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# ICC-ES Evaluation Report

# ESR-1338

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**DIVISION: 09 00 00—FINISHES**

**SECTION: 09 21 16—GYPSUM BOARD ASSEMBLIES**

**SECTION: 09 21 16.23—GYPSUM BOARD SHAFT WALL ASSEMBLIES**

**SECTION: 09 21 16.33—GYPSUM BOARD SEPARATION WALL ASSEMBLIES**

**REPORT HOLDER:**

**GYPSUM ASSOCIATION**

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Silver Spring, Maryland 20910

**EVALUATION SUBJECT:**

**GYPSUM WALL AND CEILING ASSEMBLIES AND  
GYPSUM BOARD INTERIOR AND EXTERIOR APPLICATIONS**



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## DIVISION: 09 00 00—FINISHES

Section: 09 21 16—Gypsum Board Assemblies

Section: 09 21 16.23—Gypsum Board Shaft Wall Assemblies

Section: 09 21 16.33—Gypsum Board Area Separation Wall Assemblies

## REPORT HOLDER:

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## EVALUATION SUBJECT:

**GYPSUM WALL AND CEILING ASSEMBLIES AND  
GYPSUM BOARD INTERIOR AND EXTERIOR  
APPLICATIONS**

## 1.0 EVALUATION SCOPE

### Compliance with the following codes:

- 2018, 2015, 2012 and 2009 *International Building Code*® (IBC)
- 2018, 2015, 2012 and 2009 *International Residential Code*® (IRC)
- 2013 *Abu Dhabi International Building Code* (ADIBC)<sup>†</sup>

<sup>†</sup>The ADIBC is based on the 2009 IBC. 2009 IBC code sections referenced in this report are the same sections in the ADIBC.

### Properties evaluated:

- Interior finish
- Fire-resistance
- Sound control
- Structural
- Thermal barrier
- Exterior finish

## 2.0 USES

This evaluation report recognizes gypsum products for specific interior and exterior applications, and also recognizes various load-bearing and nonload-bearing fire-resistance-rated wall, floor-ceiling and roof-ceiling gypsum board assemblies. Some assemblies also provide sound transmission control. Structural evaluation is limited to transverse loading.

## 3.0 DESCRIPTION

The gypsum products and fire-resistance-rated wall, floor-ceiling and roof-ceiling assemblies must conform to Section 4.0 of this report using materials as described below. Gypsum boards must comply with ASTM C1396-14a for use under the 2018 IBC and IRC.

### 3.1 Water-resistant Gypsum Backing Board:

The backing board must conform to ASTM C1396.

### 3.2 Gypsum Wallboard:

The wallboard must conform to ASTM C1396.

### 3.3 Exterior Gypsum Soffit Board:

The soffit board must conform to ASTM C1396.

### 3.4 Gypsum Sheathing Board:

The sheathing board must conform to ASTM C1396.

### 3.5 Gypsum Backing Board, Core Board and Gypsum Shaftliner Board:

The backing, core board and shaftliner must conform to ASTM C1396.

### 3.6 Gypsum Base for Veneer Plasters:

The gypsum base must conform to ASTM C1396.

### 3.7 Gypsum Ceiling Board:

The ceiling board must conform to ASTM C1396.

### 3.8 Screws:

Type S, Type W and Type G screws specified for the assemblies described in this report must comply with ASTM C1002 or ASTM C954.

## 4.0 INSTALLATION

### 4.1 General:

Installation of the gypsum board wall and ceiling assemblies and interior and exterior applications as described below must comply with this report and the Gypsum Association's published installation instructions. The Gypsum Association's published installation instructions must be available at the jobsite at all times during installation.

The gypsum products recognized in this report must be assembled and installed in accordance with IBC Section 2508.1 or IRC Section R702.3.1, as applicable. Gypsum board must not be used in areas subject to continuous high humidity, such as saunas, steam rooms, gang shower rooms or indoor pools.

## 4.2 Fire-resistance-rated Wall, Floor-ceiling and Roof-ceiling Gypsum Board Assemblies:

### 4.2.1 General Fire-resistance-rated Design Information:

- The axial design stress of the wood studs used in fire-resistive construction must be reduced to  $0.78F_c$ , calculated in accordance with Section 3.6 of the ANSI/AWC National Design Specification (NDS) for Wood Construction 2018 edition for the 2018 IBC, 2015 edition for the 2015 IBC, 2012 edition for the 2012 IBC and 2005 for the 2009 IBC, with the maximum design stress not greater than 78 percent of the calculated allowable stress with studs having a slenderness ratio,  $l_e/d$ , of 33.
- When gypsum board is used in fire-resistive floor/ceiling, roof/ceiling, or wall assemblies, the board thickness, type of gypsum board, and construction of the assembly must comply with Chapter 7 of the IBC; Section R302 of the IRC; the Gypsum Association Fire Resistance Design Manual, GA-600, 21<sup>st</sup> Edition for the 2018 IBC, 20<sup>th</sup> Edition for the 2015 IBC or 19<sup>th</sup> Edition for the 2012 and 2009 IBC; or current ICC-ES evaluation reports. The Gypsum Association Fire Resistance Design Manual GA-600 (21<sup>st</sup> Edition), although not specifically listed as a reference standard in the 2009, 2012, or 2015 IBC, is an acceptable alternative to the 19<sup>th</sup> and 20<sup>th</sup> Editions when approved by the code official.
- Except where otherwise noted in this report, any of the gypsum boards listed in Section 3.0, of the same size, thickness, and core type specified, may be used. The gypsum base for veneer plasters must be covered with minimum  $1/16$ -inch-thick (1.6 mm) gypsum veneer plaster.

**4.2.2 Fire-resistance-rated Assemblies:** Generic fire-resistance-rated systems (those not designated as proprietary in the listing), as listed in the Gypsum Association Fire Resistance Design Manual, GA-600, 21<sup>st</sup> Edition for the 2018 IBC, 20<sup>th</sup> Edition for the 2015 IBC, or 19<sup>th</sup> edition for the 2012 and 2009 IBC, are recognized for use. The Gypsum Association Fire Resistance Design Manual GA-600 (21<sup>st</sup> Edition), although not specifically listed as a reference standard in the 2009, 2012, or 2015 IBC, is an acceptable alternative to the 19<sup>th</sup> and 20<sup>th</sup> Editions, when approved by the code official.

**4.2.2.1 Two-hour Gypsum Board Solid Partition for Shaft Enclosure:** The assembly is similar to Item 9-1.1 of Table 721.1(2) of the 2018, 2015 and 2012 IBC (Item 9-1.1 of Table 720.1(2) of the 2009 IBC), except that the gypsum shaftliner is first installed onto 2-by-2-inch (51 by 51 mm) steel floor and ceiling runners using Type S screws spaced 12 inches (305 mm) on center. The runners must be anchored at 24 inches (610 mm) on center, using approved fasteners. Two layers of  $1/2$ -inch-thick (12.7 mm), Type X gypsum board installed with long edges parallel to wrapped coreboard edges are laminated to one side of the coreboard. All vertical joints must be offset at least 3 inches (76 mm).

The assembly may also be constructed with four layers of  $1/2$ -inch-thick (12.7 mm), Type X gypsum board, laminated together, with the joints of each layer offset at least 3 inches (76 mm) from the adjoining layers. The laminating compound must comply with ASTM C475 or be an approved powder setting-type compound. The first layer is attached to the 2-by-2-inch (51 by 51 mm) steel floor and ceiling angle runners using one  $7/8$ -inch-long (22 mm), Type S screw at each corner. The second layer is then fully laminated to the first layer and screw-attached

to the runners using  $1^{15}/16$ -inch-long (49.2 mm), Type S screws spaced 12 inches (305 mm) on center. The third layer is laminated in the same manner as the second layer, and is further attached using  $1^{1}/2$ -inch-long (38 mm), Type G screws spaced 24 inches (610 mm) on center along the edges and along the center, and held back  $2^{1}/2$  inches (63.5 mm) from the top and bottom edges. The fourth layer is fully laminated, with all of the vertical joints being offset.

### 4.2.2.2 One-hour Gypsum Board Partition with Wood Framing:

The framing consists of nominal 2-by-4 wood studs spaced 16 inches (406 mm) on center, with blocking of the same size at midheight. Each side of the wall is covered with a single layer of  $5/8$ -inch-thick (15.9 mm), Type X gypsum board applied either perpendicular to or parallel to the framing. The gypsum board is attached to the framing using No. 6 by  $1^{1}/4$ -inch-long (31.7 mm), buglehead, Type W screws spaced 8 inches (203 mm) on center along end joints and 12 inches (305 mm) on center in the field. Screws are placed no closer than  $1/2$  inch (12.7 mm) to end or edge joints. Vertical joints are staggered 16 inches (406 mm) on center, and horizontal joints are staggered 12 inches (305 mm) on center on each side. The joints are taped with joint tape and covered with two coats of joint compound. Screw heads are covered with joint compound.

### 4.2.2.3 One-hour Gypsum Board Staggered-stud Bearing Partition:

The framing consists of two rows of nominal 2-by-3 wood studs spaced at 16 inches (406 mm) on center or nominal 2-by-4 wood studs spaced at 24 inches (610 mm) on center, with blocking of the same size at midheight. Studs in opposite rows are staggered 8 inches (203 mm) or 12 inches (305 mm) on center, and the rows are spaced a minimum of 1 inch (25.4 mm) apart. The plates for each row may be of the same size and material, or common plates may be used for the two rows. The exterior face of each row is then covered with  $5/8$ -inch-thick (15.9 mm), Type X gypsum board applied horizontally or vertically using 6d cement-coated cooler nails at 7 inches (178 mm) on center, with end joints on nailing members. Fire-blocks, when required, may be of mineral wool batts, 2 inches (51 mm) thick in the intervening spaces between the two rows of studs, or  $1/2$ -inch-thick (12.7 mm) gypsum board. Where nominally 2-by-3 studs are used, they must be stress-graded lumber as set forth in Table 4C of the supplement of the NDS.

### 4.2.2.4 One-hour Gypsum Board Floor-ceiling or Roof-ceiling Assembly with Wood Framing:

The ceiling construction is identical to assembly FC5406 in the Gypsum Association Fire Resistance Design Manual. Alternate framing consists of lower chords of trussed rafters, or pitched or flat trusses spaced a maximum of 24 inches (610 mm) on center. Alternate fasteners, having the same spacing as the screws, are  $1^{7}/8$ -inch-long (47.6 mm), 6d, cooler, box or wallboard nails for the base ply, and  $2^{3}/8$ -inch-long (60 mm), 8d, cooler, box or wallboard nails for the face ply. Type G screws,  $1^{1}/2$  inches (38 mm) long, are still required at the end joints of the gypsum board face layer.

### 4.2.2.5 One-hour Gypsum Board Roof-ceiling Assembly with Steel Framing:

The assembly consists of steel roof framing with roof purlins spaced and designed to support a noncombustible ceiling grid to which is attached double  $5/8$ -inch-thick (15.9 mm), Type X gypsum board. Cold-rolled steel main runner channels at 4 feet (1219 mm) on center, with size and hanger support complying with Section 2506.2.1 of the IBC, are hung from the steel framing. Number 25 gage,  $7/8$ -inch-deep (22 mm), rigid cross-furring channels are spaced 24 inches (610 mm) on

center. Furring channels are wire-tied to the runner channels using loops of No. 16 gage wire. The base layer of  $\frac{5}{8}$ -inch-thick (15.9 mm), Type X gypsum board is applied at right angles to the furring channels using 1-inch-long (25.4 mm), Type S screws spaced at 24 inches (610 mm) on center. The face layer of  $\frac{5}{8}$ -inch-thick (15.9 mm), Type X gypsum board is applied at right angles to the furring channels, using  $1\frac{5}{8}$ -inch-long (41.3 mm), Type S screws spaced at 12 inches (305 mm) on center at joints, driven through the base layer and into the intermediate furring channels. Face layer joints are offset 24 inches (610 mm) from the base layer joints. One-and-one-half-inch-long (38 mm), Type G screws, placed 2 inches (51 mm) from either side of the face layer end joints, are also installed at 12 inches (305 mm) on center. The addition of insulation to the assembly is permitted, provided a minimum plenum space of 10 inches (254 mm) is maintained between the underside of the insulation and the gypsum panel.

#### **4.2.2.6 Two-hour Gypsum Board Bearing Wall with Minimum STC (Sound Transmission Class) 50 Sound Rating:**

The construction consists of nominally 2-by-4 wood studs spaced 16 inches (406 mm) on center, faced on each side with two layers of  $\frac{5}{8}$ -inch-thick (15.9 mm), Type X gypsum board. On one side, the gypsum board is fastened directly to the studs as specified for interior partitions in Item 14-1.5 of Table 721.1(2) of the 2018, 2015 and 2012 IBC (Item 14-1.5 of Table 720.1(2) of the 2009 IBC); on the other side, resilient furring channels spaced 24 inches (610 mm) on center are applied horizontally over the wood studs and are attached using 6d common or  $1\frac{1}{4}$ -inch (31.7 mm) wallboard nails or 1-inch-long (25.4 mm), Type W or Type S screws. The  $\frac{5}{8}$ -inch-thick (15.9 mm), Type X gypsum board is applied horizontally and is attached along longitudinal edges to the furring channels using 1-inch-long (25.4 mm), Type S screws spaced 12 inches (305 mm) on center. Six-inch-wide (152 mm) strips of gypsum board are installed behind unsupported vertical butt joints and are attached at the ends and along the length of the strips using Type G,  $1\frac{1}{2}$ -inch-long (38 mm) screws spaced 12 inches (305 mm) on center. A face layer of  $\frac{5}{8}$ -inch-thick (15.9 mm), Type X gypsum board is applied with joints staggered from the base layer joints and secured to the resilient furring channels using  $1\frac{5}{8}$ -inch-long (41.3 mm), Type S screws spaced 12 inches (305 mm) on center. With this partition, a minimum STC rating of 50 is attained. When desired, glass fiber or mineral wool insulation may be installed in the stud cavities.

#### **4.2.3 Alternate Fire-resistance-rated Construction:**

**4.2.3.1 Alternate Suspended Ceiling Construction:** Gypsum board ceilings directly attached to steel framing as set forth in Table 721.1(3) of the 2018, 2015 and 2012 IBC (Table 720.1(3) of the 2009 IBC) may be suspended by means of  $1\frac{1}{2}$ -inch (38 mm), cold-rolled steel, main runner channels, spaced 48 inches (1219 mm) on center, that are suspended with No. 8, SWG galvanized wire hangers spaced 48 inches (1219 mm) on center. Furring channels are placed perpendicular to the cold-rolled steel main runner channels and are secured thereto using No. 18, SWG galvanized wire ties (double strand); the gypsum board is then installed in the manner required for direct attachment.

**4.2.3.2 Alternate Gypsum Board Fasteners:** Screws, either Type W or Type S, depending on the framing member, may be used in lieu of nails in fire-resistance-rated assemblies described in this report or described in Tables 721.1(2) and 721.1(3) of the 2018, 2015 and 2012 IBC (Tables 720.1(2) and 720.1(3) of the 2009 IBC),

provided the screw penetration into the framing member is equivalent to the nail penetration, the screw spacing is the same as the nail spacing, and the cross-sectional area of the screws is equal to that of the specified nails.

**4.2.3.3 Joint Treatment:** For the fire-resistive assemblies in this report, taping and finishing of joints and fasteners is permitted to be omitted in the following cases:

- Where there is square-edge gypsum board or tongue-and-groove-edge (V-edge) gypsum backing board or gypsum sheathing.
- In single-layer applications on wood-framed assemblies where joints fall over framing members.
- On inner layers and outer layers of multiple-layer wood-framed or steel-framed assemblies, where the joints of adjacent layers are offset from each other.

#### **4.3 Sound Control Systems:**

Generic sound control systems, as listed in the Gypsum Association Fire Resistance Design Manual, GA-600 21<sup>st</sup> Edition for the 2018 IBC, 20<sup>th</sup> Edition for the 2015 IBC, or 19<sup>th</sup> edition for the 2012 and 2009 IBC, are recognized for use. The Gypsum Association Fire Resistance Design Manual GA-600 (21<sup>st</sup> Edition), although not specifically listed as a reference standard in the 2009, 2012, or 2015 IBC, is an acceptable alternative to the 19<sup>th</sup> and 20<sup>th</sup> Editions when approved by the code official. Partition systems must be sealed at perimeter and around cut-outs using beads of non-hardening caulking compound, except that tape and joint compound are permitted to be used in lieu of caulking above the top plate in wood-framed systems. Where carpet and pad are specified for the IIC sound rating shown in the manual, the carpet must be a 44-ounce (1492 g/m<sup>2</sup>) wool carpet with a 40-ounce (1356 g/m<sup>2</sup>) hair pad.

Except where otherwise noted in this report, any of the gypsum boards listed in Section 3.0, of the same size, thickness, and core type specified, may be used.

#### **4.4 Allowable Partition Heights:**

**4.4.1 Gypsum Board or Veneer Base:** To comply with 2018 IBC Section 1607.15 (2015 and 2012 IBC Section 1607.14 and 2009 IBC Section 1607.13) and Table 1604.3 of the 2018, 2015 and 2012 IBC, Section 1607.13 and Table 1604.3 of the 2009 IBC, the allowable height limits of non-bearing partitions are as follows:

Partitions utilizing No. 25 gage [minimum 0.0179 inch (0.454 mm) uncoated base-metal thickness] steel channel studs conforming to ASTM C645 must have maximum heights as set forth in a current ICC-ES evaluation report. Mechanical fastening of intermediate studs to the track is not required unless this is specified in the evaluation report.

#### **4.5 Joint Treatment at Areas to Receive Tile:**

Gypsum board joints, including those at all angle intersections, which are under areas to receive tile or wall panels, must be treated with joint compound and tape, but must not be finish-coated. All cut edges and openings around pipes and fixtures must be treated with an approved, water-resistant, flexible compound or caulk. Areas to be tiled that are covered with a joint compound must be skim-coated with bedding adhesive. The bedding adhesive for ceramic tile must conform to ANSI A136.1 for Organic Adhesives for Installation of Ceramic Tile, Type I.

#### **4.6 Exterior Surfaces:**

##### **4.6.1 Exterior Ceiling Surfaces:**

**4.6.1.1 Location:** Exterior gypsum soffit board may be used as a ceiling finish at exterior locations such as carports, open porches, walkways, soffits and similar installations that are horizontal or inclined downward away from the building. Gypsum wallboard is permitted for use as a ceiling finish at exterior horizontal applications not exposed to the weather as defined by Chapter 2 of the 2018 and 2015 IBC (Section 2502 of the 2012 and 2009 IBC), or Section R702.3.5 of the IRC.

**4.6.1.2 Framing:** Maximum spacing of framing members must be 16 inches (406 mm) on center when supporting  $\frac{1}{2}$ -inch-thick (12.7 mm) board, and must be 24 inches (610 mm) on center when supporting  $\frac{5}{8}$ -inch-thick (15.9 mm) board. Gypsum board applications perpendicular to framing members must comply with ASTM C840 (IBC), or Table R702.3.5 of the IRC.

**4.6.1.3 Joints:** In ceiling areas having long runs, the maximum spacing of expansion joints must be 30 feet (9.144 m). A  $\frac{1}{4}$ -inch (6.4 mm) clearance joint is required between gypsum board and adjacent walls, fascia, beams or columns. Fascia boards must extend downward past the ceiling board surface a minimum of  $\frac{1}{4}$  inch (6.4 mm). Exterior gypsum soffit board or gypsum wallboard joints and fastener heads must be provided with joint treatment. An alternate joint treatment is batten strips.

**4.6.1.4 Surface Treatment:** The exterior gypsum soffit board and the gypsum wallboard as allowed by the applicable code must have one of the following surface treatments applied at the jobsite:

- a. One coat of latex exterior paint applied over an oil-base primer.
- b. Two coats of an oil- or alkyd-based exterior paint.

#### 4.7 Thermal Barrier:

Regular gypsum board, a minimum of  $\frac{1}{2}$ -inch (12.7 mm) thick, is permitted to be used as a thermal barrier in accordance with Sections 2603.4 or 2603.5.2 of the IBC or Section R316.4 of the IRC. The gypsum board must be attached in such a manner that it will remain in place for 15 minutes of fire exposure. For walls constructed of wood framing, attachment of the gypsum board in accordance with ASTM C840 (IBC), or IRC Section R702.3.5, is permitted. For other construction, attachment of the gypsum wallboard must comply with a specific ICC-ES evaluation report, or the method of attachment must be qualified by testing in accordance with FM 4880, UL 1040, NFPA 286 or UL 1715 (IBC and IRC).

#### 4.8 Shear Walls:

Table 1 shows maximum allowable shear values for gypsum board shearwalls. Gypsum board must be applied either horizontally or vertically on nominally 2-by-4 (50 by 102 mm) wood studs. Additionally, Section 2505 of the IBC or R602.10 of the IRC is applicable.

### 5.0 CONDITIONS OF USE

The gypsum board wall and ceiling assemblies and interior and exterior applications described in this report comply

with, or are suitable alternatives to what is specified in, those codes listed in Section 1.0 of this report, subject to the following conditions:

- 5.1 Installation must comply with this report, the Gypsum Association's published installation instructions and the applicable code. In the event of a conflict between the Gypsum Association's published installation instructions and this report, this report governs.
- 5.2 Partition construction and heights are as set forth in this report. Indicated stud spacings are maximums. Stud sizes (depths) and gages are minimums.
- 5.3 In jurisdictions adopting the IBC or IRC, gypsum board must not be used to resist seismic forces in structures in Seismic Design Category E or F.
- 5.4 Documentation must be submitted to the code official verifying that the gypsum board products to be installed comply with the applicable standard noted in Section 3.0 of this report.
- 5.5 Calculations and details must be submitted to the code official for approval of structural-use applications.

### 6.0 EVIDENCE SUBMITTED

- 6.1 Reports of testing in accordance with ASTM E119 (UL 263).
- 6.2 Reports of testing in accordance with ASTM E84 (UL 723).
- 6.3 Reports of transverse load testing in accordance with UL 1296.
- 6.4 Reports of sound transmission testing in accordance with ASTM E90 and ASTM E413.
- 6.5 Reports of testing in accordance with ASTM C473.
- 6.6 Reports of racking shear wall testing in accordance with ASTM E72.

### 7.0 IDENTIFICATION

Gypsum boards must be identified by the manufacturer's name, the thickness, the brand name and the ASTM specification. Gypsum board products that have been evaluated by ICC-ES for compliance with the standards indicated in Section 3.0 of this report must also be identified by the ICC-ES report number associated with the specific product.

Bundles of steel studs must be identified as set forth in a current ICC-ES evaluation report on the product. Screws must be identified on the packaging by the name, brand or trademark of the producer or supplier and the ASTM designation.

**TABLE 1—ALLOWABLE SHEAR FOR WIND OR SEISMIC FORCES (pounds per foot)  
FOR VERTICAL DIAPHRAGMS OF GYPSUM BOARD WOOD-FRAMED WALLS<sup>1,2</sup>**

BOARD THICKNESS (in.)	WALL CONSTRUCTION	MINIMUM FASTENER SIZE <sup>3</sup>	MAXIMUM STUD SPACING (in.)	MAXIMUM FASTENER SPACING (in.)		ALLOWABLE SHEAR VALUE (plf)
				Edges	Field	
1/2	Unblocked	5d cooler or wallboard nails	24	7	7	75
				4	4	110
5/8	Unblocked	6d cooler or wallboard nails	24	4	4	145
1/2	Unblocked	No. 6 - 1 1/4-inch screws	16	8	12	60
1/2	Blocked <sup>4</sup>	No. 6 - 1 1/4-inch screws	16	4	16	160
1/2	Blocked <sup>4</sup>	No. 6 - 1 1/4-inch screws	16	4	12	155
1/2	Blocked <sup>4</sup>	No. 6 - 1 1/4-inch screws	24	8	12	70
1/2	Blocked <sup>4</sup>	No. 6 - 1 1/4-inch screws	16	6	12	90
5/8	Unblocked	No. 6 - 1 1/4-inch screws	16	8	12	70
5/8	Blocked <sup>4</sup>	No. 6 - 1 1/4-inch screws	16	8	12	90

For SI: 1 inch = 25.4 mm, 1 plf = 14.6 N/m.

<sup>1</sup>Shear walls are not permitted to resist loads imposed by masonry or concrete construction. See Section 2306.3 of the 2018, 2015 and 2012 IBC, Section 2306.7 of the 2009 IBC, or Section R602.10 of the IRC. Values are for short-term loading from wind or seismic forces. Values must be reduced by 25 percent for normal loading. Values must not be used in IBC Seismic Design Categories E and F.

<sup>2</sup>The shear values are permitted to be additive when identical materials applied as specified in the table are applied to both sides of the wall.

<sup>3</sup>Screws must be Type W or Type S drywall screws.

<sup>4</sup>All board edges must be blocked.