# G Recommendations for One- and Two-Family Residential Buildings

## G.1 Purpose and Audience

This appendix provides prescriptive guidance for enhanced construction techniques to improve performance of wood-frame residential structures when impacted by tornadoes rated EF2 or less. Accordingly, the following guidance addresses only the effects of increased wind loading resulting from tornadoes and does not consider other loading conditions such as seismic, snow, flood, or any other loads. The intended users of this appendix are building designers, homebuilders, and homeowners in the tornado-prone regions of the United States. The use of this guidance is intended to be coordinated with recommendations of the building design professional to produce a complete building design resistant to anticipated loads.

One of the goals of the committee that developed this appendix was to make the guidance simple and cost effective, and thereby foster mitigation. The building performance of one- and two-family residential wood-frame buildings during a high-wind event will be significantly elevated over code-level practices through the voluntary implementation of guidance provided in this appendix. While implementing the following guidance is voluntary, the Mitigation Assessment Team (MAT) strongly advises users to take a comprehensive approach to incorporating enhancements as applicable to ensure continuity of the building's load path.

The following guidance is not intended to replace the governing building code, as it does not address all aspects of construction. Instead, enhanced construction techniques presented in this section should be implemented in accordance with provisions of the governing building code to enhance building performance during high-wind events. If a building code has not been adopted by the authority having jurisdiction, then enhanced construction techniques in this appendix should be implemented in accordance with the requirements of the current version of the International Residential Code (IRC).

While implementing the voluntary mitigation actions proposed in this appendix for one- and two-family residential buildings will greatly enhance their performance when impacted by tornadoes rated EF2 or less, there is no substitute for a personal protection plan that includes access to a safe room in the event of a tornado emergency.

The guidance for improved building performance presented in this appendix is intended solely for enhanced property protection and should not be construed in any way as an alternative to sheltering.

The guidance in Appendix G is intended to strengthen new construction. FEMA P-804, Wind Retrofit Guide for Residential Buildings, provides guidance on retrofitting existing residential buildings to reduce their vulnerability to damage from high-wind events and wind-driven rain intrusion. Users should note that grant opportunities described in FEMA P-804 may not be available for homes located outside of hurricane-prone regions.

## G.2 Background and Applicability

The guidance in this appendix is adapted from existing guidance for high-wind regions. The primary sources referenced are Technical Fact Sheets from Federal Emergency Management Agency (FEMA) P-499, *Home Builder's Guide to Coastal Construction* (2010), the *Wood Frame Construction Manual (WFCM) Guide to Wood Construction in High Wind Areas for One- and Two-Family Dwellings, 130 mph, Exposure B* (AWC 2006), and the International Code Council's (ICC's) ICC 600-2008, *Standard for Residential Construction in High-Wind Regions.* These documents provide guidance for high-wind resistance that, when implemented in high-wind hazard areas in accordance with the applicable building code, result in enhanced performance for one- and two-family residential buildings.

It is important to note, however, that important differences exist between hurricanes and tornadoes. Hurricane-force winds affect broad areas of coastline, and the probability of their site-specific occurrence is better understood than that of tornadoes. Strengthening buildings by maintaining load path continuity and reinforcing connections has proven successful for mitigating hurricane wind damage and provides a good model for mitigating tornado wind damage.

In areas with relatively low mapped wind speeds, one way to reduce damage caused by tornadoes rated EF2 or less is to design to higher wind speeds. Because of the current lack of standards

Basic mapped wind speeds in ASCE 7-10 for Category II structures (residential buildings) are higher than those in ASCE 7-05 because they represent ultimate wind speeds or strength-based design wind speeds. Load factors for wind in ASCE 7-10 are also different from those in ASCE 7-05. In ASCE 7-10, the wind load factor in the load combinations for strength design is 1.0; in ASCE 7-05, the load factor is 1.6. The allowable stress design load factor in the load combinations for wind is 0.6; in ASCE 7-05, the load factor is 1.0.

or guidance on designing to loads associated with tornado events, and to facilitate complementary design of buildings or parts of buildings that fall outside the scope of this appendix, the wind pressures in Appendix G are based on an ASCE 7-05 wind speed of 130 mph (3-second gust) using Exposure Category B. Exposure Category B includes urban and suburban areas, wooded areas, and other terrain with numerous closely spaced obstructions the size of single-family dwellings. Residential buildings in Exposure Category C, which is defined as open terrain with scattered obstructions, are outside the scope of this appendix.

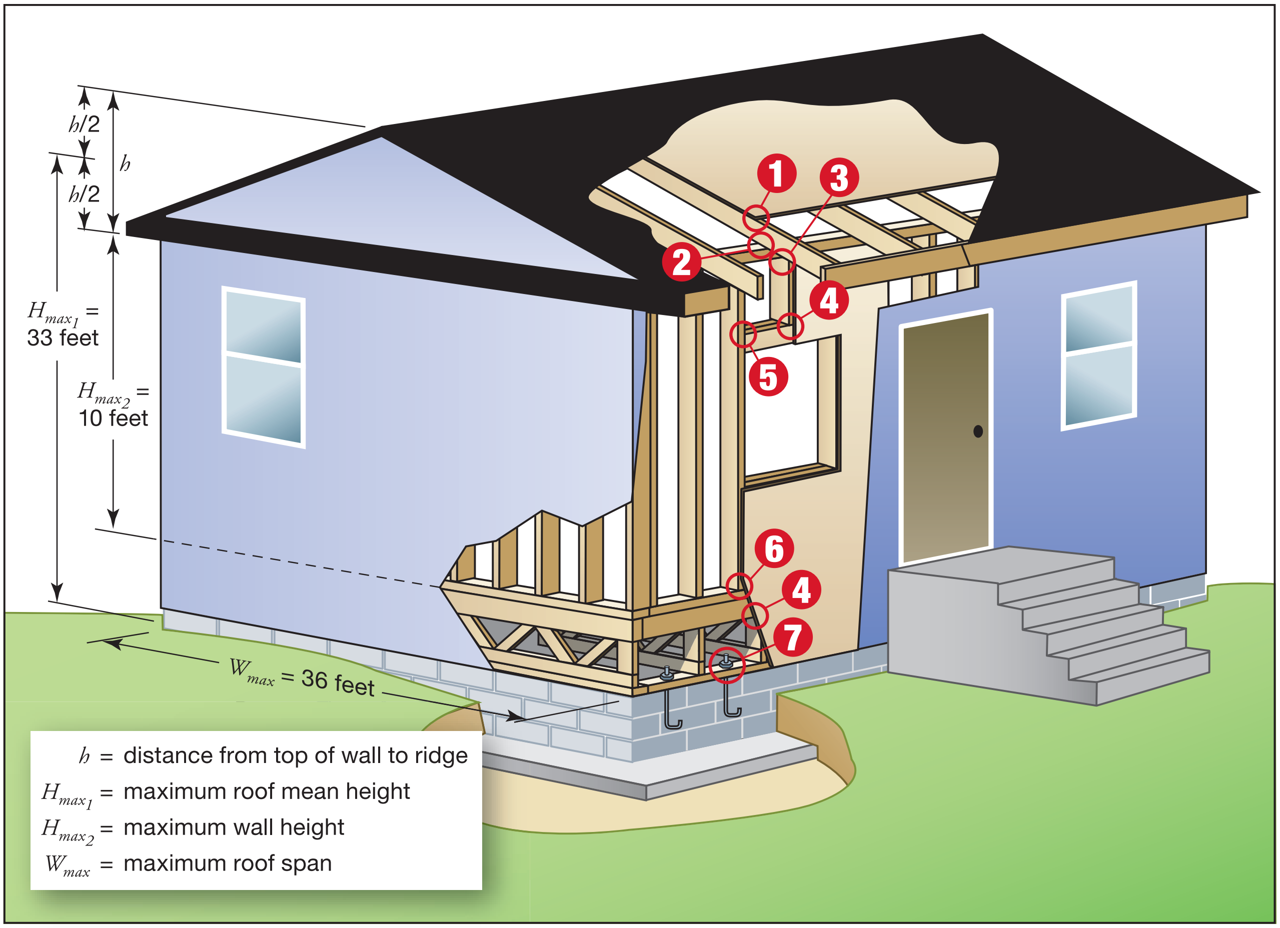
As noted in Chapter 4, tornadoes rated EF2 or less often damage window and door glazing in residential buildings, which can lead to increased pressurization of the building. Although the prescriptive solutions presented in this appendix maintain the assumption of an enclosed building consistent with the primary sources referenced above, this condition is unlikely to be met for wind speeds in excess of 110 mph (ASCE 7-05, 3-second gust) unless impact-resistant glazing is installed (described more fully in Section G.3.1.4, Glazing (Doors and Windows). For added protection of building structures without impact-resistant glazing that are subject to wind speeds in excess of 100 mph (3-second gust), a designer may choose to design for higher wind speeds or increased pressures associated with a partially enclosed building classification as described in ASCE 7.

The guidance in this appendix related to roof-to-wall, wall systems and connections is limited to the following:

- One- and two-family wood-frame residential buildings with no more than two stories.
- Mean roof heights ($H_{max}$) and roof spans ($W_{max}$) limitations as shown in Figure G-1. Continuous load path elements that are addressed in this appendix are also shown on Figure G-1.
- Percentage of full-height wall sheathing and building aspect ratios, as described in Tables G-6 and G-7.
- Openings in floors and ceilings that are the lesser of 12 feet or half the relative building dimension. Vaulted or cathedral ceilings are outside the scope of this appendix.
- Load bearing exterior wall height limited to 10 feet. Refer to Section 4 (Walls) of *Wood Frame Construction Manual (WFCM) Guide to Wood Construction in High Wind Areas for One- and Two-Family Dwellings, 130 mph, Exposure B* for complete wall framing schedules.[1]

The enhanced construction techniques described in this appendix are considered applicable for buildings with dimensions and characteristics outside the scope of those listed above, but the building design process must consider modifications to account for differences in building dimensions and characteristics.

1 The American Wood Council guide is available at http://www.awc.org/pdf/WFCM_130-B-Guide.pdf.




1. Roof sheathing connection (G3.2)
2. Rafter or truss to plate (G3.2, Table G-3, G-4)
3. Plate to stud (G3.3, Table G-11, G-12)
4. Wall sheathing connection (G3.3, Table G-6, G-7)
5. Header connection (G3.3, Table G-9, G-10)
6. Stud to plate (G3.3, Table G-14)
7. Sill anchorage (G3.3, Table G-5)

**Figure G-1: Load path elements and height and width limitations for residential buildings covered in Appendix G**
ADAPTED: COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

## G.3 Discussion of Recommendations

The following recommendations include construction specifications and details for enhanced building performance related to the following building components and systems:

G.3.1 Building Envelope Components

- Roof coverings
- Wall coverings
- Masonry veneer attachment

- Glazing (doors and windows)
- Garage doors

G.3.2 Roof Systems and Connections

- Roof decking and decking attachment
- Soffits
- Roof-to-wall connections

G.3.3 Wall Systems and Connections

- Sill plate attachment
- Wall sheathing
- Top plate splices
- Openings in walls
- Wall-to-floor connections

## G.3.1 Building Envelope Components

The following section provides guidance for roof coverings, wall coverings, masonry veneer attachment, glazing (doors and windows), and garage doors.

### G.3.1.1 Roof Coverings

The performance of asphalt shingle roof coverings can be improved by following the guidance in Technical Fact Sheet 7.3, "Asphalt Shingle Roofing for High Wind Regions," found in FEMA P-499, *Homebuilder's Guide to Coastal Construction* (2010). Specific information includes physical properties of the shingle to consider when selecting a product and the effectiveness of different wind-resistance-ratings for asphalt shingles. Proper shingle installation at eaves, rakes, hips, and ridges are also illustrated along with fastener guidelines. Other Technical Fact Sheets in P-499 also provide relevant guidance: Technical Fact Sheet 7.4, "Tile Roofing for High Wind Regions," and Technical Fact Sheet 7.6, "Metal Roof Systems in High-Wind Regions," provide similar high-wind region guidance for installing tile and metal roofs, respectively, and Technical Fact Sheet 7.2, "Roof Underlayment for Asphalt Shingle Roofs," recommends best practices for installing roof underlayment for asphalt shingle roofs to act as an enhanced secondary water barrier.

### G.3.1.2 Wall Coverings

The performance of wall coverings and sidings in high winds can be improved by following the recommendations in FEMA P-499, Technical Fact Sheet 5.3, "Siding Installation in High Wind Regions;" it covers vinyl, wood, and fiber cement siding. Figures are included that depict key differences between vinyl siding rated for high winds and standard vinyl siding. The proper method of fastening to achieve the desired performance is also illustrated. Detailed guidance includes figures showing how to install both wood siding and fiber cement siding.

### G.3.1.3 Masonry Veneer Attachment

The performance of masonry brick veneer can be improved by following the guidelines in FEMA P-499 Technical Fact Sheet 5.4, "Attachment of Brick Veneer in High-Wind Regions." The Fact Sheet includes figures that show poor versus good installation techniques and includes recommended vertical spacing of brick ties with 8d ring shank nails based on wind speed. Users should select a wind speed of 130 mph for brick ties and attachment to be consistent with other guidance provided in this appendix.

### G.3.1.4 Glazing (Doors and Windows)

Section 301.2.1.2 of the 2009 and 2012 IRC requires glazed openings to be protected from impact in areas designated as wind-borne debris regions, which are located along hurricane-prone coastlines. To protect glazing from wind-borne debris impact, the IRC specifies the use of impact-resistant coverings, such as shutters, and impact-resistant glazing. Shutters are not a practical option in tornado-prone regions because of the lead time needed to cover the glazed openings. While impact-resistant glazing may be cost prohibitive for elective installation in non-coastal tornado-prone regions, homeowners should be aware that glazing products that provide greater protection against risk associated with wind-borne debris are available. Specifically, wind-borne debris risks incurred without impact-resistant glazing include damage from water intrusion, injury from incoming missiles and shattered glazing, and a decreased level of performance because of increased pressurization.

FEMA P-499 Technical Fact Sheet 6.2, "Protection of Openings – Shutters and Glazing," provides guidance for the use of impact-resistant glazing. To qualify as impact-resistant, the glazing has to comply with the testing requirements specified in ASTM E1886 and ASTM E1996 or other approved test methods and performance criteria. There are two typical kinds of precut impact-resistant glazing: laminated glazing systems and polycarbonate systems:

- *Laminated glazing systems* typically consist of assemblies fabricated with two or more panes of glass and an interlayer of a polyvinyl butyral (or equivalent) film laminated into the glazing assembly. During impact testing, the laminated glass in the system can fracture, but the interlayer must remain intact to prevent water and wind from entering the building.

- *Polycarbonate systems* typically consist of plastic resins molded into sheets that provide lightweight, clear glazing panels with high impact-resistance qualities. The strength of the polycarbonate sheets is much higher than non-laminated glass (i.e., more than 200 times stronger) and acrylic sheets or panels (i.e., more than 30 times stronger).

While protection from impact is important, glazing must also resist wind pressures. Wind pressure resistance of glazing can be improved by installing glazing products designed to resist the design pressures shown in Table G-1. For the glazed components to perform as rated, they must be installed in accordance with manufacturer's installation instructions. The supplier should provide verification that window and door products are rated to meet or exceed the positive and negative pressures in Table G-1 and that the test values comply with one of the following testing standards:

- ANSI/AAMA/NWWDA 101/I.S.2
- ANSI/AAMA/WDMA 101/I.S.2/NAFS

- ANSI/WDMA/CSA 101/I.S.2/A440
- Florida Building Code Testing Protocol TAS 202

Products must be permanently labeled or marked to facilitate verification.

**Table G-1: Recommended Design Pressures for Doors and Windows**

| Minimum Window Size | Pressure (psf)* | Minimum Door Size | Pressure (psf)* |
|---|---|---|---|
| 2 ft 4 in. x 5 ft | 30.2, -32.8 (-40.3) | 2 ft 6 in. x 7 ft | 29.4, -32 (-38.7)** |
| 2 ft 4 in. x 7 ft | 29.5, -32.1 (-39.0) | 3 ft x 7 ft | 29.0, -31.6 (-38.0) |
| 2 ft 8 in. x 5 ft | 29.9, -32.5 (-39.8) | 5 ft x 7 ft | 28.1, -30.7 (-36.2) |
| 2 ft 8 in. x 7 ft | 29.2, -31.8 (-38.4) | 6 ft x 7 ft | 27.7, -30.2 (-35.3) |

psf = pounds per square foot   ft = feet   in. = inches

* Pressures for doors and windows are derived from Table 602(1) of ICC 600 (2008) for 130 mph 3-second gust.

** Number in parentheses represents the applicable negative pressure when the component is installed within 4 ft of wall corner.

### G.3.1.5 Garage Doors

The performance of garage door openings can be greatly improved by installing enhanced pressure-resistant overhead garage doors in accordance with the following (per ICC 600-2008 Table 602(3) for 130 mph 3-second gust):

- Single garage doors (minimum size 7 feet high x 9 feet wide) should resist minimum design pressures of +26.7 psf, -30.2 psf.[2]

- Double doors (minimum size 7 feet high x 16 feet wide) should resist minimum design pressures of +25.6 psf, -28.5 psf.

Pressure-rated garage doors should comply with the testing standards of ANSI/DASMA 108. Although some manufacturers provide wind speed and exposure ratings for their products, labels on many garage doors do not include wind speed or wind pressure ratings. While ANSI/DASMA 108 does not require wind speed or wind pressure ratings to be included on the product labeling, it does require that the positive and negative pressure used in testing be recorded on the ANSI/DASMA 108 *Test Report Form* and that the model number, description, and operating hardware be documented. If the label attached to the door does not list the positive and negative pressure rating, consult the *Test Report Form* to determine whether the garage door meets the minimum design pressures indicated above.

In addition to the door itself, practical guidance on the issue of track depth (enough to avoid wheels pulling out of the track) and proper fastening of the track to the framing at each end of the door

2 Single and double garage door pressures listed assume minimum 2-foot wall length at each end of door opening.

opening is provided in DASMA TDS 156 and 161. Both Technical Data Sheets and other guidance related to garage access systems are available at the DASMA Web site.[3]

## G.3.2 Roof Systems and Connections

The following section provides guidance for roof systems and connections, roof decking and decking attachment, soffits, and roof-to-wall connections

### G.3.2.1 Roof Decking and Decking Attachment

The performance of roof decking—also referred to as roof sheathing—can be improved by following the guidance in FEMA P-499 Fact Sheet 7.1, "Roof Sheathing Installation." Fact Sheet 7.1 provides guidance on roof decking and roof decking attachment. Insufficient fastening can lead to total building failure in a high-wind event. During wind loading, the highest uplift forces occur at the roof corners, edges, and ridgelines.

FEMA P-499 Fact Sheet 7.1 states that wood structural panel sheathing with a minimum thickness of 15/32 inch is typically required for roof decking in coastal high-wind areas. Wood structural panel sheathing may be either oriented strand board (OSB) or plywood. Sheathing panels should be rated "Exposure 1" or better.

The sheathing panels should be installed with consecutive rows staggered by half the panel length as shown in FEMA P-499 Fact Sheet 7.1. Sheathing panels should be no shorter than 4 feet long. Unless otherwise indicated by the panel manufacturer, leave a 1/8-inch gap between panel edges to allow for expansion due to changes in moisture content.

An 8d common nail (shank diameter of 0.131 inch, length of 2½ inches) is the minimum size for fastening sheathing panels. Additionally, full round heads are recommended to reduce the potential for head pull-through. Deformed-shank (i.e., ring- or screw-shank) nails provide a cost effective performance improvement over smooth-shank nails and are recommended for fastening the roof sheathing to the framing. Wood structural panel roof sheathing should be attached to roof framing with 8d ring shank nails spaced at 6 inches on center (o.c.) at panel edges and at intermediate framing. For roof sheathing within 4 feet of gable ends, fasteners should be spaced at 4 inches o.c. at panel edges and at intermediate framing. Roof sheathing should also be attached at 4 inches o.c. to blocks shown with Connector S in Table G-3. Top surface of full-height block should be in-plane with top surface of rafter or truss.

Proper fastener spacing is imperative on all sheathing panels. Loss of just one panel in a high-wind event can lead to total building failure. The builder should visually inspect work after installation to ensure that fasteners have hit the framing members. If the building design specifications require installing fasteners at less than 3 inches o.c., they should be staggered. To limit occurrence of splitting of roof framing members, 3-inch nominal roof framing members should be used at adjoining panel edges for fastener spacing less than 3 inches o.c., as required per 2012 IBC Section 2306.2.

3 The Door and Access Systems Manufacturers Association International Web site, http://www.dasma.com/pubtechdata.asp.

FEMA P-499 Technical Fact Sheet 7.1 provides further guidance on preserving the integrity of roof decking around ridge vents and ladder framing at gable overhangs.

### G.3.2.2 Soffits

Soffits are particularly vulnerable to damage from high wind pressures at the edges of the building envelope. Loss of the soffit material can cause accelerated building damage due to pressurization of the attic envelope. Soffit failure can be mitigated by implementing the installation guidance in FEMA P-499 Fact Sheet 7.5, "Minimizing Water Intrusion through Roof Vents in High-Wind Regions."

### G.3.2.3 Roof-to-Wall Connectors

Each roof truss and rafter should be attached to the framed wall double top plate with a connector designed to resist the loads for the corresponding roof truss or rafter span and spacing. Table G-3 includes recommended hardware and hardware configurations (including blocks shown on Connector S) to resist uplift and shear forces along with the number and type of nails required to resist lateral loads associated with each roof span and truss or rafter spacing condition.

If the connectors specified in Table G-2 are unavailable, users should refer to the uplift capacity values provided in Table G-4 to determine the required capacity for alternate hardware. All three connection categories listed in Table G-3—Uplift (per Connector E, F, G, H, and I), Shear (per Connector S and blocks) , and Lateral (per truss or rafter to plate attachment nailing)—are required at each roof member. For example, roof truss members spaced at 24 inches on center and spanning 32 feet would require, per Table G-3: Connector H, Connector S (with blocks), and three 16d sinker toe nails.

**WARNING**

Roof-to-wall connection failure appeared to accelerate damage to whole structures inspected by the MAT; this type of failure is a critical initiation phase of progressive collapse during a tornado.

Recent research at Iowa State University has found a 2–3 times increase over hurricane wind speeds in uplift pressure due to the inflow and updraft of tornado winds. The possible increase in uplift pressure has not been accounted for in any of the pressure values shown in this appendix.[4]

Table G-2 specifies the model numbers and installation specifications for connectors identified throughout this appendix; it is also referenced in Tables G-6, G-7, G-10, G-12, G-13, and G-14.

4 "Tornado-Induced Wind Loads on a Low-Rise Building," Dr. Partha Sarkar, *Journal of Structural Engineering,* 2010.

Table G-2: Connector Selection and Installation

| Connector Type | Simpson Strong-Tie Co. | | USP Structural Connectors | |
|---|---|---|---|---|
| | Model Number | Total Number (and Size) of Fasteners | Model Number | Total Number (and Size) of Fasteners |
| A | CS20 | (10d common) | RS250 | (10d common) |
| B | CS16 | (10d common) | RS150 | (10d common) |
| C | A34 | 8 (8d ×1½) | MP34 | 8 (8d ×1½) |
| D | A35 | 12 (8d ×1½) | MPA1 | 12 (8d ×1½) |
| E | H2.5A | 10 (8d ×1½) | RT7 | 10 (8d ×1½) |
| F | H8 | 10 (10d ×1½) | RT8A | 10 (10d ×1½) |
| G | LTS12 | 12 (10d ×1½) | RT8A | 10 (10d ×1½) |
| H | MTS12 | 14 (10d ×1½) | MTW12 | 14 (10d ×1½) |
| I | H10A | 18 (10d ×1½) | MTW12 | 14 (10d ×1½) |
| J | MTS12 | 14 (10d ×1½) | RT8A | 10 (10d ×1½) |
| K | MTS12 | 14 (10d ×1½) | MTW12 | 14 (10d ×1½) |
| L | H2.5A | 10 (8d ×1½) | RT3A | 8 (8d ×1½) |
| M | SSP | 4 (10d common) | RT3A | 8 (8d ×1½) |
| N | SP4 | 6 (10d ×1½) | 6 10d ×1½ SPT4 | 6 (10d ×1½) |
| O | SPH4 | 10 (10d ×1½) | SPTH4 | 10 (10d ×1½) |
| P | HTT5 | 26 (16d ×2½*) | PHD4A | 10 (WS3 ¼×3 screws) |
| Q | HDU11-SDS2.5 | 30 (SDS ¼×2½ screws) | PHD8 | 24 (WS3 ¼×3 screws) |
| R | HD9B** | 3 (⅞-inch bolts) | UPHD8*** | 24 (WS3 ¼×3 screws) |
| S | RBC | 12 10d ×1½ | RBC | 12 (10d ×1½) |

* Substitution of 16d common nail is acceptable

** Must be fastened to minimum of three studs

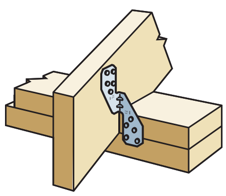
*** Must be fastened to minimum of three studs or 4×4

Note: Because not all contractors are familiar with the type of structural connectors shown in Appendix G tables, the names of two companies that manufacture connectors have been included. This list of companies is not, however, exhaustive. Additionally, this list is not intended to express a preference for those manufacturers and/or their products by the United States government nor is it an endorsement of those manufacturers and/or their products.

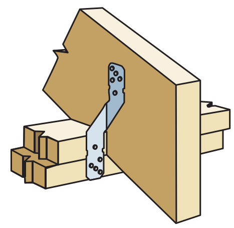
SOURCE: RANDY SHAKELFORD, PE (PERSONAL COMMUNICATION)

Table G-3: Roof-to-Wall Connector Requirements

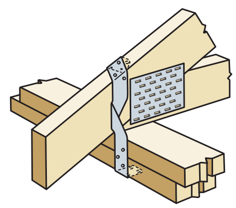
| | Roof Framing Span (ft) | | | | Connections Required in Addition to Uplift Connector | |
|---|---|---|---|---|---|---|
| | 24 | 28 | 32 | 36 | | |
| Truss or Rafter Spacing | Connector Type* (Uplift) | | | | Connector Type* (Shear) | Truss or Rafter-to-Plate Attachment (Lateral) |
| **16 in. o.c.** | E | F | F | G | S** | Three 10d sinker toe nails** |
| **24 in. o.c.** | H | H | H | I | S** | Three 16d sinker toe nails** |



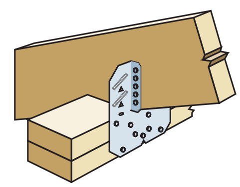
**Connector E**



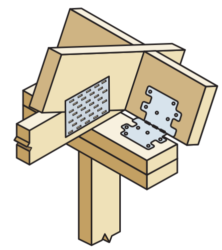
**Connector F (G Similar)**



**Connector H**



**Connector I**



**Connector S****

in. = inch ft = feet o.c. = on center

* Reference Table G-2 for model number and fasteners

** Uplift connector not shown for clarity. Connector S with blocking between rafters or trusses should be used in addition to uplift connectors and truss or rafter to plate attachment nail schedule.

SOURCE (NOT INCLUDING HARDWARE SPECIFICATIONS): COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

Table G-4: Roof-to-Wall Connection Loads

| | Roof Framing Span (ft) | | | | | |
|---|---|---|---|---|---|---|
| | 24 | 28 | 32 | 36 | | |
| Truss or Rafter Spacing | Uplift (lb) | | | | Shear (lb) | Lateral (lb) |
| **16 in. o.c.** | 442 | 499 | 247 | 611 | 109 | 247 |
| **24 in. o.c.** | 664 | 748 | 370 | 917 | 164 | 370 |

in. = inch ft = feet o.c. = on center lb = pounds

SOURCE: COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

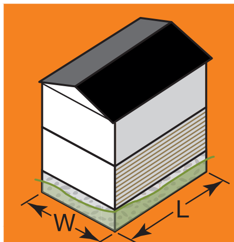
## G.3.3 Wall Systems and Connections

The following section provides guidance for sill plate attachment, wall sheathing, top plate splices, openings in walls, and wall-to-floor connections

### G.3.3.1 Sill Plate Attachment

To strengthen the connection between the sill plate and foundation, the treated sill plate should be attached to masonry or concrete foundations with 5/8-inch-diameter anchor bolts and 0.229-inch x 3-inch x 3-inch washers in accordance with Table G-5 and installed as shown in Figure G-2. To determine the appropriate building aspect ratio required, refer to the image in Table G-5.

Table G-5: Anchor Bolt Spacing Guide




| Foundation Supporting: | Stemwall Foundation Aspect Ratio (L/W) | | | | | | Slab-on-Grade Foundation |
|---|---|---|---|---|---|---|---|
| | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | |
| | 5/8-in. Anchor Bolt Spacing | | | | | | |
| **One story** | 58 in. | 51 in. | 43 in. | 36 in. | 32 in. | 28 in. | 24 in. |
| **Two-story** | 40 in. | 32 in. | 27 in. | 23 in. | 20 in. | 18 in. | 24 in. |

in. = inches

SOURCE: COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

### G.3.3.2 Wall Sheathing

All framed walls, including gable end walls, should be continuously sheathed with wood structural panels having a minimum nominal thickness of 7/16 inch. According to APA's *Building for High Wind Resistance in Light-Frame Wood Construction* (2011, page 3), "the most effective way to provide lateral and uplift continuity is to attach adjacent wall sheathing panels to one another over common framing." In order to determine the attachment schedule for wood structural panels, the following information must be determined from the construction drawings:

1. Building aspect ratio (see figures embedded in Tables G-6 and G-7).

2. Percentage of full height sheathing in the wall to be constructed by dividing the total length of that wall *not* containing openings (i.e., wall sections sheathed over full height) by the total wall line length.

The next step is to use Table G-6 or G-7 to find the required attachment schedule, hold-down hardware, and bottom plate-to-frame connector for information determined in Steps 1 and 2. Table G-6 and Table G-7 provides the attachment schedule for 7/16-inch OSB wall sheathing, wall hold-down hardware, and wall bottom plate to frame hardware. Note that the percentages indicated in Tables G-6 and G-7 are the maximum allowed for the selected aspect ratio and attachment schedule; wall conditions with percentages for the closest spaced attachment schedule in excess of those shown are outside the scope of the guidance in this appendix. While the performance of residential buildings outside the scope of these limits and provisions may be enhanced through the most conservative guidance in this appendix, a registered design professional should be consulted.

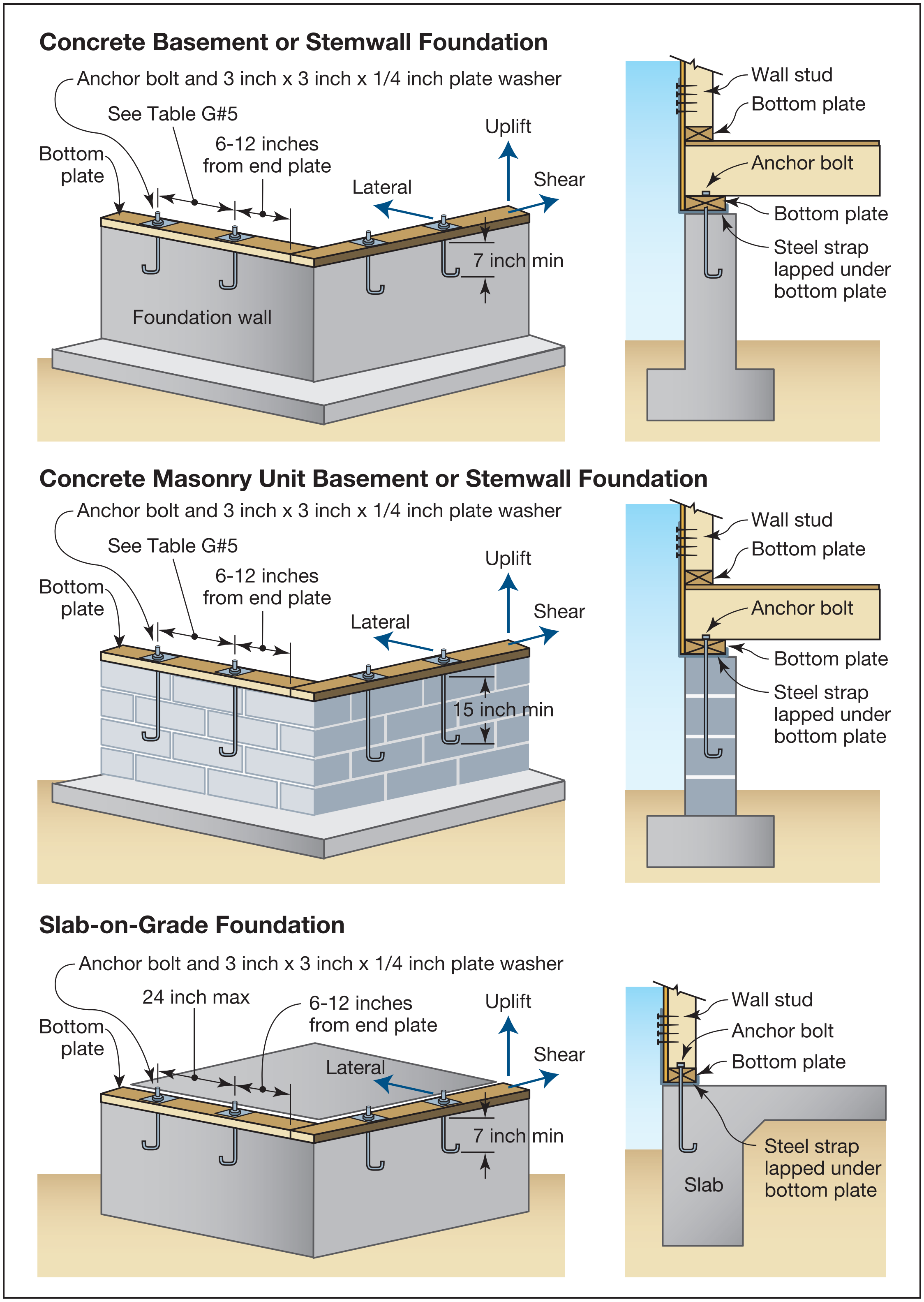
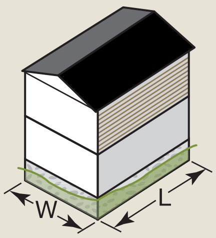
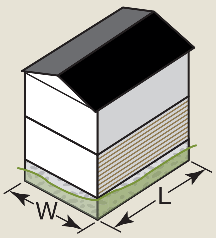
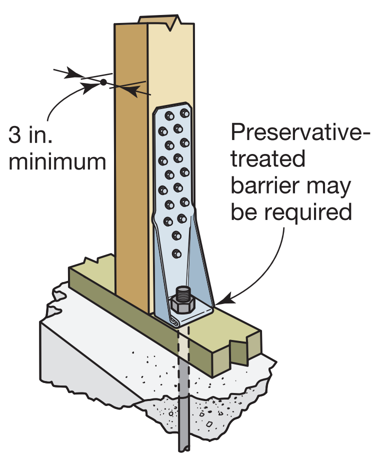



**Figure G-2: Anchor bolt installation guide**

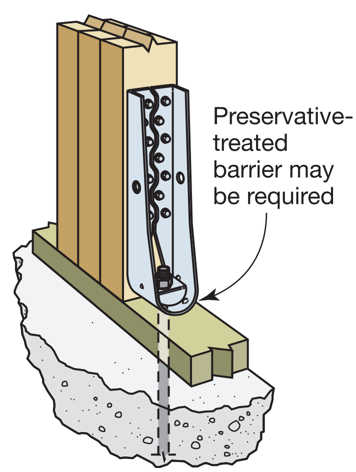
SOURCE: COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

**Table G-6: Percentage of Full-Height Sheathing in Maximum Building Dimension (Length)**

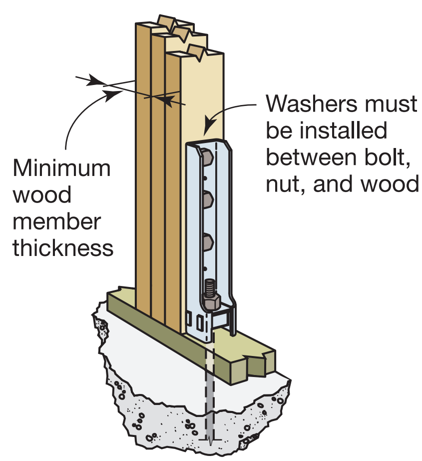
| Shear Wall Line Beneath | Building Aspect Ratio (L/W) | Percent Full-Height Sheathing on Each Exterior Wall Line | | |
|---|---|---|---|---|
|   **Roof and Ceiling** | 1.00 | 43% | 34% | 28% |
| | 1.25 | 36% | 28% | 23% |
| | 1.50 | 31% | 24% | 20% |
| | 1.75 | 27% | 21% | 17% |
| | 2.00 | 24% | 18% | 15% |
| | 2.25 | 22% | 17% | 14% |
|   **Roof, Ceiling, and One Floor** | 1.00 | 78% | 65% | 56% |
| | 1.25 | 68% | 55% | 47% |
| | 1.50 | 60% | 48% | 41% |
| | 1.75 | 54% | 43% | 36% |
| | 2.00 | 49% | 38% | 32% |
| | 2.25 | 44% | 35% | 29% |
| **Attachment Schedule for 7/16-in. Wood Structural Panel Sheathing, Plate-to-Floor, and Hold-down Requirements at Each Wall End** | Edge nail spacing (8d common nail) | 6-in. o.c. | 4-in. o.c. | 3-in. o.c. |
| | Field nail spacing (8d common nail) | 6-in. o.c. | 6-in. o.c. | 6-in. o.c. |
| | Bottom plate-to-floor shear connection (16d common nails) | 436 plf (3/ft) | 590 plf (3/ft) | 730 plf (4/ft) |
| | Hold-down loads and model # | 4,360 lb Connector P* | 5,900 lb Connector Q* | 7,300 lb Connector R* |




**Connector P (Simpson)**




**Connector Q****




**Connector R (Simpson)**

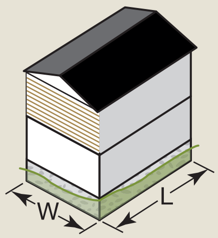
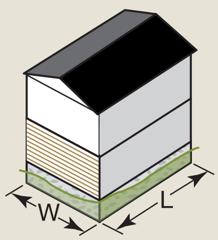
in. = inches  o.c. = on center  ft = foot  plf = pounds per linear foot

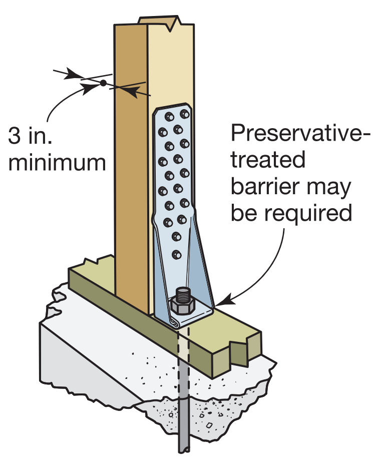
* Refer to Table G-2 for model number and fasteners

** Connector P and R (United Steel Products [USP]) are similar to Connector Q

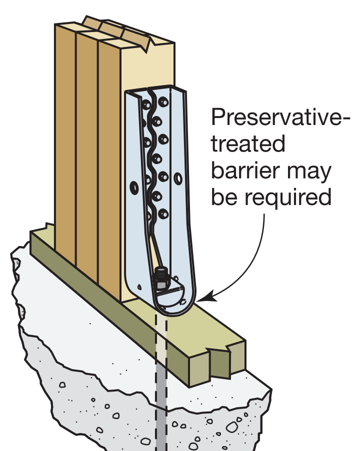
SOURCE (NOT INCLUDING HARDWARE SPECIFICATIONS): COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

**Table G-7: Percentage of Full-Height Sheathing in Maximum Building Dimension (Width)**

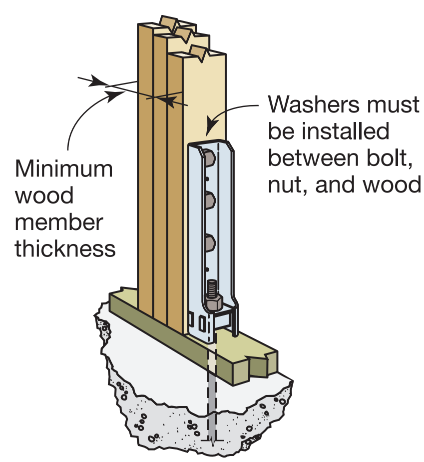
| Shear Wall Line Beneath | Building Aspect Ratio (L/W) | Percent Full-Height Sheathing on Each Exterior Wall Line | | |
|---|---|---|---|---|
|  | 1.00 | 43% | 34% | 28% |
| | 1.25 | 51% | 41% | 34% |
| | 1.50 | 58% | 47% | 40% |
| | 1.75 | 65% | 53% | 45% |
| | 2.00 | 71% | 58% | 50% |
| **Roof and Ceiling** | 2.25 | 76% | 63% | 54% |
|  | 1.00 | 78% | 65% | 56% |
| | 1.25 | 89% | 75% | 65% |
| | 1.50 | 98% | 83% | 73% |
| | 1.75 | NP | 91% | 81% |
| | 2.00 | NP | 98% | 87% |
| **Roof, Ceiling, and One Floor** | 2.25 | NP | NP | 93% |
| **Attachment Schedule for 7/16-in. Wood Structural Panel Sheathing, Plate-to-Floor, and Hold-down Requirements at Each Wall End** | Edge nail spacing (8d common nail) | 6-in. o.c. | 4-in. o.c. | 3-in. o.c. |
| | Field nail spacing (8d common nail) | 6-in. o.c. | 6-in. o.c. | 6-in. o.c. |
| | Bottom plate-to-floor shear connection (16d common nails) | 436 plf (3/ft) | 590 plf (3/ft) | 730 plf (4/ft) |
| | Hold-down loads and model # | 4,360 lb Connector P* | 5,900 lb Connector Q* | 7,300 lb Connector R* |




**Connector P (Simpson)**




**Connector Q****




**Connector R (Simpson)**

NP = Not Permitted in. = inches o.c. = on center ft = foot plf = pounds per linear foot

* Refer to Table G-2 for model number and fasteners

** Connector P and R (United Steel Products [USP]) are similar to Connector Q

SOURCE (NOT INCLUDING HARDWARE SPECIFICATIONS): COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

## EXAMPLE

**Given:**

- One-story house with building length (L) = 60 feet, building width (W) = 30 feet
- Both 30-foot-long framed walls contain one 3-foot-wide door and one 6-foot-wide double window

**Find:**

- Sheathing attachment schedule for 30-foot-long walls
- Hold-down hardware for 30-foot-long walls

**Solution:**

1. ***Find the sheathing attachment schedule***

- Determine building aspect ratio: L: W = (60 feet:30 feet) = 2
- Determine percent full-height sheathing (P) in wall using the given values:

W = Building width in feet = 30 feet

T = Total width of openings in wall in feet = 3 feet + 6 feet = 9 feet

$$P\left[=\frac{[W-T]}{W}=\frac{[30-9]}{30}\right]=0.70\text{, or 70 percent}$$

- Using Table G-7 (for (W)) select the row in the upper portion of the table showing the building aspect ratio (L/W) = 2.00, as determined above.
- Find the appropriate column for wall sheathing nailing pattern using the percentage for the full-height sheathing calculated above, where P = 70 percent.

  Select the second column (58 percent < 70 percent < 71 percent) to determine the nailing schedule, which for this example is 4-inch spacing of edge nails and 6-inch spacing of field nails (8d common nails).

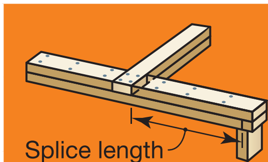
2. ***Find the recommended hold-down hardware***

- Find the hold-down hardware for the column indicated in the previous section. As shown in Table G- 7, Connector Q is recommended for each wall end that has a minimum required capacity of 5900 pounds when installed per manufacturer's installation instructions.
- Using the row in the same column labeled "Bottom plate-to-floor shear connection (16d common nails)," determine the plate-to-floor shear load connection. For this example, three 16d common nails per foot are required to transfer shear loads between the bottom plate of the wall and the solid floor band.

### G.3.3.3 Top Plate Splices

To maintain the integrity of framed walls when a top plate splice is required, attach the double top plates together per Table G-8. Please note that the maximum roof span of 36 feet (per Figure G-1) and the maximum aspect ratio of 2.25 (per Tables G-5, G-6, and G-7) limit overall building length to a maximum of 81 feet.

**Table G-8: Top Plate Splice Guide**




| Splice Length | Building Dimension of Wall Containing Top Plate Splice (ft) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 24 | 28 | 32 | 36 | 40 | 50 | 60 | 70 | 80 |
| | Number of 16d Common Nails per Each Side of Splice | | | | | | | | |
| **2 ft** | 8 | NP | NP | NP | NP | NP | NP | NP | NP |
| **4 ft** | 8 | 10 | 12 | 14 | 16 | NP | NP | NP | NP |
| **6 ft** | 8 | 10 | 12 | 14 | 16 | 20 | 24 | NP | NP |
| **8 ft** | 8 | 10 | 12 | 14 | 16 | 20 | 24 | 28 | 32 |

ft = feet NP = Not permitted

SOURCE: COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

### G.3.3.4 Openings in Walls

Wall openings disrupt the continuous load path required to transfer wind forces through framed walls. Enhanced building performance of framed walls is achieved by installing uplift connector hardware around wall openings. Headers and plates at wall openings should be attached to the framed wall studs at each end with connectors designed to resist the uplift and lateral loads shown in Table G-9 for the corresponding header spans. Table G-9 also shows the number of full-height studs required at each end. Install hardware around framed wall openings as recommended in Table G-10. Please refer to Table G-2 for hardware specifications.

**Table G-9: Connection Loads at Each End of Exterior Wall Headers**

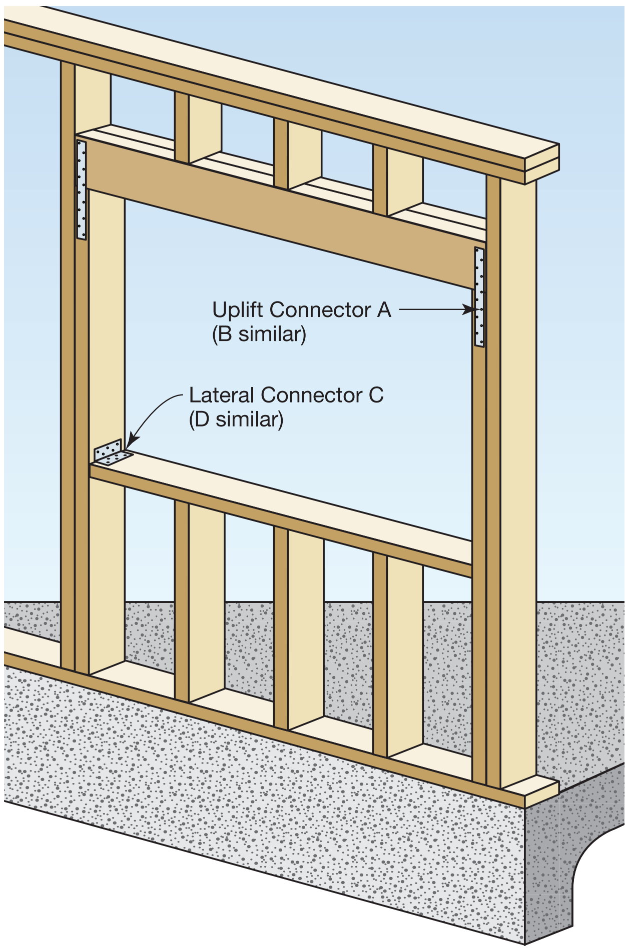
| Header Span | Number of Full-Height Studs | Uplift Load (lb) | Lateral Load (lb) |
|---|---|---|---|
| **3 ft** | 2 | 689 | 278 |
| **4 ft** | 2 | 918 | 370 |
| **5 ft** | 3 | 1,148 | 463 |
| **6 ft** | 3 | 1,377 | 555 |
| **8 ft** | 3 | 1,836 | 740 |
| **10 ft** | 4 | 2,295 | 925 |

lb = pounds ft = feet

SOURCE: COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

Table G-10: Connector Requirements at Each End of Exterior Wall Headers

| Header Span | Number of Full-Height Studs | Uplift Connector Type* (#)** | Lateral Connector Type |
|---|---|---|---|
| **3 ft** | 2 | A (10) | C |
| **4 ft** | 2 | A (12) | C |
| **5 ft** | 3 | B (14) | D |
| **6 ft** | 3 | B (18) | D |
| **8 ft** | 3 | A × 2 (12 each) | C × 2 |
| **10 ft** | 4 | B × 2 (14 each) | D × 2 |




ft = feet

* Refer to Table G-2 for model number and fasteners

** (#) = Number of nails required in each end of strap

SOURCE: ADAPTED (WITHOUT HARDWARE SPECIFICATIONS) COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

### G.3.3.5 Wall-to-Floor Connection

Table G-11 shows the uplift and lateral loads to resist between the top plate and framed wall stud based on stud spacing and roof span. As previously noted in the section on wall sheathing, APA recommends attaching adjacent wall sheathing panels to one another, over common framing, to provide lateral and uplift continuity. To this end, wood wall sheathing panels should be extended upward from the first-floor walls and downward from the second-floor walls to meet at the midpoint of the second-floor band joist. Likewise, the wood wall sheathing panels from the first-floor walls should be extended downward to lap the sill plate at the foundation level. Connector requirements to resist wall-to-wall uplift loads are shown in Tables G-12 to G-14, and hardware specifications are shown in Table G-2. The number of 16d common nails (through single plate adjacent to stud) required to resist lateral loads is shown in Tables G-12 to G-14.

Table G-11: Top Plate-to-Stud-Connection Loads

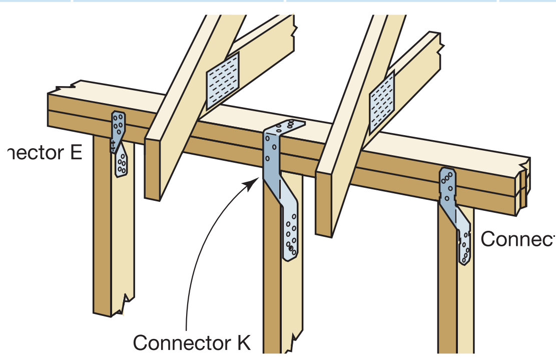
| Stud Spacing | Roof Framing Span (ft) | | | | Lateral (lb) |
|---|---|---|---|---|---|
| | 24 | 28 | 32 | 36 | |
| | Uplift (lb) | | | | |
| **12-in. o.c.** | 331 | 375 | 416 | 458 | 185 |
| **16-in. o.c.** | 442 | 499 | 555 | 611 | 247 |
| **24-in. o.c.** | 664 | 748 | 833 | 917 | 370 |

in. = inches    ft = feet    lb = pounds

SOURCE: COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

Table G-12: Top Plate-to-Stud Connector Requirements

| Stud Spacing | Roof Framing Span (ft) | | | | Lateral |
|---|---|---|---|---|---|
| | 24 | 28 | 32 | 36 | No. of 16d Common Nails (end-nailed) |
| | Connector Type* | | | | |
| **12-in. o.c.** | E | E | E | E | 2 |
| **16-in. o.c.** | E | F | F | J | 2 |
| **24-in. o.c.** | K | K | K | I | 3 |



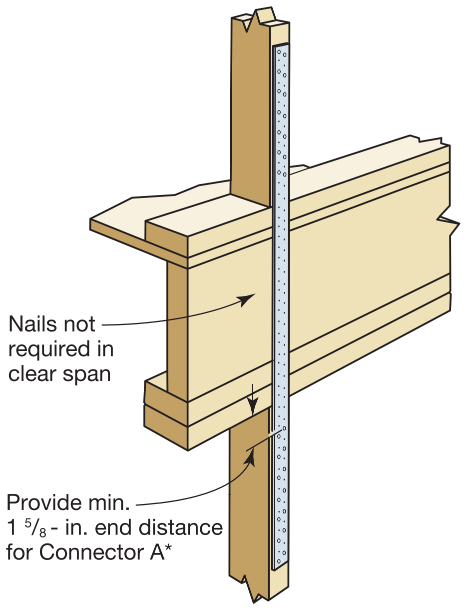

in. = inches    ft = feet    o.c. = on center

*    Refer to Table G-2 for model number and fasteners

SOURCE: ADAPTED (WITHOUT HARDWARE SPECIFICATIONS) COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

Table G-13: Stud-to-Stud Connection Requirements

| Stud Spacing | Roof Framing Span (ft) | | | | Lateral |
|---|---|---|---|---|---|
| | 24 | 28 | 32 | 36 | No. of 16d Common Nails (end-nailed) |
| | Number of 10d Common Nails in Connector A* | | | | |
| **12-in. o.c.** | 4 | 4 | 6 | 6 | 2 |
| **16-in. o.c.** | 6 | 6 | 6 | 8 | 2 |
| **24-in. o.c.** | 8 | 8 | 10 | 10 | 3 |



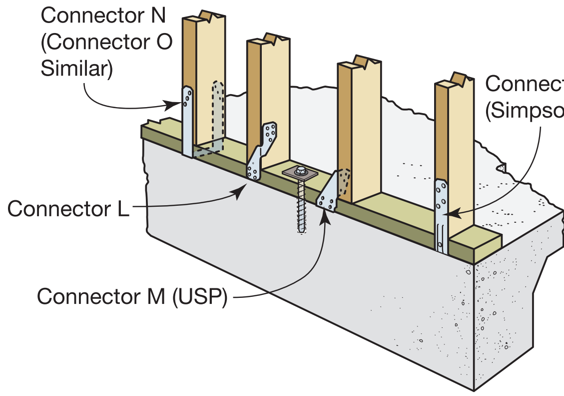

in. = inches ft = feet o.c. = on center

* Install half the nails in each end of the strap to studs. Cut strap cut to length so that required number of nails can be installed in each end. Refer to Table G-2 for model number and fasteners.

SOURCE: ADAPTED (WITHOUT HARDWARE SPECIFICATIONS) COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

Table G-14: Stud-to-Bottom Plate Connector Requirements

| Stud Spacing | Roof Framing Span (ft) | | | | Lateral |
|---|---|---|---|---|---|
| | 24 | 28 | 32 | 36 | No. of 16d Common Nails (end-nailed) |
| | Connector Type* | | | | |
| **12-in. o.c.** | L | L | M | M | 2 |
| **16-in. o.c.** | M | M | N | N | 2 |
| **24-in. o.c.** | N | N | N | O | 3 |




in. = inches ft = feet o.c. = on center

* Refer Table G-2 for model number and fasteners.

SOURCE: ADAPTED (WITHOUT HARDWARE SPECIFICATIONS) COURTESY, AMERICAN WOOD COUNCIL, LEESBURG, VA

## G.4 References

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