# LATERAL LOAD RESISTING SYSTEMS AND CONNECTIONS WORKSHEET

BACKGROUND

All loads (e.g., vertical loads, lateral loads, impact loads, etc.) on a building or structure must be provided with a continuous path to the foundation. Not only must the individual structural elements and/or structural systems resist and transfer the applied loads to the foundation, the connections must also be designed to resist and transfer the applied loads to the foundation. If all of the connections, structural elements and/or structural systems are not adequately designed, the load path will not be continuous.

The worksheets that appear on the following pages address these connections, structural elements, and/or structural systems. They are divided into 7 categories: DIAPHRAGMS, COLLECTOR ELEMENTS, SHEAR WALLS, BRACED FRAMES, MOMENT-RESISTING WALL FRAMES, ANCHORAGE and OTHER CONNECTIONS. Under each category heading are the category definitions as used in the 2000 International Building Code (IBC).

Consistent with recognized structural engineering practice, the 2000 International Building Code (IBC) requires that a continuous load path to the foundation be provided for all buildings and structures.

DIRECTIONS FOR FILLING OUT THE ACCOMPANYING WORKSHEETS

The size, type, location, spacing, and/or length (for welds) of ALL connections designed and specified in the submitted structural calculations must be shown on the corresponding building plans OR Subsequent Component Submittal. If horizontal shear values for structural systems (e.g., shear walls, diaphragms, diagonal bracing, etc.) are taken from the IBC tables, the design construction of these structural systems (fastener size, fastener type, fastener spacing, minimum penetration of fasteners, framing spacing, etc.) shall be shown on the plans to be constructed AS INDICATED in the IBC Tables for the respective horizontal shear value. If any substitutions in materials, material thickness, connections, connection spacing, etc. are made, the design values in the IBC tables CANNOT be used, unless permitted by table footnotes.

For horizontal shear values that are not listed in the IBC tables, there are two options:

1. Horizontal shear capacity data from a recognized testing agency is submitted for these non-tabular values; OR
2. Horizontal shear capacity data can be determined based on recognized principles of engineering mechanics by using structural panel shear tested values and approved fastener values. Detailed calculations are required to be submitted for this option.

For each of the items listed under the categories on the following pages, you will notice that there is only one blank that precedes the item being requested. If more than one blank is required for a particular item or items, additional worksheets may be copied, completed and submitted to relay all of the structural design and construction specifications. As indicated above, all of the design results are to be clearly shown on the accompanying building plans.

There are four types of responses that can be provided in the blank spaces next to each item. These responses are as follows:

- A TRUE (T) response indicates that the calculations and/or plans reflect the requirement specified in that item OR that the statement in that item is true and/or code-compliant;
- A FALSE (F) response indicates that the calculations and/or plans DO NOT reflect the requirement specified in that item OR that the statement in that item is false and/or non-code-compliant. If the statement is indicated to be false or non-code-compliant, additional information and/or revised plans and calculations may need to be submitted prior to approval. There should not be any FALSE responses to any of the items on the following worksheets.
- A N/A response means “not applicable” and indicates that the item does not apply to the project.
- The fourth type of response requires that an alphanumeric value be entered in the blank provided. This response can either be one of the options given in a particular line item or a design value taken from the Code, a design standard, etc. For example: 6d for the size of nails used in a shear wall, 250 plf for the shear value of a diaphragm, etc

*Every item shown on the following pages should be provided with one of the responses listed above. Another way of indicating “N/A” for a type of structural system(s) is to cross out the entire section. Please do not leave any blank spaces.*

Reset Form

*ALL CONNECTIONS SHALL BE OF SUFFICIENT SIZE AND STRENGTH TO PROVIDE A CONTINUOUS LOAD PATH TO THE FOUNDATION.*

*STRUCTURAL DESIGN CALCULATIONS MUST BE SUBMITTED TO SUBSTANTIATE THE RESPONSES TO EACH OF THE ITEMS NOT HAVING A RESPONSE OF "N/A".*

DIAPHRAGMS (ROOF AND/OR FLOOR)

*The IBC defines a DIAPHRAGM as a horizontal or nearly horizontal system acting to transmit lateral forces to the vertical-resisting elements. When the term "diaphragm" is used, it includes horizontal bracing systems.*

- **General**

_____ Where supported by masonry shear walls, the span-to-width or span-to-depth ratio of floor and/or roof diaphragms do not exceed the values shown in IBC Table 2109.2.1.3.

- **Metal Deck Diaphragms:**

_____ Calculated (actual) shear capacity, in pounds per lineal foot (plf)
_____ Tabular (allowable) shear capacity, in pounds per lineal foot (plf)
_____ Composite metal deck (C) or non-composite deck (NC)
_____ Normal weight concrete (NW) or light weight concrete (LW)
_____ Indicate weight of concrete in pounds per cubic foot (pcf)
_____ Metal deck size and type (e.g., 0.6C, 1.0C, 1.5B, 1.5BI, 2VLI, 3N, etc.)
_____ Metal deck gage (e.g., 22, 20, 18, etc.)
Typical fastener layout (e.g., 36/7, 36/4, 30/4, 32/4, 24/4, etc.)
_____ Support fasteners (puddle welds or screws)
_____ Size of support fasteners (e.g., ¾" puddle weld, #12 TEK screws)
_____ Sidelap fasteners (welded or screws)
_____ Size of sidelap fasteners (e.g., welded, #10 TEK screws)
_____ Number of sidelap fasteners per span
_____ Maximum span between supports

- **Wood Structural Panel Diaphragms** (see IBC Table 2306.3.1):

_____ Calculated (actual) shear capacity, in pounds per lineal foot (plf)
_____ Tabular (allowable) shear capacity, in pounds per lineal foot (plf)
_____ Structural panel grade (e.g., structural I grade, sheathing, etc.)
_____ Span rating (permitted spacing of support framing, inches)
_____ Common nail size or staple length and gage (e.g., 6d, 1½" 16 gage)
_____ Minimum fastener penetration in framing, in inches
_____ Minimum nominal panel thickness, in inches
_____ Minimum nominal width of framing member (2 inches or 3 inches)
_____ Blocked diaphragm (B) or unblocked diaphragm (UB)
_____ Framing case (i.e., Case 1, 2, 3, 4, 5, or 6)
_____ Fastener spacing, in inches (panel edges/intermediate)
_____ Maximum diaphragm aspect ratio is not exceeded (length-to-width limits of IBC 2305.2.3)

- **Load Transfer**

_____ Indicate the lateral unit shear value (in pounds per lineal foot, plf) being transferred to the collector element(s). REMINDER: the connections must be adequately designed to transfer all of the loads.

**COLLECTOR ELEMENTS**

***The IBC defines COLLECTOR ELEMENTS as members that serve to transfer forces between floor diaphragms and members of the lateral-force-resisting system.***

- Collector elements (e.g., bond beams, chords, drag struts, purlin anchors, truss ties, rafter ties, etc.) of sufficient size, capacity and material are provided to ensure adequate load transfer between the horizontal lateral load resisting system(s) and the vertical lateral load resisting systems.

_____ Size, type, or model number (if proprietary, specify manufacturer) of collector element
_____ Calculated (actual) lateral load to be transferred to collector element (in pounds)
_____ Tabular (allowable) lateral capacity of collector element (in pounds)
_____ Calculated (actual) uplift load to be transferred to collector element (in pounds)
_____ Tabular (allowable) uplift capacity of collector element (in pounds)

- Connections of adequate size, type, strength, and spacing is provided to ensure a continuous load path from the horizontal lateral load-resisting member or system to the vertical lateral load-resisting member or system.

_____ Calculated (actual) load on each fastener (in pounds)
_____ Tabular (allowable) capacity of each fastener (in pounds)
_____ Size and type of connections (e.g., 8d R.S. nails)
_____ Number and/or spacing of fasteners (e.g., 6 nails @ 12" o/c.)

_____ Welds: size, type, length and spacing (e.g., ¼" E70XX fillet 3" @ 12" o/c.)
_____ Concrete anchorage design and construction complies with the applicable portions of Allowable Stress Design (IBC Section 1912) or with the applicable portions of Strength Design (IBC Section 1913)

- **Load Transfer**

_____ Indicate the lateral unit shear value (in pounds per lineal foot, plf) being transferred to the shear wall(s). REMINDER: the connections must be adequately designed to transfer all of the loads.

**SHEAR WALLS**

***The IBC defines a SHEAR WALL as a wall designed to resist lateral forces parallel to the plane of the wall.***

**Shear Walls with Openings (IBC Section 2305.3.7)**

*Force Transfer around Openings (IBC Section 2305.3.7.1)*

_____ The maximum aspect ratios of IBC Table 2305.3.3 apply to the overall shear wall, including openings and to each wall pier at the side of an opening.
_____ The height and width of the wall pier(s) are as defined in Section 2305.3.7.1 and Figure 2305.3.4(b).
_____ Design of force transfer around openings is based on a rational analysis.
_____ Adequate detailing of boundary elements around the opening is provided. The IBC defines a BOUNDARY ELEMENT as diaphragms and shear wall boundary members to which sheathing transfers forces. Boundary elements include chords and drag struts at diaphragm and shear wall perimeters, interior openings, discontinuities and re-entrant corners.

*No Force Transfer around Openings (IBC Section 2305.3.7.2)*

_____ The tabulated design shear capacity (in plf), set forth in Table 2306.4.1 is adjusted in accordance with Table 2305.3.7.2 based on the maximum unrestrained opening height and the percentage of full-height sheathing.
_____ The total shear capacity (in pounds) is equal to the adjusted shear capacity (in plf), multiplied by the sum of the widths of the shear wall segments meeting the aspect ratio requirements of Table 2305.3.3.
_____ Overturning restraint at the ends of the shear wall, uplift and shear connections at the base of each shear wall segment, drag struts and collectors are calculated using the unadjusted allowable shear capacity from Table 2306.4.1 or calculated by rational analysis.
_____ Overturning restraint is located at each end of the shear wall adjacent to a shear wall segment meeting a height to width ratio set forth in Table 2305.3.3
_____ The controlling deflection of a blocked shear wall with openings uniformly nailed throughout is taken as the maximum individual deflection of the shear wall segments calculated in accordance with Section 2305.3.2, divided by the appropriate shear capacity adjustment factor calculated in accordance with Section 2305.3.7.2.

**Sheathing on Wood Framing**

- **IBC Section 2305.1.4 – Positive connections and anchorages, capable of resisting the design forces, are provided between the shear panel and the attached components**
- **Wood Structural Panel Sheathing** (see IBC Table 2306.4.1):

_____ Calculated (actual) shear capacity, in pounds per lineal foot (plf)
_____ Tabular (allowable) shear capacity, in pounds per lineal foot (plf)
_____ Structural panel grade (e.g., structural I grade, sheathing, etc.)
_____ Minimum nominal panel thickness, in inches
_____ Minimum fastener penetration in framing, in inches

Panels applied direct to framing:

_____ Size of common or galvanized box nails or staples
_____ Fastener spacing, in inches (panel edges/intermediate)

Panel applied over ½" or 5/8" gypsum sheathing:

_____ Size of common or galvanized box nails or staples
_____ Fastener spacing, in inches (panel edges/intermediate)

_____ Maximum shear wall aspect ratio is not exceeded (height-to-width limits of IBC 2305.3.3)

- **Particleboard Sheathing** (see IBC Table 2306.4.3):

_____ Calculated (actual) shear capacity, in pounds per lineal foot (plf)
_____ Tabular (allowable) shear capacity, in pounds per lineal foot (plf)
_____ Structural panel grade (M-S "Exterior Glue" or M-2 "Exterior Glue")
_____ Minimum nominal panel thickness, in inches
_____ Minimum nail penetration in framing, in inches

Panels applied direct to framing:

_____ Size of common or galvanized box nails
_____ Fastener spacing, in inches (panel edges/intermediate)

- **Lath and Plaster or Gypsum Board Sheathing** (see IBC Table 2306.4.5)

_____ Calculated (actual) shear capacity, in pounds per lineal foot (plf)
_____ Tabular (allowable) shear capacity, in pounds per lineal foot (plf)

_____ Thickness of material
_____ Wall construction (Blocked, unblocked, or two-ply)
_____ Maximum fastener spacing in inches
_____ Minimum fastener size

**Sheathing on Light Framed, Cold-Formed Steel Walls (see IBC Section 2211)**

- **Wood Structural Panel Sheathing**

_____ Nominal shear values used to establish the allowable shear value for wind forces are per IBC Table 2211.1(1) OR are determined by using the principles of mechanics by using wood structural panel shear values and approved fastener values. Submit detailed calculations if the latter option is used.
_____ Orientation of structural panels (parallel or perpendicular to framing)
_____ Screws used to attach plywood and OSB is approved and is a minimum No. 8 flat-head, self-drilling, tapping screws with a minimum head diameter of 0.292-inch (7.42 mm) in accordance with SAE J78. Such screws are of sufficient length to penetrate through the cold-formed steel framing member by at least three exposed threads.

- **Gypsum Board Panel Sheathing**

_____ The shear values listed in IBC Table 2211.1(2) are not cumulative with the shear values of other materials applied to the same wall unless otherwise permitted in IBC Section 2211.4.1
_____ Orientation of gypsum board structural panels is applied perpendicular to framing
_____ Screws used to attach gypsum board is a minimum No. 6 in accordance with ASTM C954. Such screws are of sufficient length to penetrate through the cold-formed steel framing member by at least three exposed threads.

- **Sheet Steel Sheathing**

_____ The nominal shear is based on the values listed in IBC Table 2211.1(1) for wind loads and IBC Table 2211.1(3) for seismic loads. Installing sheathing on both sides of a steel stud wall is not permitted to increase the shear resistance value.
_____ Is the orientation of steel sheets applied perpendicular or parallel to the framing?
_____ Screws used to attach steel sheets is a minimum No. 8 modified truss head. Such screws are of sufficient length to penetrate through the cold-formed steel framing member by at least three exposed threads.

**Structural Masonry Shear Walls**

- **Specify which design method was used:**

_____ Working Stress Design (IBC Section 2107). Specify which section(s) of ACI 530/ASCE 5/TMS 402 was (were) used in the submitted design calculations.
_____ Strength Design (IBC Section 2108).

*IBC Section 2108.9, Reinforced Masonry*

_____ Reinforced masonry is based on the design assumptions of IBC Section 2108.9.1
_____ Out-of-plane reinforced masonry wall loads per IBC Section 2108.9.4.
_____ In-plane reinforced masonry wall loads per IBC Section 2108.9.5.

*IBC Section 2108.10, Plain (unreinforced) masonry*

_____ Flexural strength design of unreinforced masonry is based on the assumptions IBC Section 2108.10.2.
_____ Unreinforced masonry shear strength per IBC Section 2108.10.4.

_____ Empirical Design of Masonry (IBC Section 2109) is NOT to be utilized for any of the conditions listed in Section 2109.1.1. If any one of the three listed conditions is not met, masonry is designed in accordance with the provisions of Section 2107 or Section 2108.

_____ Section 2109.2.1 – Masonry shear walls (using the Empirical Design method) is oriented parallel to the direction of the lateral forces resisted.
_____ Section 2109.2.1.1 – The minimum nominal thickness of masonry shear walls (using the Empirical Design method) is 8 inches (203 mm). Shear walls of one-story buildings are permitted to have a minimum nominal thickness of 6 inches (152 mm).
_____ Section 2109.2.1.2 – The minimum cumulative length of required shear walls (using the Empirical Design method) is 0.4 times the long dimension of the building. Cumulative length of shear walls does not include openings.

- **Lateral Support (IBC Section 2109.4)**

_____ Masonry walls are laterally supported in either the horizontal or the vertical direction at intervals not exceeding those given in Table 2109.4.1.
_____ Lateral support is provided by cross walls, pilasters, buttresses or structural frame members when the limiting distance is taken horizontally; or by floors, roofs acting as diaphragms, or structural frame members when the limiting distance is taken vertically.

**Concrete Shear Walls**

_____ IBC Sections 1909.4 and 1909.6 – Structural plain concrete walls are designed in accordance with these code sections and ACI 318-99, Section 22.4 through 22.6

_____ IBC Section 1909.5 – Precast structural plain concrete walls are designed in accordance with this code section and ACI 318-99, Section 22.9.3.

_____ IBC Section 1910.4.1 – Concrete shear walls used to resist seismic forces in Seismic Design Category C is Ordinary Reinforced Concrete Shear Walls (see Section 1910.2.3) or Special Reinforced Concrete Shear Walls (see Section 1910.2.4)

_____ IBC Section 1910.4.1 – Structural plain concrete walls are <u>not</u> permitted in buildings or structures assigned to Seismic Design Category C.

**Load Transfer**

_____Indicate the lateral unit shear value (in pounds per lineal foot, plf) being transferred to the foundation. REMINDER: the connections must be adequately designed to transfer all of the loads.

**<u>BRACED FRAMES</u>**

***The IBC defines a BRACED FRAME as an essentially vertical truss, or its equivalent, of the concentric or eccentric type that is provided in a building frame system or dual frame system to resist shear.***

- **Bracing members in tension**

_____ Indicate actual (calculated) axial design load on member(s)

_____ Indicate allowable axial design load on member(s)

_____ Size and type of fasteners used (e.g., A325 ¾" bolts, E70XX 3/16" fillet weld 3" long)

_____ Load-bearing capacity of each fastener (in pounds)

_____ Provisions are made to ensure that connections are initially free of slack and that these connections will not progressively deform or loosen under load reversals or repeated loading.

_____ Number of fasteners <u>at each end</u> of the diagonal bracing member (NOTE: the capacity of the group of fasteners at each end is not less than that required for the total calculated axial design load on the diagonal bracing member)

_____ For single diagonal bracing, load reversal on the member is considered and adequately addressed (i.e., where tension bracing member becomes compression bracing member, or vice versa)

- **Bracing members in compression**

_____ Calculated (actual) axial design load on member(s)

_____ Allowable axial design load on member(s)

_____ Size and type of fasteners used (e.g., A325 ¾" bolts, E70XX 3/16" fillet weld 3" long)

_____ Load-bearing capacity of each fastener (in pounds)

_____ Provisions are made to ensure that connections are initially free of slack and that these connections will not progressively deform or loosen under load reversals or repeated loading

_____ For single diagonal bracing, load reversal on the member is considered and adequately addressed (i.e., where compression bracing member becomes tension bracing member, or vice versa)

_____ Maximum allowable unbraced length of compression member is not exceeded

- **Load Transfer**

_____ Indicate the lateral load (in pounds) being transferred to the foundation. REMINDER: the connections must be adequately designed to transfer all of the loads.

**<u>MOMENT-RESISTING WALL FRAMES</u>**

***The IBC defines a MOMENT FRAME as a structural frame in which members and joints are capable of resisting forces by flexure as well as along the axis of the members.***

- **Steel**

_____ Connections for steel moment frames is in accordance with the applicable design standard listed in IBC Section 2204.1

- **Concrete**

_____ IBC Section 1910.3.1 – Concrete moment frames in buildings or structures used to resist seismic forces in Seismic Design Category B is Ordinary Moment Frames.

_____ IBC Section 1910.4.1 – Concrete moment frames in buildings or structures used to resist seismic forces in Seismic Design Category C is Intermediate Moment Frames or Special Moment Frames.

- **Masonry**

_____ Special masonry moment frames (wall frames) is designed in accordance with IBC Section 2108.9.6

- **Load Transfer**

_____ Indicate the lateral load (in pounds) being transferred to the foundation. REMINDER: the connections must be adequately designed to transfer all of the loads.

**ANCHORAGE**

***The IBC defines an ANCHOR as a metallic element used to transmit applied loads.***

- Connections of adequate size, type, strength, and spacing is provided to ensure a continuous load path from the horizontal and/or vertical lateral load-resisting members or systems to the foundation.
- **Wood construction**

_____ Positive, horizontal anchorage is provided to prevent the walls from pulling away from the diaphragm edge (Positive anchorage means that the anchorage does not rely on such things as nail withdrawal or the lateral force on toe-nails).

*Holddowns or Tiedowns*

_____ Size and type
_____ Calculated (actual) tensile load (in pounds)
_____ Allowable tensile capacity (in pounds)
_____ Locations

*Anchor Bolts*

_____ Size, type and spacing
_____ Embedment length (inches)
_____ Calculated (actual) shear load (in pounds)
_____ Allowable shear capacity (in pounds)
_____ Calculated (actual) tensile load (in pounds)
_____ Allowable tensile capacity (in pounds)

- **Steel construction**

_____ Size and type of anchor bolts and baseplates
_____ Capacity and layout of anchor bolts and baseplates

- **Masonry Construction**

_____ IBC Section 2108.6.5 - Anchor bolts is placed so as to meet the edge distance, embedment depth and spacing requirements of ACE 530/ASCE 5/TMS 402.
_____ Empirical design of masonry anchorage is in accordance with the applicable provisions of IBC Section 2109.7. Cite the applicable portion(s) of this code section.

- **Concrete**

_____ Concrete anchorage design and construction complies with the applicable portions of Allowable Stress Design (IBC Section 1912) or with the applicable portions of Strength Design (IBC Section 1913)
_____ Size, type and orientation of doweling and/or hooking of reinforcing bars
_____ Lateral tie size and development length is detailed on plans

**OTHER CONNECTIONS**

***The IBC defines a CONNECTOR as a mechanical device for securing two or more pieces, parts or members together, including anchors, wall ties and fasteners.***

- **Wood Construction**

_____ Connections and fasteners for wood construction is in accordance with the applicable sections of IBC Section 2304.9. Cite the applicable portion(s) of this code section.
_____ All other connections and fasteners for wood construction is designed in accordance with a recognized engineering standard (e.g., NDS). Cite the applicable portion(s) of the design standard used to obtain fastener values.

- **Steel Construction**

_____ Connections and fasteners for steel construction is in accordance with the applicable portion(s) of AISC-ASD, AISC-LRFD, or AISC-HSS. Cite the design manual used and its applicable portion(s).
_____ Anchor bolts is placed in accordance with IBC Section 2209.2

- **Concrete Construction**

_____ Concrete anchorage design and construction complies with the applicable portions of Allowable Stress Design (IBC Section 1912) or with the applicable portions of Strength Design (IBC Section 1913)