AMERICAN WOOD COUNCIL

January 2021

ERRATA
to the 2018 and Prior Editions of
the National Design Specification® (NDS®) for Wood Construction

Page	**Revision**
91	Revise footnote 1 in Table 12.5.1D as follows:

1. The ℓ/D ratio used to determine the minimum ~~edge distance~~ spacing between rows shall be the lesser of:
   (a) length of fastener in wood main member/D = ℓ_m/D
   (b) total length of fastener in wood side member(s)/D = ℓ_s /D

222 Catoctin Circle, SE, Suite 201 ▪ Leesburg, VA 20175 ▪ 202-463-2766 ▪ www.awc.org ▪ info@awc.org

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Page	**Revision**
166	Clarifies that the following calculations in Example E.7 Sample Solution of Row of Bolts is intended for a single-row bolted connection with a 3-1/2″ thick main member and 1-1/2″ thick side member:

E.7 Sample Solution of Row of Bolts

Calculate the net section area tension and row tear-out adjusted ASD design capacities for the single-shear single-row bolted connection represented in Figure E2.

Main and Side Members:
#2 grade Hem-Fir ~~2x4~~ lumber. See *NDS Supplement* Table 4A – Visually Graded Dimension Lumber for reference design values. Adjustment factors C_D, C_T, C_M, and C_i are assumed to equal 1.0 in this example for calculation of adjusted design values.

$F_t' = 525 \text{ psi } (C_F) = 525(1.5) = 788 \text{ psi}$

$F_v' = 150 \text{ psi}$

Connection Details:
Bolt diameter, D: 1/2 in.
Bolt hole diameter, D_h: 0.5625 in.
Adjusted ASD bolt design value, $Z_{||}'$: 550 lbs (See NDS Table 12A for 3-1/2″ main member thickness and 1-1/2″ side member thickness. For this trial design, the group action factor, C_g, is taken as 1.0).

Adjusted ASD Connection Capacity, n $Z_{||}'$:

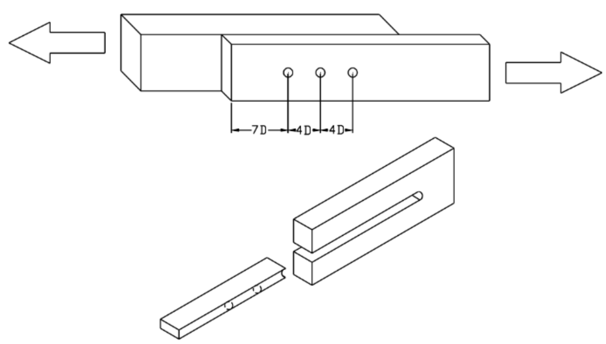
$nZ_{||}' = (3 \text{ bolts})(550 \text{ lbs}) = 1{,}650 \text{ lbs}$

~~Adjusted~~ For side member, adjusted ASD Net Section Area Tension Capacity, Z_{NT}':

$$Z_{NT}' = F_t' \, t \, [w - n_{row} D_h]$$

$$Z_{NT}' = (788 \text{ psi})(1.5'')[3.5'' - 1(0.5625'')] = 3{,}470 \text{ lbs}$$

Figure E2 Single Row of Bolts



~~Adjusted~~ For side member, adjusted ASD Row Tear-Out Capacity, Z_{RT}':

$$Z_{RTi}' = n_i F_v' \, t s_{critical}$$

$$Z_{RT1}' = 3(150 \text{ psi})(1.5'')(2'') = 1{,}350 \text{ lbs}$$

In this sample calculation, the adjusted ASD connection capacity is limited to 1,350 pounds by row tear-out, Z_{RT}'.

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Changes in the 2001 *NDS*® *for Wood Construction*

Philip Line, P.E.; Dr. Robert Taylor, P.Eng.; John "Buddy" Showalter, P.E.; Bradford K. Douglas, P.E.

Introduction

The 2001 Edition of the *National Design Specification*® *(NDS*®*) for Wood Construction* has been published and is available from the American Forest & Paper Association's (AF&PA) American Wood Council. Publication of the 2001 *NDS* culminates 3 years of development by AF&PA's NDS Canvass Committee dedicated to providing state-of-the art information for wood design. The 2001 *NDS* was approved as an American National Standard on November 30, 2001 with a designation *ANSI/AF&PA NDS-2001*.

The 2001 *NDS* contains many changes from the previous edition, which are summarized in this article. Some significant changes include:

New:

- product chapters (prefabricated wood I-joists, structural composite lumber, wood structural panels, and poles)
- appendix for local stresses in members at connections
- chapter for shear walls and diaphragms
- chapter for fire design

Revised:

- provisions for shear design (coinciding with increased shear design values)
- provisions for notching
- provisions for end grain bearing
- volume factor for glued laminated timber
- connection design provisions
- connection tables

The *NDS Supplement: Design Values for Wood Construction*, an integral part of the *NDS*, has also been updated to provide the latest design values for lumber and glued laminated timber.

New Products

Three new product chapters have been added: Structural Composite Lumber, Wood Structural Panels, and Prefabricated Wood I-joists. These chapters parallel the format of chapters for sawn lumber and glued laminated timber. Product definitions, identification, design value adjustments, and special design considerations have been provided. To clarify applicability of adjustments for each product type, separate tables have been developed for each product chapter in the *NDS*. An example of one of these tables is provided in Table 1.

Table 4.3.1 Applicability of Adjustment Factors for Sawn Lumber

		Load Duration Factor	Wet Service Factor	Temperature Factor	Beam Stability Factor	Size Factor	Flat Use Factor	Incising Factor	Repetitive Member Factor	Form Factor	Column Stability Factor	Buckling Stiffness Factor	Bearing Area Factor
$F_b' = F_b$	x	C_D	C_M	C_t	C_L	C_F	C_{fu}	C_i	C_r	C_f	-	-	-
$F_t' = F_t$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	-	-	-
$F_v' = F_v$	x	C_D	C_M	C_t	-	-	-	C_i	-	-	-	-	-
$F_{c\perp}' = F_{c\perp}$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	-	C_b
$F_c' = F_c$	x	C_D	C_M	C_t	-	C_F	-	C_i	-	-	C_P	-	-
$E' = E$	x	-	C_M	C_t	-	-	-	C_i	-	-	-	C_T	-

Table 1. Applicability of Adjustment Factors for Sawn Lumber *(as it appears in NDS 2001)*

Design information for construction poles has been added and combined with an existing chapter on piles. Like other product chapters, the new chapter titled *Round Timber Poles and Piles* contains information such as applicable product standards and standard adjustments to design values. Construction pole design values per ASTM D3200 have also been added.

Note: Design values for utility poles are developed using ANSI O5.1. If used as construction poles with NDS provisions, these poles must be regraded in accordance with ASTM D3200.

Member Design - Shear

Review of ASTM procedures used to establish allowable shear stresses revealed that shear values were being reduced by two separate factors for effects of splits, checks and/or shakes. One of these adjustments was made to the base value, the other was an adjustment to design values for grade effects. In 2000, ASTM standard D245 was revised to remove one of these adjustments, which resulted in an increase of nearly two for allowable shear design values; however, grade effect adjustments were eliminated.

In the 2001 *NDS Supplement*, shear design values for sawn lumber are generally 1.95 times higher than values printed in the 1997 edition in response to the change in D245. With this change, shear-related provisions in the *NDS* were re-evaluated and modified where necessary to provide appropriate designs. Changes include:

- Removal of the shear strength increase factor, C_H, which previously permitted shear design values to be increased based on limited occurrences of splits, checks and shakes.

- Revised provisions for ignoring shear loads near supports as follows:

  3.4.3.1 (a) For beams supported by full bearing on one surface and loads applied to the opposite surface, uniformly distributed loads within a distance from supports equal to the depth of the bending member, d, shall be permitted to be ignored. For beams supported by full bearing on one surface and loads applied to the opposite surface, concentrated loads within a distance, d, from supports shall be permitted to be multiplied by x/d where x is the distance from the beam support face to the load (see Figure 1).

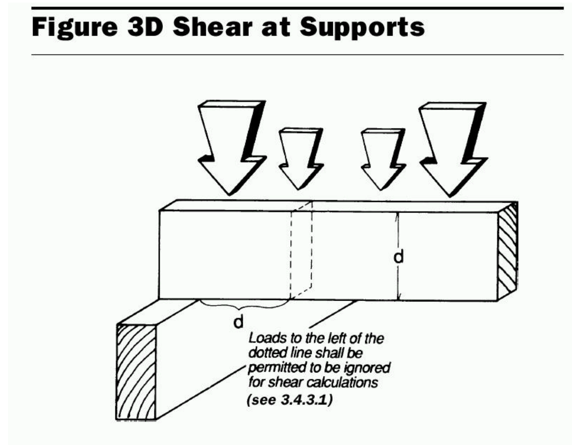


Figure 1. Shear at supports. *(as it appears in NDS 2001)*

- Revised provisions for shear strength at notches (where permitted). Changes include addition of the squared component on the strength reduction term and reformat of the shear equation in an "allowable shear" format versus the "actual shear stress" format in the 1997 edition. New provisions of the *2001 NDS* for notching are shown below. A comparison to 1997 provisions is provided in Figure 2.

  Notches:
  3.4.3.2. (a) For bending members with rectangular cross section and notched on the tension face, the allowable design shear, V_r', shall be calculated as follows:

$$V_r' = \left[\frac{2}{3}F_v' b d_n\right]\left[\frac{d_n}{d}\right]^2$$

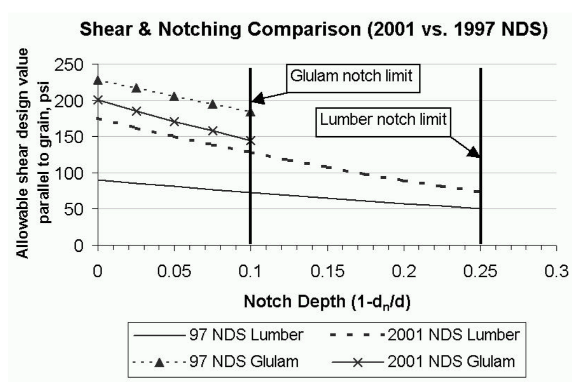


Figure 2. Comparison of shear and notching provisions for 2001 versus 1997 *NDS*.

- Revised provisions for shear strength at connections less than 5*d* from member ends.

Changes parallel those made for notched bending members:

> *Connections:*
> *3.4.3.3. (a) When the connection is less than five time the depth, 5d, of the member from its end, the allowable design shear, V_r', shall be calculated as follows:*

$$V_r' = \left[\frac{2}{3}F_v' b d_e\right]\left[\frac{d_e}{d}\right]^2$$

- Removal of 50% shear increases when connections are more than 5*d* from the member end.

- Removal of two-beam shear provisions which permitted load reductions for shear design of single span sawn lumber bending members. This provision was linked with assumptions used to develop previous shear design values and is no longer applicable.

End Grain Bearing

End grain bearing values, F_g, are no longer tabulated in the *NDS Supplement*. Instead, provisions of the *NDS* specify use of compression parallel to grain design values for end grain bearing (bearing parallel to grain) as follows:

> *3.10.1.1 The actual compressive bearing stress parallel to grain shall be based on the net bearing area and shall not exceed the tabulated compression design value parallel to grain multiplied by all applicable adjustment factors except the column stability factor, $f_c \leq F_c^*$.*

For dimension lumber, compression parallel to grain design values, F_c, are generally higher than bearing design values, F_g. For timbers, F_g is typically higher than F_c. This results in a small capacity increase for higher grade dimension lumber, while timbers and lower grade dimension lumber capacities are lower.

Notching

Recommendations to avoid notching wherever possible are continued in the *2001 NDS*. For sawn lumber, permitted notch locations and notch depths remain unchanged (see Figure 3) but clarification is added that interior notch limits and locations are applicable to single span bending members.

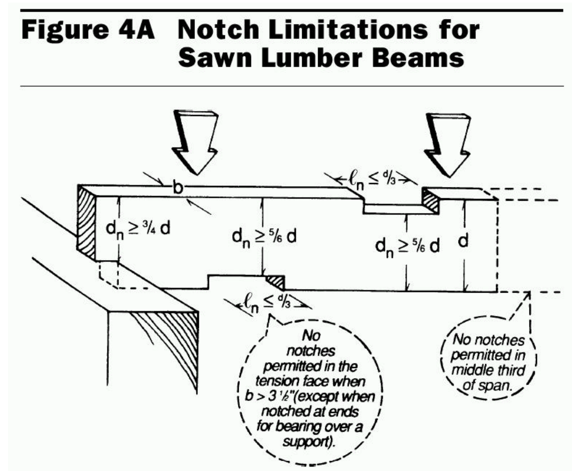


Figure 3. Notch limitations for sawn lumber beams. *(as it appears in NDS 2001)*

For glued laminated timber, an upper limit of 3 inches has been added for tension side end notches as follows:

> *5.4.4.1 The tension side of glued-laminated timber bending members shall not be notched, except at ends of members for bearing over a support, and notch depth shall not exceed the lesser of 1/10 the depth of the member or three inches….*

The 3 inch limit was developed in response to preliminary research which supported current shear strength provisions for notched beam depths up to 30 inches.

Volume Factor

The loading condition coefficient, K_L, has been removed from calculation of the volume factor. The K_L factor comes from provisions of ASTM D3737 where it is used to statistically adjust certain load cases when developing design values from glulam test data. This simplification was considered to be appropriate since the K_L factor was only available for a few idealized loading conditions and the overall range in adjustment is small. For glulam, removal of this coefficient will result in a 9% reduction and 4% increase in capacity for the single concentrated load case and third-point load case, respectively.

Connections – Local Stresses

Provisions for stresses in members at connections have been clarified in the 2001 *NDS*. Provisions have been re-written as follows:

10.1.2 Structural members shall be checked for load carrying capacity at connections in accordance with all applicable provisions of this standard including 3.1.2, 3.1.3, and 3.4.3.3. Local stresses in connections using multiple fasteners shall be checked in accordance with principles of engineering mechanics. One method for determining these stresses is provided in Appendix E.

Appendix E – Local Stresses in Fastener Groups is new to the *2001 NDS* and provides one method to evaluate capacity of a fastener group limited by wood related failure mechanisms. Example problems are added to demonstrate application of Appendix E provisions for checking net section tension capacity, row tear-out capacity, and group tear-out capacity. These provisions are applicable to all previous editions of the *NDS*.

Connections – Dowel-type Fasteners

Separate chapters for design of bolts, lag screws, wood screws, and nails have been consolidated into a single chapter in the 2001 edition entitled "Dowel-type Fasteners (Bolts, Lag Screws, Wood Screws, Nails/Spikes, Drift Bolts and Drift Pins)." The new format was introduced to provide a consistent method for determining lateral strength of dowel-type fasteners and minimize duplication of design provisions. Significant changes that improve consistency and minimize duplication of provisions include:

- One set of yield mode equations, describing behavior of dowels under lateral loads, is provided for all dowel-type fasteners. A requirement to check all yield modes is coupled with removal of the penetration depth factor, C_d. In previous NDS-versions, different yield limit equations were used for lag screws, wood screws and nails and penetration depth factors were used in lieu of checking all yield mode equations.

- Capacity reduction terms are based on fastener diameter rather than fastener type. For fasteners with diameter, *D*, greater than or equal to ¼ inch ($D \geq$ ¼ inch), strength reductions vary by yield mode and are consistent with reductions used for bolts in the 1997 edition. For $D <$ ¼ inch, strength reduction terms vary linearly with diameter and are consistent with reductions used for nails in the 1997 edition.

- Differences in dowel bearing strength parallel and perpendicular to grain are recognized when $D \geq$ ¼ inch. Previously, differences in dowel bearing strength parallel and perpendicular to grain were not recognized for nails and wood screws.

- Revisions of the group action factor to be applicable to dowel-type fasteners with $D \geq$ ¼ inch. For fasteners with $D <$ ¼ inch, the group action factor is taken as 1.0.

Other changes to connection provisions:

- Dowel bearing strengths for steel side members, used to develop wood-to-steel connection values, are increased to be consistent with AISC and AISI standards.

- Appendix J is expanded to include Hankinson's Formula for determining bolt or lag screw connection design values, *Z*, from tabular values, when members are loaded at an angle to grain between 0° and 90°. The new equation is as follows:

$$Z'_\theta = \frac{Z'_\parallel Z'_\perp}{Z'_\parallel \sin^2\theta + Z'_\perp \cos^2\theta}$$

- Appendix L is expanded to include figures and typical dimensions for bolts, lag screws, wood screws, and nails. For lag screws, a footnote is revised to clarify that tabulated thread lengths represent minimum thread lengths for lag screws. Figures of cut thread and rolled thread wood screws show differences between types of wood screws and tabular information identifies wood screws by "number" rather than "gage" used in previous editions.

- Root diameter, D_r, is used to calculate lag screw and wood screw lateral connection capacity, unless a more detailed analysis is performed to account for the varying moment capacity of the fastener.

- Minimum penetration for wood screws loaded laterally is increased to 6*D* for consistency with requirements for nails since the tapered tip is included in the penetration length. The change is also more consistent with connections made with lag screws where the tip is not included in the penetration length.

- Removal of tabulated design values for threaded hardened nails since this nail type is not specifically standardized in ASTM F1667.

- Dowel bearing strengths are added for wood structural panels (see Table 2).

Table 11.3.2B Dowel Bearing Strengths for Wood Structural Panels

Wood Structural Panel	Specific[1] Gravity G	Dowel Bearing Strength, F_e, in Pounds Per Square Inch (psi)
Plywood		
Structural 1, Marine	0.50	4650
Other Grades[1]	0.42	3350
Oriented Strand Board		
All Grades	0.50	4650

1. Use G = 0.42 when species of the plies is not known. When species of the plies is known, specific gravity listed for the actual species and the corresponding dowel bearing strength may be used, or the weighted average may be used for mixed species.

Table 2. Dowel Bearing Strengths for Wood Structural Panels *(as it appears in NDS 2001)*

Connections – Tabulated design values

Tabulated design values for dowel-type fastener connections have been revised to be consistent with changes in calculation design provisions. Bolt, lag screw, wood screw and nail connection tables include structural composite lumber sizes. Nail connection tables have been expanded to include connections with wood structural panel side members. Added footnotes to nail, lag screw, and wood screw connection tables provide a simple and conservative method for determining design values for connections with reduced penetration.

For bolted connections between wood members, tabulated design values remain unchanged from the 1997 edition. Bolted wood-to-steel connection strengths have increased slightly compared to the 1997 edition due to increased bearing strength of steel. Similarly, nailed wood-to-steel connection strength also increased when compared to the 1997 edition.

Tabulated design values for lag screws are based on a "reduced body diameter" lag screw and tabulated values for wood screws are based on "rolled thread" wood screws. Because "reduced body diameter" lag screws and "rolled thread" wood screws have a shank diameter approximately equal to the root diameter, design values for these fasteners are smaller than those provided in the 1997 edition for "full body diameter" lag screws and "cut thread" wood screws. This change in basis was implemented to better address use of reduced body diameter fasteners and the condition where the full length of the fastener is threaded.

Shear Walls and Diaphragms

A new chapter on shear walls and diaphragms covering general requirements for framing members, fasteners, and sheathing has been added to parallel similar language in *AF&PA/ASCE 16 Standard for Load and Resistance Factor Design (LRFD) for Engineered Wood Construction*.

Fire Design

A new chapter on fire design of exposed wood members has been added. Provisions include procedures that can be used to calculate fire endurance of tension, compression and bending members and members subjected to combined loading. Special provisions for glued laminated timber beams are incorporated as well.

NDS Supplement

Design provisions in the 2001 *NDS* are integral with design values in the *2001 NDS Supplement*. As such, it is not appropriate to mix design values and provisions from different editions of the *NDS*. The 2001 *NDS Supplement* contains increased shear design values for sawn lumber to reflect changes in ASTM D245 and provisions of the *2001 NDS* have been revised to address these increases. Other changes in the *2001 NDS Supplement* include addition of design value tables for non-North American dimension lumber and expanded design value tables for mechanically graded dimension lumber.

For glued laminated timber, revised tables for glued laminated hardwood timber design values are provided in a format consistent with tables for softwood glued laminated timber. For softwood glued laminated timber, a consolidated table of design values grouped by stress class is provided in addition to the familiar combination symbol tables from the 1997 edition. Increased shear design values for prismatic members are tabulated. For notched members and certain other conditions, reduction in design values is required as specified in table footnotes.

NDS Commentary

The Commentary to the 1997 and earlier editions of the *NDS* will be posted to the AWC website for free access. Once an update to the Commentary for the *2001 NDS* is complete, it will be included on the AWC website as well.

2001 NDS and the Model Codes

The 2001 *NDS* will be the reference document for allowable stress design of wood construction in the 2003 edition of the *International Building Code*, 2002 edition of *ASCE 7 – Minimum Design Loads for Buildings and Other Structures*, and the 2002 edition of *NFPA 5000 Building Code*.

ASD Manual

The *Allowable Stress Design (ASD) Manual for Engineered Wood Construction*, containing additional product supplements (lumber, glulam, poles & piles, panels, shearwalls & diaphragms, and wind/seismic provisions) and product guidelines (I-joists, SCL, trusses, and hangers) along with the 2001 *NDS* and *NDS Supplement*, has also been revised and updated (see Figure 4). To order a copy of the 2001 *ASD Manual*, contact the AWC Publications Department at 1-800-890-7732, or visit the AWC website at www.awc.org for online ordering information.

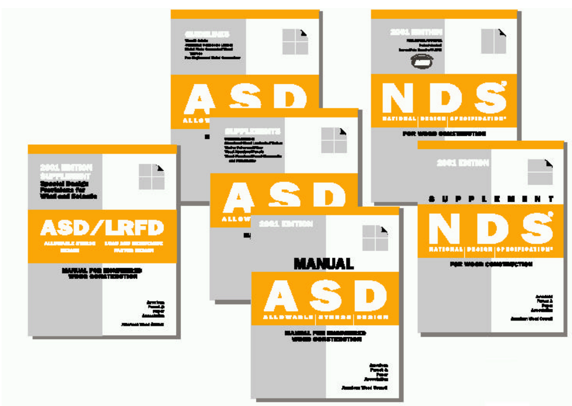


Figure 4. *Allowable Stress Design (ASD) Manual for Engineered Wood Construction, 2001 Edition* comes with *2001 NDS* and *NDS Supplement,* and additional *Supplements* and *Guidelines* for traditional and engineered wood products.

eCourses

Additional details regarding changes to the *2001 NDS* is available in slide presentation format at www.awc.org. The specific location is under Outreach/eCourses, and the course number is STD103.

2001 EDITION SUPPLEMENT

Special Design Provisions for Wind and Seismic

ASD/LRFD

ALLOWABLE STRESS DESIGN

LOAD AND RESISTANCE FACTOR DESIGN

MANUAL FOR ENGINEERED WOOD CONSTRUCTION

American Forest & Paper Association

American Wood Council

2001 EDITION SUPPLEMENT

Special Design Provisions for Wind and Seismic

ASD/LRFD

ALLOWABLE STRESS DESIGN

LOAD AND RESISTANCE FACTOR DESIGN

MANUAL FOR ENGINEERED WOOD CONSTRUCTION

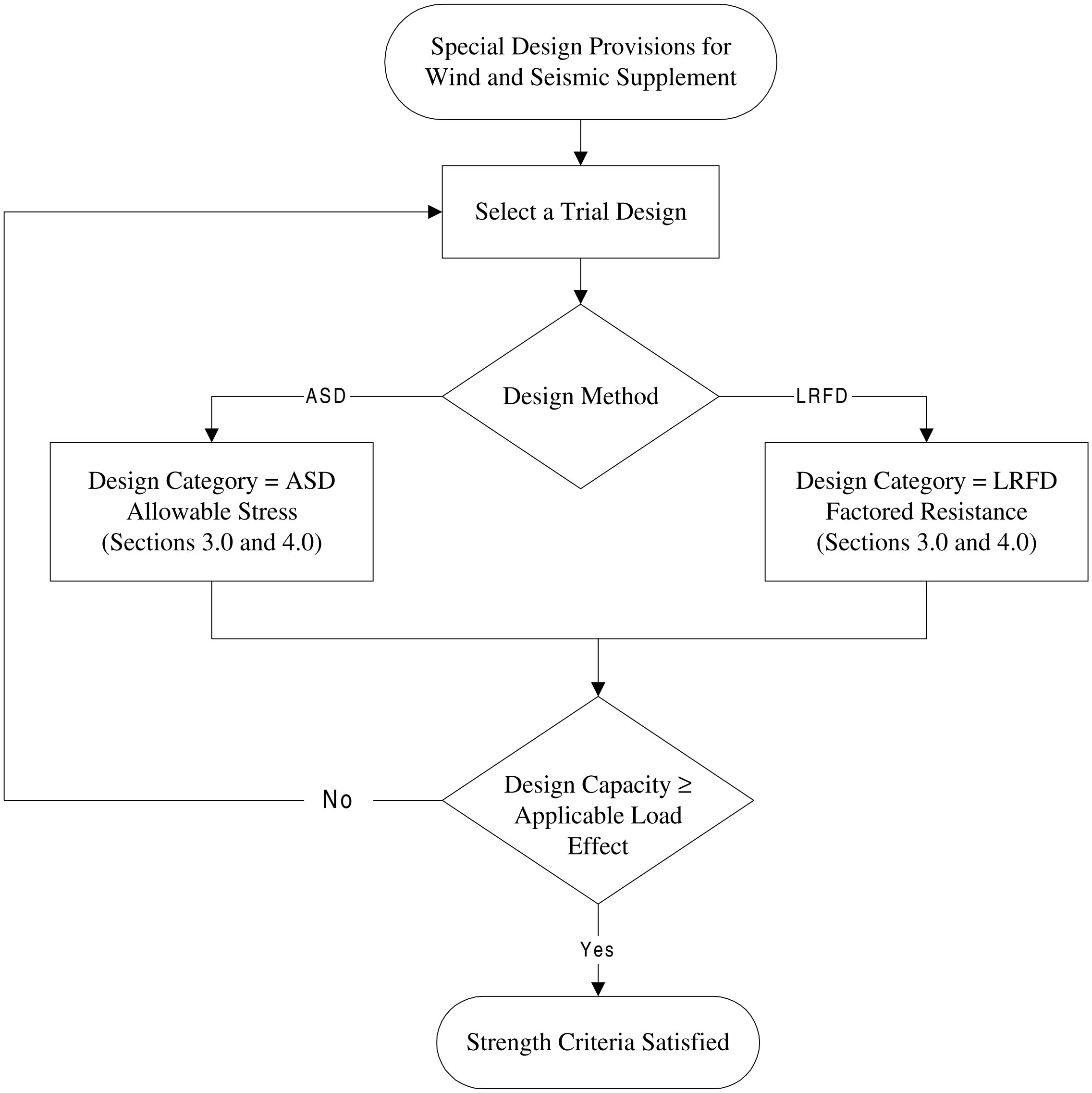
Table of Contents

List of Tables

1

DESIGNER FLOWCHART

1.1 Flowchart



GENERAL DESIGN REQUIREMENTS

2.1 General

2.1.1 Scope

The provisions of this Supplement 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 or seismic forces shall be by one of the methods described in Section 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/AF&PA NDS-2001), its supplements, and provisions of this Supplement.

2.1.2.2 Strength Design: Load and resistance factor design (LRFD) of wood structures shall be in accordance with the *Load and Resistance Factor Standard for Engineered Wood Construction* (AF&PA/ASCE 16-95), its supplements, and provisions of this Supplement.

2.2 Terminology

ALLOWABLE STRESS DESIGN A method of proportioning structural members such that elastically computed stresses produced in the members by nominal loads does not exceed specific allowable stresses (also called working stress design).

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 is assumed to resist axial stresses due to the induced moment.

COLLECTOR A diaphragm or shear wall element parallel and in line with the applied force that collects and transfers diaphragm shear forces to the vertical elements of the lateral force-resisting system and/or distributes forces withing the diaphragm.

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 sheathing edges are fastened to either common framing or common blocking.

DIAPHRAGM, FLEXIBLE A diaphragm is flexible for the purpose of distribution of story shear when the computed maximum in-plane deflection of the diaphragm itself under lateral load is greater than two times the average deflection of adjoining vertical elements of the lateral force-resisting system of the associated story under equivalent tributary lateral load.

DIAPHRAGM, RIGID A diaphragm is rigid for the purpose of distribution of story shear and torsional moment 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. For analysis purposes, it can be assumed that a rigid diaphragm distributes story shear and torsional moment into lines of shear walls by the relative lateral stiffness of the shear walls.

[*For the first iteration, an arbitrary load is applied to each line of shear walls to determine the relative stiffness of the lines of walls. Once the relative stiffnesses of the wall lines have been determined, the applied lateral load is distributed proportionally. The shear walls are redesigned and the lateral stiffness is recalculated and the applied load is re-apportioned. This is continued until convergence.*]

DIAPHRAGM, UNBLOCKED A diaphragm that has edge nailing at supporting members only. Blocking between supporting structural members at panel edges is not included. Diaphragm panels are field nailed to supporting members.

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.

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 (497 kg/m^3) but more than 10 pounds per cubic foot (160 kg/m^3).

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.

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

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 sheathed wall with openings, but which has not been specifically designed and detailed for force transfer around wall openings.

PERFORATED SHEAR WALL SEGMENT A section of a perforated shear wall with full height sheathing which meets the requirements for maximum aspect ratio in Section 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 unavoidable deviations of the actual strength from the nominal value and the manner and consequences of failure.

SEISMIC DESIGN CATEGORY A classification assigned to a structure based on its Seismic Use Group 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 LINE A series of shear walls in a line at a given story level.

SUBDIAPHRAGM A portion of a larger wood diaphragm designed to anchor and transfer local forces to primary diaphragm struts and the main diaphragm.

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

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

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

C = Compression chord force, lbs.

C_o = Shear capacity adjustment factor from Table 4.3.3.4.

E = Modulus of elasticity of end posts, psi

E = Modulus of elasticity of diaphragm chords, psi

G = Specific gravity

G_a = Apparent shear wall shear stiffness from nail slip and panel shear deformation, kips/in. (from Column A, Table 4.3).

G_a = Apparent diaphragm shear stiffness from nail slip and panel shear deformation, kips/in. (from Column A, Table 4.2).

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, Table 4.3).

G_{a2} = Apparent shear wall shear stiffness for side 2, kips/in. (from Column A, Table 4.3).

K_{min} = Minimum ratio of v_1/G_{a1} or v_2/G_{a2}

L = The dimension of a diaphragm perpendicular to the direction of application of force. For open-front structures, L is the length from the edge of the diaphragm at the open front to the vertical resisting elements parallel to the direction of the applied force.

L_c = The length of the cantilever for a cantilever diaphragm, ft. (see figure 4.2.5.2)

ΣL_i = Sum of perforated shear wall segment lengths, ft.

R = Response modification coefficient

T = Tension chord force, lbs.

V = Induced shear force in perforated shear wall, lbs.

W = Diaphragm width, ft.

W = The width of a diaphragm in the direction of application of force measured as the sheathed dimension of the diaphragm.

b = The length of a shear wall or shearwall segment measured as the sheathed dimension of the shear wall.

b_s = Shear wall length for determining apect ratio. For perforated shearwalls, use the minimum shearwall segment length included in the L_i, ft.

h = The height of a shear wall or shearwall segment measured as:

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

t = Uniform uplift force, lbs./ft.

ν = Induced unit shear, lbs./ft.

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

ν_{max} = Maximum induced unit shear force, 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 side 1, lbs./ft. (from Column A, Table 4.3).

ν_{s2} = Nominal unit shear capacity for side 2, lbs./ft. (from Column A, Table 4.3).

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, in.

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

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.

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_D = Sheathing resistance factor for in-plane shear of shearwalls 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 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 Stress Increase: The bending stress for sawn lumber wood studs resisting out of plane wind loads shall be permitted to be increased by the factors in Table 3.1.1.1, in lieu of the 1.15 repetitive member factor, to take into consideration the load sharing and composite action provided by wood structural panel sheathing. The factor applies when studs are designed for bending, spaced no more than 16 inches on center, covered on the inside with a minimum of ½-inch gypsum wallboard, and sheathed on the exterior with a minimum of 3/8-inch wood structural panel sheathing that is attached to the studs using a minimum of 8d common nails spaced a maximum of 6 inches o.c. at panel edges and 12 inches o.c. at intermediate framing members.

Table 3.1.1.1 Wall Stud Bending Stress Increase Factors

Stud Size	System Factor
2x4	1.5
2x6	1.4
2x8	1.3
2x10	1.2
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 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 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 out of plane wind loads to the wall framing. Maximum spans and nominal uniform load capacities for wall sheathing materials are given in Table 3.2A. The ASD allowable uniform load capacities to be used for wind design shall be determined by dividing the nominal uniform load capacities by a safety 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 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.

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.

Table 3.2A Nominal Uniform Load Capacities, psf, for Wall Sheathing Resisting Wind Loads[1]

Sheathing Type[3]	Span Rating or Grade	Minimum Thickness (in.)	Sheathing Long Dimension Orientation:							
			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[4] (Sheathing Grades, C-C, C-D, C-C Plugged, OSB)	24/0 24/16 32/16 40/20 48/24	3/8 7/16 15/32 19/32 23/32	24 24 24 24 24	425 540 625 950 1160	240 305 355 595 805	105 135 155 265 360	24 24 24 24 24	90 110 155 255 380	50 60 90 145 215	– 25[2] 40[2] 65[2] 90[2]
Particleboard Sheathing (M-S Exterior Glue)		3/8 1/2	16 16	(contact manufacturer)			16 16	(contact manufacturer)		
Particleboard Panel Siding (M-S Exterior Glue)		5/8 3/4	16 24	(contact manufacturer)			16 24	(contact manufacturer)		
Hardboard Siding (Direct to Studs)	Lap Siding Shiplap Edge Panel Siding Square Edge Panel Siding	7/16 7/16 7/16	16 24 24	460 460 460	260 260 260	- 115 115	- 24 24	- 460 460	- 260 260	- 115 115
Cellulosic Fiberboard Sheathing	Regular Structural Structural	1/2 1/2 25/32	- - -	- - -	- - -	- - -	16 16 16	90 135 165	50 75 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. Sheathing shall be OSB or plywood with 4 or more plies.
3. Wood structural panels shall conform to the requirements for its type in DOC PS 1 or PS2. Particleboard sheathing shall conform to ANSI A208.1. Hardboard panel and siding shall conform to the requirements of AHA A135.5 or AHA A135.4 as applicable. Cellulosic fiberboard sheathing shall conform to AHA A194.1 or ASTM C208.
4. Tabulated values are for maximum bending loads from wind. Loads are limited by bending or shear stress assuming a 2-span continuous condition. For more information, see the *ASD Wood Structural Panels Supplement*.

3.2.3 Roof Sheathing

Roof sheathing and its fasteners shall be capable of resisting and transferring out of plane wind and gravity loads to the roof framing. Maximum spans and nominal uniform load capacities for roof sheathing materials are given in Table 3.2B. The ASD allowable uniform load capacities to be used for out of plane wind design shall be determined by dividing the nominal uniform load capacities by a safety 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 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 3.2B Nominal Uniform Load Capacities, psf, for Roof Sheathing Resisting Wind Loads[1]

Sheathing Type	Span Rating or Grade	Minimum Thickness (in.)	Sheathing Long Dimension Applied Perpendicular to Supports			
			Rafter/Truss Spacing (in.)			
			12	16	19.2	24
			Nominal Uniform Loads (psf)			
Wood Structural Panels[2,3] (Sheathing Grades, C-C, C-D, C-C Plugged, OSB)	24/0	3/8	425	240	165	105
	24/16	7/16	540	305	210	135
	32/16	15/32	625	355	245	155
	40/20	19/32	950	595	415	265
	48/24	23/32	1160	805	560	360
Wood Structural Panels[2,3] (Single Floor Grades, Underlayment, C-C Plugged)	16 o.c.	19/32	705	395	275	175
	20 o.c.	19/32	815	455	320	205
	24 o.c.	23/32	1085	610	425	270
	32 o.c.	7/8	1390	830	575	370
	48 o.c.	1-3/32	1790	1295	1060	680

1. Nominal capacities shall be adjusted in accordance with Section 3.2.3 to determine ASD uniform load capacity and LRFD uniform resistances.
2. Wood structural panels shall conform to the requirements for its type in DOC PS 1 or PS2.
3. Tabulated values are for maximum bending loads from wind. Loads are limited by bending or shear stress assuming a 2-span continuous condition. For more information, see the *ASD Wood Structural Panels Supplement*.

3.3 Connections

3.3.1 Connections

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

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 methods referenced 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 4.2 and 4.3, 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 Systems Resisting Horizontal Seismic Forces Contributed by Masonry and Concrete

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

Exceptions:

1. Wood floor and roof assemblies shall be permitted to be used in diaphragms and horizontal trusses to resist horizontal seismic forces (including those due to masonry veneer, fireplaces, and chimneys) provided such forces do not result in torsional force distribution through the truss or diaphragm.
2. Vertical wood structural panel sheathed shear walls shall be permitted to be used to provide resistance to seismic forces in two-story structures of masonry or concrete construction, provided the following requirements are met:
   a. Story-to-story wall heights shall not exceed 12 feet.
   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 story drift of supported masonry or concrete walls to exceed 0.7% of the story height.
   d. Wood structural panel sheathing in diaphragms shall have all unsupported edges blocked. Wood structural panel sheathing for both stories of shear walls shall have all unsupported edges blocked and, for the lower story, shall have a minimum thickness of 15/32 inch.
   e. There shall be no out-of-plane horizontal offsets between the first and second stories of wood structural panel shear walls.

4.1.6 Toenails

In seismic categories D, E, and F, toenails shall not be used to transfer lateral forces greater than 150 pounds per lineal foot from diaphragms to shearwalls, drag struts to other elements, or from shear walls to other elements.

4.2 Wood Diaphragms

4.2.1 Application Requirements

Wood diaphragms are permitted to be used to resist horizontal forces provided the deflection in the plane of the diaphragm, as determined by calculations, tests, or analogies drawn therefrom, does not exceed the permissible deflection of attached load distributing or resisting elements. Connections and blocking shall extend into the diaphragm a sufficient distance to develop the force transferred into the diaphragm.

4.2.2 Deflection

Permissible deflection shall be that deflection up to which the diaphragm and any attached load distributing or resisting element will maintain its structural integrity under design load conditions, such that the resisting element will continue to support design loads without danger to occupants of the structure.

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

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

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

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, Table 4.2)

L = Diaphragm length, ft.

ν = Induced unit shear in diaphragm, lbs./ft.

W = Diaphragm width, ft.

x = Distance from chord splice to nearest support, in.

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

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

Alternatively, for wood structural panel diaphragms, deflection is 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 Shear Capacities

The nominal unit shear capacities for seismic design are provided in Column A of Tables 4.2A, B, and C and for wind design in Column B of Tables 4.2A, B, and C. The ASD allowable unit shear capacity shall be determined by dividing the nominal unit shear capacity by a safety factor of 2.0. No further increases shall be permitted. The LRFD factored unit resistance shall be determined by multiplying the nominal unit shear capacity by a resistance factor, ϕ_D, of 0.65.

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

Diaphragms shall be defined as rigid or flexible for the purposes of distributing shear loads and designing for torsional moments. When a diaphragm is defined as flexible, the diaphragm shear forces shall be distributed to the vertical resisting elements based on tributary area. When a diaphragm is defined as rigid, the diaphragm shear forces shall be distributed based on the relative lateral stiffnesses of the vertical resisting elements for the story below.

4.2.5.1 Torsional Irregularity: Structures with rigid wood diaphragms shall be considered as torsionally irregular when the maximum story drift, computed 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 torsional irregularity exists, diaphragms shall meet the following requirements:

1. The diaphragm conforms to 4.2.7.1 - 4.2.7.3.
2. The L/W ratio of the diaphragm is less than 1:1 for one-story structures or 1:1½ for structures over one story in height.

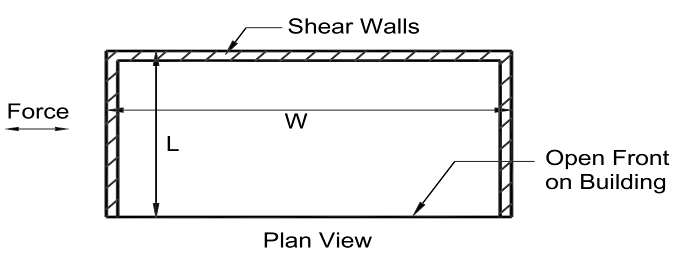
Exception: Where calculations show that diaphragm deflections can be tolerated, the length, L, shall be permitted to be increased to an L/W ratio not greater than 1½:1 when sheathed in conformance with 4.2.7.1 or to 1:1 when sheathed in conformance with 4.2.7.2 or 4.2.7.3.

4.2.5.1.1 Open Front Structures: Open front structures utilizing rigid wood diaphragms to distribute shear forces through torsion shall be permitted provided:

1. The diaphragm length, L, (normal to the open side) does not exceed 25 feet.
2. The L/W ratio (as shown in Figure 4.2.5.1) of the diaphragm is less than 1:1 for one-story structures or 1:1½ for structures over one story in height.

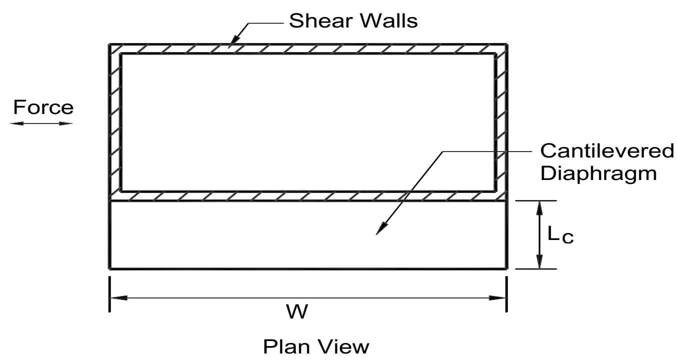
Exception: Where calculations show that diaphragm deflections can be tolerated, the length, L, (normal to the open side) shall be permitted to be increased to an L/W ratio not greater than 1½:1 when sheathed in conformance with 4.2.7.1 or 4.2.7.3 or to 1:1 when sheathed in conformance with 4.2.7.2.

Figure 4.2.5.1 Open Front Building



4.2.5.2 Cantilevered Diaphragms: Rigid wood diaphragms shall be permitted to cantilever past the outermost supporting shear wall (or other vertical resisting element) a distance, L_c, of not more than 25 feet or two thirds of the diaphragm width, W, whichever is smaller. Figure 4.2.5.2 illustrates the dimensions of L_c and W for a cantilevered diaphragm.

Figure 4.2.5.2 Cantilevered Diaphragm



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, B, and C.

4.2.6.3 Fasteners: Sheathing shall be attached to framing using approved fasteners and/or adhesives. Nails or other approved sheathing connectors shall be driven flush with the surface of the sheathing. Details on type, size, and spacing of mechanical fasteners for typical floor, roof, and ceiling diaphragm assemblies are provided in 4.2.7 and Tables 4.2A, B, and C.

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.

Exception: Wood structural panel sheathing in a diaphragm is permitted to be fastened over solid lumber planking or laminated decking provided the panel joints and lumber planking or laminated decking joints do not coincide. In addition, adjacent panel edges shall be fastened to a common member and fasteners shall not be spaced less than 3/8 inches from the edges of panels or joints in the substrate.

Where diaphragms are designated as blocked, all joints in sheathing shall occur over and be fastened to common framing members. The size and spacing of fasteners at wood diaphragm boundaries, panel edges, and intermediate supports shall be as prescribed in Tables 4.2A and B. The diaphragm shall be constructed as follows:

1. Panels not less than 4 ft. x 8 ft. except at ends where reduced widths are permitted.
2. Nails spaced not less than 3/8 inches from edges and ends of panels and framing. Maximum nail spacing of 6 inches along intermediate framing members when supports are spaced 48 inches o.c. Maximum nail spacing along intermediate framing of 12 inches for other conditions.
3. 2x nominal or wider framing at adjoining panel edges except that 3x nominal or wider framing and staggered nailing are required where:
   a) nails are spaced 2 inches o.c. or 2 ½ inches o.c., or
   b) 10d nails having penetration into framing of more than 1-1/2 in. are spaced 3 inches o.c. or less
4. Wood structural panels shall conform to the requirements for its type in DOC PS1 or PS2.

4.2.7.2 Diaphragms Diagonally Sheathed with Single-Layer of Lumber: Single diagonally sheathed lumber diaphragms are permitted to be used to resist seismic and wind forces. Single diagonally sheathed lumber diaphragms shall be constructed of minimum 1-inch thick nominal sheathing boards or 2-inch 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 4.2C. Single diagonally sheathed lumber diaphragms shall be permitted to consist of 2x nominal lumber (1½ inches thick) where the supports are not less than 3x nominal (2½ inches thick) in width or 4x nominal (3½ inches deep) in depth.

4.2.7.3 Diaphragms Diagonally Sheathed with Double-Layer of Lumber: Double diagonally sheathed lumber diaphragms are 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 4.2C.

4.2.7.4 Diaphragms Horizontally Sheathed with Single-Layer of Lumber: Horizontally sheathed lumber diaphragms are permitted to be used to resist seismic and wind forces. Horizontally sheathed lumber diaphragms shall be constructed of minimum 1-inch thick nominal sheathing boards or minimum 2-inch 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 4.2C.

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

Blocked Wood Structural Panel Diaphragms[a,b]

Sheathing Grade	Common Nail Size	Minimum Fastener Penetration in Framing (inches)	Minimum Nominal Panel Thickness (inches)	Minimum Nominal Framing Width (inches)	A SEISMIC: Nail Spacing (in.) at Diaphragm Boundries (All Cases), at Continuous Panel Edges Parallel to Load (Cases 3 & 4), and at All Panel Edges (Cases 5 & 6)								B WIND: Nail Spacing (in.) at Diaphragm Boundries (All Cases), at Continuous Panel Edges Parallel to Load (Cases 3 & 4), and at All Panel Edges (Cases 5 & 6)			
					6		4		2.5		2		6	4	2.5	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)
Structural I[c]	6d	1 1/4	5/16	2	370	15.0	500	8.5	750	12.0	840	20.0	520	700	1050	1175
				3	420	12.0	560	7.0	840	9.5	950	17.0	590	785	1175	1330
	8d	1 3/8	3/8	2	540	14.0	720	9.0	1060	13.0	1200	21.0	755	1010	1485	1680
				3	600	12.0	800	7.5	1200	10.0	1350	18.0	840	1120	1680	1890
	10d	1 1/2	15/32	2	640	24.0	850	15.0	1280	20.0	1460	31.0	895	1190	1790	2045
				3	720	20.0	960	12.0	1440	16.0	1640	26.0	1010	1345	2015	2295
Sheathing and Single-Floor[c]	6d	1 1/4	5/16	2	340	15.0	450	9.0	670	13.0	760	21.0	475	630	940	1065
				3	380	12.0	500	7.0	760	10.0	860	17.0	530	700	1065	1205
			3/8	2	370	13.0	500	7.0	750	10.0	840	18.0	520	700	1050	1175
				3	420	10.0	560	5.5	840	8.5	950	14.0	590	785	1175	1330
	8d	1 3/8	3/8	2	480	15.0	640	9.5	960	13.0	1090	21.0	670	895	1345	1525
				3	540	12.0	720	7.5	1080	11.0	1220	18.0	755	1010	1510	1710
			7/16	2	510	14.0	680	8.5	1010	12.0	1150	20.0	715	950	1415	1610
				3	570	11.0	760	7.0	1140	10.0	1290	17.0	800	1065	1595	1805
			15/32	2	540	13.0	720	7.5	1060	11.0	1200	19.0	755	1010	1485	1680
				3	600	10.0	800	6.0	1200	9.0	1350	15.0	840	1120	1680	1890
	10d	1 1/2	15/32	2	580	25.0	770	15.0	1150	21.0	1310	33.0	810	1080	1610	1835
				3	650	21.0	860	12.0	1300	17.0	1470	28.0	910	1205	1820	2060
			19/32	2	640	21.0	850	13.0	1280	18.0	1460	28.0	895	1190	1790	2045
				3	720	17.0	960	10.0	1440	14.0	1640	24.0	1010	1345	2015	2295

a. Nominal unit shear values 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.

b. For framing grades 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. The Specific Gravity Adjustment Factor shall not be greater than 1.

c. Apparent shear stiffness values, G_a, are based on nail slip and panel stiffness values for diaphragms constructed with OSB panels. When plywood panels are used, diaphragm deflections should be calculated in accordance with the ASD Wood Structural Panels Supplement.

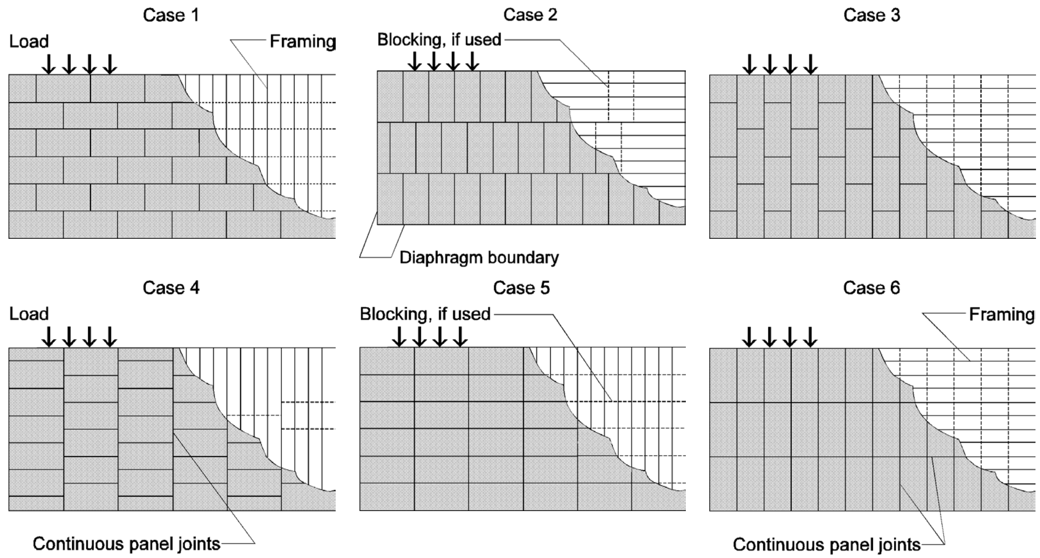


Table 4.2B Nominal Unit Shear Values for Wood-Frame Diaphragms

Unblocked Wood Structural Panel Diaphragms [a,b]

Sheathing Grade	Common Nail Size	Minimum Fastener Penetration in Framing (inches)	Minimum Nominal Panel Thickness (inches)	Minimum Nominal Framing Width	A SEISMIC Edge Nail Spacing : 6 inches Case 1 v_s (plf)	A SEISMIC Case 1 G_a (kips/in)	A SEISMIC Cases 2,3,4,5,6 v_s (plf)	A SEISMIC Cases 2,3,4,5,6 G_a (kips/in)	B WIND Edge Nail Spacing: 6 inches Case 1 v_w (plf)	B WIND Cases 2,3,4,5,6 v_w (plf)
Structural I[c]	6d	1 1/4	5/16	2	330	6.5	250	4.5	460	350
				3	370	7.0	280	4.5	520	390
	8d	1 3/8	3/8	2	480	8.5	360	6.0	670	505
				3	530	7.5	400	5.0	740	560
	10d	1 1/2	15/32	2	570	14.0	430	9.5	800	600
				3	640	12.0	480	8.0	895	670
Sheathing and Single-Floor[c]	6d	1 1/4	5/16	2	300	9.0	220	6.0	420	310
				3	340	7.0	250	5.0	475	350
			3/8	2	330	7.5	250	5.0	460	350
				3	370	6.0	280	4.0	520	390
	8d	1 3/8	3/8	2	430	9.0	320	6.0	600	450
				3	480	7.5	360	5.0	670	505
			7/16	2	460	8.5	340	5.5	645	475
				3	510	7.0	380	4.5	715	530
			15/32	2	480	7.5	360	5.0	670	505
				3	530	6.5	400	4.0	740	560
	10d	1 1/2	15/32	2	510	15.0	380	10.0	715	530
				3	580	12.0	430	8.0	810	600
			19/32	2	570	13.0	430	8.5	800	600
				3	640	10.0	480	7.0	895	670

a. Nominal unit shear values 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.

b. For framing grades 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. The Specific Gravity Adjustment Factor shall not be greater than 1.

c. Apparent shear stiffness values, G_a, are based on nail slip and panel stiffness values for diaphragms constructed with OSB panels. When plywood panels are used, diaphragm deflections should be calculated in accordance with the *ASD Wood Structural Panels Supplement.*

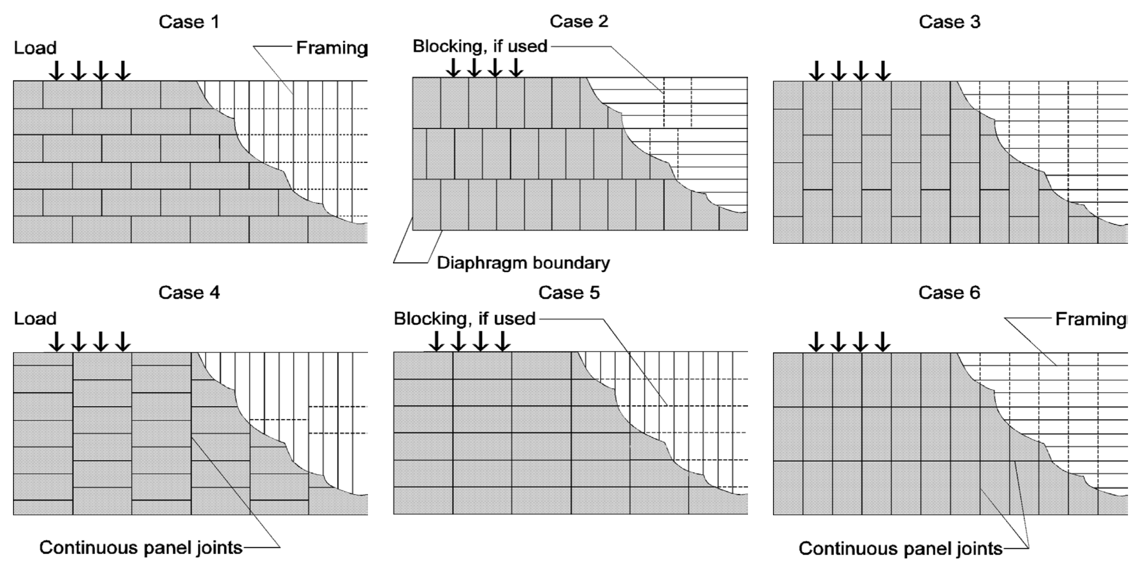


Table 4.2C Nominal Unit Shear Values for Wood-Frame Diaphragms

Lumber Diaphragms[a]

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)			

a. Nominal unit shear values 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.

4.3 Wood Shear Walls

4.3.1 Application Requirements

Wood shear walls are permitted to resist horizontal forces provided the deflection of the shear wall, as determined by calculations, tests, or analogies drawn therefrom, does not exceed the permissible deflection.

4.3.2 Deflection

Permissible deflection shall be that deflection up to which the shear wall and any attached distributing or resisting element will maintain its structural integrity under design load conditions and continue to support design loads without danger to occupants of the structure.

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}, is permitted to be calculated by use of the following equation:

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

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, (from Column A, Table 4.3), kips/in.
- 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 is 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 Section 4.3.2, where ν is equal to ν_{max} in Equation 4.3-1 and b is taken as the sum of the perforated shear wall segments $\sum L_i$.

4.3.3 Shear Capacities

The ASD allowable unit shear capacity shall be determined by dividing the nominal unit shear capacity by a safety factor of 2.0. No further increases shall be permitted. The LRFD factored unit resistance shall be determined by multiplying the nominal unit shear capacity by a resistance factor, ϕ_D, of 0.65.

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, B, and C and for wind design in Column B of Tables 4.3A, B, and C.

4.3.3.2 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.

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}, shall be calculated using the following equations:

$$G_{ac} = G_{a1} + G_{a2} \qquad (4.3\text{-}2)$$

$$V_{sc} = K_{min} G_{ac} \qquad (4.3\text{-}3)$$

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, Table 4.3)
- G_{a2} = Apparent shear wall shear stiffness for side 2, kips/in. (from Column A, Table 4.3)
- 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, Table 4.3)

4

LATERAL FORCE-RESISTING SYSTEMS

ν_{s2} = Nominal unit shear capacity for side 2, lbs./ft. (from Column A, Table 4.3)

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

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 and gypsum wall-board on opposite sides shall equal the sum of the sheathing capacities of each side separately.

4.3.3.3 Summing Shear Wall Lines: The nominal shear capacity for shear walls in a line utilizing shear walls sheathed with the same construction and materials, shall be permitted to be combined.

4.3.3.4 Shear Capacity of Perforated Shear Walls: The nominal shear capacity of a perforated shear wall shall be taken as the 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 4.3.3.4.

Table 4.3.3.4 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 below an opening remain unsheathed, the height of the opening shall be defined as the height of the wall.

2 The sum of the lengths of the perforated shear wall segments divided by the total length of the perforated shear wall.

4.3.4 Shear Wall Aspect Ratios

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

Table 4.3.4 Maximum Shear Wall Aspect Ratios

Shear Wall Sheathing Type	Maximum h/b_s Ratio
Wood structural panels, all edges nailed	3½:1[1]
Particleboard, all edges nailed	2:1
Diagonal Sheathing, conventional	2:1
Gypsum wallboard[2]	2:1
Portland Cement Plaster[2]	2:1
Fiberboard	1½:1

1 For design to resist seismic forces, the shear wall aspect ratio shall not exceed 2:1 unless the nominal unit shear capacity is multiplied by $2b_s/h$. In no case shall the aspect ratio exceed 3½:1.
2 Walls having aspect ratios exceeding 1½:1 shall be blocked.

4.3.4.1 Aspect Ratio of Perforated Shear Wall Segments: The aspect ratio limitations of 4.3.4 shall apply to perforated shear wall segments within a perforated shear wall. For design to resist seismic forces, the nominal shear capacity of the perforated shear wall shall be multiplied by $2b_s/h$ when the aspect ratio of any perforated shear wall segment included in the sum of shear wall segment lengths, $\sum L_i$, is greater than 2:1, but does not exceed 3½:1. Portions of walls with aspect ratios in excess of 3½:1 shall not be counted in the sum of shear wall segments.

4.3.5 Shear Walls With Openings

The provisions of this section shall apply to the design of shear walls with openings. Where framing and connections around the openings are designed for force transfer around the openings the provisions of 4.3.5.1 shall apply. Where framing and connections around the opening are not designed for force transfer around the openings the provisions of 4.3.5.2 shall apply.

4.3.5.1 Force Transfer Around Openings: Where shear walls with openings are designed for force transfer around the openings, the aspect ratio limitations of 4.3.4 shall apply to the overall shear wall including openings and to each wall pier at the sides of an opening. The height of a wall pier shall be defined as the clear height of the pier at the side of an opening. The length of a wall pier shall be defined as the sheathed length of the pier. Design for force transfer shall be based on a rational analysis. The length of a wall pier shall not be less than 2 feet.

4.3.5.2 Perforated Shear Walls: Where wood structural panel shear walls with openings are not designed for force transfer around the opening, they shall be designed as perforated shear walls. The following limitations shall apply:

a. 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, however the length of such openings shall not be included in the length of the perforated shear wall.
b. The nominal unit shear capacity shall not exceed 2,000 plf.
c. Where out of plane offsets occur, portions of the wall on each side of the offset shall be considered as separate perforated shear walls.
d. Collectors for shear transfer shall be provided through the full length of the perforated shear wall.
e. 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.
f. Perforated shear wall height, h, shall not exceed 20 feet.

4

LATERAL FORCE-RESISTING SYSTEMS

4.3.6 Construction Requirements

4.3.6.1 Framing Requirements: All framing used for shear wall construction shall be 2x nominal or larger members. 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.

a. 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:

$$T = C = \nu h \quad (4.3\text{-}4)$$

where:

C = Compression chord force, lbs.

h = Shear wall height, ft.

T = Tension chord force, lbs.

ν = Induced unit shear, lbs./ft.

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 forces at each story level shall be calculated in accordance with the following:

$$T = C = \frac{Vh}{C_o \sum L_i} \tag{4.3-5}$$

where:

C_o = Shear capacity adjustment factor from Table 4.3.3.4

V = Induced shear force in perforated shear wall, lbs.

ΣL_i = Sum of perforated shear wall segment lengths, ft.

4.3.6.2 Sheathing: Shear walls shall be sheathed with approved materials. Sheathing nails or other approved sheathing connectors shall be driven flush with the surface of the sheathing. Details on sheathing types and thicknesses for commonly used shear wall assemblies are provided in 4.3.7 and Tables 4.3A, B, and C.

4.3.6.3 Fasteners: Sheathing shall be attached to framing using approved fasteners. Details on type, size, and spacing of mechanical fasteners in commonly used shear wall assemblies are provided in 4.3.7 and Tables 4.3A, B, and C.

a. Adhesives: Adhesive attachment of shear wall sheathing is not permitted as a substitute for mechanical fasteners. Approved adhesive attachment systems shall be permitted in Seismic Design Categories A and B where R = 1.5 and Ω_0 = 2.5 unless other values are approved. In Seismic Design Categories C-F, adhesive attachment of shear wall sheathing is not permitted.

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.

a. Anchorage for In-plane Shear: Connections shall be provided to transfer the induced unit shear force, ν, into and out of each shear wall.
   (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 (drag struts) connecting shear wall segments, shall be calculated in accordance with the following:

$$\nu_{max} = \frac{V}{C_o \sum L_i} \tag{4.3-6}$$

b. 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 4.3.6.1a), an anchoring device shall be provided at the end of each shear wall.
   (1) Uplift Anchorage for Perforated Shear Walls: In addition to the requirements of 4.3.6.4.b, 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, determined in Section 4.3.6.4.a.(1) or calculated by rational analysis.

c. Anchor Bolts: Foundation anchor bolts shall have a steel plate washer under each nut not less than 2½" x 2½" x ¼". The plate washer shall extend to within ½" of the edge of the bottom plate on the sheathed side.

d. 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, panel edges, and intermediate supports shall be as provided in Table 4.3A. The shear wall shall be constructed as follows:

a. Panels installed either horizontally or vertically with panel joints occurring over common studs or blocking. Panels not less than 4 ft. x 8 ft. except that a single panel with a minimum dimension of 1 foot is permitted if it is fully blocked and nailed.

b. Nails spaced not less than 3/8 inch from edges and ends of panels, studs, blocking, and top and bottom plates. Maximum nail spacing of 6 inches along intermediate framing members for 3/8-inch and 7/16-inch panels installed on studs spaced 24 inches o.c. Maximum nail spacing along intermediate framing of 12 inches for other conditions.

c. 2x or wider framing at adjoining panel edges except that 3x or wider framing and staggered nailing are required where:
   (1) nails are spaced 2 inches o.c., or
   (2) 10d nails having penetration into framing of more than 1-1/2 inches are spaced 3 inches o.c., or less, or
   (3) nominal unit shear capacity exceeds 700 plf in seismic Design Category D, E, or F.

d. Maximum stud spacing of 24 inches.

e. Wood structural panels shall conform to the requirements for its type in DOC PS1 or PS2.

4.3.7.2 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, panel edges, and intermediate supports shall be as provided in Table 4.3A. The shear wall shall be constructed as follows:

a. Panels installed either horizontally or vertically with panel joints occurring over common studs or blocking. Panels not less than 4 feet x 8 feet except that a single panel with a minimum dimension of 1 foot is permitted if it is fully blocked and nailed.

b. Nails spaced not less than 3/8 inch from edges and ends of panels, studs, blocking, and top and bottom plates. Maximum nail spacing of 6 inches along intermediate framing members for 3/8-inch panels installed on studs spaced 24 inches o.c. Maximum nail spacing along intermediate framing of 12 inches for other conditions.

c. 2x or wider framing at adjoining panel edges.

d. Maximum stud spacing of 24 inches.

e. Particleboard shall conform to ANSI A208.1.

4.3.7.3 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, panel edges, and intermediate supports shall be as provided in Table 4.3A. The shear wall shall be constructed as follows:

a. 4 feet x 8 feet fiberboard sheathing shall be applied vertically (long dimension parallel to studs) with panel joints occurring over common studs or blocking.

b. Nails spaced not less than 3/8 inch from edges and ends of panels, studs, blocking, and top and bottom plates. Maximum nail spacing 6 inches along intermediate framing members.

c. 2x or wider framing at adjoining panel edges.

d. Maximum stud spacing of 16 inches.

e. Minimum length of galvanized roofing nails is 1½" for ½ inch thick sheathing and 1¾" for 25/32 inch thick sheathing.

f. Fiberboard sheathing shall conform to either AHA 194.1 or ASTM C208.

4.3.7.4 Gypsum Wallboard, Gypsum Veneer Base, Water-Resistant Backing Board, Gypsum Sheathing, Gypsum Lath and Plaster, or Portland Cement Plaster Shear Walls: Shear walls sheathed with gypsum wallboard, gypsum veneer base, water-resistant backing board, gypsum sheathing, 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-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 4.3B. Nails shall be spaced not less than 3/8 inch from edges and ends of panels, studs, blocking, and top and bottom plates. Wood framing shall be 2x or wider.

a. Gypsum Wallboard, Gypsum Veneer Base, Water-Resistant Backing Board: Gypsum wallboard, gypsum veneer base, or water-resistant backing board shall be applied parallel or perpendicular to studs. Gypsum wallboard shall conform to ASTM C36 and shall be installed in accordance with ASTM C 840. Gypsum veneer base shall conform to ASTM C 588 and shall be installed in accordance with ASTM C 844. Water-resistant backing board shall conform to ASTM C630 and shall be installed in accordance with ASTM C 840.

b. Gypsum Sheathing: Four-foot-wide pieces of gypsum sheathing shall be applied parallel or perpendicular to studs. Two-foot-wide pieces of gypsum sheathing shall be applied perpendicular to the studs. Gypsum sheathing shall conform to ASTM C79 and shall be installed in accordance with ASTM C 1280.

c. Gypsum Lath and Plaster: Gypsum lath shall be applied perpendicular to the studs. Gypsum lath shall conform to ASTM C37 and shall be installed in accordance with ASTM C 841. Gypsum plaster shall conform to the requirements of ASTM C 28.

d. Expanded Metal or Woven Wire Lath and Portland Cement: Expanded metal or woven wire lath and portland cement shall conform to ASTM C847, ASTM 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.

4.3.7.5 Shear Walls Diagonally Sheathed with Single-Layer of Lumber: Single diagonally sheathed lumber shear walls are permitted to be used to resist wind forces and seismic forces in Seismic Design Catergories A, B, C, and D. Single diagonally sheathed lumber shear walls shall be constructed of minimum 1-inch 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 4.3C.

4.3.7.6 Shear Walls Diagonally Sheathed with Double-Layer of Lumber: Double diagonally sheathed lumber shear walls are 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-inch 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 4.3C.

4.3.7.7 Shear Walls Horizontally Sheathed with Single-Layer of Lumber: Horizontally sheathed lumber shear walls are 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-inch 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 4.3C.

4.3.7.8 Shear Walls Sheathed with Vertical Board Siding: Vertical board siding shear walls are 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-inch thick nominal sheathing boards applied directly to studs and blocking. Nailing of vertical board siding shear walls shall be in accordance with Table 4.3C.

Table 4.3A Nominal Unit Shear Values for Wood-Frame Shear Walls[a,c]

Wood-based Sheathing

Sheathing Material	Minimum Nominal Panel Thickness (inches)	Minimum Fastener Penetration in Framing (inches)	Fastener Type & Size	A SEISMIC: Panel Edge Fastener Spacing (inches) 6		4		3		2		B WIND: Panel Edge Fastener Spacing (inches) 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)
Wood Structural Panels - Structural I[d]			Nail (common or galvanized box)												
	5/16	1-1/4	6d	400	13.0	600	18.0	780	23.0	1020	35.0	560	840	1090	1430
	3/8[b]	1-3/8	8d	460	19.0	720	24.0	920	30.0	1220	43.0	645	1010	1290	1710
	7/16[b]			510	16.0	790	21.0	1010	27.0	1340	40.0	715	1105	1415	1875
	15/32			560	14.0	860	18.0	1100	24.0	1460	37.0	785	1205	1540	2045
	15/32	1-1/2	10d	680	22.0	1020	29.0	1330	36.0	1740	50.0	950	1430	1860	2435
Wood Structural Panels - Sheathing[d]	5/16	1-1/4	6d	360	13.0	540	18.0	700	24.0	900	37.0	505	755	980	1260
	3/8			400	11.0	600	15.0	780	20.0	1020	32.0	560	840	1090	1430
	3/8[b]	1-3/8	8d	440	17.0	640	25.0	820	31.0	1060	45.0	615	895	1150	1485
	7/16[b]			480	15.0	700	22.0	900	28.0	1170	42.0	670	980	1260	1640
	15/32			520	13.0	760	19.0	980	25.0	1280	39.0	730	1065	1370	1790
	15/32	1-1/2	10d	620	22.0	920	30.0	1200	37.0	1540	52.0	870	1290	1680	2155
	19/32			680	19.0	1020	26.0	1330	33.0	1740	48.0	950	1430	1860	2435
Plywood Siding			Nail (galvanized casing)												
	5/16	1-1/4	6d	280	13.0	420	16.0	550	17.0	720	21.0	392	588	770	1008
	3/8	1-1/2	8d	320	16.0	480	18.0	620	20.0	820	22.0	448	672	868	1148
Particleboard Sheathing - (M-S "Exterior Glue" and M-2 "Exterior Glue")			Nail (common or galvanized box)												
	3/8		6d	240	15.0	360	17.0	460	19.0	600	22.0	335	505	645	840
	3/8		8d	260	18.0	380	20.0	480	21.0	630	23.0	365	530	670	880
	1/2			280	18.0	420	20.0	540	22.0	700	24.0	390	590	755	980
	1/2		10d	370	21.0	550	23.0	720	24.0	920	25.0	520	770	1010	1290
	5/8			400	21.0	610	23.0	790	24.0	1040	26.0	560	855	1105	1455
Fiberboard Sheathing Structural			Nail (common or galvanized roofing)												
	1/2		8d common or 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		8d common or 11 ga. galv. roofing nail (0.120" x 1 3/4" long x 7/16" head)			360	4.0	480	5.0	540	5.5		505	670	755

a. Nominal unit shear values 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.

b. Shears are permitted to be increased to values shown for 15/32 inch sheathing with same nailing provided (a) studs are spaced a maximum of 16 inches o.c., or (b) if panels are applied with long dimension across studs.

c. For framing grades 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. The Specific Gravity Adjustment Factor shall not be greater than 1.

d. Apparent shear stiffness values, G_a, are based on nail slip and panel stiffness values for shear walls constructed with OSB panels. When plywood panels are used, shear wall deflections should be calculated in accordance with the *ASD Wood Structural Panels Supplement.*

Table 4.3B Nominal Unit Shear Values for Wood-Frame Shear Walls[a]

Gypsum and Cement Plaster

Sheathing Material	Material Thickness	Fastener Type & Size[b]	Max. Fastener Edge Spacing[c]	Max. Stud Spacing		A SEISMIC v_s (plf)	A SEISMIC G_a (kips/in)	B WIND v_w (plf)
Gypsum wallboard, gypsum veneer base, 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	6.5	220
			7"	16"	unblocked	200	5.5	200
			4"	16"	unblocked	250	7.0	250
		No. 6 Type S or W drywall screws 1-1/4" long	7"	16"	blocked	250	6.5	250
			4"	16"	blocked	300	9.0	300
		No. 6 Type S or W drywall screws 1-1/4" long	8/12"	16"	unblocked	120	3.0	120
			4/16"	16"	blocked	320	8.5	320
			4/12"	24"	blocked	310	9.5	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	8.0	290
		No. 6 Type S or W drywall screws 1-1/4" long	7"	16"	blocked	290	7.5	290
			4"	16"	blocked	350	10.0	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	4.0	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 2-38" 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	17.0	500
Gypsum sheathing	1/2" x 2' x 8'	0.120" nail x 1 3/4" long, 7/16" head, diamond-point, galvanized	4"	16"	unblocked	150	5.0	150
	1/2" x 4'		4"	24"	blocked	350	10.0	350
			7"	16"	unblocked	200	5.0	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	13.0	400
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	6.5	200
Expanded metal or woven wire lath and portland cement plaster	7/8"	0.120" nail x 1½" long, 7/16" head	6"	16"	unblocked	360	12.0	360

a. Nominal unit shear values 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.

b. Type S or W drywall screws shall conform to requirements of ASTM C 1002.

c. 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 in the field.

Table 4.3C Nominal Unit Shear Values for Wood-Frame Shear Walls[a]

Lumber Shear Walls

Sheathing Material	Sheathing Nominal Dimensions	Type, Size and Number of Nails per Board: Nailing at Intermediate Studs (nails/board/support)	Type, Size and Number of Nails per Board: Nailing at Shear Wall 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 & 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	10.0	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

a. Nominal unit shear values 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 - 4.3.7.8.

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