extremely hazards areas (hurricane-prone regions) and near-fault areas in seismic zones, an engineered design is required. Alternatively, a prescriptive design in accordance with reference standards in Section R301 of the IRC may be used. In Pennsylvania, such high-hazard wind or seismic conditions do not exist.

When a house is subjected to wind or earthquake load, various types of failure must be prevented:

- slipping off the foundation (sliding)
- overturning and uplift (anchorage failure)
- shear distortion (drift or racking deflection)
- collapse (excessive racking deflection)

The first three types of failure are schematically shown in the Figure 2. Clearly, the entire system must be tied together to prevent building collapse or significant deformation. To illustrate, a house acts as a three dimensional system that can be compared to a cardboard box - relatively flexible cardboard is assembled into a rigid box. One missing wall of the box will make the cardboard easy to deform. A similar concept can be applied to a more complex house; one need only expand it and stack several of the “boxes” and tie them together.

For additional information, a thorough explanation of wall bracing concepts, design principles, and supplemental design data is found in the Residential Structural Design Guide – 2000 Edition (HUD, 2000).

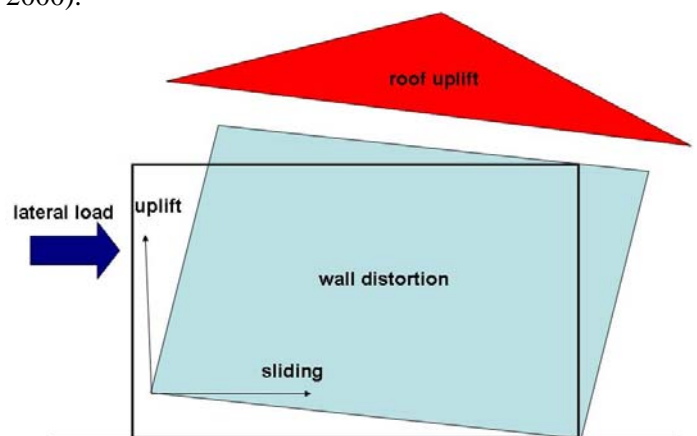


Figure 2: Schematic of the deformations of the structure due to the lateral loads

Basic Concepts & Definitions in IRC R602.10 Wall Bracing

Wall bracing in accordance with the IRC (Section R602.10) involves placement of code-compliant bracing elements or *braced wall panels* in required amounts on wall lines that are required to resist lateral loads. Consequently, these wall lines are known as *braced wall lines*. Different braced wall lines in a given building plan require different amounts of bracing depending on their individual share of the lateral load acting on the building as a whole. Therefore, the amount of bracing required for a given wall line according to the IRC depends on:

- The design wind or earthquake load (magnitude of hazard).
- The size of the building and how many stories are supported by a braced wall line.
- The spacing between braced wall lines.
- The type or method of wall bracing used (strength of brace).

Obviously, buildings located in higher hazard areas with large design wind speeds or earthquake ground motions, experience greater potential lateral load and vice-versa. Also, walls supporting multiple stories have greater lateral load than those supporting only a roof. Lower story walls serve to resist an accumulation of lateral load from upper story levels that must be passed down to the foundation and then to earth. For buildings that have widely-spaced wall lines and large interior open areas, the lateral load shared by each wall line is increased relative to a building that has many closely-spaced wall lines in each plan direction. Finally, the method of bracing will determine how much bracing is needed on a given braced wall line. Generally, narrower walls will require a more effective bracing method. These lateral load and bracing strength principles are reflected in IRC Section R602.10 Wall Bracing.

The following concepts and definitions are fundamental to wall bracing provisions in IRC Section R602.10 as discussed and applied later in Part 2 of this series of guides. They also have significant potential impacts on the architectural design of individual building walls as well as the plan layout of walls. These concepts should be understood to the point of becoming routine in planning and design of dwellings.

Braced Wall Line (R602.10.1)

Walls that are braced to resist lateral are known as braced wall lines. Essentially all exterior walls are considered to be braced wall lines and are required to be properly constructed with *braced wall panels*. Although not always required, interior walls also may be used as braced wall lines. A braced wall line can have limited offsets as shown in Figure 3 and still be considered as a single braced wall line. When an offset does not comply with those limits, the wall lines to either side of the offset are required to be considered as separate braced wall lines. Such offsets affect the amount and location of braced wall panels and, thus, the layout of openings for windows and doors in a series of braced wall lines on a given building side or elevation.

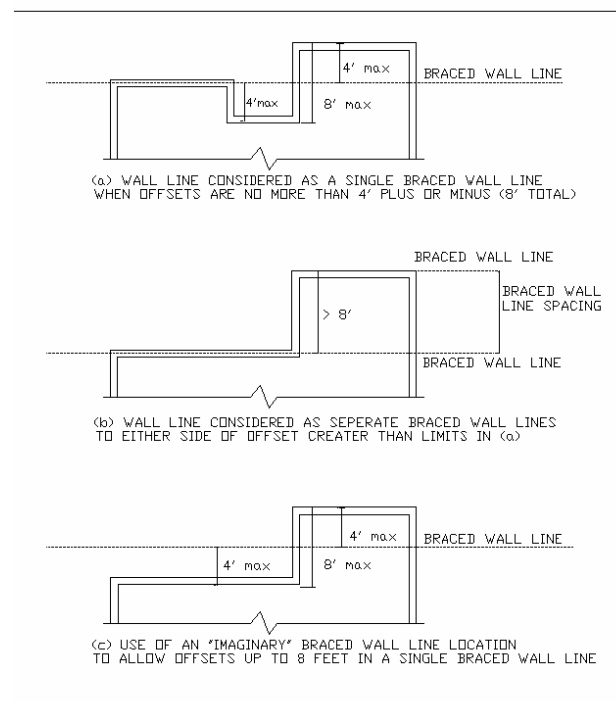


Figure 3: Braced Wall Line Offset Limitations (2)

Braced Wall Line Spacing (R602.10.1.1)

Braced wall line spacing determines the amount of lateral load that is shared by the two or more parallel braced wall lines in each plan direction (see

Figure 3b). The lateral load must be resisted by use of an adequate amount of braced wall panels on each braced wall line. Therefore, bracing amounts are dependent on the spacing of braced wall lines. This consideration influences the space that is available for wall openings on exterior walls, which may necessitate the use of interior braced wall lines to help share the bracing load (reduce the amount of bracing on exterior braced wall lines) in a given building plan direction.

Braced Wall Panel (R602.10.1)

A braced wall panel is a section of a braced wall line that is braced with a code compliant bracing method such as a let-in brace, a wood structural panel, or other bracing methods (see Figure 4). Braced wall panels must meet minimum width requirements (length of wall covered) to count toward required bracing amounts. The minimum widths required for braced wall panels of the various bracing methods constrain the layout and spacing of wall openings. While braced wall panels that are narrower than allowed still contribute to bracing, this contribution may only be considered through an engineered design or supplemental solutions (see Part 3 in this series).

Braced Wall Panel Location (R602.10.1)

In addition to being used to meet minimum bracing amounts, the location of braced wall panels on braced wall lines must meet a couple of additional constraints (see Figure 4):

1. braced wall panels must be spaced no greater than 25 feet on center along a braced wall line, and
2. braced wall panels must begin no more than 12.5 feet from the end of a braced wall line (usually defined by an inside or outside building corner).¹

¹ For the continuous wood structural sheathing method (IRC Section R602.10.5) a minimum 2-foot panel must be located at both ends of a braced wall line using this method as discussed further in Part 2 of this series of guides.

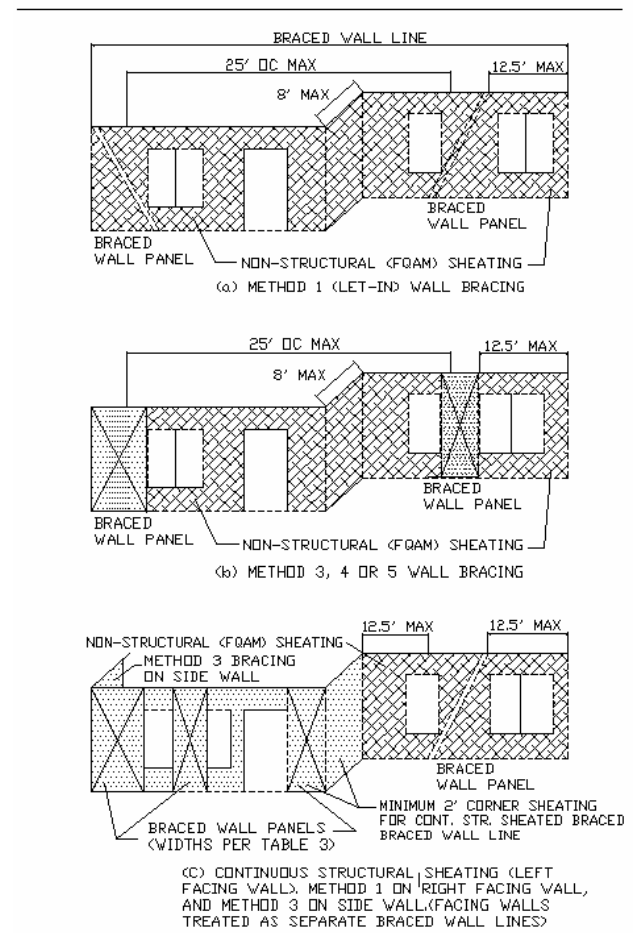


Figure 4: Illustration of Bracing Methods (2)

Compatibility of bracing methods

The compatibility of bracing methods in the IRC is not addressed in general. However, the IRC recognizes specific instances where one brace type can be substituted for another (e.g., IRC Section R602.10.6). Because each code-compliant bracing method is intended to provide equivalent minimum performance, they may be used interchangeably on different braced wall lines of the same building or within the same braced wall line provided each bracing method complies with its specific requirements. This concept is important because it allows bracing methods to be selected and used on the basis of conditions that may be unique for a given building. Thus, the overall bracing design of a building may be optimized for cost and performance. For example, continuous structural sheathing (IRC Section R602.10.5) may be used on one building wall where narrow braced panel widths are necessary due to window and door layout. However,

other wall lines or building sides may be braced with other code-compliant bracing methods that provide equivalent minimum performance at a more competitive cost or for other reasons. Refer to Figure 4c for an example. Use of various bracing methods in IRC R602.10.3 is discussed in greater detail in Part 2 of this series of guides.

When should I consider wall bracing?

The above factors impact the amount of space available on a given wall for placement of windows, doors, and non-structural sheathing products such as insulating foam sheathing. Furthermore, the practicality and value of construction may be negatively affected by a poorly conceived plan for wall bracing. In some cases, an engineered solution may be required where a suitable prescriptive solution in the code is inadequate or does not exist and architectural modifications to the building plan are considered unacceptable (see Part 3). Therefore, wall bracing should be considered as early as possible in the building planning process. At the planning stage, simple plan adjustments often make the difference between an efficient, code-compliant plan and one that is inefficient or non-compliant. Performing this task competitively and adequately requires an in-depth understanding of the IRC bracing provisions of Section R602.10, their proper application, their limitations, and alternative solutions (see Parts 2 and 3 in this series of guides).

Conclusions

In the Part 1 of this series we have discussed the fundamental concepts lateral loads in the buildings and basic terminology and bracing requirements as related to the 2006 International Residential Code. Code-compliant bracing methods are prescriptive rules and as such, they cannot cover the entire range of geometries and designs. Engineering analysis and design may be required if the code prescriptive guidelines are not fully satisfied. Such design involving principles of mechanics may be more cost effective and permit designs that would be hard to achieve using the IRC rules. This will be discussed in the part three of this series.

References

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