AMERICAN WOOD COUNCIL

SDPWS

Special Design Provisions for Wind & Seismic

2015 EDITION

ANSI/AWC SDPWS-2015
Approval date September 8, 2014

Approved American National Standard
ANSI

Updates and Errata
While every precaution has been taken to ensure the accuracy of this document, errors may have occurred during development. Updates or Errata are posted to the American Wood Council website at www.awc.org. Technical inquiries may be addressed to info@awc.org.

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Dedicated to the memory of James E. Russell, who passed away on February 14, 2013. As Chairman of AWC's Wind & Seismic Task Committee since its inception in 2005, Jim gave generously of his time, expertise, and leadership. He was a gifted Committee Chair, advisor, and friend to all at AWC and will be missed immensely.

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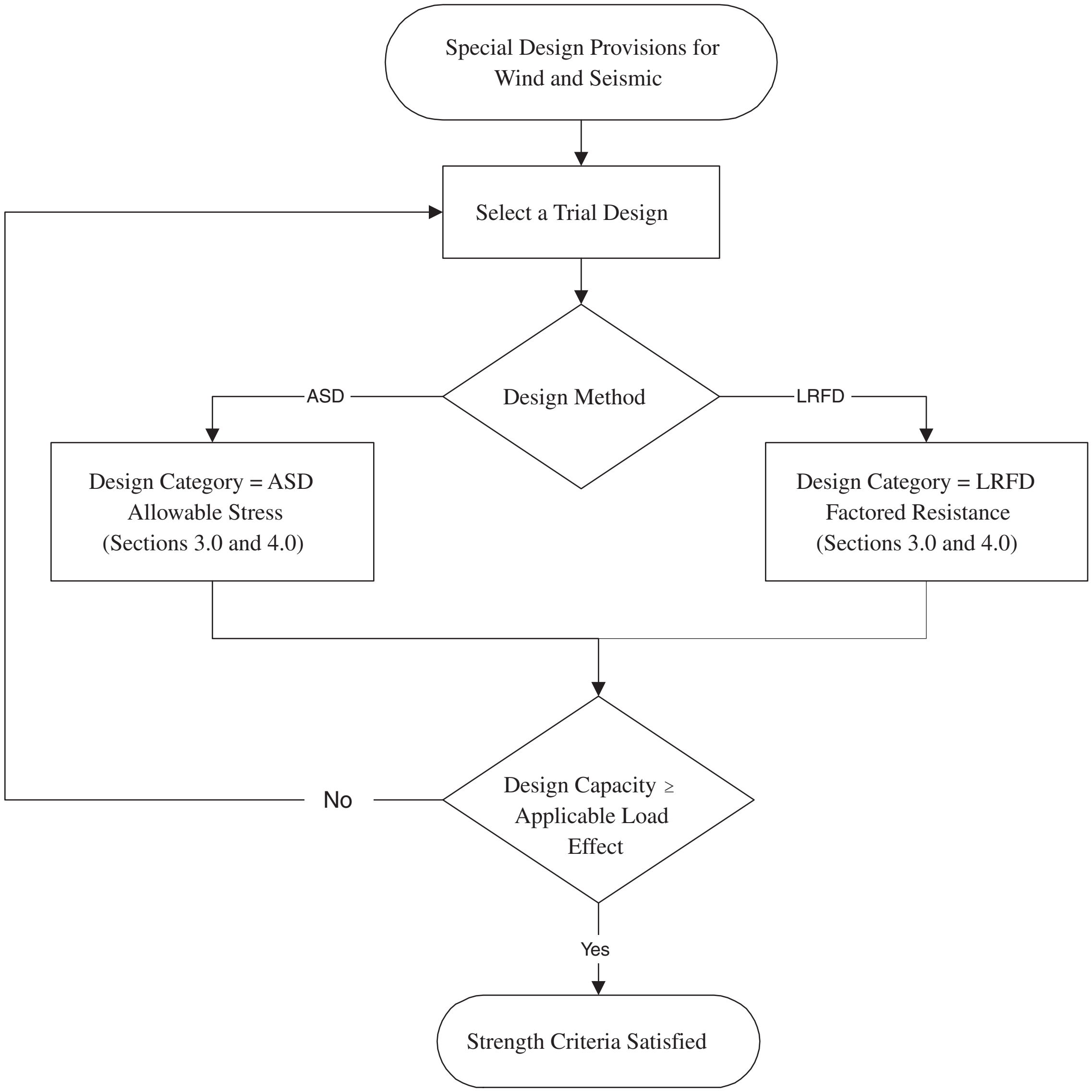
1.1 Flowchart



GENERAL DESIGN REQUIREMENTS

2.1 General

2.1.1 Scope

The provisions of this document cover materials, design and construction of wood members, fasteners, and assemblies to resist wind and seismic forces.

2.1.2 Design Methods

Engineered design of wood structures to resist wind and seismic forces shall be by one of the methods described in 2.1.2.1 and 2.1.2.2.

> **Exception:** Wood structures shall be permitted to be constructed in accordance with prescriptive provisions permitted by the authority having jurisdiction.

2.1.2.1 Allowable Stress Design: Allowable stress design (ASD) shall be in accordance with the *National Design Specification® (NDS®) for Wood Construction* (ANSI/AWC NDS) and provisions of this document.

2.1.2.2 Strength Design: Load and resistance factor design (LRFD) of wood structures shall be in accordance with the *National Design Specification (NDS) for Wood Construction* (ANSI/AWC NDS) and provisions of this document.

2.1.3 Sizes

Wood product sizes are stated in terms of standard nominal, standard net, or special sizes. For wood structural panels produced in accordance with PS 1 or PS 2, use of the term "nominal panel thickness" in this standard refers to the "Performance Category" value for these products.

2.2 Terminology

ALLOWABLE STRESS DESIGN. A method of proportioning structural members and their connections such that stresses do not exceed specified allowable stresses when the structure is subjected to appropriate load combinations (also called working stress design).

ASD REDUCTION FACTOR. A factor to reduce nominal strength to an allowable stress design level.

BOUNDARY ELEMENT. Diaphragm and shear wall boundary members to which sheathing transfers forces. Boundary elements include chords and collectors at diaphragm and shear wall perimeters, interior openings, discontinuities, and re-entrant corners.

CHORD. A boundary element perpendicular to the applied load that resists axial stresses due to the induced moment.

COLLECTOR. A diaphragm or shear wall boundary element parallel to the applied load that collects and transfers diaphragm shear forces to the vertical force-resisting elements or distributes forces within the diaphragm or shear wall.

COMPOSITE PANELS. A wood structural panel comprised of wood veneer and reconstituted wood-based material bonded together with a waterproof adhesive.

DIAPHRAGM. A roof, floor, or other membrane bracing system acting to transmit lateral forces to the vertical resisting elements. When the term "diaphragm" is used, it includes horizontal bracing systems.

DIAPHRAGM, BLOCKED. A diaphragm in which all adjacent panel edges are fastened to either common framing members or common blocking.

DIAPHRAGM BOUNDARY. A location where shear is transferred into or out of the diaphragm sheathing. Transfer is either to a boundary element or to another force-resisting element.

DIAPHRAGM, UNBLOCKED. A diaphragm that has fasteners at boundaries and supporting members only. Blocking between supporting structural members at panel edges is not included.

FIBERBOARD. A fibrous, homogeneous panel made from lignocellulosic fibers (usually wood or cane) and having a density of less than 31 pounds per cubic foot but more than 10 pounds per cubic foot.

FORCE-TRANSFER SHEAR WALL. A shear wall with openings in the wall that has been specifically designed and detailed for force transfer around the openings.

HARDBOARD. A fibrous-felted, homogeneous panel made from lignocellulosic fibers consolidated under heat and pressure in a hot press to a density not less than 31 pounds per cubic foot.

LATERAL STIFFNESS. The inverse of the deformation of shear walls under an applied unit load, or the force required to deform a shear wall a unit distance.

LOAD AND RESISTANCE FACTOR DESIGN (LRFD). A method of proportioning structural members and their connections using load and resistance factors such that no applicable limit state is reached when the structure is subjected to appropriate load combinations.

NOMINAL STRENGTH. Strength of a member, cross section, or connection before application of any strength reduction factors.

OPEN FRONT STRUCTURE. A structure in which any diaphragm edge cantilevers beyond vertical elements of the lateral force-resisting system.

ORIENTED STRAND BOARD. A mat-formed wood structural panel product composed of thin rectangular wood strands or wafers arranged in oriented layers and bonded with waterproof adhesive.

PARTICLEBOARD. A generic term for a panel primarily composed of cellulosic materials (usually wood), generally in the form of discrete pieces or particles, as distinguished from fibers. The cellulosic material is combined with synthetic resin or other suitable bonding system by a process in which the interparticle bond is created by the bonding system under heat and pressure.

PERFORATED SHEAR WALL. A shear wall with openings in the wall that has not been specifically designed and detailed for force transfer around wall openings, and meets the requirements of 4.3.5.3.

PERFORATED SHEAR WALL SEGMENT. A section of a perforated shear wall with full height sheathing that meets the requirements for maximum aspect ratio limits in 4.3.4.

PLYWOOD. A wood structural panel comprised of plies of wood veneer arranged in cross-aligned layers. The plies are bonded with an adhesive that cures on application of heat and pressure.

REQUIRED STRENGTH. Strength of a member, cross section, or connection required to resist factored loads or related internal moments and forces.

RESISTANCE FACTOR. A factor that accounts for deviations of the actual strength from the nominal strength and the manner and consequences of failure.

SEISMIC DESIGN CATEGORY. A classification assigned to a structure based on its Seismic Use Group (see building code) and the severity of the design earthquake ground motion at the site.

SHEAR WALL. A wall designed to resist lateral forces parallel to the plane of a wall.

SHEAR WALL, BLOCKED. A shear wall in which all adjacent panel edges are fastened to either common framing members or common blocking.

SHEAR WALL, UNBLOCKED. A shear wall that has fasteners at boundaries and vertical framing members only. Blocking between vertical framing members at adjacent panel edges is not included.

SHEAR WALL LINE. A series of shear walls in a line at a given story level.

SUBDIAPHRAGM. A portion of a diaphragm used to transfer wall anchorage forces to diaphragm cross ties.

TIE-DOWN (HOLD-DOWN). A device used to resist uplift of the chords of shear walls.

WALL PIER. A section of wall adjacent to an opening and equal in height to the opening, which is designed to resist lateral forces in the plane of the wall according to the force-transfer method (4.3.5.2).

WOOD STRUCTURAL PANEL. A panel manufactured from veneers; or wood strands or wafers; or a combination of veneer and wood strands or wafers; bonded together with waterproof synthetic resins or other suitable bonding systems. Examples of wood structural panels are plywood, oriented strand board (OSB), or composite panels.

2.3 Notation

A = area, in.^{2}

A_o = total area of openings in a perforated shear wall, ft^2

C = compression chord force, lbs

C_o = shear capacity adjustment factor

E = modulus of elasticity, psi

G = specific gravity

G_a = apparent shear stiffness from nail slip and panel shear deformation, kips/in.

G_{ac} = combined apparent shear wall shear stiffness of two-sided shear wall, kips/in.

G_{a1} = apparent shear wall shear stiffness for side 1, kips/in.

G_{a2} = apparent shear wall shear stiffness for side 2, kips/in.

K_{min} = minimum ratio of ν_{s1}/G_{a1} or ν_{s2}/G_{a2}

L = dimension of a diaphragm in the direction perpendicular to the application of force, ft

L' = dimension of cantilevered diaphragm in the direction perpendicular to the application of force and measured as the distance from the edge of the cantilevered diaphragm at the open front to the nearest vertical resisting element of the lateral-force resisting system, ft

ΣL_i = sum of perforated shear wall segment lengths, ft

L_{tot} = total length of a perforated shear wall, ft

R = response modification coefficient

T = tension chord force, lbs

V = induced shear force in perforated shear wall, lbs

W = dimension of a diaphragm in the direction parallel to the application of force and is measured as the distance between diaphragm chords, ft

W' = dimension of a cantilevered diaphragm in the direction parallel to the application of force and is measured as the distance between outermost vertical lateral force resisting elements of the diaphragm, ft

b = length of a shear wall or shear wall segment measured as the sheathed dimension of the shear wall or segment, ft

b_s = length of a shear wall or shear wall segment for determining aspect ratio, ft. For perforated shear walls, use the minimum shear wall segment length included in ΣL_i. For force-transfer shear walls, see 4.3.4.4.

h = height of a shear wall or shear wall segment, ft, measured as:

1. maximum clear height from top of foundation to bottom of diaphragm framing above, ft, or
2. maximum clear height from top of diaphragm below to bottom of diaphragm framing above, ft

r = sheathing area ratio

t = uniform uplift force, lbs/ft

ν = induced unit shear, lbs/ft

ν_{max} = maximum induced unit shear force, lbs/ft

ν_s = nominal unit shear capacity for seismic design, lbs/ft

ν_{sc} = combined nominal unit shear capacity of two-sided shear wall for seismic design, lbs/ft

ν_{s1} = nominal unit shear capacity for designated side 1, lbs/ft

ν_{s2} = nominal unit shear capacity for designated side 2, lbs/ft

ν_w = nominal unit shear capacity for wind design, lbs/ft

ν_{wc} = combined nominal unit shear capacity of two-sided shear wall for wind design, lbs/ft

x = distance from chord splice to nearest support, ft

Δ_a = total vertical elongation of wall anchorage system (including fastener slip, device elongation, rod elongation, etc.), in., at the induced unit shear in the shear wall

Δ_c = diaphragm chord splice slip at the induced unit shear in diaphragm, in.

δ_{dia} = maximum diaphragm deflection determined by elastic analysis, in.

δ_{sw} = maximum shear wall deflection determined by elastic analysis, in.

ϕ_b = sheathing resistance factor for out-of-plane bending

ϕ_z = resistance factor for connections

ϕ_D = sheathing resistance factor for in-plane shear of shear walls and diaphragms

Ω_0 = system overstrength factor

MEMBERS AND CONNECTIONS

3.1 Framing

3.1.1 Wall Framing

In addition to gravity loads, wall framing shall be designed to resist induced wind and seismic forces. The framing shall be designed using the methods referenced in 2.1.2.1 for allowable stress design (ASD) and 2.1.2.2 for strength design (LRFD).

3.1.1.1 Wall Stud Bending Strength and Stiffness Design Value Increase: The reference bending design value, F_b, for sawn lumber wood studs resisting out-of-plane wind loads shall be permitted to be multiplied by the repetitive member factors in Table 3.1.1.1, in lieu of the NDS repetitive member factor, C_r=1.15. The bending stiffness, EI, for sawn lumber studs shall be permitted to be multiplied by the repetitive member factors in Table 3.1.1.1 for the purposes of calculating out-of-plane deflection under wind load. The repetitive member factors in Table 3.1.1.1 apply when studs are designed for bending strength and stiffness, spaced no more than 24" on center, covered on the inside with a minimum of 1/2" gypsum wallboard, attached in accordance with minimum building code requirements and sheathed on the exterior with a minimum of 3/8" (nominal) wood structural panel sheathing with all panel joints occurring over studs or blocking and attached using a minimum of 8d common nails spaced a maximum of 6" on center at panel edges and 12" on center at intermediate framing members.

Table 3.1.1.1 Wall Stud Repetitive Member Factors

Stud Size	System Factor
2x4	1.50
2x6	1.35
2x8	1.25
2x10	1.20
2x12	1.15

3.1.2 Floor Framing

In addition to gravity loads, floor framing shall be designed to resist induced wind and seismic forces. The framing shall be designed using the methods referenced in 2.1.2.1 for allowable stress design (ASD) and 2.1.2.2 for strength design (LRFD).

3.1.3 Roof Framing

In addition to gravity loads, roof framing shall be designed to resist induced wind and seismic forces. The framing shall be designed using the methods referenced in 2.1.2.1 for allowable stress design (ASD) and 2.1.2.2 for strength design (LRFD).

3.2 Sheathing

3.2.1 Wall Sheathing

Exterior wall sheathing and its fasteners shall be capable of resisting and transferring wind loads to the wall framing. Maximum spans and nominal uniform load capacities for wall sheathing materials are given in Table 3.2.1. The ASD allowable uniform load capacities to be used for wind design shall be determined by dividing the nominal uniform load capacities in Table 3.2.1 by an ASD reduction factor of 1.6. The LRFD factored uniform load capacities to be used for wind design shall be determined by multiplying the nominal uniform load capacities in Table 3.2.1 by a resistance factor, ϕ_b, of 0.85. Sheathing used in shear wall assemblies to resist lateral forces shall be designed in accordance with 4.3. Walls sheathed with wood structural panel sheathing or siding that are designed to resist uplift from wind, or combined shear and uplift from wind shall be in accordance with 4.4.

Table 3.2.1 Nominal Uniform Load Capacities (psf) for Wall Sheathing Resisting Out-of-Plane Wind Loads[1]

Sheathing Type[4]	Span Rating or Grade	Minimum Thickness (in.)	Strength Axis[6]							
			Perpendicular to Supports				Parallel to Supports			
			Maximum Stud Spacing (in.)	Actual Stud Spacing (in.)			Maximum Stud Spacing (in.)	Actual Stud Spacing (in.)		
				12	16	24		12	16	24
				Nominal Uniform Loads (psf)				Nominal Uniform Loads (psf)		
Wood Structural Panels (Sheathing Grades, C-C, C-D, C-C Plugged, OSB)[2,5]	24/0	3/8	24	425	240	105	24	90	50	30[3]
	24/16	7/16	24	540	305	135	24	110	60	35[3]
	32/16	15/32	24	625	355	155	24	155	90	45[3]
	40/20	19/32	24	955	595	265	24	255	145	75[3]
	48/24	23/32	24	1160[3]	840[3]	395[3]	24	455[3]	255[3]	115[3]
Particleboard Sheathing (M-S Exterior Glue)		3/8	16	(contact manufacturer)			16	(contact manufacturer)		
		1/2	16				16			
Particleboard Panel Siding (M-S Exterior Glue)		5/8	16	(contact manufacturer)			16	(contact manufacturer)		
		3/4	24				24			
Hardboard Siding (Direct to Studs)	Lap Siding	7/16	16	460	260	-	-	-	-	-
	Shiplap Edge Panel Siding	7/16	24	460	260	115	24	460	260	115
	Square Edge Panel Siding	7/16	24	460	260	115	24	460	260	115
Cellulosic Fiberboard Sheathing	Regular	1/2	16	90	50	-	16	90	50	-
	Structural	1/2	16	135	75	-	16	135	75	-
	Structural	25/32	16	165	90	-	16	165	90	-

1. Nominal capacities shall be adjusted in accordance with Section 3.2.1 to determine ASD uniform load capacity and LRFD uniform resistances.
2. Unless otherwise noted, tabulated values are based on the lesser of nominal values for either OSB or plywood with 3 or more plies.
3. Tabulated values are based on the lesser of nominal values for either OSB or plywood with 4 or more plies.
4. Wood structural panels shall conform to the requirements for its type in DOC PS 1 or PS 2. Particleboard sheathing shall conform to ANSI A208.1. Hardboard panel and siding shall conform to the requirements of ANSI/CPA A135.6. Cellulosic fiberboard sheathing shall conform to ASTM C 208.
5. Tabulated values are for maximum bending loads from wind. Loads are limited by bending or shear stress assuming a 2-span continuous condition. Where panels are continuous over 3 or more spans the tabulated values shall be permitted to be increased in accordance with the *ASD/LRFD Manual for Engineered Wood Construction.*
6. Strength axis is defined as the axis parallel to the face and back orientation of the flakes or the grain (veneer), which is generally the long panel direction, unless otherwise marked.

3.2.2 Floor Sheathing

Floor sheathing shall be capable of resisting and transferring gravity loads to the floor framing. Sheathing used in diaphragm assemblies to resist lateral forces shall be designed in accordance with 4.2.

3.2.3 Roof Sheathing

Roof sheathing and its fasteners shall be capable of resisting and transferring wind and gravity loads to the roof framing. Maximum spans and nominal uniform load capacities for roof sheathing materials are given in Table 3.2.2. The ASD allowable uniform load capacities to be used for wind design shall be determined by dividing the nominal uniform load capacities in Table 3.2.2 by an ASD reduction factor of 1.6. The LRFD factored uniform load capacities to be used for wind design shall be determined by multiplying the nominal uniform load capacities in Table 3.2.2 by a resistance factor, ϕ_b, of 0.85. Sheathing used in diaphragm assemblies to resist lateral forces shall be designed in accordance with 4.2.

Table 3.2.2 Nominal Uniform Load Capacities (psf) for Roof Sheathing Resisting Out-of-Plane Wind Loads[1,2,6]

Sheathing Type[5]	Span Rating or Grade	Minimum Thickness (in.)	Strength Axis[7] Applied Perpendicular to Supports						Strength Axis[7] Applied Parallel to Supports		
			Rafter/Truss Spacing (in.)						Rafter/Truss Spacing (in.)		
			12	16	19.2	24	32	48	12	16	24
			Nominal Uniform Loads (psf)						Nominal Uniform Loads (psf)		
Wood Structural Panels	24/0	3/8	425	240	165	105	-	-	90	50	30[3]
(Sheathing Grades, C-C,	24/16	7/16	540	305	210	135	-	-	110	60	35[3]
C-D, C-C Plugged, OSB)	32/16	15/32	625	355	245	155	90	-	155	90	45[3]
	40/20	19/32	955	595	415	265	150	-	255	145	75[3]
	48/24	23/32	1160[3]	840[3]	615[3]	395[3]	220[3]	100[3]	455[3]	255[3]	115[3]
Wood Structural Panels	16 o.c.	19/32	705	395	275	175	100	-	170	95	50[3]
(Single Floor Grades,	20 o.c.	19/32	815	455	320	205	115	-	235	135	70[3]
Underlayment, C-C Plugged)	24 o.c.	23/32	1160[3]	670[3]	465[3]	300[3]	170[3]	-	440[3]	250[3]	110[3]
	32 o.c.	7/8	1395[4]	1000[4]	695[4]	445[4]	250[4]	110[4]	1160[4]	655[4]	290[4]
	48 o.c.	1-1/8	1790[4]	1295[4]	1060[4]	805[4]	455[4]	200[4]	1790[4]	1145[4]	510[4]

1. Nominal capacities shall be adjusted in accordance with Section 3.2.3 to determine ASD uniform load capacity and LRFD uniform resistances.
2. Unless otherwise noted, tabulated values are based on the lesser of nominal values for either OSB or plywood with 3 or more plies.
3. Tabulated values are based on the lesser of nominal values for either OSB or plywood with 4 or more plies.
4. Tabulated values are based on the lesser of nominal values for either OSB or plywood with 5 or more plies.
5. Wood structural panels shall conform to the requirements for its type in DOC PS 1 or PS 2.
6. Tabulated values are for maximum bending loads from wind. Loads are limited by bending or shear stress assuming a 2-span continuous condition. Where panels are continuous over 3 or more spans, the tabulated values shall be permitted to be increased in accordance with the *ASD/LRFD Manual for Engineered Wood Construction.*
7. Strength axis is defined as the axis parallel to the face and back orientation of the flakes or the grain (veneer), which is generally the long panel direction, unless otherwise marked.

3.3 Connections

Connections resisting induced wind and seismic forces shall be designed in accordance with the methods referenced in 2.1.2.1 for allowable stress design (ASD) and 2.1.2.2 for strength design (LRFD).

3.4 Uplift Force Resisting Systems

3.4.1. General

The proportioning, design, and detailing of engineered wood systems, members, and connections resisting wind uplift shall be in accordance with the reference documents in 2.1.2 and the provisions of 3.4.2. A continuous load path, or paths, with adequate strength and stiffness shall be provided to transfer all forces from the point of application to the final point of resistance.

3.4.2 Design Requirements

Uplift force resisting systems shall comply with the following:

1. Metal connectors, continuous tie rods, or other similar connection devices used in the wind uplift load path shall be of adequate strength and stiffness to transfer induced forces to supporting elements.
2. The design strength and stiffness of wood members and connections used in combination with metal connectors, continuous tie rods, or other similar connection devices shall be determined in accordance with 3.3.
3. Where wind uplift load path connections are not aligned from point of load application to point of resistance, additional forces and deflections resulting from such eccentricities shall be accounted for in the design of supporting load path elements.

Exception: Walls sheathed with wood structural panel sheathing or siding that are designed to resist uplift from wind, or combined shear and uplift from wind shall be in accordance with 4.4.

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4

LATERAL FORCE-RESISTING SYSTEMS

4.1 General

4.1.1 Design Requirements

The proportioning, design, and detailing of engineered wood systems, members, and connections in lateral force-resisting systems shall be in accordance with the reference documents in 2.1.2 and provisions in this chapter. A continuous load path, or paths, with adequate strength and stiffness shall be provided to transfer all forces from the point of application to the final point of resistance.

4.1.2 Shear Capacity

Nominal shear capacities of diaphragms and shear walls are provided for reference assemblies in Tables 4.2A, 4.2B, 4.2C, and 4.2D and Tables 4.3A, 4.3B, 4.3C, and 4.3D, respectively. Alternatively, shear capacity of diaphragms and shear walls shall be permitted to be calculated by principles of mechanics using values of fastener strength and sheathing shear capacity.

4.1.3 Deformation Requirements

Deformation of connections within and between structural elements shall be considered in design such that the deformation of each element and connection comprising the lateral force-resisting system is compatible with the deformations of the other lateral force-resisting elements and connections and with the overall system.

4.1.4 Boundary Elements

Shear wall and diaphragm boundary elements shall be provided to transfer the design tension and compression forces. Diaphragm and shear wall sheathing shall not be used to splice boundary elements. Diaphragm chords and collectors shall be placed in, or in contact with, the plane of the diaphragm framing unless it can be demonstrated that the moments, shears, and deflections, considering eccentricities resulting from other configurations, can be tolerated without exceeding the framing capacity and drift limits.

4.1.5 Wood Members and Systems Resisting Seismic Forces Contributed by Masonry and Concrete Walls

Wood-frame shear walls, wood-frame diaphragms, trusses, and other wood members and systems shall not be used to resist seismic forces contributed by masonry or concrete walls in structures over one story in height.

Exceptions:

1. Wood floor and roof members shall be permitted to be used in diaphragms and horizontal trusses to resist horizontal seismic forces contributed by masonry or concrete walls provided such forces do not result in torsional force distribution through the diaphragm or truss.
2. Vertical wood structural panel sheathed shear walls shall be permitted to be used to provide resistance to seismic forces contributed by masonry or concrete walls in two-story structures, provided the following requirements are met:
   a. Story-to-story wall heights shall not exceed 12'.
   b. Diaphragms shall not be considered to transmit lateral forces by torsional force distribution or cantilever past the outermost supporting shear wall.
   c. Combined deflections of diaphragms and shear walls shall not permit design story drift of supported masonry or concrete walls to exceed the allowable story drift in accordance with Section 12.12.1 of *ASCE 7*.
   d. Wood structural panel diaphragms shall be blocked diaphragms.
   e. Wood structural panel shear walls shall be blocked shear walls and, for the lower story, the sheathing shall have a minimum nominal panel thickness of 15/32".
   f. There shall be no out-of-plane horizontal offsets between the first and second stories of wood structural panel shear walls.

4.1.5.1 Anchorage of Concrete or Masonry Structural Walls to Diaphragms: In Seismic Design Categories C, D, E, or F, diaphragms shall be provided with continuous ties or struts between diaphragm chords to distribute concrete or masonry structural wall anchorage forces in accordance with Section 12.11.2 of ASCE

7 into the diaphragms. Subdiaphragms shall be permitted to be used to transmit the anchorage forces to the main continuous cross-ties. The maximum length-to-width ratio of the structural subdiaphragm shall be 2.5:1. Connections and anchorages capable of resisting the prescribed forces shall be provided between the diaphragm and the attached components.

4.1.5.1.1 Anchorage shall not be accomplished by use of nails subject to withdrawal or toe-nails nor shall wood ledgers or framing be used in cross-grain bending or cross-grain tension.

4.1.5.1.2 The diaphragm sheathing shall not be considered effective as providing the ties or struts required by this section.

4.1.6 Wood Members and Systems Resisting Seismic Forces from Other Concrete or Masonry Construction

Wood members and systems shall be permitted to be used where designed to resist seismic forces from concrete, or masonry components other than walls, including but not limited to: chimneys, fireplaces, concrete or masonry veneers, and concrete floors.

4.1.7 Toe-Nailed Connections

In seismic design categories D, E, and F, the capacity of toe-nailed connections shall not be used when calculating lateral load resistance to transfer seismic lateral forces greater than 150 pounds per lineal foot for ASD and 205 pounds per lineal foot for LRFD from diaphragms to shear walls, collectors, or other elements, or from shear walls to other elements.

4.2 Wood-Frame Diaphragms

4.2.1 Application Requirements

Wood-frame diaphragms shall be permitted to be used to resist lateral forces provided the deflection in the plane of the diaphragm, as determined by calculations, tests, or analogies drawn therefrom, does not exceed the maximum permissible deflection limit of attached load distributing or resisting elements. Permissible deflection shall be that deflection that will permit the diaphragm and any attached elements to maintain their structural integrity and continue to support their prescribed loads as determined by the applicable building code or standard. Framing members, blocking, and connections shall extend into the diaphragm a sufficient distance to develop the force transferred into the diaphragm.

4.2.2 Deflection

Calculations of diaphragm deflection shall account for bending and shear deflections, fastener deformation, chord splice slip, and other contributing sources of deflection.

The diaphragm deflection, δ_{dia}, shall be permitted to be calculated by use of the following equation:

$$\delta_{dia} = \frac{5\nu L^3}{8EAW} + \frac{0.25\nu L}{1000G_a} + \frac{\sum(x\Delta_c)}{2W} \qquad (4.2\text{-}1)$$

where:

E = modulus of elasticity of diaphragm chords, psi

A = area of chord cross-section, in.^{2}

G_a = apparent diaphragm shear stiffness from nail slip and panel shear deformation, kips/in. (from Column A, Tables 4.2A, 4.2B, 4.2C, or 4.2D)

L = diaphragm length, ft

ν = induced unit shear in diaphragm, lbs/ft

W = diaphragm width, ft

x = distance from chord splice to nearest support, ft

Δ_c = diaphragm chord splice slip, in., at the induced unit shear in diaphragm

δ_{dia} = maximum mid-span diaphragm deflection determined by elastic analysis, in.

Alternatively, for wood structural panel diaphragms, deflection shall be permitted to be calculated using a rational analysis where apparent shear stiffness accounts for panel shear deformation and non-linear nail slip in the sheathing-to-framing connection.

4.2.3 Unit Shear Capacities

Tabulated nominal unit shear capacities for seismic design are provided in Column A of Tables 4.2A, 4.2B, 4.2C, and 4.2D; and for wind design in Column B of Tables 4.2A, 4.2B, 4.2C, and 4.2D. The ASD allowable unit shear capacity shall be determined by dividing the tabulated nominal unit shear capacity, modified by applicable footnotes, by the ASD reduction factor of 2.0. The LRFD factored unit resistance shall be determined by multiplying the tabulated nominal unit shear capacity, modified by applicable footnotes, by a resistance factor, ϕ_D, of 0.80. No further increases shall be permitted.

4.2.4 Diaphragm Aspect Ratios

Size and shape of diaphragms shall be limited to the aspect ratios in Table 4.2.4.

Table 4.2.4 Maximum Diaphragm Aspect Ratios (Horizontal or Sloped Diaphragms)

Diaphragm Sheathing Type	Maximum L/W Ratio
Wood structural panel, unblocked	3:1
Wood structural panel, blocked	4:1
Single-layer straight lumber sheathing	2:1
Single-layer diagonal lumber sheathing	3:1
Double-layer diagonal lumber sheathing	4:1

4.2.5 Horizontal Distribution of Shear

The distribution of shear to vertical resisting elements shall be based on an analysis where the diaphragm is modeled as semi-rigid, idealized as flexible, or idealized as rigid. When a diaphragm is idealized as flexible, the diaphragm shear forces shall be distributed to the vertical resisting elements based on tributary area. When a diaphragm is idealized as rigid, the diaphragm shear forces shall be distributed based on the relative lateral stiffnesses of the vertical-resisting elements of the story below. It shall be permitted to idealize a diaphragm as rigid when the computed maximum in-plane deflection of the diaphragm itself under lateral load is less than or equal to two times the average deflection of adjoining vertical elements of the lateral force-resisting system of the associated story under equivalent tributary lateral load.

When a diaphragm is not idealized as rigid or flexible, the diaphragm shear forces shall be distributed to the vertical resisting elements using a semi-rigid diaphragm analysis based on the relative stiffnesses of the diaphragm and the vertical resisting elements accounting for both shear and flexural deformations. In lieu of using a semi-rigid diaphragm analysis for distribution of story shear forces, it shall be permitted to use an enveloped analysis whereby distribution of horizontal diaphragm shear to each vertical resisting element is the larger of the shear forces resulting from analyses where the diaphragm is idealized as flexible and the diaphragm is idealized as rigid.

4.2.5.1 Torsional Irregularity: Structures with wood-frame diaphragms modeled as semi-rigid or idealized as rigid shall be considered as torsionally irregular under seismic load when the maximum story drift, computed from seismic design forces including accidental torsion, at one end of the structure is more than 1.2 times the average of the story drifts at the two ends of the structure. Where a torsional irregularity exists in structures assigned to Seismic Design Category B, C, D, E, or F, diaphragms shall meet all of the following requirements:

1. The diaphragm conforms to 4.2.7.1, 4.2.7.2, or 4.2.7.3.
2. The L/W ratio is not greater than 1.5:1 when sheathed in conformance with 4.2.7.1 or not greater than 1:1 when sheathed in conformance with 4.2.7.2 or 4.2.7.3.
3. The maximum story drift at each edge of the structure shall not exceed the ASCE 7 allowable story drift when subject to seismic design forces including torsion, and accidental torsion.

4.2.5.2 Open Front Structures: For resistance to seismic loads, wood-frame diaphragms in open front structures shall comply with all of the following requirements:

1. The diaphragm conforms to 4.2.7.1, 4.2.7.2, or 4.2.7.3.
2. The L′/W′ ratio (as shown in Figure 4A (a through d)) is not greater than 1.5:1 when

sheathed in conformance with 4.2.7.1 or not greater than 1:1 when sheathed in conformance with 4.2.7.2 or 4.2.7.3. For open front structures that are also torsionally irregular as defined in 4.2.5.1, the L′/W′ ratio shall not exceed 0.67:1 for structures over one story in height, and 1:1 for structures one story in height.

3. For loading parallel to the open side, diaphragms shall be modeled as semi-rigid or idealized as rigid, and the maximum story drift at each edge of the structure shall not exceed the ASCE 7 allowable story drift when subject to seismic design forces including torsion and accidental torsion and shall include shear and bending deformations of the diaphragm.
4. The cantilevered diaphragm length, L′, (normal to the open side) shall not exceed 35 feet.

Exception: Wood frame diaphragms in open front structures in which the diaphragm edge cantilevers no more than six feet beyond the nearest line of vertical elements of the lateral force-resisting system need not comply with Section 4.2.5.2.

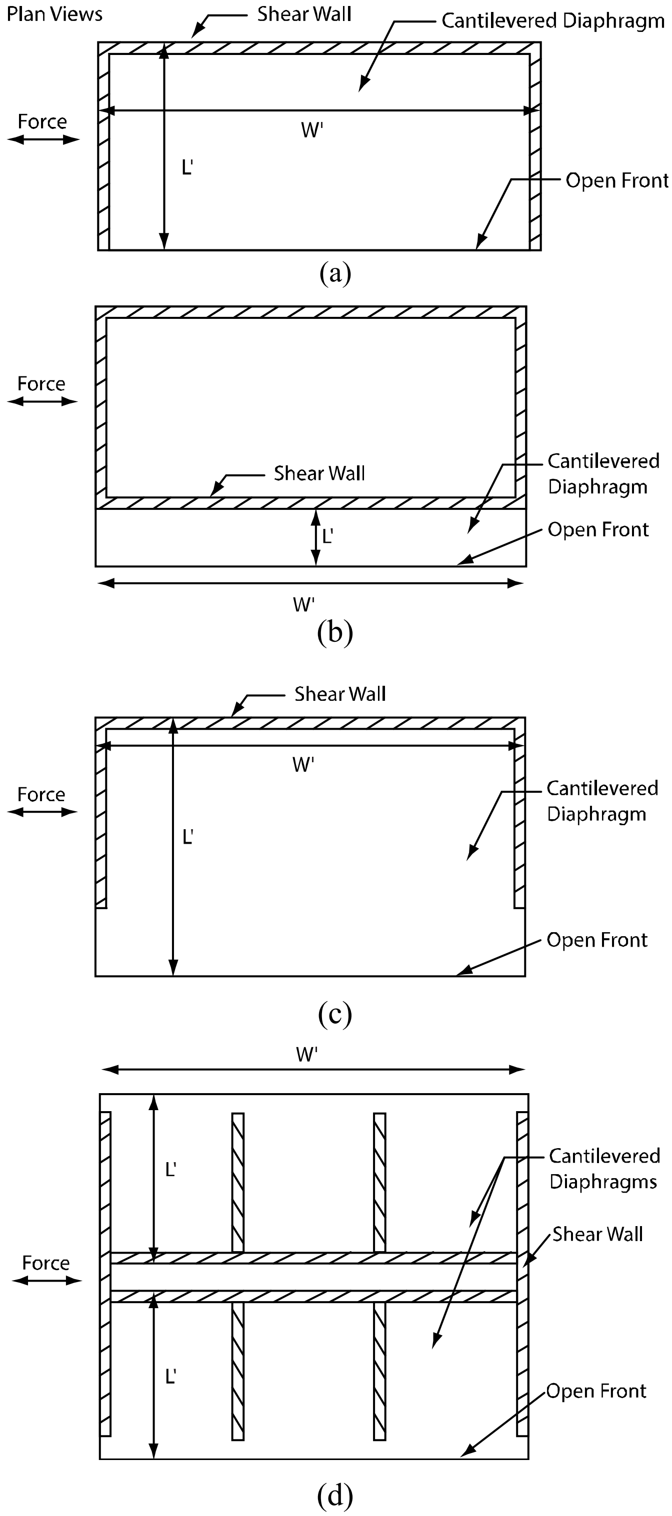
4.2.5.2.1 For open front structures one story in height, where L′ is not more than 25′ and L′/W′ is less than or equal to 1:1, the cantilevered diaphragm defined by L′ x W′ (as shown in Figure 4A) shall be permitted to be idealized as rigid for purposes of distribution of shear forces through torsion.

4.2.6 Construction Requirements

4.2.6.1 Framing Requirements: Diaphragm boundary elements shall be provided to transmit the design tension, compression, and shear forces. Diaphragm sheathing shall not be used to splice boundary elements. Diaphragm chords and collectors shall be placed in, or in contact with, the plane of the diaphragm framing unless it can be demonstrated that the moments, shears, and deflections, considering eccentricities resulting from other configurations, can be tolerated without exceeding the framing capacity and drift limits.

4.2.6.2 Sheathing: Diaphragms shall be sheathed with approved materials. Details on sheathing types and thicknesses for commonly used floor, roof, and ceiling diaphragm assemblies are provided in 4.2.7 and Tables 4.2A, 4.2B, 4.2C, and 4.2D.

Figure 4A Examples of Open Front Structures



4 LATERAL FORCE-RESISTING SYSTEMS

4.2.6.3 Fasteners: Sheathing shall be attached to framing members using nails or other approved fasteners alone, or in combination with adhesives. Nails shall be driven with the head of the nail flush with the surface of the sheathing. Other approved fasteners shall be driven as required for proper installation of that fastener.

4.2.7 Diaphragm Assemblies

4.2.7.1 Wood Structural Panel Diaphragms: Diaphragms sheathed with wood structural panel sheathing shall be permitted to be used to resist seismic and wind forces. Wood structural panel sheathing used for diaphragms that are part of the lateral force-resisting system shall be applied directly to the framing members and blocking.

Exception: Wood structural panel sheathing in a diaphragm is permitted to be fastened over solid lumber planking or laminated decking provided the following requirements are met:

1. Panel edges do not coincide with joints in the lumber planking or laminated decking.
2. Adjacent panel edges parallel to the planks or decking are fastened to a common member.
3. The planking or decking shall be of sufficient thickness to satisfy minimum fastener penetration in framing members and blocking as required in Table 4.2A.
4. Diaphragm aspect ratio (L/W) does not exceed that for a blocked wood structural panel diaphragm (4:1).
5. Diaphragm forces are transferred from wood structural panel sheathing to diaphragm boundary elements through planking or decking or by other methods.

4.2.7.1.1 Blocked Diaphragms: Where diaphragms are designated as blocked, all joints in sheathing shall occur over and be fastened to common framing members or common blocking. The size and spacing of fasteners at wood-frame diaphragm boundaries and panel edges shall be as prescribed in Table 4.2A. The diaphragm shall be constructed as follows:

1. Panels shall not be less than 4' x 8' except at boundaries and changes in framing where minimum panel dimension shall be 24" unless all edges of the undersized panels are supported by and fastened to framing members or blocking.
2. Nails shall be located at least 3/8" from the edges of panels. Maximum nail spacing at panel edges shall be 6" on center. Nails along intermediate framing members and blocking for panels shall be the same size as installed at the panel edges. Maximum nail spacing shall be 6" on center when support spacing of 48" on center is specified and 12" on center for closer support spacings.
3. The width of the nailed face of framing members and blocking shall be 2" nominal or greater at adjoining panel edges except that a 3" nominal or greater width at adjoining panel edges and staggered nailing at all panel edges are required where:
   a. Nail spacing of 2-1/2" on center or less at adjoining panel edges is specified, or
   b. 10d common nails having penetration into framing members and blocking of more than 1-1/2" are specified at 3" on center or less at adjoining panel edges.
4. Wood structural panels shall conform to the requirements for their type in DOC PS1 or PS2.

4.2.7.1.2 High Load Blocked Diaphragms: All joints in sheathing shall occur over and be fastened to common framing members or common blocking. The size and spacing of fasteners at wood-frame diaphragm boundaries and panel edges shall be as prescribed in Table 4.2B and Figure 4B. The diaphragms shall be constructed as follows:

1. Panels shall not be less than 4' x 8' except at boundaries and changes in framing where minimum panel dimension shall be 24" unless all edges of the undersized panels are supported by and fastened to framing members or blocking.
2. Nails shall be located at least 3/8" from panel edges but not less than distances shown in Figure 4B. Maximum nail spacing at panel edges shall be 6" on center. Nails along intermediate framing members for panels shall be the same size as installed at the panel edges. Maximum nail spacing shall be 6" on center when support spacing of greater than 32" on center is specified. Maximum nail spacing shall be 12" on center for specified support spacing of 32" on center or less.
3. In diaphragm boundary members, lines of fasteners shall be equally spaced and fasteners within each line shall be staggered where spacing is 3" on center or less.
4. The depth of framing members and blocking into which the nail penetrates shall be 3" nominal or greater.

5. The width of the nailed face of framing members and blocking at boundaries and adjoining panel edges shall be 3" nominal or greater. The width of the nailed face not located at boundaries or adjoining panel edges shall be 2" nominal or greater.
6. Wood structural panels shall conform to the requirements for their type in DOC PS1 or PS2.

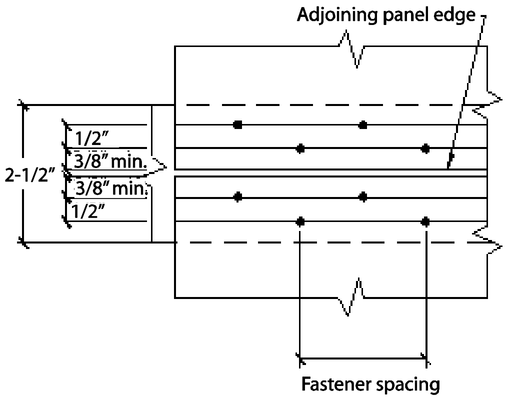
4.2.7.1.3 Unblocked Diaphragms: Where diaphragms are designated as unblocked, the diaphragms shall be constructed as specified in 4.2.7.1.1, except that blocking between supporting structural members at panel edges shall not be required. The size and spacing of fasteners at wood-frame diaphragm boundaries and panel edges shall be as prescribed in Table 4.2C.

4.2.7.2 Diaphragms Diagonally Sheathed with Single-Layer of Lumber: Single diagonally sheathed lumber diaphragms shall be permitted to be used to resist seismic and wind forces. Single diagonally sheathed lumber diaphragms shall be constructed of minimum 1" thick nominal sheathing boards or 2" thick nominal lumber laid at an angle of approximately 45° to the supports. End joints in adjacent boards shall be separated by at least one joist space and there shall be at least two boards between joints on the same support. Nailing of diagonally sheathed lumber diaphragms shall be in accordance with Table 4.2D. Single diagonally sheathed lumber diaphragms shall be permitted to consist of 2" nominal lumber (1-½" thick) where the supports are not less than 3" nominal (2-½" thick) in width or 4" nominal (3-½" deep) in depth.

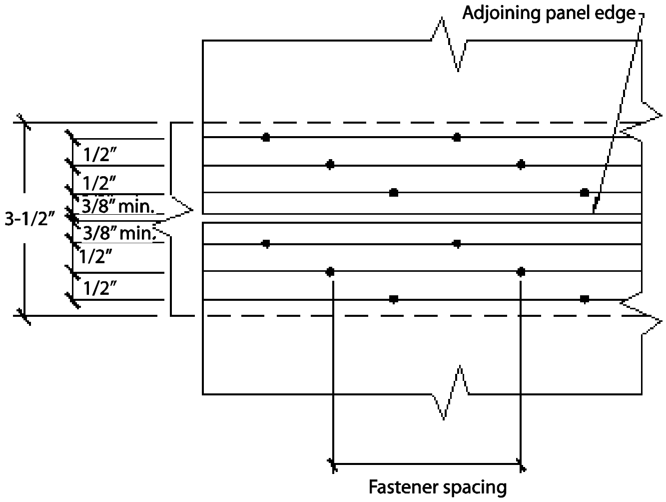
4.2.7.3 Diaphragms Diagonally Sheathed with Double-Layer of Lumber: Double diagonally sheathed lumber diaphragms shall be permitted to be used to resist seismic and wind forces. Double diagonally sheathed lumber diaphragms shall be constructed of two layers of diagonal sheathing boards laid perpendicular to each other on the same face of the supporting members. Each chord shall be considered as a beam with uniform load per foot equal to 50% of the unit shear due to diaphragm action. The load shall be assumed as acting normal to the chord in the plane of the diaphragm in either direction. Nailing of diagonally sheathed lumber diaphragms shall be in accordance with Table 4.2D.

4.2.7.4 Diaphragms Horizontally Sheathed with Single-Layer of Lumber: Horizontally sheathed lumber diaphragms shall be permitted to be used to resist seismic and wind forces. Horizontally sheathed lumber diaphragms shall be constructed of minimum 1" thick nominal sheathing boards or minimum 2" thick nominal lumber laid perpendicular to the supports. End joints in adjacent boards shall be separated by at least one joist space and there shall be at least two boards between joints on the same support. Nailing of horizontally sheathed lumber diaphragms shall be in accordance with Table 4.2D.

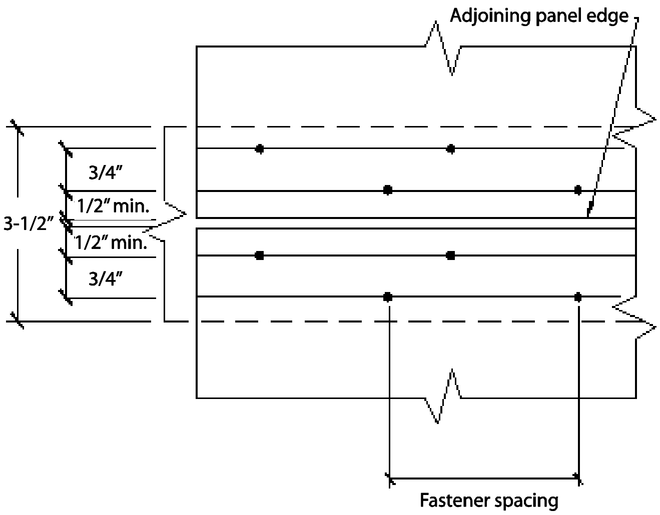
Figure 4B **High Load Diaphragm**



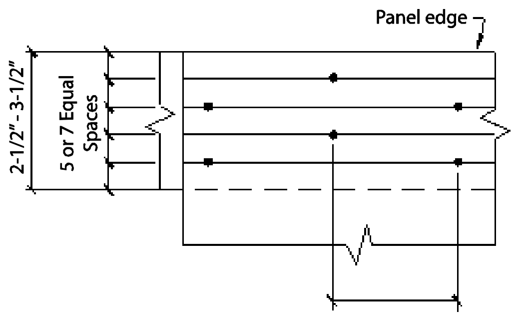
4″ nominal - three lines of fasteners



4″ nominal - three lines of fasteners



4″ nominal - three lines of fasteners



Boundary fastening (two lines staggered is shown)

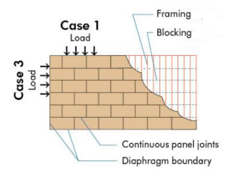
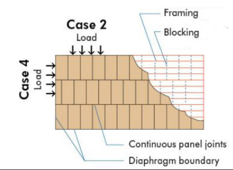
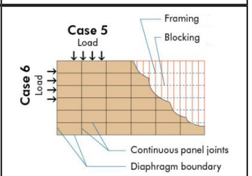
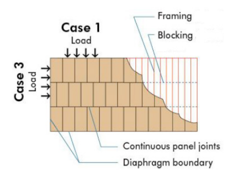
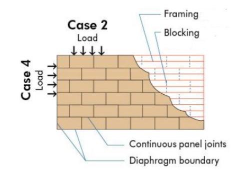
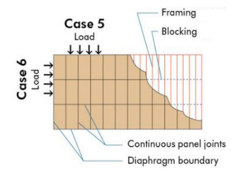
Note: Space adjoining panel edge joists 1/8″. Minimum spacing between lines of fasteners is 3/8″.

Table 4.2A Nominal Unit Shear Capacities for Wood-Frame Diaphragms

Blocked Wood Structural Panel Diaphragms[1,2,3,4,5]

Sheathing Grade	Common Nail Size	Minimum Fastener Penetration in Framing Member or Blocking (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Adjoining Panel Edges and Boundaries (in.)	A SEISMIC												B WIND			
					Nail Spacing (in.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 & 4), and at all panel edges (Cases 5 & 6)												Nail Spacing (in.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 & 4), and at all panel edges (Cases 5 & 6)			
					6			4			2-1/2			2			6	4	2-1/2	2
					Nail Spacing (in.) at other panel edges (Cases 1, 2, 3, & 4)												Nail Spacing (in.) at other panel edges (Cases 1, 2, 3, & 4)			
					6			6			4			3			6	6	4	3
					v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_w (plf)	v_w (plf)	v_w (plf)	v_w (plf)
						OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY				
Structural I	6d	1-1/4	5/16	2	370	15	12	500	8.5	7.5	750	12	10	840	20	15	520	700	1050	1175
				3	420	12	9.5	560	7.0	6.0	840	9.5	8.5	950	17	13	590	785	1175	1330
	8d	1-3/8	3/8	2	540	14	11	720	9.0	7.5	1060	13	10	1200	21	15	755	1010	1485	1680
				3	600	12	10	800	7.5	6.5	1200	10	9.0	1350	18	13	840	1120	1680	1890
	10d	1-1/2	15/32	2	640	24	17	850	15	12	1280	20	15	1460	31	21	895	1190	1790	2045
				3	720	20	15	960	12	9.5	1440	16	13	1640	26	18	1010	1345	2015	2295
Sheathing and Single-Floor	6d	1-1/4	5/16	2	340	15	10	450	9.0	7.0	670	13	9.5	760	21	13	475	630	940	1065
				3	380	12	9.0	500	7.0	6.0	760	10	8.0	860	17	12	530	700	1065	1205
			3/8	2	370	13	9.5	500	7.0	6.0	750	10	8.0	840	18	12	520	700	1050	1175
				3	420	10	8.0	560	5.5	5.0	840	8.5	7.0	950	14	10	590	785	1175	1330
	8d	1-3/8	3/8	2	480	15	11	640	9.5	7.5	960	13	9.5	1090	21	13	670	895	1345	1525
				3	540	12	9.5	720	7.5	6.0	1080	11	8.5	1220	18	12	755	1010	1510	1710
			7/16	2	510	14	10	680	8.5	7.0	1010	12	9.5	1150	20	13	715	950	1415	1610
				3	570	11	9.0	760	7.0	6.0	1140	10	8.0	1290	17	12	800	1065	1595	1805
			15/32	2	540	13	9.5	720	7.5	6.5	1060	11	8.5	1200	19	13	755	1010	1485	1680
				3	600	10	8.5	800	6.0	5.5	1200	9.0	7.5	1350	15	11	840	1120	1680	1890
	10d	1-1/2	15/32	2	580	25	15	770	15	11	1150	21	14	1310	33	18	810	1080	1610	1835
				3	650	21	14	860	12	9.5	1300	17	12	1470	28	16	910	1205	1820	2060
			19/32	2	640	21	14	850	13	9.5	1280	18	12	1460	28	17	895	1190	1790	2045
				3	720	17	12	960	10	8.0	1440	14	11	1640	24	15	1010	1345	2015	2295

1. Nominal unit shear capacities shall be adjusted in accordance with 4.2.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.2.6. For specific requirements, see 4.2.7.1 for wood structural panel diaphragms. See Appendix A for common nail dimensions.
2. For species and grades of framing other than Douglas-Fir-Larch or Southern Pine, reduced nominal unit shear capacities shall be determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor = [1-(0.5-G)], where G = Specific Gravity of the framing lumber from the *NDS* (Table 12.3.3A). The Specific Gravity Adjustment Factor shall not be greater than 1.
3. Apparent shear stiffness values, G_a, are based on nail slip in framing with moisture content less than or equal to 19% at time of fabrication and panel stiffness values for diaphragms constructed with either OSB or 3-ply plywood panels. When 4-ply or 5-ply plywood panels or composite panels are used, G_a values shall be permitted to be multiplied by 1.2.
4. Where moisture content of the framing is greater than 19% at time of fabrication, G_a values shall be multiplied by 0.5.
5. Diaphragm resistance depends on the direction of continuous panel joints with respect to the loading direction and direction of framing members, and is independent of the panel orientation.

	Cases 1&3:Continuous Panel Joints Perpendicular to Framing	**Cases 2&4**: Continuous Panel Joints Parallel to Framing	**Cases 5&6**: Continuous Panel Joints Perpendicular and Parallel to Framing
Long Panel Direction Perpendicular to Supports			
Long Panel Direction Parallel to Supports[a]			

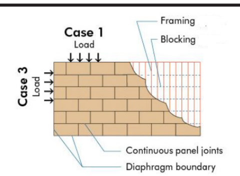
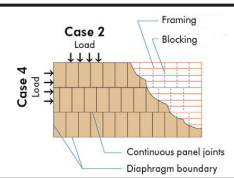
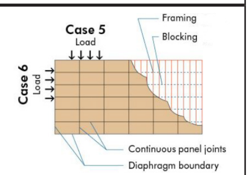
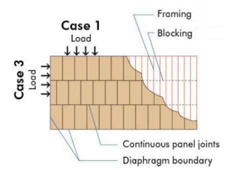
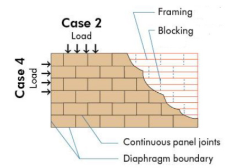
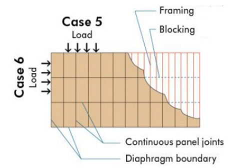
(a) Panel span rating for out-of-plane loads may be lower than the span rating with the long panel direction perpendicular to supports (See Section 3.2.2 and Section 3.2.3)

Table 4.2B Nominal Unit Shear Capacities for Wood-Frame Diaphragms

Blocked Wood Structural Panel Diaphragms Utilizing Multiple Rows of Fasteners (High Load Diaphragms)[1,2,3,4,5]

Sheathing Grade	Common Nail Size	Minimum Fastener Penetration in Framing Member or Blocking (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Adjoining Panel Edges and Boundaries (in.)	Lines of Fasteners	A SEISMIC												B WIND			
						Nail Spacing (in.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 & 4), and at all panel edges (Cases 5 & 6)												Nail Spacing (in.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 & 4), and at all panel edges (Cases 5 & 6)			
						4			4			2-1/2			2-1/2			4	4	2-1/2	2-1/2
						Nail Spacing (in.) at other panel edges (Cases 1, 2, 3, & 4)												Nail Spacing (in.) at other panel edges (Cases 1, 2, 3, & 4)			
						6			4			4			3			6	4	4	3
						v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_w (plf)	v_w (plf)	v_w (plf)	v_w (plf)
							OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY				
Structural I	10d	1-1/2	15/32	3	2	1210	40	24	1630	53	28	1750	50	27	2300	56	29	1695	2280	2450	3220
				4	2	1400	33	21	1830	48	27	2010	44	25	2580	51	28	1960	2560	2815	3610
				4	3	1750	50	27	2440	61	30	2570	59	30	2790	70	32	2450	3415	3600	3905
			19/32	3	2	1340	36	23	1760	52	29	1930	47	27	2510	54	29	1875	2465	2700	3515
				4	2	1560	29	20	1980	46	27	2220	40	25	2880	48	27	2185	2770	3110	4030
				4	3	1930	47	27	2640	60	31	2810	57	30	3580	64	32	2700	3695	3935	5010
			23/32	3	2	1460	33	22	1910	50	29	2100	45	27	2730	53	30	2045	2675	2940	3820
				4	2	1710	26	19	2140	43	27	2420	37	24	3130	45	27	2395	2995	3390	4380
				4	3	2100	45	27	2860	59	32	3050	56	31	3600	68	34	2940	4005	4270	5040
Sheathing and Single-Floor	10d	1-1/2	15/32	3	2	1050	43	21	1450	55	23	1530	53	23	2020	58	24	1470	2030	2140	2830
				4	2	1210	36	19	1630	50	22	1750	46	21	2210	55	23	1695	2280	2450	3095
				4	3	1530	53	23	2170	62	24	2260	61	24	2390	72	26	2140	3040	3165	3345
			19/32	3	2	1300	34	19	1720	49	23	1870	45	22	2450	52	23	1820	2410	2620	3430
				4	2	1510	27	16	1930	43	21	2160	37	20	2740	46	22	2115	2700	3025	3835
				4	3	1870	45	22	2580	57	24	2730	55	24	2970	68	26	2620	3610	3820	4160
			23/32	3	2	1420	30	18	1870	46	23	2040	42	22	2670	50	24	1990	2620	2855	3740
				4	2	1650	24	16	2100	40	21	2350	34	20	2890	45	23	2310	2940	3290	4045
				4	3	2040	42	22	2800	56	25	2960	53	25	3130	71	28	2855	3920	4145	4380

1. Nominal unit shear capacities shall be adjusted in accordance with 4.2.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.2.6. For specific requirements, see 4.2.7.1 for wood structural panel diaphragms. See Appendix A for common nail dimensions.
2. For species and grades of framing other than Douglas-Fir-Larch or Southern Pine, reduced nominal unit shear capacities shall be determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor = [1-(0.5-G)], where G = Specific Gravity of the framing lumber from the *NDS* (Table 12.3.3A). The Specific Gravity Adjustment Factor shall not be greater than 1.
3. Apparent shear stiffness values, G_a, are based on nail slip in framing with moisture content less than or equal to 19% at time of fabrication and panel stiffness values for diaphragms constructed with either OSB or 3-ply plywood panels. When 4-ply or 5-ply plywood panels or composite panels are used, G_a values shall be permitted to be multiplied by 1.2.
4. Where moisture content of the framing is greater than 19% at time of fabrication, G_a values shall be multiplied by 0.5.
5. Diaphragm resistance depends on the direction of continuous panel joints with respect to the loading direction and direction of framing members, and is independent of the panel orientation.

	Cases 1&3:Continuous Panel Joints Perpendicular to Framing	**Cases 2&4**: Continuous Panel Joints Parallel to Framing	**Cases 5&6**: Continuous Panel Joints Perpendicular and Parallel to Framing
Long Panel Direction Perpendicular to Supports			
Long Panel Direction Parallel to Supports[a]			

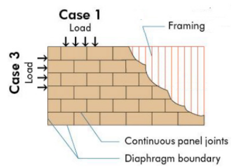
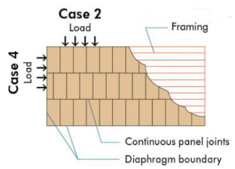
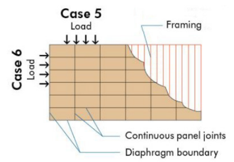
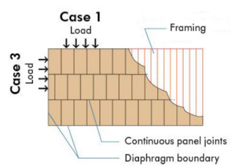
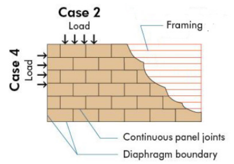
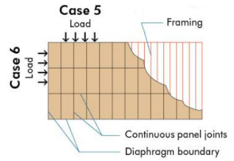
(a) Panel span rating for out-of-plane loads may be lower than the span rating with the long panel direction perpendicular to supports (See Section 3.2.2 and Section 3.2.3)

Table 4.2C Nominal Unit Shear Capacities for Wood-Frame Diaphragms

Unblocked Wood Structural Panel Diaphragms[1,2,3,4,5]

Sheathing Grade	Common Nail Size	Minimum Fastener Penetration in Framing (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Supported Edges and Boundaries (in.)	A SEISMIC: 6 in. Nail Spacing at diaphragm boundaries and supported panel edges						B WIND: 6 in. Nail Spacing at diaphragm boundaries and supported panel edges	
					Case 1			Cases 2,3,4,5,6			Case 1	Cases 2,3,4,5,6
					v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_w (plf)	v_w (plf)
						OSB	PLY		OSB	PLY		
Structural I	6d	1-1/4	5/16	2	330	9.0	7.0	250	6.0	4.5	460	350
				3	370	7.0	6.0	280	4.5	4.0	520	390
	8d	1-3/8	3/8	2	480	8.5	7.0	360	6.0	4.5	670	505
				3	530	7.5	6.0	400	5.0	4.0	740	560
	10d	1-1/2	15/32	2	570	14	10	430	9.5	7.0	800	600
				3	640	12	9.0	480	8.0	6.0	895	670
Sheathing and Single-Floor	6d	1-1/4	5/16	2	300	9.0	6.5	220	6.0	4.0	420	310
				3	340	7.0	5.5	250	5.0	3.5	475	350
			3/8	2	330	7.5	5.5	250	5.0	4.0	460	350
				3	370	6.0	4.5	280	4.0	3.0	520	390
	8d	1-3/8	3/8	2	430	9.0	6.5	320	6.0	4.5	600	450
				3	480	7.5	5.5	360	5.0	3.5	670	505
			7/16	2	460	8.5	6.0	340	5.5	4.0	645	475
				3	510	7.0	5.5	380	4.5	3.5	715	530
			15/32	2	480	7.5	5.5	360	5.0	4.0	670	505
				3	530	6.5	5.0	400	4.0	3.5	740	560
	10d	1-1/2	15/32	2	510	15	9.0	380	10	6.0	715	530
				3	580	12	8.0	430	8.0	5.5	810	600
			19/32	2	570	13	8.5	430	8.5	5.5	800	600
				3	640	10	7.5	480	7.0	5.0	895	670

1. Nominal unit shear capacities shall be adjusted in accordance with 4.2.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.2.6. For specific requirements, see 4.2.7.1 for wood structural panel diaphragms. See Appendix A for common nail dimensions.
2. For species and grades of framing other than Douglas-Fir-Larch or Southern Pine, reduced nominal unit shear capacities shall be determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor = [1-(0.5-G)], where G = Specific Gravity of the framing lumber from the *NDS* (Table 12.3.3A). The Specific Gravity Adjustment Factor shall not be greater than 1.
3. Apparent shear stiffness values, G_a, are based on nail slip in framing with moisture content less than or equal to 19% at time of fabrication and panel stiffness values for diaphragms constructed with either OSB or 3-ply plywood panels. When 4-ply or 5-ply plywood panels or composite panels are used, G_a values shall be permitted to be multiplied by 1.2.
4. Where moisture content of the framing is greater than 19% at time of fabrication, G_a values shall be multiplied by 0.5.
5. Diaphragm resistance depends on the direction of continuous panel joints with respect to the loading direction and direction of framing members, and is independent of the panel orientation.

	Cases 1&3:Continuous Panel Joints Perpendicular to Framing	**Cases 2&4**: Continuous Panel Joints Parallel to Framing	**Cases 5&6**: Continuous Panel Joints Perpendicular and Parallel to Framing
Long Panel Direction Perpendicular to Supports			
Long Panel Direction Parallel to Supports[a]			

(a) Panel span rating for out-of-plane loads may be lower than the span rating with the long panel direction perpendicular to supports (See Section 3.2.2 and Section 3.2.3)

Table 4.2D Nominal Unit Shear Capacities for Wood-Frame Diaphragms

Lumber Diaphragms[1]

Sheathing Material	Sheathing Nominal Dimensions	Type, Size, and Number of Nails per Board: Nailing at Intermediate and End Bearing Supports (Nails/board/support)	Type, Size, and Number of Nails per Board: Nailing at Boundary Members (Nails/board/end)	A SEISMIC v_s (plf)	A SEISMIC G_a (kips/in)	B WIND v_w (plf)
Horizontal Lumber Sheathing	1x6	2-8d common nails (3-8d box nails)	3-8d common nails (5-8d box nails)	100	1.5	140
	1x8	3-8d common nails (4-8d box nails)	4-8d common nails (6-8d box nails)			
	2x6	2-16d common nails (3-16d box nails)	3-16d common nails (5-16d box nails)			
	2x8	3-16d common nails (4-16d box nails)	4-16d common nails (6-16d box nails)			
Diagonal Lumber Sheathing	1x6	2-8d common nails (3-8d box nails)	3-8d common nails (5-8d box nails)	600	6.0	840
	1x8	3-8d common nails (4-8d box nails)	4-8d common nails (6-8d box nails)			
	2x6	2-16d common nails (3-16d box nails)	3-16d common nails (5-16d box nails)			
	2x8	3-16d common nails (4-16d box nails)	4-16d common nails (6-16d box nails)			
Double Diagonal Lumber Sheathing	1x6	2-8d common nails (3-8d box nails)	3-8d common nails (5-8d box nails)	1200	9.5	1680
	1x8	3-8d common nails (4-8d box nails)	4-8d common nails (6-8d box nails)			
	2x6	2-16d common nails (3-16d box nails)	3-16d common nails (5-16d box nails)			
	2x8	3-16d common nails (4-16d box nails)	4-16d common nails (6-16d box nails)			

1. Nominal unit shear capacities shall be adjusted in accordance with 4.2.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.2.6. For specific requirements, see 4.2.7.2 for diaphragms diagonally sheathed with a single-layer of lumber, see 4.2.7.3 for diaphragms diagonally sheathed with a double-layer of lumber, and see 4.2.7.4 for diaphragms horizontally sheathed with a single-layer of lumber. See Appendix A for common and box nail dimensions.

4.3 Wood-Frame Shear Walls

4.3.1 Application Requirements

Wood-frame shear walls shall be permitted to resist lateral forces provided the deflection of the shear wall, as determined by calculations, tests, or analogies drawn therefrom, does not exceed the maximum permissible deflection limit. Permissible deflection shall be that deflection that permits the shear wall and any attached elements to maintain their structural integrity and continue to support their prescribed loads as determined by the applicable building code or standard. Framing members, blocking, and connections shall extend into the shear wall a sufficient distance to develop the force transferred into the shear wall.

4.3.2 Deflection

Calculations of shear wall deflection shall account for bending and shear deflections, fastener deformation, anchorage slip, and other contributing sources of deflection.

The shear wall deflection, δ_{sw}, shall be permitted to be calculated by use of the following equation:

$$\delta_{sw} = \frac{8\nu h^3}{EAb} + \frac{\nu h}{1000G_a} + \frac{h\Delta_a}{b} \qquad (4.3\text{-}1)$$

where:

b = shear wall length, ft

Δ_a = total vertical elongation of wall anchorage system (including fastener slip, device elongation, rod elongation, etc.) at the induced unit shear in the shear wall, in.

E = modulus of elasticity of end posts, psi

A = area of end post cross-section, in.^{2}

G_a = apparent shear wall shear stiffness from nail slip and panel shear deformation, kips/in. (from Column A, Tables 4.3A, 4.3B, 4.3C, or 4.3D)

h = shear wall height, ft

ν = induced unit shear, lbs/ft

δ_{sw} = maximum shear wall deflection determined by elastic analysis, in.

Alternatively, for wood structural panel shear walls, deflection shall be permitted to be calculated using a rational analysis where apparent shear stiffness accounts for panel shear deformation and non-linear nail slip in the sheathing to framing connection.

4.3.2.1 Deflection of Perforated Shear Walls: The deflection of a perforated shear wall shall be calculated in accordance with 4.3.2, where ν in equation 4.3-1 is equal to ν_{max} obtained in equation 4.3-9 and *b* is taken as ΣL_i.

4.3.2.2 Deflection of Unblocked Wood Structural Panel Shear Walls: The deflection of an unblocked wood structural panel shear wall shall be permitted to be calculated in accordance with 4.3.2 using a G_a for 24" stud spacing and nails spaced at 6" on center at panel edges and 12" on center at intermediate framing members. The induced unit shear, ν, in pounds per foot used in Equation 4.3-1 shall be divided by C_{ub}, from Table 4.3.3.2.

4.3.2.3 Deflection of Structural Fiberboard Shear Walls: For a structural fiberboard shear wall with an aspect ratio (h/b_s) greater than 1.0, the deflection obtained from equation 4.3-1 shall be multiplied by $(h/b_s)^{1/2}$.

4.3.3 Unit Shear Capacities

The ASD allowable unit shear capacity shall be determined by dividing the tabulated nominal unit shear capacity, modified by applicable footnotes, by the ASD reduction factor of 2.0. The LRFD factored unit resistance shall be determined by multiplying the tabulated nominal unit shear capacity, modified by applicable footnotes, by a resistance factor, ϕ_D, of 0.80. No further increases shall be permitted.

4.3.3.1 Tabulated Nominal Unit Shear Capacities: Tabulated nominal unit shear capacities for seismic design are provided in Column A of Tables 4.3A, 4.3B, 4.3C, and 4.3D; and for wind design in Column B of Tables 4.3A, 4.3B, 4.3C, and 4.3D.

4.3.3.2 Unblocked Wood Structural Panel Shear Walls: Wood structural panel shear walls shall be permitted to be unblocked provided nails are installed into framing in accordance with Table 4.3.3.2 and the strength is calculated in accordance with Equation 4.3-2. Unblocked shear wall height shall not exceed 16

4

LATERAL FORCE-RESISTING SYSTEMS

feet. Design coefficients and factors for blocked shear walls as specified in 4.3.3 shall be used.

The nominal unit shear capacity of an unblocked wood structural panel shear wall, ν_{ub}, shall be calculated using the following equation:

$$\nu_{ub} = \nu_b C_{ub} \quad (4.3\text{-}2)$$

where:

C_{ub} = Unblocked shear wall adjustment factor rom Table 4.3.3.2

ν_b = Nominal unit shear capacity (lbs/ft) from Table 4.3A for wood structural panel blocked shear walls with 24" stud spacing and nails spaced at 6" on center at panel edges.

ν_{ub} = Nominal unit shear capacity (lbs/ft) for unblocked shear wall.

Table 4.3.3.2 Unblocked Shear Wall Adjustment Factor, C_{ub}

Nail Spacing (in.)		Stud Spacing (in.)			
Supported Edges	Intermediate Framing	12	16	20	24
6	6	1.0	0.8	0.6	0.5
6	12	0.8	0.6	0.5	0.4

4.3.3.3 Summing Shear Capacities: For shear walls sheathed with the same construction and materials on opposite sides of the same wall, the combined nominal unit shear capacity, ν_{sc} or ν_{wc}, shall be permitted to be taken as twice the nominal unit shear capacity for an equivalent shear wall sheathed on one side.

4.3.3.3.1 For seismic design of shear walls sheathed with the same construction and materials on opposite sides of a shear wall, the shear wall deflection shall be calculated using the combined apparent shear wall shear stiffness, G_{ac} and the combined nominal unit shear capacity, ν_{sc}, using the following equations:

$$G_{ac} = G_{a1} + G_{a2} \quad (4.3\text{-}3)$$

$$\nu_{sc} = K_{min} G_{ac} \quad (4.3\text{-}4)$$

where:

G_{ac} = combined apparent shear wall shear stiffness of two-sided shear wall, kips/in.

G_{a1} = apparent shear wall shear stiffness for side 1, kips/in. (from Column A, Tables 4.3A, 4.3B, 4.3C, or 4.3D)

G_{a2} = apparent shear wall shear stiffness for side 2, kips/in. (from Column A, Tables 4.3A, 4.3B, 4.3C, or 4.3D)

K_{min} = minimum ratio of ν_{s1}/G_{a1} or ν_{s2}/G_{a2}

ν_{s1} = nominal unit shear capacity for side 1, lbs/ft (from Column A, Tables 4.3A, 4.3B, 4.3C, or 4.3D)

ν_{s2} = nominal unit shear capacity for side 2, lbs/ft (from Column A, Tables 4.3A, 4.3B, 4.3C, or 4.3D)

ν_{sc} = Combined nominal unit shear capacity of two-sided shear wall for seismic design, lbs/ft

4.3.3.3.2 Nominal unit shear capacities for shear walls sheathed with dissimilar materials on the same side of the wall are not cumulative. For shear walls sheathed with dissimilar materials on opposite sides, the combined nominal unit shear capacity, ν_{sc} or ν_{wc}, shall be either two times the smaller nominal unit shear capacity or the larger nominal unit shear capacity, whichever is greater.

Exception: For wind design, the combined nominal unit shear capacity, ν_{wc}, of shear walls sheathed with a combination of wood structural panels, hardboard panel siding, or structural fiberboard on one side and gypsum wallboard on the opposite side shall equal the sum of the sheathing capacities of each side.

4.3.3.4 Shear Walls in a Line: The provisions of this section are limited to shear distribution to individual shear walls in a shear wall line where the individual shear walls have the same materials and construction.

4.3.3.4.1 Shear distribution to individual shear walls in a shear wall line shall provide the same calculated deflection, δ_{sw}, in each shear wall.

Exceptions:
1. Where nominal shear capacities of all wood structural panel shear walls with aspect ratios (h/b_s) greater than 2:1 are multiplied by $2b_s/h$ for design, shear distribution to individual full-height wall segments shall be permitted to be taken as proportional to the shear capacities of individual full height wall segments used in design. Where multiplied by $2b_s/h$, the nominal shear capacities need not be reduced by the adjustment in 4.3.4.2.

2. Where nominal shear capacities of all structural fiberboard shear walls with aspect ratios (h/b_s) greater than 1:1 are multiplied by $0.1 + 0.9b_s/h$ for design, shear distribution to individual full-height wall segments shall be permitted to be taken as proportional to the shear capacities of individual full height wall segments used in design. Where multiplied by $0.1 + 0.9b_s/h$, the nominal shear capacities need not be reduced by the adjustment in 4.3.4.2.

4.3.3.5 Shear Capacity of Perforated Shear Walls: The nominal shear capacity of a perforated shear wall shall be taken as the tabulated nominal unit shear capacity multiplied by the sum of the shear wall segment lengths, ΣL_i, and the appropriate shear capacity adjustment factor, C_o, from Table 4.3.3.5 or calculated using the following equation:

$$C_o = \left(\frac{r}{3-2r}\right)\frac{L_{tot}}{\sum L_i} \qquad (4.3\text{-}5)$$

$$r = \frac{1}{1+\frac{A_o}{h\sum L_i}} \qquad (4.3\text{-}6)$$

where:

r = sheathing area ratio

L_{tot} = total length of a perforated shear wall including the lengths of perforated shear wall segments and the lengths of segments containing openings, ft

A_o = total area of openings in the perforated shear wall where individual opening areas are calculated as the opening width times the clear opening height, ft^2. Where sheathing is not applied to framing above or below the opening, these areas shall be included in the total area of openings. Where the opening height is less than h/3, an opening height of h/3 shall be used

h = height of the perforated shear wall, ft

ΣL_i = sum of perforated shear wall segment lengths L_i, ft. Lengths of perforated shear wall segments with aspect ratios greater than 2:1 shall be adjusted in accordance with 4.3.4.3.

4.3.4 Shear Wall Aspect Ratios and Capacity Adjustments

4.3.4.1 The size and shape of shear walls shall be limited to the aspect ratios in Table 4.3.4.

4.3.4.2 For wood structural panel shear walls with aspect ratios (h/b_s) greater than 2:1, the nominal shear capacity shall be multiplied by the Aspect Ratio Factor (WSP) = $1.25 - 0.125h/b_s$. For structural fiberboard shear walls with aspect ratios (h/b_s) greater than 1:1, the nominal shear capacity shall be multiplied by the Aspect Ratio Factor (fiberboard) = $1.09 - 0.09\ h/b_s$.

4.3.4.3 Aspect Ratio of Perforated Shear Wall Segments: The aspect ratio limitations of Table 4.3.4 shall apply to perforated shear wall segments within a perforated shear wall as illustrated in Figure 4C. Portions of walls with aspect ratios exceeding 3.5:1 shall not be considered in the sum of shear wall segments. In the design of perforated shear walls, the length of each perforated shear wall segment with an aspect ratio greater than 2:1 shall be multiplied by $2b_s/h$ for the purposes of determining L_i and ΣL_i. The provisions of Section 4.3.4.2 and the exceptions to Section 4.3.3.4.1 shall not apply to perforated shear wall segments.

Table 4.3.3.5 Shear Capacity Adjustment Factor, C_o

Wall Height, h	Maximum Opening Height[1]				
	h/3	h/2	2h/3	5h/6	h
8' Wall	2'-8"	4'-0"	5'-4"	6'-8"	8'-0"
10' Wall	3'-4"	5'-0"	6'-8"	8'-4"	10'-0"
Percent Full-Height Sheathing[2]	**Effective Shear Capacity Ratio**				
10%	1.00	0.69	0.53	0.43	0.36
20%	1.00	0.71	0.56	0.45	0.38
30%	1.00	0.74	0.59	0.49	0.42
40%	1.00	0.77	0.63	0.53	0.45
50%	1.00	0.80	0.67	0.57	0.50
60%	1.00	0.83	0.71	0.63	0.56
70%	1.00	0.87	0.77	0.69	0.63
80%	1.00	0.91	0.83	0.77	0.71
90%	1.00	0.95	0.91	0.87	0.83
100%	1.00	1.00	1.00	1.00	1.00

1 The maximum opening height shall be taken as the maximum opening clear height in a perforated shear wall. Where areas above and/or below an opening remain unsheathed, the height of each opening shall be defined as the clear height of the opening plus the unsheathed areas.

2 The sum of the perforated shear wall segment lengths, $\sum L_i$, divided by the total length of the perforated shear wall, L_{tot}. Lengths of perforated shear wall segments with aspect ratios greater than 2:1 shall be adjusted in accordance with Section 4.3.4.3.

4.3.4.4 Aspect Ratio of Force-transfer Shear Walls: The aspect ratio limitations of Table 4.3.4 shall apply to the overall shear wall including openings and to each wall pier at the sides of openings. The height of a wall pier with an opening on one side shall be defined as the clear height of the pier at the side of the opening. The height of a wall pier with an opening on each side shall be defined as the larger of the clear heights of the pier at the sides of the openings. The length of a wall pier shall be defined as the sheathed length of the pier. Wall piers with aspect ratios exceeding 3.5:1 shall not be considered as portions of force-transfer shear walls.

Table 4.3.4 Maximum Shear Wall Aspect Ratios

Shear Wall Sheathing Type	Maximum h/b_s Ratio
Wood structural panels, unblocked	2:1
Wood structural panels, blocked	3.5:1
Particleboard, blocked	2:1
Diagonal sheathing, conventional	2:1
Gypsum wallboard	2:1[1]
Portland cement plaster	2:1[1]
Structural Fiberboard	3.5:1

1 Walls having aspect ratios exceeding 1.5:1 shall be blocked shear walls.

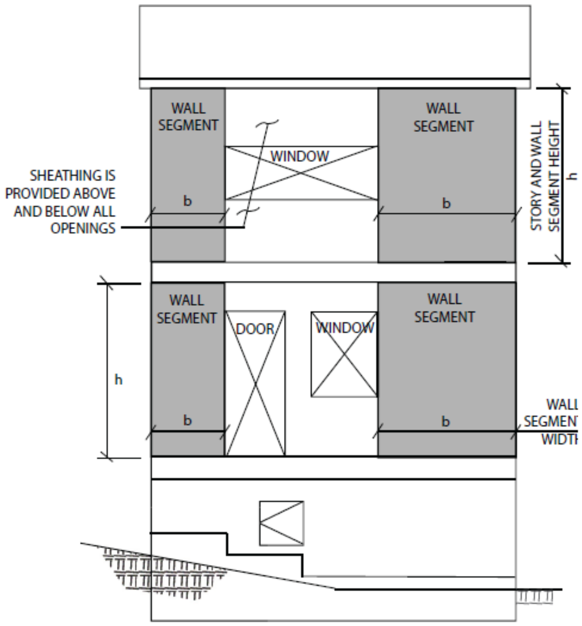
4.3.5 Shear Wall Types

Where individual full-height wall segments are designed as shear walls, the provisions of 4.3.5.1 shall apply. For shear walls with openings, where framing members, blocking, and connections around the openings are designed for force transfer around the openings (force-transfer shear walls) the provisions of 4.3.5.2 shall apply. For shear walls with openings, where framing members, blocking, and connections around the opening are not designed for force transfer around the openings (perforated shear walls) the provisions of 4.3.5.3 shall apply or individual full-height wall segments shall be designed per 4.3.5.1

4.3.5.1 Individual Full-Height Wall Segments: Where individual full-height wall segments are designed as shear walls without openings, the aspect ratio limitations of 4.3.4 shall apply to each full-height wall segment as illustrated in Figure 4D. The following limitations shall apply:

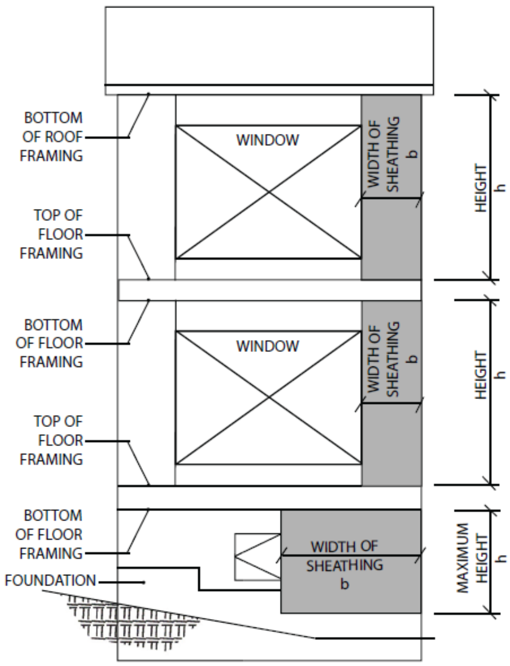
1. Openings shall be permitted to occur beyond the ends of a shear wall. The length of such openings shall not be included in the length of the shear walls.
2. Where out-of-plane offsets occur, portions of the wall on each side of the offset shall be considered as separate shear walls.
3. Collectors for shear transfer to individual full-height wall segments shall be provided.

Figure 4C Typical Shear Wall Height-to-Width Ratio for Perforated Shear Walls



Note: b_s is the minimum shear wall segment length, b, in the perforated shear wall.

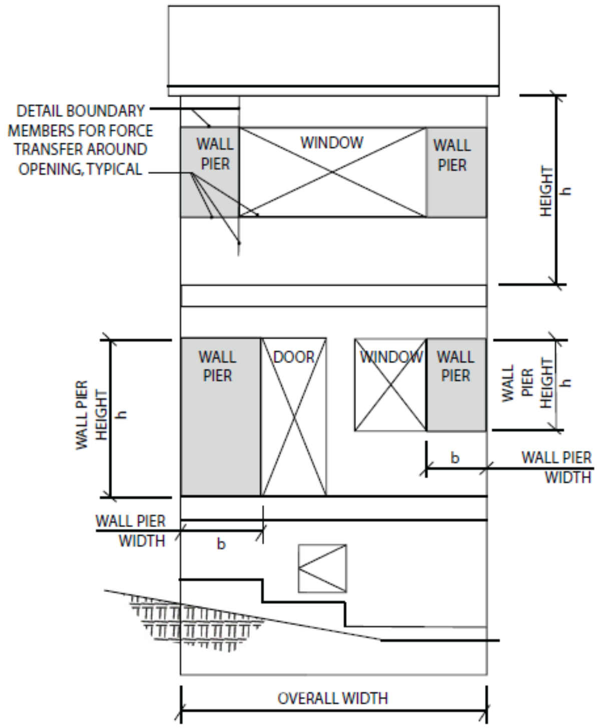
Figure 4D Typical Individual Full-Height Wall Segments Height-to-Width Ratio



4.3.5.2 Force-transfer Shear Walls: Where shear walls with openings are designed for force transfer around the openings, the aspect ratio limitations of 4.3.4.4 shall apply as illustrated in Figure 4E. Design for force transfer shall be based on a rational analysis. The following limitations shall apply:

1. The length of each wall pier shall not be less than 2'.
2. A full-height wall segment shall be located at each end of a force-transfer shear wall.
3. Where out-of-plane offsets occur, portions of the wall on each side of the offset shall be considered as separate force-transfer shear walls.
4. Collectors for shear transfer shall be provided through the full length of the force-transfer shear wall.

Figure 4E Typical Shear Wall Height-to-Width Ratio for Shear Walls Designed for Force Transfer Around Openings



4.3.5.3 Perforated Shear Walls: Where shear walls with openings are not designed for force transfer around the openings, they shall be designed as perforated shear walls. Perforated shear walls shall be sheathed on one or both sides with wood structural panel sheathing. The combined nominal unit shear

capacity of perforated shear walls sheathed with wood structural panel sheathing on one side and gypsum wallboard on the opposite side shall be permitted to be determined in accordance with Section 4.3.3.3.2. The following limitations shall apply:

1. A perforated shear wall segment shall be located at each end of a perforated shear wall. Openings shall be permitted to occur beyond the ends of the perforated shear wall, provided the lengths of such openings are not included in the length of the perforated shear wall.
2. The aspect ratio limitations of Section 4.3.4.3 shall apply.
3. The nominal unit shear capacity for a single-sided wall shall not exceed 1,740 plf for seismic or 2,435 plf for wind as given in Table 4.3A. The nominal unit shear capacity for a double-sided wall shall not exceed 2,435 plf for wind.
4. Where out-of-plane offsets occur, portions of the wall on each side of the offset shall be considered as separate perforated shear walls.
5. Collectors for shear transfer shall be provided through the full length of the perforated shear wall.
6. A perforated shear wall shall have uniform top-of-wall and bottom-of-wall elevations. Perforated shear walls not having uniform elevations shall be designed by other methods.
7. Perforated shear wall height, h, shall not exceed 20'.

4.3.6 Construction Requirements

4.3.6.1 Framing Requirements: All framing members and blocking used for shear wall construction shall be 2" nominal or greater. Where shear walls are designed as blocked, all joints in sheathing shall occur over and be fastened to common framing members or common blocking. Shear wall boundary elements, such as end posts, shall be provided to transmit the design tension and compression forces. Shear wall sheathing shall not be used to splice boundary elements. End posts (studs or columns) shall be framed to provide full end bearing.

4.3.6.1.1 Common Framing Member: Where a common framing member is required at adjoining panel edges, two framing members that are at least 2" in nominal thickness shall be permitted provided they are fastened together with fasteners designed in accordance with the NDS to transfer the induced shear between members. When fasteners connecting the two framing members are spaced less than 4" in center, they shall be staggered.

4.3.6.1.2 Tension and Compression Chords: Tension force, T, and a compression force, C, resulting from shear wall overturning forces at each story level shall be calculated in accordance with the following:

$$T = C = \nu h \qquad (4.3\text{-}7)$$

where:

C = compression force, lbs

h = shear wall height, ft

T = tension force, lbs

ν = induced unit shear, lbs/ft

4.3.6.1.3 Tension and Compression Chords of Perforated Shear Walls: Each end of each perforated shear wall shall be designed for a tension force, T, and a compression force, C. Each end of each perforated shear wall segment shall be designed for a compression force, C, in each segment. For perforated shear walls, the values for T and C resulting from shear wall overturning at each story level shall be calculated in accordance with the following:

$$T = C = \frac{Vh}{C_o \sum L_i} \qquad (4.3\text{-}8)$$

where:

C_o = shear capacity adjustment factor from Table 4.3.3.5

V = induced shear force in perforated shear wall, lbs

ΣL_i = sum of perforated shear wall segment lengths L_i, ft. Lengths of perforated shear wall segments with aspect ratios greater than 2:1 shall be adjusted in accordance with 4.3.4.3.

4.3.6.2 Sheathing: Shear walls shall be sheathed with approved materials attached directly to the framing members, and blocking where required, except as permitted in 4.3.7.2. Details on sheathing types and thicknesses for commonly used shear wall assemblies are provided in 4.3.7 and Tables 4.3A, 4.3B, 4.3C, and 4.3D.

4.3.6.3 Fasteners: Sheathing shall be attached to framing members using nails or other approved fasteners. Nails shall be driven with the head of the nail flush with the surface of the sheathing. Other approved fasteners shall be driven as required for proper installation of that fastener. See Appendix A for common, box, and sinker nail dimensions.

4.3.6.3.1 Adhesives: Adhesive attachment of shear wall sheathing shall not be used alone, or in combination with mechanical fasteners.

Exception: Approved adhesive attachment systems shall be permitted for wind and seismic design in Seismic Design Categories A, B, and C where R = 1.5 and Ω_0 = 2.5, unless other values are approved.

4.3.6.4 Shear Wall Anchorage and Load Path Design of shear wall anchorage and load path shall conform to the requirements of this section, or shall be calculated using principles of mechanics.

4.3.6.4.1 Anchorage for In-plane Shear: Connections shall be provided to transfer the induced unit shear force, ν, into and out of each shear wall.

4.3.6.4.1.1 In-plane Shear Anchorage for Perforated Shear Walls: The maximum induced unit shear force, ν_{max}, transmitted into the top of a perforated shear wall, out of the base of the perforated shear wall at full height sheathing, and into collectors connecting shear wall segments, shall be calculated in accordance with the following:

$$\nu_{max} = \frac{V}{C_o \sum L_i} \qquad (4.3\text{-}9)$$

4.3.6.4.2 Uplift Anchorage at Shear Wall Ends: Where the dead load stabilizing moment is not sufficient to prevent uplift due to overturning moments on the wall (from 4.3.6.1.2 or 4.3.6.1.3), an anchoring device shall be provided at the end of each shear wall.

4.3.6.4.2.1 Uplift Anchorage for Perforated Shear Walls: In addition to the requirements of 4.3.6.4.2, perforated shear wall bottom plates at full height sheathing shall be anchored for a uniform uplift force, t, equal to the unit shear force, ν_{max}, determined in 4.3.6.4.1.1, or calculated by rational analysis.

4.3.6.4.3 Anchor Bolts: Foundation anchor bolts shall have a steel plate washer under each nut not less than 0.229"x3"x3" in size. The hole in the plate washer shall be permitted to be diagonally slotted with a width of up to 3/16" larger than the bolt diameter and a slot length not to exceed 1-3/4", provided a standard cut washer (see Appendix A) is placed between the plate washer and the nut. The plate washer shall extend to within 1/2" of the edge of the bottom plate on the side(s) with sheathing or other material with nominal unit shear capacity greater than 400 plf for wind or seismic.

Exception: Standard cut washers shall be permitted to be used where anchor bolts are designed to resist shear only and the following requirements are met:

a. The shear wall is designed in accordance with provisions of 4.3.5.1 with required uplift anchorage at shear wall ends sized to resist overturning neglecting dead load stabilizing moment.
b. Shear wall aspect ratio, h:b, does not exceed 2:1.
c. The nominal unit shear capacity of the shear wall does not exceed 980 plf for seismic or 1370 plf for wind.

4.3.6.4.4 Load Path: A load path to the foundation shall be provided for uplift, shear, and compression forces. Elements resisting shear wall forces contributed by multiple stories shall be designed for the sum of forces contributed by each story.

4.3.7 Shear Wall Systems

4.3.7.1 Wood Structural Panel Shear Walls: Shear walls sheathed with wood structural panel sheathing shall be permitted to be used to resist seismic and wind forces. The size and spacing of fasteners at shear wall boundaries and panel edges shall be as provided in Table 4.3A. The shear wall shall be constructed as follows:

1. Panels shall not be less than 4' x 8', except at boundaries and changes in framing. All edges of all panels shall be supported by and fastened to framing members or blocking.

   Exception: Horizontal blocking shall be permitted to be omitted, provided that the shear wall is designed in accordance with all of the following:

   a. The deflection of the unblocked wood structural panel shear wall shall be permit-

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ted to be calculated in accordance with Section 4.3.2.2.

b. The strength of the unblocked wood structural panel shear wall is determined in accordance with Section 4.3.3.2, and

c. Specified nail spacing at supported edges is no closer than 6" o.c.

2. Nails shall be located at least 3/8" from the panel edges. Maximum nail spacing at panel edges shall be 6" on center.
3. Nails along intermediate framing members shall be the same size as nails specified for panel edge nailing. At intermediate framing members, the maximum nail spacing shall be 6" on center.

   Exception: Where panels are thicker than 7/16" (nominal) or studs are spaced less than 24" on center, the maximum nail spacing shall be 12" on center.

4. The width of the nailed face of framing members and blocking shall be 2" nominal or greater.
5. Where any of the following conditions occur, the width of the nailed face of a common framing member or blocking at adjoining panel edges shall be 3" nominal or greater and nailing shall be staggered at all panel edges:
   a. Nail spacing of 2" on center at adjoining panel edges is specified, or
   b. 10d common nails having penetration into framing members and blocking of more than 1-1/2" are specified at 3" on center, or less at adjoining panel edges, or
   c. The nominal unit shear capacity on either side of the shear wall exceeds 700 plf in Seismic Design Category D, E, or F.

   In lieu of a single common framing member, two framing members that are at least 2" in nominal thickness shall be permitted where designed in accordance with 4.3.6.1.1.

6. Maximum stud spacing shall be 24" on center.
7. Wood structural panels shall conform to the requirements for its type in DOC PS 1 or PS 2.

4.3.7.2 Shear Walls using Wood Structural Panels over Gypsum Wallboard or Gypsum Sheathing Board: Shear walls sheathed with wood structural panel sheathing over gypsum wallboard or gypsum sheathing board shall be permitted to be used to resist seismic and wind forces. The size and spacing of fasteners at shear wall boundaries and panel edges shall be as provided in Table 4.3B. The shear wall shall be constructed in accordance with Section 4.3.7.1.

4.3.7.3 Particleboard Shear Walls: Shear walls sheathed with particleboard sheathing shall be permitted to be used to resist wind forces and seismic forces in Seismic Design Categories A, B, and C. The size and spacing of fasteners at shear wall boundaries and panel edges shall be as provided in Table 4.3A. The shear wall shall be constructed as follows:

1. Panels shall not be less than 4' x 8', except at boundaries and changes in framing. All edges of all panels shall be supported by and fastened to framing members or blocking.
2. Nails shall be located at least 3/8" from the panel edges. Maximum nail spacing at panel edges shall be 6" on center.
3. Nails along intermediate framing members shall be the same size as nails specified for panel edge nailing. At intermediate framing members, the maximum nail spacing shall be 6" on center.

   Exception: Where panels are thicker than 3/8" (nominal) or studs are spaced less than 24" on center, the maximum nail spacing shall be 12" on center.

4. The width of the nailed face of framing members and blocking shall be 2" nominal or greater.
5. Where any of the following conditions occur, the width of the nailed face of a common framing member or blocking at adjoining panel edges shall be 3" nominal or greater and nailing shall be staggered at all panel edges:
   a. Nail spacing of 2" on center at adjoining panel edges is specified, or
   b. 10d common nails having penetration into framing members and blocking of more than 1-1/2" are specified at 3" on center, or less at adjoining panel edges.

   In lieu of a single common framing member, two framing members that are at least 2" in nominal thickness shall be permitted where designed in accordance with 4.3.6.1.1.

6. Maximum stud spacing shall be 24" on center.
7. Particleboard shall conform to ANSI A208.1.

4.3.7.4 Structural Fiberboard Shear Walls: Shear walls sheathed with fiberboard sheathing shall be permitted to be used to resist wind forces and seismic forces in Seismic Design Categories A, B, and C. The size and spacing of fasteners at shear wall boundaries and panel edges shall be as provided in Table 4.3A. The shear wall shall be constructed as follows:

1. Panels shall not be less than 4' x 8', except at boundaries and changes in framing. All edges of all panels shall be supported by and fastened to framing members or blocking.
2. Nails shall be located at least 3/4" from edges of panels at top and bottom plates and at least 3/8" from all other edges of panels. Maximum nail spacing at panel edges shall be 4" on center.
3. Nails along intermediate framing members and blocking shall be the same size as installed at the panel edges. Maximum nail spacing shall be 6" on center.
4. The width of the nailed face of framing members and blocking shall be 2" nominal or greater at adjoining panel edges.
5. Maximum stud spacing shall be 16" on center.
6. Fiberboard sheathing shall conform to ASTM C 208.

4.3.7.5 Gypsum Wallboard, Gypsum Base for Veneer Plaster, Water-Resistant Gypsum Backing Board, Gypsum Sheathing Board, Gypsum Lath and Plaster, or Portland Cement Plaster Shear Walls: Shear walls sheathed with gypsum wallboard, gypsum base for veneer plaster, water-resistant gypsum backing board, gypsum sheathing board, gypsum lath and plaster, or portland cement plaster shall be permitted to be used to resist wind forces and seismic forces in Seismic Design Categories A, B, C, and D. End joints of adjacent courses of gypsum wallboard or sheathing shall not occur over the same stud. The size and spacing of fasteners at shear wall boundaries, panel edges, and intermediate supports shall be as provided in Table 4.3C. Nails shall be located at least 3/8" from the edges and ends of panels. The width of the nailed face of framing members and blocking shall be 2" nominal or greater.

4.3.7.5.1 Gypsum Wallboard, Gypsum Base for Veneer Plaster, Water-Resistant Gypsum Backing Board: Gypsum wallboard, gypsum base for veneer plaster, or water resistant gypsum backing board shall be applied parallel or perpendicular to studs. Gypsum wallboard shall conform to ASTM C 1396 and shall be installed in accordance with ASTM C 840. Gypsum base for veneer plaster shall conform to ASTM C 1396 and shall be installed in accordance with ASTM C 844. Water-resistant gypsum backing board shall conform to ASTM C 1396 and shall be installed in accordance with ASTM C 840.

4.3.7.5.2 Gypsum Sheathing Board: Four-foot-wide pieces of gypsum sheathing board shall be applied parallel or perpendicular to studs. Two-foot-wide pieces of gypsum sheathing board shall be applied perpendicular to the studs. Gypsum sheathing board shall conform to ASTM C 1396 and shall be installed in accordance with ASTM C 1280.

4.3.7.5.3 Gypsum Lath and Plaster: Gypsum lath shall be applied perpendicular to the studs. Gypsum lath shall conform to ASTM C 1396 and shall be installed in accordance with ASTM C 841. Gypsum plaster shall conform to the requirements of ASTM C 28.

4.3.7.5.4 Expanded Metal or Woven Wire Lath and Portland Cement: Expanded metal or woven wire lath and portland cement shall conform to ASTM C 847, ASTM C 1032, and ASTM C 150 and shall be installed in accordance with ASTM C 926 and ASTM C 1063. Metal lath and lath attachments shall be of corrosion-resistant material.

4.3.7.6 Shear Walls Diagonally Sheathed with Single-Layer of Lumber: Single diagonally sheathed lumber shear walls shall be permitted to be used to resist wind forces and seismic forces in Seismic Design Categories A, B, C, and D. Single diagonally sheathed lumber shear walls shall be constructed of minimum 1" thick nominal sheathing boards laid at an angle of approximately 45° to the supports. End joints in adjacent boards shall be separated by at least one stud space and there shall be at least two boards between joints on the same support. Nailing of diagonally sheathed lumber shear walls shall be in accordance with Table 4.3D.

4.3.7.7 Shear Walls Diagonally Sheathed with Double-Layer of Lumber: Double diagonally sheathed lumber shear walls shall be permitted to be used to resist wind forces and seismic forces in Seismic Design Categories A, B, C, and D. Double diagonally sheathed lumber shear walls shall be constructed of two layers of 1" thick nominal diagonal sheathing boards laid perpendicular to each other on the same face of the supporting members. Nailing of diagonally

sheathed lumber shear walls shall be in accordance with Table 4.3D.

4.3.7.8 Shear Walls Horizontally Sheathed with Single-Layer of Lumber: Horizontally sheathed lumber shear walls shall be permitted to be used to resist wind forces and seismic forces in Seismic Design Categories A, B, and C. Horizontally sheathed lumber shear walls shall be constructed of minimum 1" thick nominal sheathing boards applied perpendicular to the supports. End joints in adjacent boards shall be separated by at least one stud space and there shall be at least two boards between joints on the same support. Nailing of horizontally sheathed lumber shear walls shall be in accordance with Table 4.3D.

4.3.7.9 Shear Walls Sheathed with Vertical Board Siding: Vertical board siding shear walls shall be permitted to be used to resist wind forces and seismic forces in Seismic Design Categories A, B, and C. Vertical board siding shear walls shall be constructed of minimum 1" thick nominal sheathing boards applied directly to studs and blocking. Nailing of vertical board siding shear walls shall be in accordance with Table 4.3D.

Table 4.3A Nominal Unit Shear Capacities for Wood-Frame Shear Walls[1,3,6,7]

Wood-based Panels[4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimun Fastener Penetration in Framing Member or Blocking (in.)	Fastener Type & Size	A SEISMIC												B WIND			
				Panel Edge Fastener Spacing (in.)												Panel Edge Fastener Spacing (in.)			
				6			4			3			2			6	4	3	2
				v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_w (plf)	v_w (plf)	v_w (plf)	v_w (plf)
			Nail (common or galvanized box)		OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY				
Wood Structural Panels - Structural I[4,5]	5/16	1-1/4	6d	400	13	10	600	18	13	780	23	16	1020	35	22	560	840	1090	1430
	3/8[2]	1-3/8	8d	460	19	14	720	24	17	920	30	20	1220	43	24	645	1010	1290	1710
	7/16[2]			510	16	13	790	21	16	1010	27	19	1340	40	24	715	1105	1415	1875
	15/32			560	14	11	860	18	14	1100	24	17	1460	37	23	785	1205	1540	2045
	15/32	1-1/2	10d	680	22	16	1020	29	20	1330	36	22	1740	51	28	950	1430	1860	2435
Wood Structural Panels – Sheathing[4,5]	5/16	1-1/4	6d	360	13	9.5	540	18	12	700	24	14	900	37	18	505	755	980	1260
	3/8			400	11	8.5	600	15	11	780	20	13	1020	32	17	560	840	1090	1430
	3/8[2]	1-3/8	8d	440	17	12	640	25	15	820	31	17	1060	45	20	615	895	1150	1485
	7/16[2]			480	15	11	700	22	14	900	28	17	1170	42	21	670	980	1260	1640
	15/32			520	13	10	760	19	13	980	25	15	1280	39	20	730	1065	1370	1790
	15/32	1-1/2	10d	620	22	14	920	30	17	1200	37	19	1540	52	23	870	1290	1680	2155
	19/32			680	19	13	1020	26	16	1330	33	18	1740	48	22	950	1430	1860	2435
Plywood Siding			Nail (galvanized casing)																
	5/16	1-1/4	6d	280	13		420	16		550	17		720	21		390	590	770	1010
	3/8	1-3/8	8d	320	16		480	18		620	20		820	22		450	670	870	1150
Particleboard Sheathing - (M-S "Exterior Glue" and M-2 "Exterior Glue")			Nail (common or galvanized box)																
	3/8		6d	240	15		360	17		460	19		600	22		335	505	645	840
	3/8		8d	260	18		380	20		480	21		630	23		365	530	670	880
	1/2			280	18		420	20		540	22		700	24		390	590	755	980
	1/2		10d	370	21		550	23		720	24		920	25		520	770	1010	1290
	5/8			400	21		610	23		790	24		1040	26		560	855	1105	1455
Structural Fiberboard Sheathing	1/2		Nail (galvanized roofing) 11 ga. galv. roofing nail (0.120" x 1-1/2" long x 7/16" head)				340	4.0		460	5.0		520	5.5			475	645	730
	25/32		11 ga. galv. roofing nail (0.120" x 1-3/4" long x 3/8" head)				340	4.0		460	5.0		520	5.5			475	645	730

1. Nominal unit shear capacities shall be adjusted in accordance with 4.3.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.3.6. For specific requirements, see 4.3.7.1 for wood structural panel shear walls, 4.3.7.2 for particleboard shear walls, and 4.3.7.3 for fiberboard shear walls. See Appendix A for common and box nail dimensions.
2. Shears are permitted to be increased to values shown for 15/32 inch (nominal) sheathing with same nailing provided (a) studs are spaced a maximum of 16 inches on center, or (b) panels are applied with long dimension across studs.
3. For species and grades of framing other than Douglas-Fir-Larch or Southern Pine, reduced nominal unit shear capacities shall be determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor = [1-(0.5-G)], where G = Specific Gravity of the framing lumber from the NDS (Table 12.3.3A). The Specific Gravity Adjustment Factor shall not be greater than 1.
4. Apparent shear stiffness values G_a, are based on nail slip in framing with moisture content less than or equal to 19% at time of fabrication and panel stiffness values for shear walls constructed with either OSB or 3-ply plywood panels. When 4-ply or 5-ply plywood panels or composite panels are used, G_a values shall be permitted to be multiplied by 1.2.
5. Where moisture content of the framing is greater than 19% at time of fabrication, G_a values shall be multiplied by 0.5.
6. Where panels are applied on both faces of a shear wall and nail spacing is less than 6" on center on either side, panel joints shall be offset to fall on different framing members as shown below. Alternatively, the width of the nailed face of framing members shall be 3" nominal or greater at adjoining panel edges and nails at all panel edges shall be staggered.
7. Galvanized nails shall be hot-dipped or tumbled.

Table 4.3B Nominal Unit Shear Capacities for Wood-Frame Shear Walls[1,2,5,6]

Wood Structural Panels Applied over 1/2" or 5/8" Gypsum Wallboard or Gypsum Sheathing Board

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimum Fastener Penetration in Framing Member or Blocking (in.)	Fastener Type & Size	A SEISMIC Panel Edge Fastener Spacing (in.)												B WIND Panel Edge Fastener Spacing (in.)			
				6			4			3			2			6	4	3	2
				v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_w (plf)	v_w (plf)	v_w (plf)	v_w (plf)
			Nail (common or galvanized box)		OSB	PLY		OSB	PLY		OSB	PLY		OSB	PLY				
Wood Structural Panels - Structural I[3,4]	5/16	1-1/4	8d	400	13	10	600	18	13	780	23	16	1020	35	22	560	840	1090	1430
	3/8, 7/16, 15/32	1-3/8	10d	560	14	11	860	18	14	1100	24	17	1460	37	23	785	1205	1540	2045
Wood Structural Panels - Sheathing[3,4]	5/16	1-1/4	8d	360	13	9.5	540	18	12	700	24	14	900	37	18	505	755	980	1260
	3/8			400	11	8.5	600	15	11	780	20	13	1020	32	17	560	840	1090	1430
	3/8, 7/16, 15/32	1-3/8	10d	520	13	10	760	19	13	980	25	15	1280	39	20	730	1065	1370	1790
			Nail (galvanized casing)																
Plywood Siding	5/16	1-1/4	8d (2-1/2" x0.113")	280		13	420		16	550		17	720		21	390	590	770	1010
	3/8	1-3/8	10d (3"x0.128")	320		16	480		18	620		20	820		22	450	670	870	1150

1. Nominal unit shear capacities shall be adjusted in accordance with 4.3.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.3.6. For specific requirements, see 4.3.7.1 for wood structural panel shear walls. See Appendix A for common and box nail dimensions.
2. For species and grades of framing other than Douglas-Fir-Larch or Southern Pine, reduced nominal unit shear capacities shall be determined by multiplying the tabulated nominal unit shear capacity by the Specific Gravity Adjustment Factor = [1-(0.5-G)], where G = Specific Gravity of the framing lumber from the *NDS* (Table 12.3.3A). The Specific Gravity Adjustment Factor shall not be greater than 1.
3. Apparent shear stiffness values, G_a, are based on nail slip in framing with moisture content less than or equal to 19% at time of fabrication and panel stiffness values for shear walls constructed with either OSB or 3 ply plywood panels. When 4-ply or 5-ply plywood panels or composite panels are used, G_a values for plywood shall be permitted to be multiplied by 1.2.
4. Where moisture content of the framing is greater than 19% at time of fabrication, G_a values shall be multiplied by 0.5.
5. Where panels are applied on both faces of a shear wall and nail spacing is less than 6" on center on either side, panel joints shall be offset to fall on different framing members. Alternatively, the width of the nailed face of framing members shall be 3" nominal or greater at adjoining panel edges and nails at all panel edges shall be staggered.
6. Galvanized nails shall be hot-dipped or tumbled.

Table 4.3C Nominal Unit Shear Capacities for Wood-Frame Shear Walls[1]

Gypsum and Portland Cement Plaster

Sheathing Material	Material Thickness	Fastener Type & Size[2]	Max. Fastener Edge Spacing (in)[3]	Max. Stud Spacing (in.)		A SEISMIC v_s (plf)	A SEISMIC G_a (kips/in)	B WIND v_w (plf)
Gypsum wallboard, gypsum base for veneer plaster, or water-resistant gypsum backing board	1/2"	5d cooler (0.086" x 1-5/8" long, 15/64" head) or wallboard nail (0.086" x 1-5/8" long, 9/32" head) or 0.120" nail x 1-1/2" long, min 3/8" head	7	24	unblocked	150	4.0	150
			4	24	unblocked	220	6.0	220
			7	16	unblocked	200	5.5	200
			4	16	unblocked	250	6.5	250
			7	16	blocked	250	6.5	250
			4	16	blocked	300	7.5	300
		No. 6 Type S or W drywall screws 1-1/4" long	8/12	16	unblocked	120	3.5	120
			4/16	16	blocked	320	8.0	320
			4/12	24	blocked	310	8.0	310
			8/12	16	blocked	140	4.0	140
			6/12	16	blocked	180	5.0	180
	5/8"	6d cooler (0.092" x 1-7/8" long, 1/4" head) or wallboard nail (0.0915" x 1-7/8" long, 19/64" head) or 0.120" nail x 1-3/4" long, min 3/8" head	7	24	unblocked	230	6.0	230
			4	24	unblocked	290	7.5	290
			7	16	blocked	290	7.5	290
			4	16	blocked	350	8.5	350
		No. 6 Type S or W drywall screws 1-1/4" long	8/12	16	unblocked	140	4.0	140
			8/12	16	blocked	180	5.0	180
	5/8" (Two-Ply)	Base ply--6d cooler (0.092" x 1-7/8" long, 1/4" head) or wallboard nail (0.0915" x 1-7/8" long, 19/64" head) or 0.120"nail x 1-3/4" long, min 3/8" head Face ply--8d cooler (0.113" x 2-3/8" long, 0.281" head) or wallboard nail (0.113" x 2-3/8" long, 3/8" head) or 0.120" nail x 2-3/8" long, min 3/8" head	Base: 9 Face: 7	16	blocked	500	11	500
Gypsum sheathing board	1/2" x 2' x 8'	0.120" nail x 1-3/4" long, 7/16" head, diamond-point, galvanized	4	16	unblocked	150	4.0	150
	1/2" x 4'		4	24	blocked	350	8.5	350
			7	16	unblocked	200	5.5	200
	5/8" x 4'	6d galvanized cooler (0.092" x 1-7/8" long, 1/4" head) or wallboard nail (0.0915" x 1-7/8" long, 19/64" head) or 0.120" nail x 1-3/4" long, min 3/8" head	4/7	16	blocked	400	9.5	400
Gypsum lath, plain or perforated with vertical joints staggered	3/8" lath and ½" plaster	0.092"x 1-1/8" long, 19/64" head, gypsum wallboard blued nail or 0.120" nail x1-1/4" long, min 3/8" head	5	16	unblocked	360	9.0	360
Gypsum lath, plain or perforated	3/8" lath and 1/2" plaster	0.092"x 1-1/8" long, 19/64" head, gypsum wallboard blued nail or 0.120" nail x1-1/4" long, min 3/8" head	5	16	unblocked	200	5.5	200
Expanded metal or woven wire lath and Portland cement plaster	7/8"	0.120" nail x 1-½" long, 7/16" head	6	16	unblocked	360	9.0	360

1. Nominal unit shear capacities shall be adjusted in accordance with 4.3.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.3.6. For specific requirements, see 4.3.7.4.
2. Type S or W drywall screws shall conform to requirements of ASTM C 1002.
3. Where two numbers are given for maximum fastener edge spacing, the first number denotes fastener spacing at the edges and the second number denotes fastener spacing along intermediate framing members.

Table 4.3D Nominal Unit Shear Capacities for Wood-Frame Shear Walls[1]

Lumber Shear Walls

Sheathing Material	Sheathing Nominal Dimensions	Type, Size, and Number of Nails per Board		A SEISMIC		B WIND
		Nailing at Intermediate Studs (nails/board/support)	Nailing at Shear Wall Boundary Members (nails/board/end)	v_s (plf)	G_a (kips/in.)	v_w (plf)
Horizontal Lumber Sheathing	1x6 & smaller 1x8 & larger	2-8d common nails (3-8d box nails) 3-8d common nails (4-8d box nails)	3-8d common nails (5-8d box nails) 4-8d common nails (6-8d box nails)	100	1.5	140
Diagonal Lumber Sheathing	1x6 & smaller 1x8 & larger	2-8d common nails (3-8d box nails) 3-8d common nails (4-8d box nails)	3-8d common nails (5-8d box nails) 4-8d common nails (6-8d box nails)	600	6.0	840
Double Diagonal Lumber Sheathing	1x6 & smaller 1x8 & larger	2-8d common nails (3-8d box nails) 3-8d common nails (4-8d box nails)	3-8d common nails (5-8d box nails) 4-8d common nails (6-8d box nails)	1200	10	1680
Vertical Lumber Siding	1x6 & smaller 1x8 & larger	2-8d common nails (3-8d box nails) 3-8d common nails (4-8d box nails)	3-8d common nails (5-8d box nails) 4-8d common nails (6-8d box nails)	90	1.0	125

1. Nominal unit shear capacities shall be adjusted in accordance with 4.3.3 to determine ASD allowable unit shear capacity and LRFD factored unit resistance. For general construction requirements see 4.3.6. For specific requirements, see 4.3.7.5 through 4.3.7.8. See Appendix A for common and box nail dimensions.

4.4 Wood Structural Panels Designed to Resist Combined Shear and Uplift from Wind

4.4.1 Application

Walls sheathed with wood structural panel sheathing or siding shall be permitted to be designed for simultaneously resisting shear and uplift from wind forces. The ASD allowable unit uplift capacity shall be determined by dividing the tabulated nominal uplift capacity in Table 4.4.1, modified by applicable footnotes, by the ASD reduction factor of 2.0. The LRFD factored unit uplift resistance shall be determined by multiplying the tabulated nominal uplift capacity in Table 4.4.1 modified by applicable footnotes, by a resistance factor, ϕ_z, of 0.65. Uplift anchorage at shear wall ends shall be designed in accordance with 4.3.6.4.2.

4.4.1.1 Nails: Nails in any single row shall not be spaced closer than 3" on center.

4.4.1.2 Panels: Panels shall have a minimum nominal panel thickness of 7/16" and shall be installed with the strength axis parallel or perpendicular to the studs.

4.4.1.3 Horizontal Joints: All horizontal joints shall occur over common framing members or common blocking and shall meet all other requirements of Section 4.3.

4.4.1.4 Openings: Where windows and doors interrupt wood structural panel sheathing or siding, framing anchors or connectors shall be provided to resist and transfer the appropriate uplift loads around the opening and into the foundation.

4.4.1.5 Sheathing Extending to Top Plate: The following requirements shall apply:

1. The top edge of the wood structural panel shall be attached to the upper top plate. Nail row, end spacing, and edge spacing shall be as shown in Figure 4F.
2. Roof or upper level uplift connectors shall be on the same side of the wall as the sheathing unless other methods are used to prevent twisting of the top plate due to eccentric loading.

4.4.1.6 Sheathing Extending to Bottom Plate or Sill Plate: The following requirements shall apply:

1. The bottom edge of the wood structural panel shall extend to and be attached to the bottom plate or sill plate as shown in Figure 4F.
2. Anchorage of bottom plates or sill plates to the foundation shall be designed to resist the combined uplift and shear forces developed in the wall. Anchors shall be spaced in accordance with Table 4.4.1.6.
   a. Where anchor bolts are used, a minimum 0.229" x 3" x 3" steel plate washer shall be used at each anchor bolt location. The edge of the plate washer shall extend to within 1/2" of the edge of the bottom plate on the sheathed side.
   b. Where other anchoring devices are used to anchor the wall to the foundation, they shall be installed on the same side of the wall as the sheathing unless other approved methods are used.
3. An anchor bolt shall be provided at each end of each plate. Anchor bolts at the end of the plate shall be at least 7 times the anchor bolt diameter from the end, but not more than ½ the tabulated anchor bolt spacing in accordance with Table 4.4.1.6 or 12", whichever is less.

   Exception: Where a hold-down anchor is used at the end of the plate, the end distance shall be permitted to be measured from the anchor bolt to the center of the hold-down anchor.

4.4.1.7 Sheathing Splices:

1. In multi-story applications where the upper story and lower story sheathing adjoin over a common horizontal framing member, the nail spacing shall not be less than 3" o.c. for a single row nor 6" o.c. for a double row in Table 4.4.1 (see Figure 4G).
2. In single or multi-story applications where horizontal joints in the sheathing occur over blocking between studs, nailing of the sheathing to the studs above and below the joint shall be designed to transfer the uplift across the joint (see Figure 4H). The uplift capacity shall not exceed the capacity in Table 4.4.1. Blocking shall be designed in accordance with Section 4.4.1.3 for shear transfer.

Exception: Horizontal blocking and sheathing tension splices placed between studs and

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LATERAL FORCE-RESISTING SYSTEMS

backing the horizontal joint shall be permitted to be used to resist both uplift and shear at sheathing splices over studs provided the following conditions are met (see Figure 4I):

a. Sheathing tension splices shall be made from the same thickness and grade as the shear wall sheathing.
b. Edges of sheathing shall be nailed to sheathing tension splices using the same nail size and spacing as the sheathing or siding nails at the bottom plate.

4.4.2 Wood Structural Panels Designed to Resist Only Uplift from Wind

Where walls sheathed with wood structural panel sheathing or siding are designed to resist only uplift from wind forces, they shall be in accordance with Section 4.4.1, except that panels with a minimum nominal panel thickness of 3/8" shall be permitted when installed with the strength axis parallel to the studs. The ASD allowable unit uplift shall be determined by dividing the tabulated nominal uplift capacity in Table 4.4.2, modified by applicable footnotes, by the ASD reduction factor of 2.0. The LRFD factored uplift resistance shall be determined by multiplying the tabulated nominal unit uplift capacity in Table 4.4.2, modified by applicable footnotes, by a resistance factor, ϕ_Z, of 0.65.

Figure 4F Panel Attachment

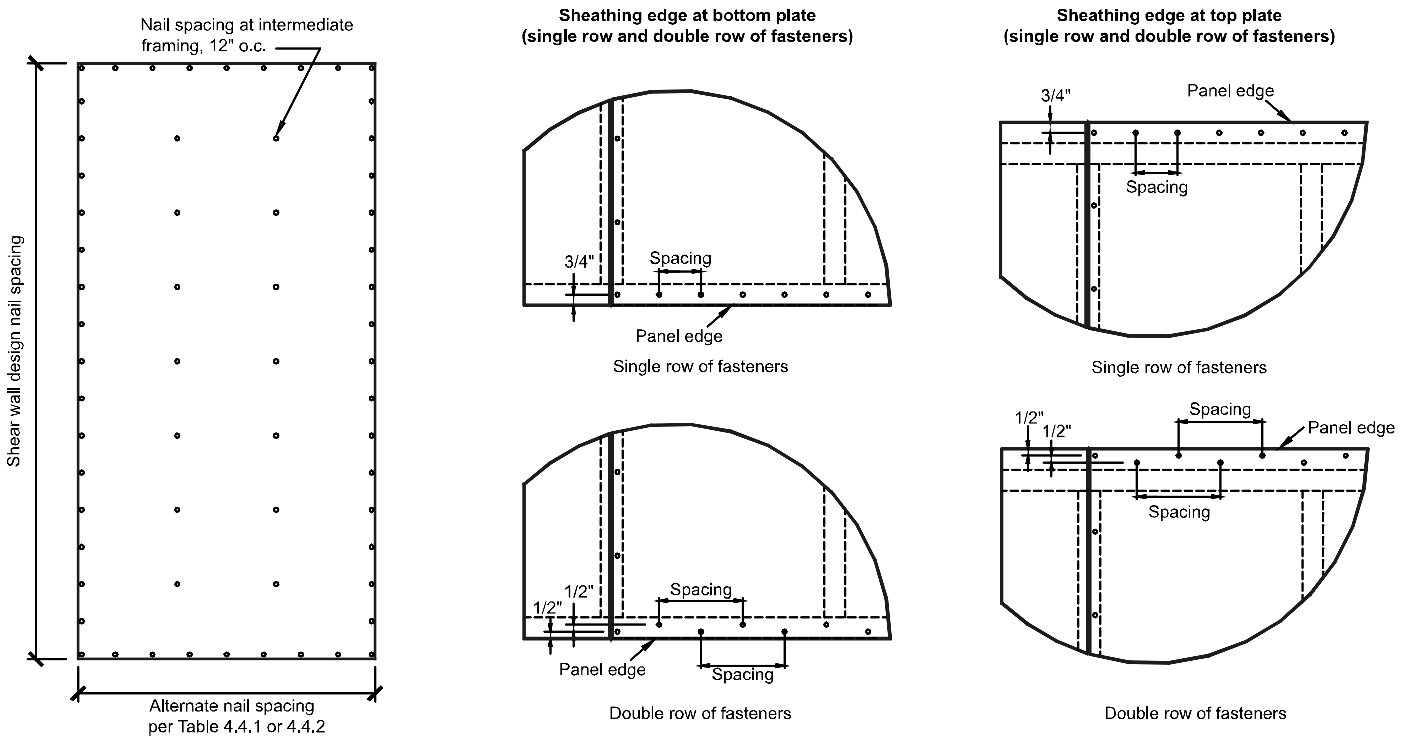


Figure 4G Panel Splice Occurring over Horizontal Framing Member

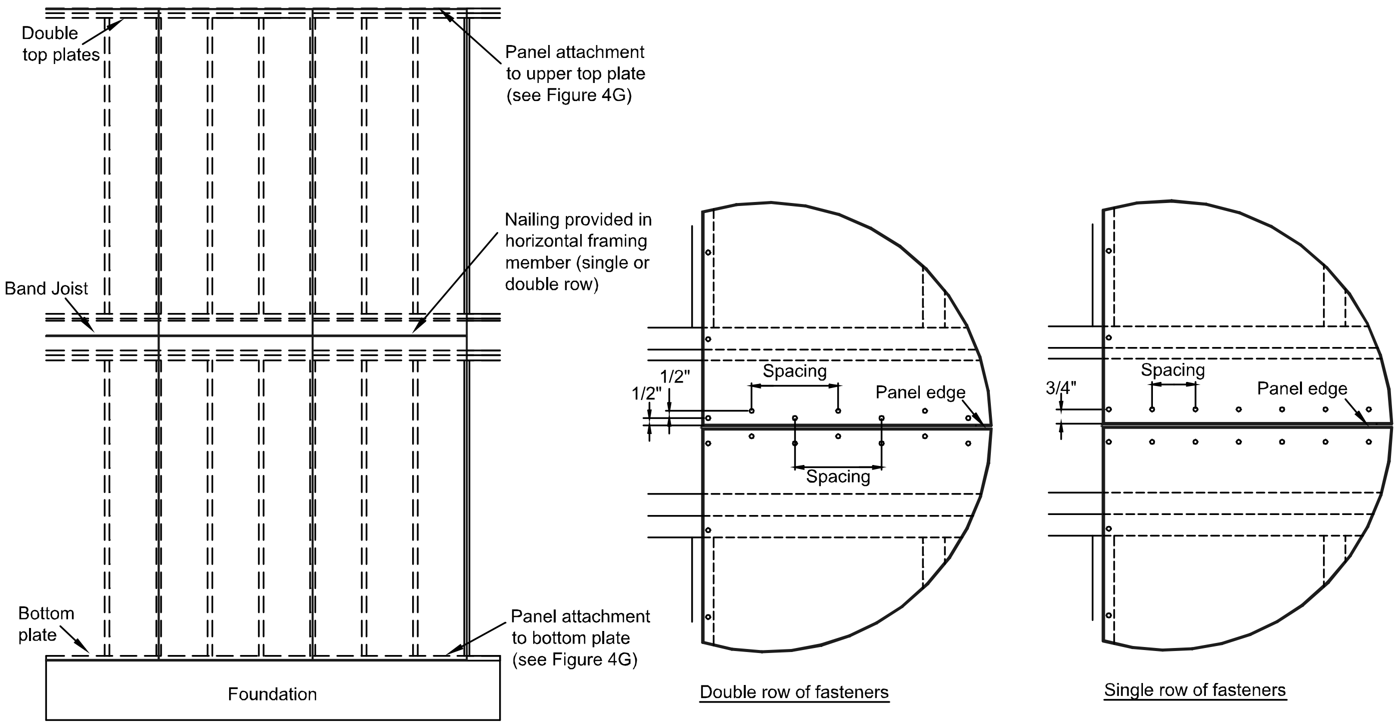


Figure 4H Panel Splice Occurring across Studs

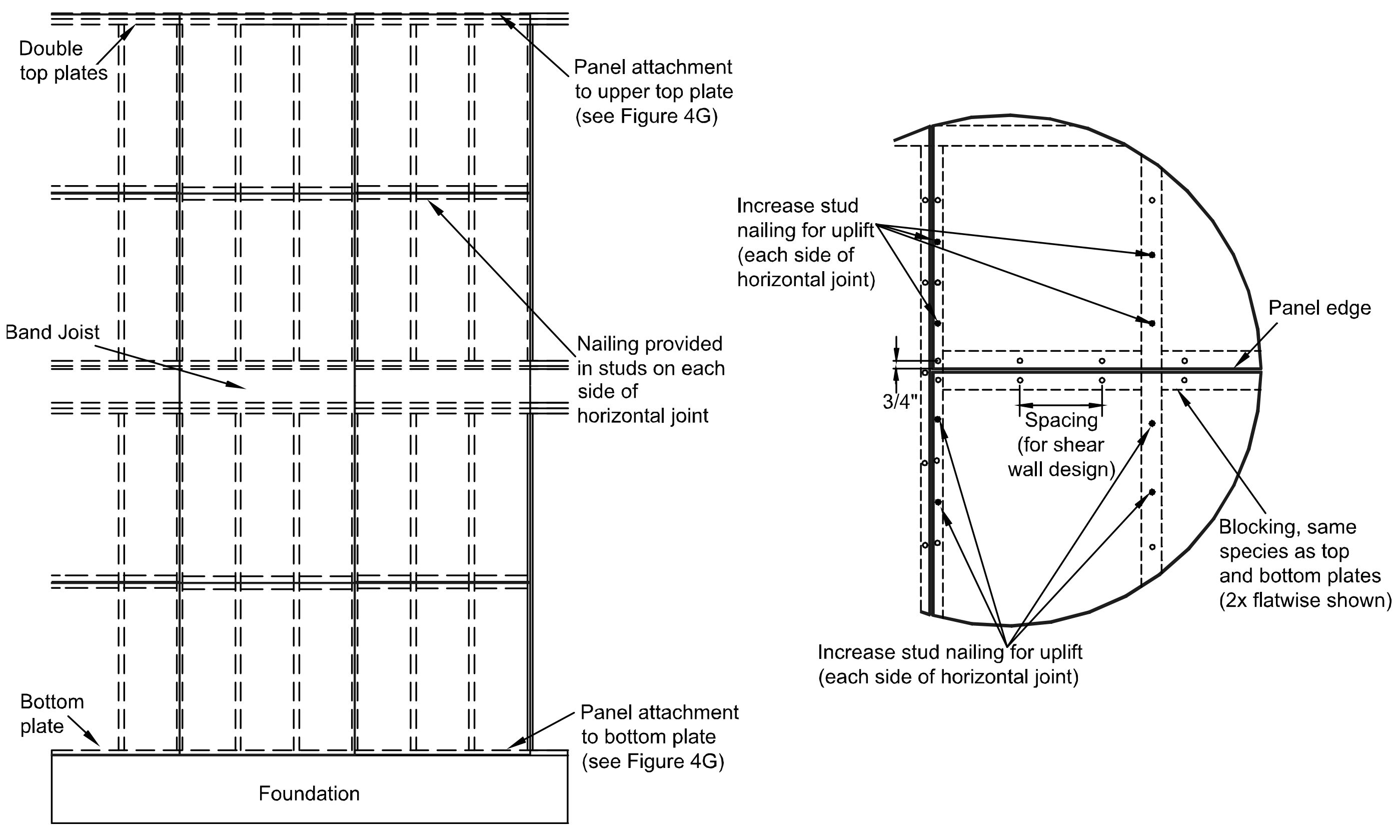


Figure 4I Sheathing Splice Plate (Alternate Detail)

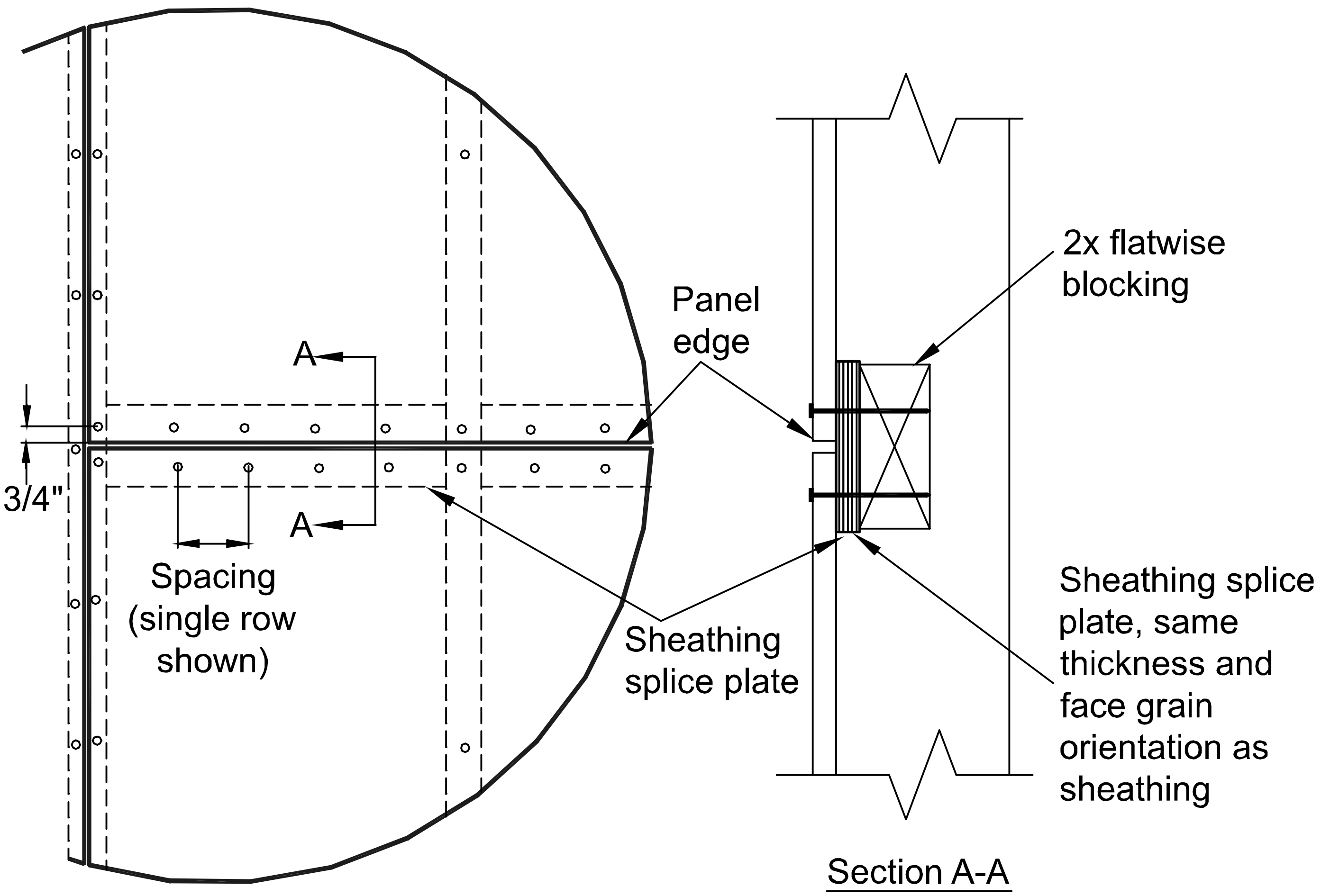


Table 4.4.1 Nominal Uplift Capacity of 7/16" (Nominal) Minimum Wood Structural Panel Sheathing or Siding When Used for Both Shear Walls and Wind Uplift Simultaneously over Framing with a Specific Gravity of 0.42 or Greater [1]

	Nail Spacing Required for Shear Wall Design											
	6d Common Nail 6" panel edge spacing 12" field spacing			8d Common Nail 6" panel edge spacing 12" field spacing			8d Common Nail 4" panel edge spacing 12" field spacing			10d Common Nail 6" panel edge spacing 12" field spacing		
	Alternate Nail Spacing at Top and Bottom Plate Edges											
	6"	4"	3"	6"	4"	3"	6"	4"	3"	6"	4"	3"
	Uplift Capacity (plf) of Wood Structural Panel Sheathing or Siding [2,3]											
Nails-Single Row [4]	0	168	336	0	216	432	NA	0	216	0	262	524
Nails-Double Row [5]	336	672	1008	432	864	1296	216	648	1080	524	1048	1572

1. Nominal unit uplift capacities shall be adjusted in accordance with 4.4.1 to determine ASD allowable unit uplift capacity and LRFD factored unit resistance. Anchors shall be installed in accordance with this section. See Appendix A for common nail dimensions.
2. Where framing has a specific gravity of 0.49 or greater, uplift values in table 4.4.1 shall be permitted to be multiplied by 1.08.
3. Where nail size is 6d common or 8d common, the tabulated uplift values are applicable to 7/16" (nominal) minimum OSB panels or 15/32" (nominal) minimum plywood with species of plies having a specific gravity of 0.49 or greater. Where nail size is 10d common, the tabulated uplift values are applicable to 15/32" (nominal) minimum OSB or plywood with a species of plies having a specific gravity of 0.49 or greater. For plywood with other species, multiply the tabulated uplift values by 0.90.
4. Wood structural panels shall overlap the top member of the double top plate and bottom plate by 1-1/2" and a single row of fasteners shall be placed ¾" from the panel edge.
5. Wood structural panels shall overlap the top member of the double top plate and bottom plate by 1-1/2". Rows of fasteners shall be ½" apart with a minimum edge distance of ½". Each row shall have nails at the specified spacing.

Table 4.4.1.6 Maximum Anchor Bolt Spacing (inches) for Combined Shear and Wind Uplift[1,2]

Nail Size	Nominal Unit Shear Capacity (plf)		Nominal Uplift Capacity (plf)										
	G=0.50		0	216	432	648	864	1080	1296	1458	1728	1944	2160
		G=0.42	0	200	400	600	800	1000	1200	1350	1600	1800	2000
8d common (0.131" x 2-1/2")	0	0	48[3]	42	36	36	32	24	24	19.2	16	-	-
	400	368	48	42	36	36	32	24	24	19.2	16	-	-
	670	616	36	32	24	24	24	24	19.2	19.2	16	-	-
	980	902	24	24	19.2	19.2	19.2	16	16	-	-	-	-
10d common (0.148" x 3")	0	0	48[3]	42	36	36	32	24	24	19.2	16	16	16
	400	368	48	42	36	36	32	24	24	19.2	16	-	-
	870	800	24	24	24	19.2	19.2	19.2	16	16	-	-	-

G = Specific Gravity of framing members
- Not Permitted
1. The minimum nominal panel thickness of wall sheathing shall be in accordance with Section 4.4.1.2.
2. Tabulated anchor bolt spacings are for minimum ½" diameter "full-body diameter" bolts (see NDS Appendix Table L1)
3. This anchor bolt spacing is provided for interpolation purposes.

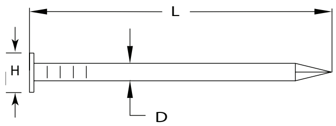
Table 4.4.2 Nominal Uplift Capacity of 3/8" (Nominal) Minimum Wood Structural Panel Sheathing or Siding When Used for Wind Uplift Only over Framing with a Specific Gravity of 0.42 or Greater [1]

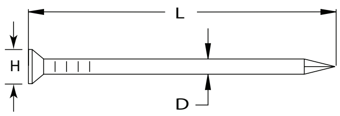
	6d Common Nail 6" panel edge spacing 12" field spacing			8d Common Nail 6" panel edge spacing 12" field spacing			10d Common Nail 6" panel edge spacing 12" field spacing		
	Alternate Nail Spacing at Top and Bottom Panel Edges								
	6"	4"	3"	6"	4"	3"	6"	4"	3"
	Uplift Capacity (plf) of Wood Structural Panel Sheathing or Siding [2,3]								
Nails-Single Row [4]	320	480	640	416	624	832	500	750	1000
Nails-Double Row [5]	640	960	1280	832	1248	1664	1000	1500	2000

1. Nominal unit uplift capacities shall be adjusted in accordance with 4.4.2 to determine ASD allowable unit uplift capacity and LRFD factored unit resistance. Anchors shall be installed in accordance with this section. See Appendix A for common nail dimensions.
2. Where framing has a specific gravity of 0.49 or greater, uplift values in table 4.4.2 shall be permitted to be multiplied by 1.08.
3. The tabulated uplift values are applicable to 3/8" (nominal) minimum OSB panels or plywood with species of plies having a specific gravity of 0.49 or greater. For plywood with other species, multiply the tabulated uplift values by 0.90.
4. Wood structural panels shall overlap the top member of the double top plate and bottom plate by 1-1/2" and a single row of fasteners shall be placed ¾" from the panel edge.
5. Wood structural panels shall overlap the top member of the double top plate and bottom plate by 1-1/2". Rows of fasteners shall be ½" apart with a minimum edge distance of ½". Each row shall have nails at the specified spacing.

APPENDIX A

Table A1 Standard Common, Box, and Sinker Nails[1]





D = diameter
L = length
H = head diameter

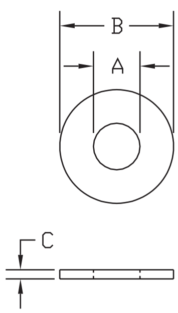
Type		Pennyweight										
		6d	7d	8d	10d	12d	16d	20d	30d	40d	50d	60d
Common	L	2"	2-1/4"	2-1/2"	3"	3-1/4"	3-1/2"	4"	4-1/2"	5"	5-1/2"	6"
	D	0.113"	0.113"	0.131"	0.148"	0.148"	0.162"	0.192"	0.207"	0.225"	0.244"	0.263"
	H	0.266"	0.266"	0.281"	0.312"	0.312"	0.344"	0.406"	0.438"	0.469"	0.5"	0.531"
Box	L	2"	2-1/4"	2-1/2"	3"	3-1/4"	3-1/2"	4"	4-1/2"	5"	-	-
	D	0.099"	0.099"	0.113"	0.128"	0.128"	0.135"	0.148"	0.148"	0.162"	-	-
	H	0.266"	0.266"	0.297"	0.312"	0.312"	0.344"	0.375"	0.375"	0.406"	-	-
Sinker	L	1-7/8"	2-1/8"	2-3/8"	2-7/8"	3-1/8"	3-1/4"	3-3/4"	4-1/4"	4-3/4"	-	5-3/4"
	D	0.092"	0.099"	0.113"	0.12"	0.135"	0.148"	0.177"	0.192"	0.207"	-	0.244"
	H	0.234"	0.250"	0.266"	0.281"	0.312"	0.344"	0.375"	0.406"	0.438"	-	0.5"

1. Tolerances specified in ASTM F 1667. Typical shape of common, box, and sinker nails shown. See ASTM F1667 for other nail types.

Table A2 Standard Cut Washers

Dimensions of Standard Cut Washers[1]			
Nominal Washer Size (in.)	A Inside Diameter (in.) Basic	B Outside Diameter (in.) Basic	C Thickness (in.) Basic
3/8	0.438	1.000	0.083
1/2	0.562	1.375	0.109
5/8	0.688	1.750	0.134
3/4	0.812	2.000	0.148
7/8	0.938	2.250	0.165
1	1.062	2.500	0.165

1. For other standard cut washers, see ANSI/ASME B18.21.1. Tolerances are provided in ANSI/ASME B18.21.1.



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