2021 Special Design Provisions for Wind and Seismic

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The 2021 Edition of *Special Design Provisions for Wind and Seismic* (SDPWS) was approved as an American National Standard on July 22, 2020, with the designation ANSI/AWC SDPWS-2021 (*Figure 1*). The 2021 SDPWS was developed by the American Wood Council's (AWC's) Wood Design Standards Committee (WDSC) and contains provisions for the design of wood members, fasteners, and assemblies to resist wind and seismic forces. Notable revisions are summarized below (*also see Table 1 online for a summary of changes by Chapter*):

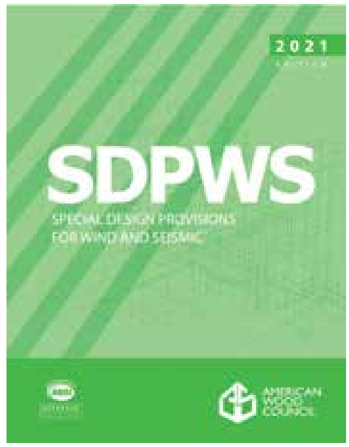

Figure 1. 2021 SDPWS is referenced in the 2021 International Building Code.

- Revised Chapter 3 tables of nominal uniform load capacities for resistance to out of plane wind loads;
- Revised organization of requirements in Chapter 4 to differentiate between sheathed wood-frame systems and new cross-laminated timber (CLT) systems;
- Added language to clarify reference conditions (framing materials and nail type and size) for applicability of design value tables;
- Revised format of diaphragm and shear wall nominal unit shear capacity tables to a single nominal value for each configuration (in contrast to tables in prior editions that tabulated separate nominal values for wind design and seismic design), coupled with revised ASD reduction factors and LRFD resistance factors to work with the revised format;
- Added provisions for the vertical distribution of seismic force-resisting system (SFRS) strength for structures assigned to Seismic Design Category D, E, or F;

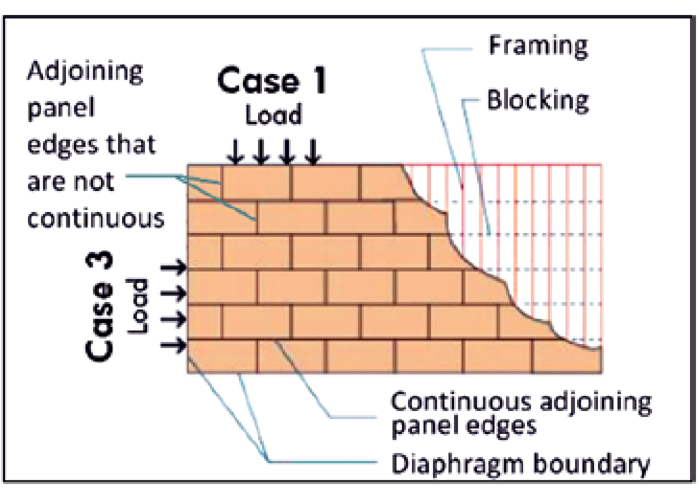

Figure 2. Adjoining panel edge locations, sheathed wood-frame diaphragm (select cases).

- Added equations for calculating the deflection of cantilevered diaphragms;
- Added provisions for and reference to ASTM D7989 Standard Practice for Demonstrating Equivalent In-Plane Lateral Seismic Performance to Wood-Frame Shear Walls Sheathed with Wood Structural Panels;
- Added an 8% shear strength reduction for wood-frame shear walls nailed with 10d common nails and using hold-downs installed on the inside face of end posts;
- Revised equation for calculation of the perforated shear wall shear capacity adjustment factor, C_o; and,
- Added provisions for the design of CLT diaphragms and CLT shear walls.

Out-of-Plane Wind Load Resistance

Revised tables in Chapter 3 expand the tabulation of nominal uniform load capacities for wall sheathing and roof sheathing resisting out of plane wind loads. Table 3.2.1A (for wall sheathing) and Table 3.2.2 (for roof sheathing) now include separate nominal uniform load capacities for OSB and plywood resisting out-of-plane wind loads, as well as capacities for W24 wall sheathing and Structural I sheathing panels.

Revised Organization

Organization of SDPWS Chapter 4 is revised to better differentiate between general requirements (i.e., those that are generally applicable to all systems addressed by the standard) and those requirements specific to either sheathed wood-frame systems or new CLT systems. Chapter 4, Lateral Force-Resisting Systems, is now organized as follows:

4.1 General
4.2 Sheathed Wood-Frame Diaphragms
4.3 Sheathed Wood-Frame Shear Walls
4.4 Wood Structural Panels Designed to Resist Combined Shear and Uplift from Wind
4.5 Cross-Laminated Timber (CLT) Diaphragms
4.6 Cross-Laminated Timber (CLT) Shear Walls

Reference Conditions for Framing and Fasteners

Reference framing materials for wood structural panel diaphragms and shear walls are sawn lumber or structural glued-laminated timber (Section 4.1.2.1). Use of other framing materials in diaphragm and shear wall construction (such as Structural Composite Lumber (SCL)) is required to be per the manufacturer's approved instructions or an approved evaluation report. This clarification was added to account for product-specific nail size and spacing requirements to limit the potential for splitting in products that may exhibit more splitting than reference framing materials.

Similarly, reference fastener types and dimensions used for sheathing attachment in diaphragms and shear walls and associated with the tabulated nominal unit shear capacity values (such as those provided in Table 4.2A for diaphragms and Table 4.3A for shear walls) are now prescribed in the tables. They are located side-by-side with tabulated nominal unit shear capacities. Revisions to prescribe nail dimensions in nominal unit shear capacity tables and replacement of the term “fastener penetration” with “fastener bearing length” in table column headings were to clarify the full-length nail basis of the tabulated nominal unit shear capacities. Nails of different types or dimensions are considered alternatives to the specified nails.

For diaphragms, Section 4.2.8.1.1 was revised, and a new Figure 4B was added to clarify differences in framing requirements (i.e., either 2x nominal minimum or 3x nominal minimum width of nailed face) for framing at adjoining panel edges that are not continuous and for framing at continuous adjoining panel edges (*Figure 2*). In addition, for consistency with the full-length nail basis of tabulated unit shear capacities for diaphragms, revisions to 4.2.8.1.1(b) also removed the minimum 1½-inch penetration criterion for closely spaced 10d common nails.

Nominal Unit Shear Capacity – Single Value Format

Nominal unit shear capacity tables for wood-frame diaphragms and wood-frame shear walls tabulate a single nominal design value that is applicable for both wind and seismic design for a given combination of sheathing, fastening schedule, and framing (in prior editions, separate nominal values were tabulated for wind design and seismic design). Coupled with this new tabulation of a single nominal unit shear capacity for wind and seismic are new ASD reduction factors and LRFD resistance factors for wind and seismic design. For wind design, there is no change in either ASD or LRFD design strengths from prior editions. For the seismic design of wood-frame diaphragms (in SDPWS Tables 4.2A, 4.2B, 4.2C, and 4.2D) and wood-frame shear walls (in SDPWS Tables 4.3A, 4.3B, and 4.3D), there is no change in ASD design strengths. However, for LRFD design strengths, there is a reduction of approximately 11% from the previous edition. For the seismic design of wood-frame shear walls using nominal unit shear capacities from Table 4.3C for gypsum board, gypsum lath and plaster, and Portland cement plaster, ASD design strength is approximately 70% of that obtained from prior editions. The reduction in design strength results from the application of a consistent ASD reduction factor of 2.8 (a factor of 2.0 was used in prior editions for SDPWS Table 4.3C sheathing systems) across all shear wall systems in the standard. The revised format using a single nominal unit shear capacity for both wind and seismic better represents minimum strength expectations for wood-frame diaphragms and wood-frame shear wall systems in SDPWS. Also, it simplifies design requirements tied to nominal unit shear capacity.

Vertical Distribution of Story Lateral Strength

To reduce the potential for a degraded seismic response due to the presence of a weaker lower story as predicted from FEMA P695 numerical studies of wood-frame wood structural panel shear wall building models, new provisions in Section 4.1.8 prohibit designs in which the seismic force-resisting system (SFRS) lateral design strength for a lower story in wood buildings is less than the SFRS lateral design strength of the story above in seismic design categories D, E, and F. An exception to this prohibition allows the lower story SFRS lateral design strength, $V_{r(i)}$, to be less than the SFRS lateral design strength of the story above, $V_{r(i+1)}$, if the lower story SFRS lateral design strength exceeds the lateral design load for that story by the ratio of $V_{r(i+1)}/V_{r(i)}$. This criterion is more stringent than weak-story irregularity limits in ASCE 7-16 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, which allow a lower story SFRS to be as much as 35% less than the upper story SFRS in Seismic Design Category D and as much as 20% less than the upper-story SFRS in Seismic Design Categories E and F without requiring strengthening of the weaker lower story to exceed the lateral design load.

Cantilevered Diaphragms

Table 4.2.3 provides two new equations for calculating diaphragm deflection at the end of a cantilevered diaphragm from i) a uniformly distributed load and ii) a concentrated load at the end. The equations rely on the use of apparent shear stiffness, G_a, used in the standard for calculating shear deformations.

Seismic Equivalency to Wood-Frame Wood Structural Panel Shear Walls

Recognizing the variety of products used in wood-frame wood structural panel shear wall systems (e.g., framing, sheathing, and fastening) and that alternative bracing systems are common and often evaluated for equivalence, the reference to ASTM D7989 (Section 4.3.7.1.1) is made to provide for consistent evaluations of an alternative system's "seismic-equivalence" to the wood-frame wood structural panel shear walls addressed in the standard.

Shear Wall Strength Reduction

Footnote 10 of Table 4.3A requires the application of a 0.92 factor to the nominal unit shear capacity of wood-structural panel sheathed wood-frame shear walls having sheathing attached with 10d common nails and with a hold-down mounted to the inside face of the shear wall end post. The factor accounts for reduced strength observed in standardized cyclic shear wall testing that employs eccentric hold-downs attached to the inside face (e.g., within the wall cavity, *Figure 3*). The reduced strength (not observed with other sheathing nail sizes) is believed to be associated with reduced effectiveness of the eccentric hold-down leading to prying and sheathing nail damage at shear wall corners. However, no such strength reductions have been observed in testing performed on walls with different end post details, such as hold-downs mounted on the outside face or both faces of end posts and rod hold-down systems.

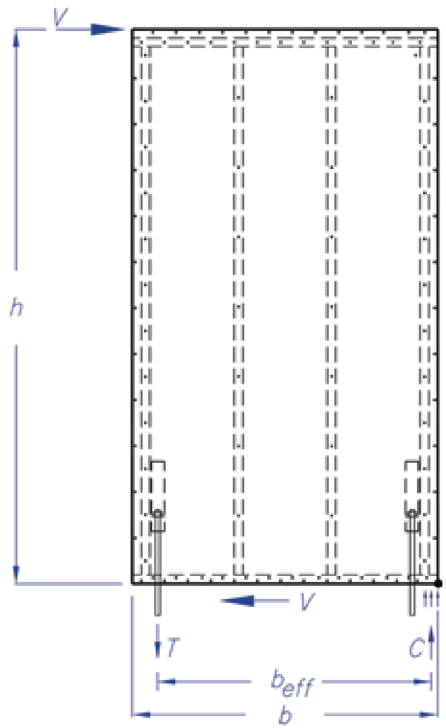

Figure 3. Wood-frame shear wall notations (hold-down on the inside face of post shown).

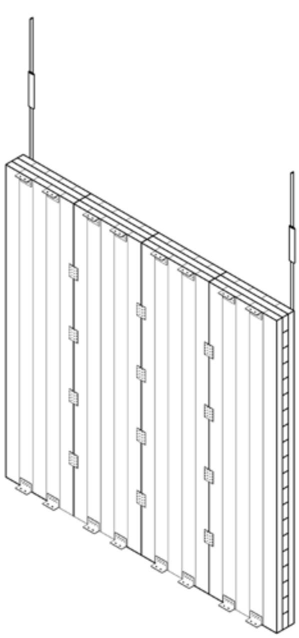

Figure 4. Cross-laminated timber shear wall, multi-panel configuration.

Perforated Shear Wall

Revisions clarify that sheathed areas around openings are to have the same nailing (i.e., nail size and spacing) associated with the design shear capacity of the full-height perforated shear wall segments or be included in the area of openings (Section 4.3.2.3(9). The same nailing of sheathed areas above and below openings has been used in perforated shear wall testing that forms the basis of empirical opening adjustment factors. Revised equations for calculating the Shear Capacity Adjustment Factor, C_o, simplify the presentation and are more consistent with the underlying empirical equations over the full range of opening area ratios. The Shear Capacity Adjustment Factor Table (Table 4.3.5.6) is updated accordingly.

Cross-Laminated Timber Diaphragms

New Section 4.5 CLT Diaphragms adds provisions for the design of CLT diaphragms using principles of engineering mechanics and values of wood member and connection strength in accordance with the *National Design Specification*® (NDS) *for Wood Construction*. Requirements include diaphragm shear strength to be based on dowel-type fasteners exhibiting yield modes Mode IIIs or Mode IV per the NDS and use of design force increase factors for the design of wood elements, steel parts, and wood or steel chord splice connections (factors ranging from 1.0 for wind design to 2.0 for seismic). Combining these requirements is intended to ensure the development of a minimum level of diaphragm overstrength consistent with that provided by nailed wood-frame wood structural panel diaphragms.

Cross-Laminated Timber Shear Walls

New Section 4.6 CLT Shear Walls adds provisions for the design of CLT shear walls (*Figure 4*), including prescriptive requirements for fasteners, connectors, and individual CLT panel aspect ratios per Appendix B. Two CLT shear wall systems are defined: i) CLT shear wall, and ii) CLT shear wall with shear resistance provided by high aspect ratio panels only. Associated seismic design coefficients (i.e., R = 3 or 4, respectively) are included in the 2020 NEHRP *Recommended Seismic Provisions for New Buildings and Other Structures* and have been proposed for inclusion in ASCE 7-22. CLT shear walls not conforming to requirements of Appendix B are subject to approval as an alternative method of construction, with default use limited to Seismic Design Categories A and B and seismic design coefficients limited to R = 1.5, C_d = 1.5, and Ω_o = 2.5 unless other values are approved.

Conclusion

The 2021 SDPWS is available in a free view-only electronic format and for purchase at **www.awc.org**. Additional information on SDPWS provisions is available in the SDPWS *Commentary*. The 2021 SDPWS *Commentary* is scheduled to be available in June 2021. The 2021 SDPWS represents the state-of-the-art design of wood members and connections to resist wind and seismic loads. Reference to the 2021 SDPWS is included in the 2021 *International Building Code*.▪

Table 1 is included in the PDF version of the article at **STRUCTUREmag.org.**

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Table 1. Summary of Changes in 2021 SDPWS

Chapter 1 – No changes
Chapter 2 – General Design Requirements 1) Revised Section 2.1.2 Design Methods to address seismic requirements for buildings in Seismic Design Category A (i.e. need to comply with general structural integrity provisions of ASCE 7). 2) Added Section 2.1.4 Use of Standard to clarify that table footnotes are considered to be a mandatory part of the table. 3) Revised Section 2.2 Terminology to: • add terms – Approved, Gypsum Board, Lateral Force Resisting System (LFRS), Seismic Force-Resisting System (SFRS), and Shear Wall Sheathing System; • revise terms – Chord, Force-Transfer Around Openings (FTAO) Shear Wall; • remove term – Required Strength (unused term); • throughout standard, clarify that "induced" means "induced by design loads" or similar wording. 4) Revised Section 2.3 Notations for consistency with notation changes in the Chapters 3 and 4 and Appendix B.
Chapter 3 – Members and Connections 5) Separated Table 3.2.1 (Nominal Uniform Load Capacities for Wall Sheathing Resisting Out-of-Plane Wind Loads) into two tables – one for wood structural panel wall sheathing (Table 3.2.1A) and one for other wall sheathing types (Table 3.2.1B for particleboard, hardboard, and fiberboard). Table 3.2.1A includes expanded break-out of wood structural panel configurations for OSB, plywood, W24 span rating, and Structural I sheathing panels. 6) Revised Table 3.2.2 (Nominal Uniform Load Capacities for Roof Sheathing Resisting Out-of-Plane Wind Loads) to include expanded break-out of wood structural panel configurations for OSB, plywood, and Structural I sheathing panels. 7) Revised pointer to directly refer to 2.1.2 Design Methods applicable to members and connections in Section 3.4.2(2) Design Requirements for uplift force-resisting systems.
Chapter 4 – Lateral Force-Resisting Systems 8) Revised organization of Chapter 4 to differentiate between general requirements, requirements specific to sheathed wood-frame systems (such as wood structural panel sheathed diaphragms and shear walls with repetitive wood framing), and new requirements for cross-laminated timber (CLT) diaphragms and shear walls. **General Design Requirements** 9) In Section 4.1.1, added hierarchy of requirements for design in accordance with the applicable building code and ASCE 7. 10) In Section 4.1.2.1, added clarification that reference framing materials for wood structural panel diaphragms and shear walls are sawn lumber or structural glued-laminated timber. For other framing materials used in diaphragm and shear wall construction, use is per the manufacturer's approved instructions or approved evaluation report. In Sections 4.1.2.1 and 4.1.2.2 added clarification that wood lateral force resisting systems are permitted to be designed by "approved alternate procedures" that are in accordance with principles of engineering mechanics. 11) In Section 4.1.4 Shear Capacities, shear capacity adjustments for diaphragms and shear walls are revised to utilize separate values of the ASD reduction factor and LRFD resistance factor for wind and seismic design. The specified factors are coordinated with revised nominal unit shear capacity tables for diaphragms and shear walls that tabulate a single nominal design value applicable for wind and seismic design. For wind design of diaphragms and shear walls, the revised adjustment factors (i.e., ASD reduction factor and LRFD resistance factor) produce the same design strengths as obtained from the prior SDPWS version. For seismic design of wood-frame diaphragms (in Tables 4.2A, 4.2B, 4.2C, 4.2D) and wood-frame shear walls (in Tables 4.3A, 4.3B, and 4.3D) (i.e., wood-frame wood structural panel and lumber sheathed systems), there is no change in design strengths when using ASD and an approximate 11% reduction in LRFD design strength from the prior edition. For seismic design of wood-frame shear walls using nominal unit shear capacities from Table 4.3C for gypsum board, gypsum lath and plaster, and Portland cement plaster, ASD design strength is approximately 70% of that obtained from prior editions. 12) In Section 4.1.7 Horizontal Distribution of Shear, added criteria for rigid diaphragm idealization is provided for the cantilevered diaphragm configuration in which the cantilever length dimension is associated with a line of vertical lateral force-resisting elements. 13) Added a new Section 4.1.8 Vertical Distribution of Seismic Force-Resisting System (SFRS) Strength, which specifies an adjacent story lateral strength criteria applicable in Seismic Design Category D, E, or F. The lower story SFRS lateral design strength, $V_{r(i)}$, is required to be equal to or greater than the adjacent upper story SFRS lateral design strength, $V_{r(i+1)}$, unless the lower story SFRS lateral design strength exceeds the lateral design load by the ratio of $V_{r(i+1)}/V_{r(i)}$.

Sheathed Wood-Frame Diaphragms

14) Revised Tables 4.2A, 4.2B, and 4.2C (Nominal Unit Shear Capacities for Wood Structural Panel Diaphragms) and 4.2D (Nominal Unit Shear Capacities for Lumber Sheathed Diaphragms) to:
    - utilize a single nominal design value applicable for both wind and seismic design
    - include a detailed description of reference fasteners for diaphragms (i.e., carbon steel, smooth shank nails) and dimensions including diameter, length, and head diameter associated with the tabulated nominal unit shear capacity values;
    - update diaphragm footnote figures to use terminology (i.e., "adjoining panel edges that are not continuous" and "continuous adjoining panel edges") consistent with revisions to Section 4.2.8.1.1; and
    - use a revised column heading that replaces "fastener penetration" with "fastener bearing length" for consistency with NDS lateral calculations tied to bearing length and in recognition that full-length nails may penetrate through the supporting framing (i.e., top chord of a 2x nominal parallel chord truss) in diaphragm construction.
15) Added new Table 4.2.3 Diaphragm Deflection Equations and two new equations for calculating diaphragm deflection at the end of a cantilevered diaphragm from i) a uniformly distributed load, and ii) a concentrated load at the end.
16) In Section 4.2.8.1.1 for wood structural panel diaphragms, revised requirements for width of nailed face of framing members and blocking to clarify permissible use of 2x nominal in certain locations where 10d common nails are used. Figure 4B is added to clarify the phrase "adjoining panel edges that are not continuous," and removed criteria for closely spaced 10d common nails having exactly 1-1/2 in. penetration into the framing.

Sheathed Wood-Frame Shear Walls

17) Revised Tables 4.3A, 4.3B, 4.3C, and 4.3D (Nominal Unit Shear Capacities for Sheathed Wood-Frame Shear Walls) to:
    - utilize a single nominal design value applicable for both wind and seismic design;
    - include a detailed description of reference fasteners for shear walls (i.e., carbon steel, smooth shank nails) and dimensions including length, diameter, and head diameter associated with the tabulated nominal unit shear capacity values; and
    - use a revised column heading that replaces "fastener penetration" with "fastener bearing length" for consistency with NDS lateral calculations tied to bearing length and in recognition that full-length nails may penetrate through the supporting framing (i.e., 2x nominal flatwise blocking) in shear wall construction.
18) For Table 4.3.A Nominal Unit Shear Capacities for Sheathed Wood-Frame Shear Walls, added footnote 10 which requires a 0.92 factor (e.g., an 8% strength reduction) to be applied where wood structural panel sheathed shear walls having sheathing attached with 10d common nails and the hold-down attached to the inside face of the shear wall end post.
19) In Section 4.3.2.3(9) Perforated Shear Walls, added a requirement that sheathed areas around openings shall have the same nailing associated with the design shear capacity or such areas shall be included in the area of openings.
    - use a revised column heading that replaces "fastener penetration" with "fastener bearing length" for consistency with NDS lateral calculations tied to bearing length and in recognition that full-length nails may penetrate through the supporting framing (i.e., top chord of a 2x nominal parallel chord truss) in diaphragm construction.
20) In Section 4.3.5.6 Shear Capacity of Perforated Shear Walls, revised calculation of the C_o factor to be consistent with the underlying empirical equation across the full range of applicability. The Shear Capacity Adjustment Factor Table (Table 4.3.5.6) is updated to the results of the revised C_o factor equation.
21) In Table 4.3.3 Maximum Shear Wall Aspect Ratios, revised terminology to utilize h/b for aspect ratio instead of h/b_s.
22) In Equation 4.3-1 for shear wall deflection, revised definition of Δ_a term for vertical deformation of the wall overturning anchorage system to include tension elongation, compression deformation, and uncompensated shrinkage.
23) In Section 4.3.5.4 Shear Stiffness and Shear Capacity for Shear Walls Sheathed on Opposing Sides of Common Framing, expanded descriptions for shear walls sheathed on opposing sides with similar (4.3.5.4.1) and dissimilar (4.3.5.4.2) shear wall sheathing systems. Revised descriptions, applicable for wind and seismic design, coordinated with the single nominal unit shear capacity format in the 2021 edition.
24) In Section 4.3.5.5.1 shear distribution to individual shear walls in a line, expanded the Exception criteria to address shear walls sheathed on opposing sides with similar shear wall sheathing systems.
25) In Equation 4.3-7 for Tension and Compression Chords, utilized new term b_{eff} in T and C force calculation where b_{eff} is the effective length (e.g., moment arm).
26) In Section 4.3.7 Sheathed Wood-Frame Shear Wall Systems, added listing of sheathed wood-frame shear wall systems in the standard utilizing Wood Structural Panels, Particleboard, Structural Fiberboard, Gypsum Board, Plaster, Single-Layer Diagonally-Sheathed Lumber, Double-Layer Diagonally-Sheathed Lumber, Horizontally-Sheathed Lumber, and Vertical Board Siding.
27) Added new Section 4.3.7.1.1 Seismic Equivalency of Alternative Sheathed Wood-Frame Shear Wall Systems, which adds reference to ASTM D7989.
28) In Section 4.3.7.1(5) and 4.3.7.3(5) on fastening requirements for wood structural panel and particle board shear walls, respectively, removed reference to 1-1/2 in. nail penetration because actual penetration will vary by nail length and sheathing thickness as prescribed in the shear wall nominal unit shear capacity tables.
29) In Table 4.4.1 and Table 4.4.2 for nominal uplift capacities for wood structural panels used to resist wind uplift, revised column headings to better align with footnote requirements and clarify reference nail dimensions (e.g., length, diameter, and head diameter) of the prescribed sheathing nails.

Cross-Laminated Timber (CLT) Diaphragms 30) Added new Section 4.5 CLT Diaphragms to provide requirements for the engineered design of CLT diaphragms using principles of engineering mechanics and values of wood member and connection strength in accordance with the NDS. **Cross-Laminated Timber (CLT) Shear Walls** 31) Added new Section 4.6 CLT Shear Walls which references a new Appendix B for design and detailing requirements for two defined CLT shear wall systems i) cross-laminated timber shear wall, and ii) cross-laminated timber shear wall with shear resistance provided by high aspect ratio panels only. CLT shear walls not conforming to requirements of Appendix B are subject to approval as an alternative method with default use limited to Seismic Design Categories A and B and seismic design coefficients limited to $R=1.5$, $C_d=1.5$, and $\Omega_o=2.5$ unless other values are approved.
Appendix A 32) Table A1. Revised depiction of common and box nail lengths to be measured from the underside of the nail head.
Appendix B (Mandatory) Requirements for CLT Shear Walls 33) New Appendix B is referenced from Section 4.6 and adds design and detailing requirements for CLT shear walls.
References 34) Updated references.