Wall Bracing and the Codes

Introduction

Wall bracing is one of the most important structural elements of any house, but it can also be one of the most confusing, because designing houses to resist lateral loads is complex, and the prescriptive conventional construction provisions of the codes are often not clear. The 2003 International Residential Code (IRC) outlines a number of options for wall bracing, but it can easily leave builders and building officials with questions.

• What forces act on a house?
• Why is wall bracing so important?
• What are braced wall segments and braced wall lines?
• How wide do the bracing segments have to be?
• How much bracing is needed, and where?
• How is the percentage of bracing in a wall line determined?
• When are adjustments to the amount of bracing required?
• What about corner windows or bracing segments not at the end of braced wall lines?
• What about corner windows or bracing segments not at the end of braced wall lines in certain Seismic Design Categories?
• Are offsets permitted in a braced wall line?

This unit answers these questions and more and teaches how to meet basic requirements for wall bracing per the 2003 IRC.

What forces act on a house?

Any building, regardless of size or location, must be designed to safely resist the structural loads anticipated during its lifetime. These loads can be divided into two categories: vertical loads and lateral loads.

Vertical loads are loads acting in the "up and down" direction due to gravity. 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 these loads are easy to understand, typical construction practice has evolved into an efficient system that does a good job of accommodating them.

The challenge lies with the "other loads," the lateral loads. Lateral loads are those that act in a direction parallel to the ground. The two major sources of lateral load on house are wind, and seismic (earthquake) forces.

Wind forces

During a wind event, the wind pushes against one end wall while pulling on the opposite end wall. Because the two end walls push and pull the roof in the same direction as the wind, the walls on the other two sides of the structure must hold the roof from moving. Thus, walls must be strong enough to resist the wind forces that push against the home.

Walls with adequate bracing are unlikely to rack or collapse during high wind or an earthquake.

Seismic forces

Seismic forces are generated by ground motions during an earthquake. The ground motion causes the structure’s mass to be accelerated back and forth, up and down. This acceleration causes forces to develop within the structure in locations where the structure’s mass is the largest. Essentially, the seismic ground motion acts on the foundation, while inertia attempts to keep the roof from moving with the foundation, causing forces on the walls.

Because high-wind events or earthquakes are infrequent, it can be difficult to understand the lateral load path, or grasp possible damaging effects on a structure. Ensuring that homes can withstand lateral loads is critical to the safety of the building and its occupants in the event of high wind or an earthquake.

Why is wall bracing so important?

During a high wind event or an earthquake, a house must be able to resist lateral loads. Wall studs alone, as shown in the first illustration, cannot resist the racking forces, but braced walls, such as those in the second illustration, have much more strength to resist the loads.

Without sufficient bracing, the walls of a house can rack, causing cosmetic damage, performance problems, and even structural failure.

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What are braced wall segments and braced wall lines?
The building codes (IBC and IRC) use the terms braced wall panel and braced wall line throughout. To help avoid confusion between the terms "wall panel" and "braced wall panel," this course uses the term "braced wall segment." (Braced wall panel = braced wall segment.)

A "braced wall segment," shown in the first illustration, is a segment or portion of a braced wall line. It consists of the wall panel (e.g., plywood or OSB Rated Sheathing), the framing, and the fasteners. Multiple braced wall segments form braced wall lines, as shown in the second illustration.

Braced wall lines are what resist lateral loads in a house, as shown in the third illustration. Parallel braced wall lines can be no more than 25 feet apart in high seismic regions (Seismic Design Category D or higher) and 35 feet elsewhere (SDC A-C), but IRC Sections R602.10.1.1 and R602.10.11 provide exceptions for using greater spacing.

The code provisions (IRC R602.10) dictate proper size and construction of braced wall segments, including materials, fastener spacing, and minimum width of the panel.

Properly spaced braced wall lines, made up of braced wall segments, resist racking loads.

How wide do bracing segments have to be?
The table below summarizes the minimum braced wall segment width requirements in the IRC. The minimum width depends on the bracing method and the type of construction material specified. The narrowest wall bracing segments the IRC allows are 24 inches, for the continuous wood structural panel sheathing method (IRC R602.10.5).

<table>
<thead>
<tr>
<th>IRC Section</th>
<th>Bracing Method</th>
<th>Sandwich Description</th>
<th>Minimum Width of Braced Wall Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>R602.10.3</td>
<td>Nominal lath bracing</td>
<td>55°/96°</td>
<td></td>
</tr>
<tr>
<td>R602.10.5</td>
<td>Wood structural panel sheathing</td>
<td>48°</td>
<td></td>
</tr>
<tr>
<td>R602.10.6</td>
<td>Fiber board sheathing</td>
<td>48°</td>
<td></td>
</tr>
<tr>
<td>R602.10.7</td>
<td>Gypsum sheathing</td>
<td>96°</td>
<td></td>
</tr>
<tr>
<td>R602.10.8</td>
<td>Particle board sheathing</td>
<td>48°</td>
<td></td>
</tr>
<tr>
<td>R602.10.9</td>
<td>Plywood</td>
<td>48°</td>
<td></td>
</tr>
<tr>
<td>R602.10.10</td>
<td>Hardboard panel siding</td>
<td>48°</td>
<td></td>
</tr>
</tbody>
</table>

The code allows a narrower width for the continuous wood structural panel sheathing method because of its superior structural performance. See Table 2. Wood structural panels form a strong, stiff shell when properly connected together. APA built on this concept in the development of the Narrow Wall Bracing Method, which enables the minimum width of a braced wall segment to be as narrow as 16 inches. For more information on the APA Narrow Wall Bracing Method, consult APA publication Narrow Walls That Work, Form D420, or take Unit 2 of this course (forthcoming).

Minimum bracing widths for wood structural panel sheathing

The table details the minimum bracing segment widths using continuous wood structural panel sheathing, with both the methods listed in IRC R602.10.5 and the APA Narrow Wall Bracing Method.

<table>
<thead>
<tr>
<th>Bracing Method</th>
<th>Minimum Width of Braced Wall Segment Width (in.)</th>
<th>Maximum Opening Height (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRC R602.10.5</td>
<td>3.1 32 36 40 48 72 100%</td>
<td>6.1 16 18 20 24 Up to 10 feet</td>
</tr>
<tr>
<td>APA Narrow Wall Bracing Method</td>
<td>6.1 16 18 20 24 Up to 10 feet</td>
<td></td>
</tr>
</tbody>
</table>

This figure demonstrates how the minimum bracing segment widths in Table 2 are determined (for 3:1 and 4:1 height-to-width ratios). The same principles apply to 2:1 or 6:1 height-to-width ratio panels.

### Table 2
<table>
<thead>
<tr>
<th>Table 2: Minimum Width of Braced Wall Segments Using Continuous Wood Structural Panel Sheathing</th>
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<tbody>
<tr>
<td><strong>Bracing Method</strong></td>
</tr>
<tr>
<td>--------------------</td>
</tr>
<tr>
<td>IRC R602.10.5</td>
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<tr>
<td>APA Narrow Wall Bracing Method</td>
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</tbody>
</table>

### Table 1
<table>
<thead>
<tr>
<th>Table 1: IRC B RACING METHODS AND MINIMUM B RACED SEGMENT WIDTHS (See referenced sections for detailed requirements)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bracing Method</strong></td>
</tr>
<tr>
<td>--------------------</td>
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<tr>
<td>IRC R602.10.5</td>
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<tr>
<td>APA Narrow Wall Bracing Method</td>
</tr>
</tbody>
</table>

See APA publication Narrow Walls That Work, Form D420, for details and latest code requirements.
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How much bracing is needed, and where?
The amount of wall bracing needed in each braced wall line, as specified by the building codes, depends on the Seismic Design Category (SDC) or wind speed, the stories above the braced wall line, and the method of bracing being used.

Braced segments must occur at each end of the braced wall line and at least every 25 feet on center. They must also make up a certain percentage of the braced wall line. The table below summarizes the bracing requirements.

### Table 3: Bracing Requirements

<table>
<thead>
<tr>
<th>Seismic Design Category (SDC)</th>
<th>Stories Above Braced Wall Line</th>
<th>Method of Bracing Required</th>
<th>Amount of Bracing</th>
<th>Minimum Percentage Required</th>
<th>Notes</th>
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<td>D1 or D2</td>
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<td>Method B: 62.0</td>
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<td>Method B: 94.0</td>
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<td>56</td>
<td>Method B: 100.0</td>
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</tbody>
</table>

How is the percentage of bracing in a wall line determined?
The bracing percent in a given wall line is simply the sum of the length of the qualifying braced wall segments in the braced wall line divided by the total length of the braced wall line. For example, the percentage of bracing in the first figure is the sum of the two bracing segments E and F, divided by the length L and multiplied by 100%. The second figure illustrates the percentage of wall bracing in a line with the continuous wood structural panel sheathing bracing described in IRC R602.10.5.

To calculate the percentage of bracing in a wall line in this figure, consider the following:

\[
\text{% Bracing in wall line } = \left( \frac{\text{E} + \text{F}}{\text{L}} \right) \times 100\%
\]

In this example using the continuous wood structural panel sheathing bracing (IRC R602.10.5), the percentage of bracing present in the braced wall line calculates to be 31%. Minimum bracing widths are in accordance with Table 2. The 24-inch-wide segment next to the door is too narrow to count as a bracing segment because, as shown in Table 2, a braced wall segment next to the door must be 32 inches wide for the 8-foot wall.

When are adjustments to the amount of bracing required?
The code allows for reductions in the percentage of bracing required in a wall line when using continuous wood structural panel sheathing (IRC R602.10.5). When using tall walls however, the code requires increases in the percentage of bracing (IRC R301.3).

### Reductions
When using continuous wood structural panel sheathing bracing (IRC R602.10.5), the amounts of bracing required may be decreased by a factor of:

- 0.9 for walls with openings 0.85 x the wall height and less, or
- 0.8 for walls with openings of 0.65 x wall height and less.

Increases
For walls 12 feet tall, the amount of bracing required must be increased by 1.2. In accordance with IRC Section R301.3, a braced wall can be 12 feet tall if three conditions are met:
1. It is wood framed,
2. It is braced in accordance with IRC Table R602.10.1, and
3. The amount of bracing required by IRC Table R602.10.1 is increased by 1.2.

Note that stud heights greater than 10 feet must be justified by analysis or in accordance with IRC Table R602.3.1 (IRC Section R602.3.1), as applicable.

For High Seismic (SDC D1 and D2)
For Seismic Design Category (SDC) D1 and D2, adjustments to bracing amounts for interior braced wall lines based on wall line spacing (IRC R602.10.11) and adjustments when using stone and masonry veneer (IRC R703.7), may be made.

For SDC D1 and D2, when the dead load of the roof/ceiling exceeds 15 psf, the bracing amounts must be multiplied by 1.1 for walls supporting a roof only and 1.2 for walls supporting a roof and one story (IRC Table R301.2.2.4).

What about corner windows or bracing segments not at the end of braced wall lines?
Bracing segments may occur away from the end of a braced wall line and still be code compliant, as shown in the next two lessons.

For all bracing methods in Seismic Design Category A-C except
continuous sheathing (IRC R602.10.5), bracing located less than 12.5 feet from the end of the wall line is considered to be at the end, as shown in the figure below. If bracing is located more than 12.5 feet from the end, then an engineered collector is needed to help transfer lateral loads per code (IRC R602.10.1). See APA Technical Topic Collector Design for Bracing in Conventional Construction, Form TT-102, for more information on design of a collector.

Braced wall segments can occur up to 12.5 feet from the end of a wall in SDC A-C.

What about corner windows or bracing segments not at the end of braced wall lines in Seismic Design Category D1 and D2?

Per IRC R602.10.11, a braced wall segment must occur at the end of a braced wall line for all bracing methods except Method 3 (wood structural panel bracing). Wood structural panel bracing may be placed up to 8 feet from the end, provided one of the following provisions is met, as shown below:

1. A minimum 1800 lbf tie-down device is on each braced wall segment closest to the corner, as shown in the illustration at left, or
2. A minimum 24-inch-wide segment is at the corners, as shown in the illustration at right.

Are offsets permitted in a braced wall line?

Many home designs feature offsets along the wall length. IRC R602.10.1 permits offsets up to 4 feet, provided that the total out-to-out offset dimension is not greater than 8 feet.

A braced wall line can have 4-foot offsets.

The code permits 8 feet total out-to-out offsets (4 feet each way) in a braced wall line.

Offsets may also occur in discontinuous braced wall lines.

Interior braced wall lines

Interior braced wall lines must comply with the same provisions as exterior braced wall lines. Thus, the amount of bracing required for an interior braced wall line is the same as that required for an exterior braced wall line.

There are no special foundation requirements for interior braced walls except for houses located in Seismic Design Category D2. Per Section R602.10.9, interior braced wall lines must be supported on continuous foundations.

The top and bottom plates of interior braced wall lines must be connected to the framing above and below the braced wall segment the same as for exterior braced wall segments, which is described in Lesson 18.

Gypsum walls often form interior braced wall lines required due to large braced wall line spacing.

Story height limits

For wood or steel wall framing, story heights are limited to 10-foot stud heights plus a height of floor framing not to exceed 16 inches (IRC R301.3). As mentioned in Lesson 11, for wood framed walls there is an exception to allow 12-foot stud heights if three conditions are met:

1. It is wood framed,
2. It is braced in accordance with IRC Table R602.10.1 (the table in Lesson 9 of this unit), and
3. The amount of bracing required is increased by 1.2.

Note that stud heights greater than 10 feet must be justified by analysis or in accordance with IRC Table R602.3.1 (IRC Section R602.3.1), as applicable.

When the limits of the conventional construction provisions of the IRC are exceeded, engineering is required for at least the non-compliant elements (IRC R301.1.3). There are also alternative provisions, such as the Wood Frame Construction Manual, which may contain provisions for designing taller stories (IRC R301.1.1).

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Maximum spacing between braced wall line exceptions
Lesson 6 described the basic requirement that parallel braced wall lines can be no more than 25 feet apart in high seismic regions (Seismic Design Category D1 or D2) and 35 feet elsewhere (SDC A-C), but IRC Sections R602.10.1.1 and R602.10.11 provide exceptions for using greater spacing.

For SDC A-C, braced wall line spacing may be increased up to 50 feet where:

1. The wall bracing required to be provided must be increased by a factor equal to the braced wall line spacing divided by 35 feet, and
2. The length-to-width ratio for the floor or roof diaphragm does not exceed 3:1.

The figure below provides an example using spacing more than 35 feet. The roof diaphragm has an aspect ratio of 45:20 (2.25:1), which is less than 3:1 and meets the aspect ratio requirement. The bracing amounts on braced wall lines 1 and 2 must be increased by 45/35 = 1.29 times the amount required for 35-foot spacing. Per Lesson 9, if the amount of bracing required for the house shown were to be 16% for 35-foot spacing, it would have to be increased to 16% x 1.29 = 21% to accommodate the 45-foot braced wall line spacing.

For SDC D1 and D2, braced wall line spacing may be increased up to 35 feet in one- and two-story buildings in order to accommodate one single room not exceeding 900 square feet. When the braced wall line spacing is greater than 25 feet, the wall bracing required to be provided must be increased by a factor equal to the braced wall line spacing divided by 25 feet. For example, for 35-foot braced wall line spacing, the amount required must be increased by 35/25 = 1.4 (IRC R602.10.11).

Braced wall segment attachment and foundation requirements
In Table R602.3(1), the IRC requires that the sole plate (or bottom plate) of braced wall segments be nailed with three 16d nails every 16 inches o.c. into the joist or blocking below braced wall panels. Where joists are perpendicular to the braced wall lines above, blocking must be provided under and in line with the braced wall segment. The braced wall segment top plate must be connected to the framing above with at least 8d nails spaced every 6 inches o.c. (IRC Table R602.3(1) and R602.10.8).

When braced wall panels are supported directly on concrete foundations, the wall sill plate must be anchored to the foundation with anchor bolts spaced a maximum of 6 feet o.c. There must be a minimum of two bolts per sill plate section with one bolt located not more than 12 inches or less than seven bolt diameters from each end of the plate section (IRC R403.1.6). Bolts should be at least _" diameter and should extend a minimum of 7 inches into the concrete or masonry foundation. A nut and washer is required to be tightened on each bolt to hold the plate to the foundation.

In SDC D1 and D2, the plate washers are required to be _" x 3" x 3" (IRC R602.11.1 errata to first IRC printing January 2003). In addition to all of the above requirements, interior braced wall panels in SDC D1 and D2 require:

1. Floor joists parallel to the braced wall segment top plate must be toe nailed to the top plate with at least 8d nails spaced a maximum of 6 inches o.c. (IRC R602.11.2).
2. Top plate lap splices must be face nailed with at least eight 16d nails on each side of the splice to maintain continuity.

Several of the alternate braced wall segments require specific tie-down devices and certain anchor bolt spacings and plate washer sizes.

Unit summary
This unit is intended to illustrate the basic wall bracing requirements in the 2003 IRC and to explain the importance of wall bracing. Most of the concepts described in this unit are illustrated in the figure below.

The difference between braced wall lines and braced wall segments and how they may occur in an actual structure can be seen below.

For a wall segment to count as bracing, it must be a certain width, depending on the method of bracing used. Bracing segments must occur at ends (or a distance from the end) of each wall line, be spaced no more than 25 feet on center, and not be less than a certain percentage, depending on location in the house, design wind speed or Seismic Design Category, and bracing type. Lesson 9 of this guide gives the required percentage of bracing that a wall must have, and Lesson 10 shows how to calculate the percentage of bracing that a wall has.

Four-foot offsets can occur in a braced wall line.
Wall Bracing and the Codes

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ALA Continuing Education Questionnaire

Wall Bracing and the Codes

Program Title: Wall Bracing and the Codes
ALA/CEP Credit: This article qualifies for 1.0 LU’s (health, safety, and welfare) of State Required Learning Units and may qualify for other LU requirements. (Valid through February 2009.)

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1. Bracing is used to resist racking forces caused by lateral loads, such as from winds or earthquakes.
   - True
   - False

2. Braced wall segments make up braced wall lines.
   - True
   - False

3. The minimum required width of the bracing in methods 1-8 is:
   - 1 foot
   - 2 feet
   - 3 feet
   - 4 feet

4. The minimum required width of bracing segments using continuous wood structural panel sheathing is 16 inches.
   - True
   - False

5. How much bracing is required for a given braced wall line is determined by:
   - Wind speed and/or Seismic Design Category
   - The number of stories above the braced wall line
   - The bracing method being used
   - All of the above

6. Determine the percent of bracing contained in the wall line, given:
   - Length of braced wall line = 25 feet
   - Braced wall line has a total of 10 feet of bracing
   - The percent of bracing contained in the wall line is:
     - 50%
     - 40%
     - 30%
     - 25%

7. Braced wall segments can occur up to 12-1/2 feet from the end of a braced wall line in Seismic Design Categories (SDC) A-C.
   - True
   - False

8. In SDC D1 and D2, bracing must occur at ends of braced wall lines, except method 3 (wood structural panels), where bracing may be placed away from the end.
   - True
   - False

9. Offsets may not occur in interior braced wall lines.
   - True
   - False

10. The total amount bracing must be increased when using continuous wood structural panel sheathing and opening heights are limited.
    - True
    - False

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