Expert Tips

CLT Shear Wall Options in the U.S.

Covers cross-laminated timber (CLT) and light-frame wood shear wall systems available for use now and in development

Peavy Hall / Oregon State University Forest Science Complex / photo Equilibrium

References the 2024 International Building Code (IBC), 2021 Special Design Provisions for Wind and Seismic (SDPWS), and ASCE 7-22 – Minimum Design Loads and Associated Criteria for Buildings and Other Structures (and prior ASCE 7 editions)

Cross-laminated timber (CLT) panels are noted for their significant strength and stiffness when subjected to in-plane forces, making them highly suitable for use in shear walls. This application is of great interest to North American building designers, as the ability to use a CLT shear wall system means that a structure can be built using mass timber for 100% of its vertical and horizontal framing. While the adoption of new seismic-resisting systems requires significant research and product development beyond the work needed for gravity systems, there are several CLT shear wall systems available for use on U.S. projects and others in development.

Background

CLT was first recognized for structural use in U.S. buildings in the 2015 IBC and its referenced design standard, the 2015 National Design Specification® (NDS®) for Wood Construction. Since then, it has seen a rapid rise in use—usually as decking in floors and roofs and less frequently as vertical wall elements.

Since its earliest uses, there has been a recognized need for codified lateral (seismic and wind) force-resisting systems made from CLT. Some construction styles benefit from an all-timber building construction; however, for this to be allowed, design standards must recognize CLT to handle both vertical gravity loads and horizontal seismic and wind loads.

ASCE 7 provides a list of recognized seismic lateral force-resisting systems, including wood-framed shear walls sheathed in wood structural panels (WSPs). In ASCE 7-16 there are no recognized CLT shear wall systems. However, the 2021 edition of the American Wood Council's SDWPS provided a significant advancement by defining CLT diaphragm requirements[1] and two CLT shear wall systems. CLT shear wall requirements are referenced in SDPWS Section 4.6 with the bulk of specific provisions found in Appendix B. CLT shear walls designed and detailed following these provisions represent one specific CLT shear wall system in a large range of possibilities. It is common among seismic force-resisting systems for one material to be used in several systems with different design requirements and seismic performance. For example, ASCE 7 recognizes no less than six concrete shear wall systems. CLT shear walls are following a similar path toward having multiple systems for different applications and levels of seismic risk.

SDPWS Appendix B CLT Shear Walls

Resulting from years of research and development and the rigorous FEMA P-695[2] validation process, 2021 SDPWS Appendix B provides specific design and detailing requirements for the first code-recognized CLT shear wall system in the U.S. In multi-story applications, the system is required to be platform-framed with CLT floors. The walls are required to be constructed of individual wall *panels* with a height-to-width ratio ($h{:}b_s$) between 2:1 and 4:1, inclusive. By using smaller, interconnected panels, these walls provide deformation capacity and energy dissipation under seismic loading. Figure 1 illustrates a multi-panel CLT shear wall configuration, where each panel can shift and rotate slightly, relative to adjacent panels, enhancing the shear wall's overall ductility and energy dissipation during seismic events.

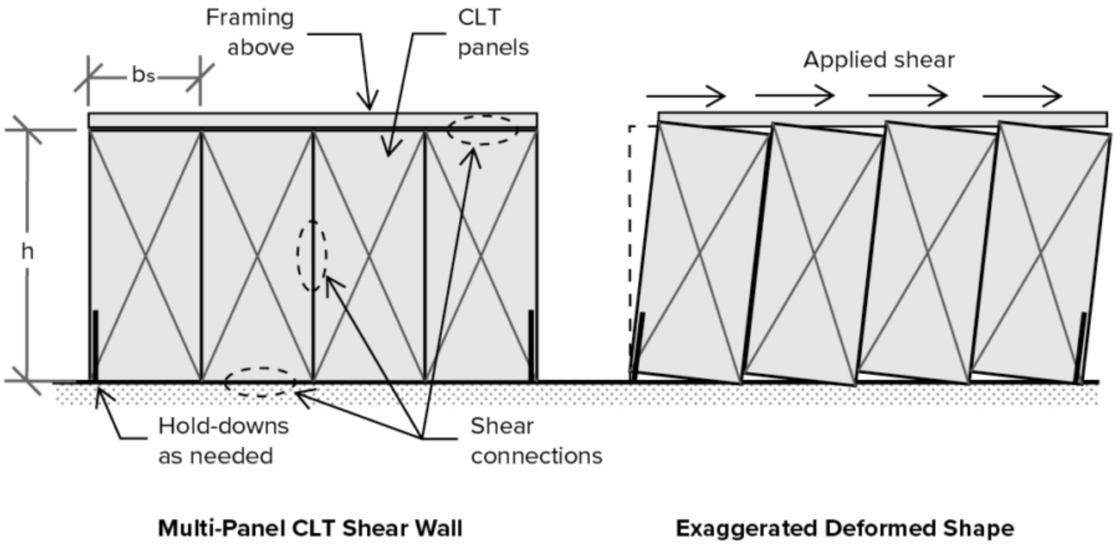

FIGURE 1: Multi-panel CLT shear wall construction*

Connection detailing plays a crucial role in this system's performance. Shear connections around the sides of the panels within the shear wall require metal plate connections, of a specific size, steel grade, and thickness, along with 10d box nails. Other requirements include designing the hold-downs at the ends of a shear wall to the force corresponding to two times the shear wall capacity. When using the SDPWS Appendix B provisions, specific detailing and analysis requirements apply to both the designated lateral force-resisting CLT shear walls and other CLT walls in the structure (not part of the lateral system).

The seismic design parameters for this system are found in ASCE 7-22 Table 12.2-1 with two sets of values. The seismic response modification coefficient, R, of 3.0 is for walls comprised of individual panels with an aspect ratio ranging from 2:1 to 4:1, and an R of 4.0 is for walls comprised of individual panels with an aspect ratio of 4:1 only. The $R = 4.0$ system is labeled "CLT shear walls with shear resistance provided by high-aspect-ratio panels only" in ASCE 7 and SDPWS. ASCE 7 provides an allowable structural height of 65 ft for the SDPWS Appendix B shear walls in Seismic Design Category (SDC) B through F.

Further information on this shear wall system, including reference to a design example, is available in this Structure magazine article.

SDPWS Section 4.6.3 Exception CLT Shear Walls

While the SDPWS Appendix B shear walls are recognized for use in any ASCE 7 SDC, there are applications where this approach is not required.

Where CLT shear walls are not specifically detailed for seismic resistance, they are similar to ordinary seismic systems made from other materials, such as ordinary plain concrete shear walls or ordinary steel moment frames. Such CLT shear walls are recognized in Section 4.6.3 of the 2021 SDPWS through an exception that can apply in SDC A or B. For CLT shear walls following the exception, the requirements of 2021 SDPWS Appendix B do not apply. The exception provides seismic design parameters of $R = 1.5$, $C_d = 1.5$, and $\Omega = 2.5$ for this system.

Structurally, these walls are designed to resist code-specified wind and seismic forces and other structural integrity requirements. With no requirements on the size or shape of the CLT panels, this approach can maximize efficient use of CLT in construction.

These CLT shear walls can be constructed using either balloon-framed or platform-framed configurations. Figure 2 shows a schematic of a platform-framed system. In this scenario, one option is to configure panels so their short dimension (width) is the floor-to-ceiling height and their long dimension (length) is in the plan length of the walls. This style of construction minimizes the number of panels needed to frame the wall. The strength direction of the panels is generally oriented vertically to maximize their gravity load-carrying capacity as bearing walls. Manufacturing and transportation limits on the width of panels, which is in the 8 to 12-ft range, should be considered with this approach. Schematic connection details, as shown in Figure 3, can involve various fasteners such as screws or nails, and hardware that suits both structural requirements and aesthetic preferences, especially when CLT panels are left exposed to the interior of the building.

Figure 4 shows multi-story balloon-framed CLT shear walls used in core wall systems, often seen in stair and elevator shafts, where the rapid assembly of CLT panels provides a significant advantage over traditional site-built masonry or concrete cores. For large, open spaces like warehouses, gymnasiums, or retail buildings, CLT can be used similarly to concrete tilt-up construction, running the full height of exterior walls, potentially extending above the roofline to form parapets.

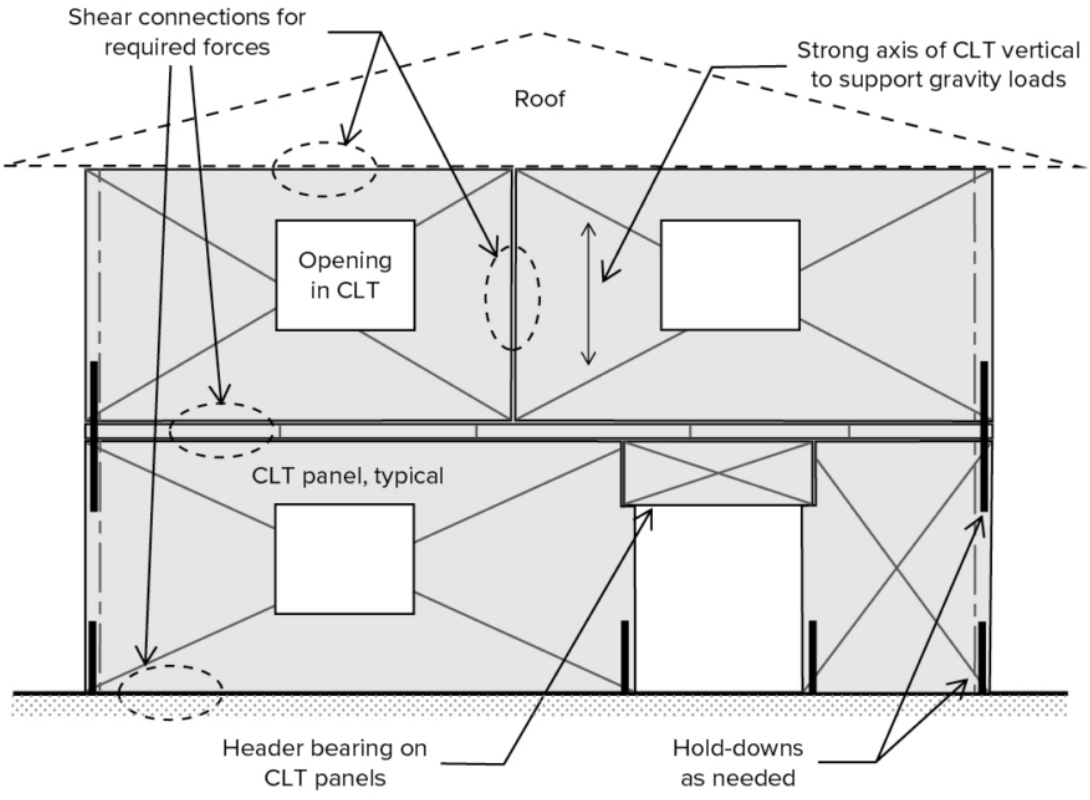

FIGURE 2: Platform-framed CLT shear walls*

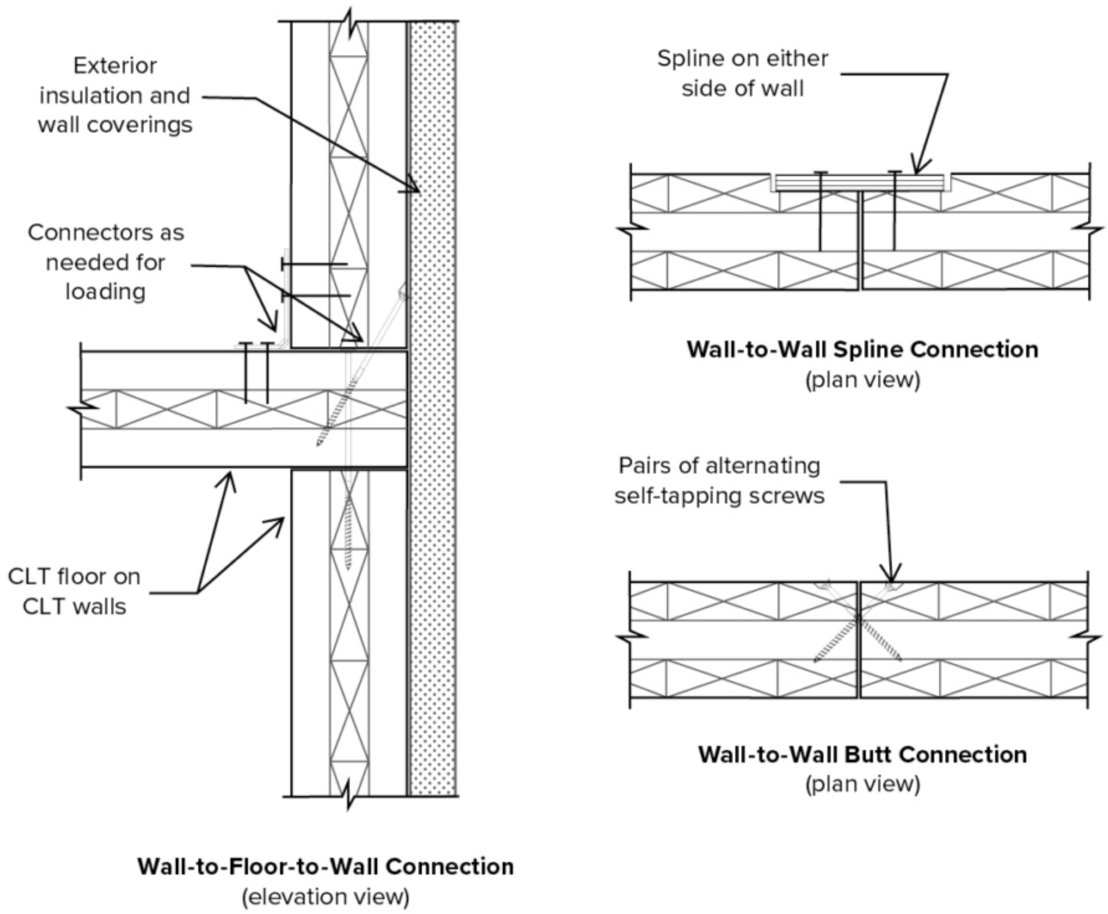

FIGURE 3: Platform-framed CLT shear wall details*

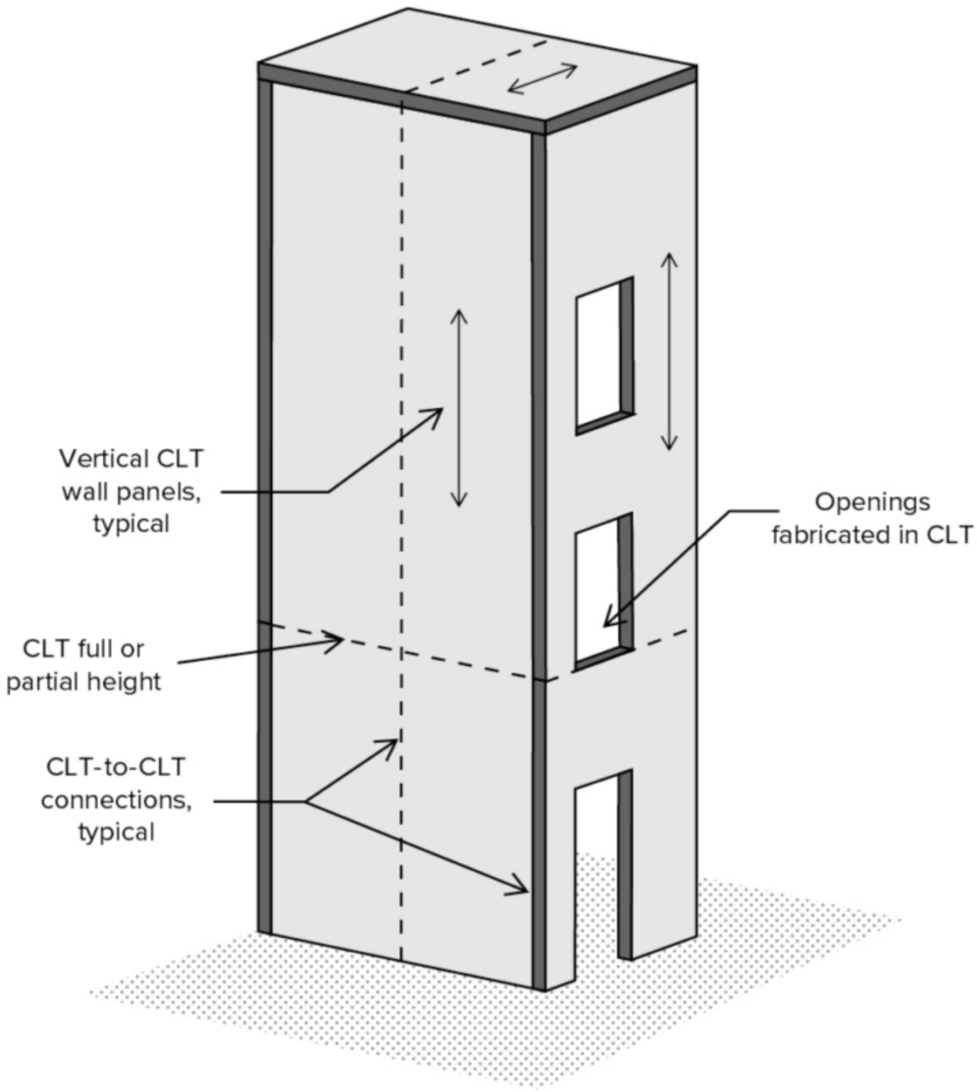

FIGURE 4: Balloon-framed CLT shear wall*

The details in Figures 2, 3, and 4 do not meet the requirements of SPDWS Appendix B CLT shear walls.

Mass Timber Rocking Shear Walls

With IBC Type IV construction allowing mass timber in buildings up to 18 stories, there is significant interest in a timber seismic lateral system for use in taller structures. Building on the development of concrete and steel rocking systems, mass timber rocking shear walls can meet this need. These shear walls are characterized by their ability to rock and lift at one end during seismic events, allowing for controlled deformation and energy dissipation. As shown in Figure 5, they are designed with special detailing to enable this rocking motion while keeping the wall panels and main connections undamaged. Such walls commonly include post-tensioned (PT) hold-downs that provide restoring forces to bring the walls back to their original position after lateral displacement. These systems are particularly suitable for high-seismic regions, where traditional shear walls might suffer significant damage.

Mass timber rocking shear walls use supplemental energy dissipation through devices such as U-shaped flexural plates (UFPs) or other dampers. The connections at the roof, floor, and foundation levels must be carefully detailed to accommodate the rocking motion, often using shear keys or pins that allow for vertical uplift while effectively transferring horizontal shear forces. Projects such as Catalyst in Spokane, Washington and Peavy Hall at Oregon State University in Corvallis have successfully implemented mass timber rocking shear walls through alternative means approval processes, showcasing their potential for resilient seismic design. The Natural Hazards Engineering Research Infrastructure (NHERI) TallWood research program successfully tested a 10-story prototype of this system at the University of California San Diego, which included over 100 earthquake tests on one of the world’s largest outdoor shake tables. Results from this test program are informing the ongoing ASCE 7-28 and SDPWS 2027 standards development process. While standardization is not complete, the effort is targeting an *R* value greater than 5 usable in structures over 100 ft tall.

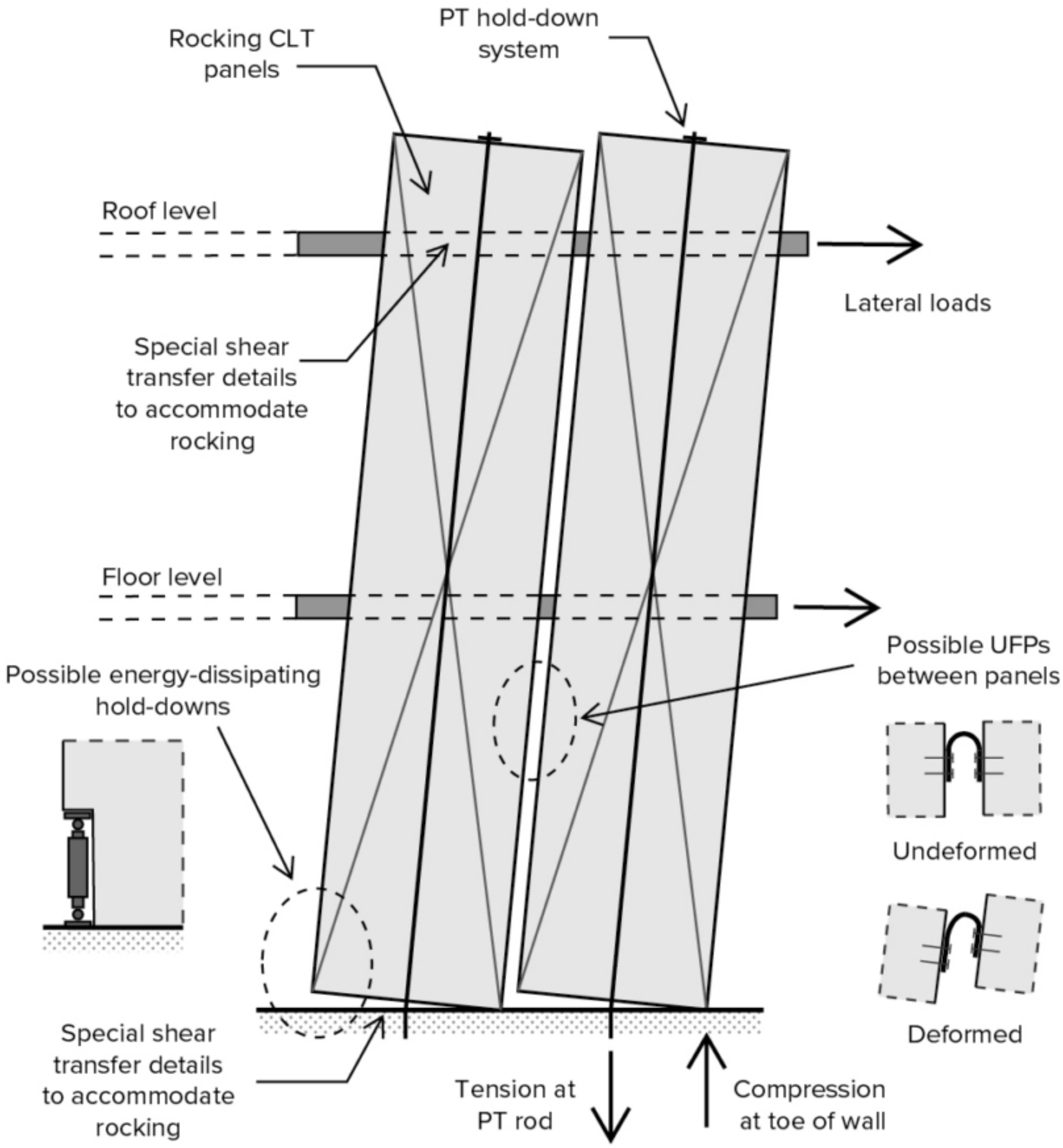

FIGURE 5: Mass timber rocking shear wall system*

Oregon Statewide Alternate Method CLT Shear Walls

Building on past research and documentation and in consultation with seismic experts from around the country, the State of Oregon has developed a state-wide alternate method (SAM) for CLT shear walls. The Oregon SAM includes path 1 shear walls that follow SDPWS Appendix B and path 2 shear walls that have requirements within the SAM. When compared based on design and detailing constraints and seismic design coefficients, the path 2 shear walls fit between the SDPWS Appendix B shear walls and Section 4.6.3 Exception shear walls. This path includes engineering requirements to ensure the system strength is controlled by ductile connections described as “moderately ductile.” Path 2 shear walls are assigned R = 2 and usable up to 65 ft tall in all SDCs. While officially recognized for use in Oregon, this alternative has been used outside the state with approval by the local jurisdiction.

Finding a Good Timber Shear Wall System

With multiple options for CLT shear walls, designers are now more likely to find a timber system that suits the needs and requirements of a particular project. Table 1 consolidates the different CLT shear wall methods discussed, their seismic design coefficients, and the structural height limits by SDC. As a timber shear wall system frequently used in some mass timber styles of construction, light-frame wood shear walls sheathed with wood structural panels (WSPs) are included.

All current CLT shear wall systems except the mass timber rocking system in development have a maximum height limit of 65 ft for higher SDCs. This limit also applies to light-frame wood shear walls in SDC D. Taller mass timber buildings will benefit from continued development of the mass timber rocking shear wall system given its targeted height limit of more than 100 ft.

TABLE 1 – Timber shear wall structural parameters

System	Standards	Seismic Design Coefficients			Structural Height Limit per Seismic Design Category (ft)			
		R	Ω_0	C_d	A	B	C	D
SDPWS Appendix B CLT shear walls	SDPWS 2021 ASCE 7-22	3	3	3	NL	65	65	65
(with shear resistance provided by high-aspect-ratio panels only)		4	3	4	NL	65	65	65
SDPWS Section 4.6.3 Exception CLT shear walls	SDPWS 2021	1.5	2.5	1.5	NL	65	NP	NP
Mass timber rocking shear walls	Targeting SDPWS 2027 and ASCE 7-28	TBD (> 5)	TBD	TBD	NL	TBD (> 100 ft)		
Oregon SAM CLT path 2 shear walls	Oregon SAM 15-01	2	2.5	2	NL	65	65	65
Light-frame wood walls sheathed with WSPs	SDPWS ASCE 7	6.5	3	4	NL	NL	NL	65

NL = No Limit
NP = Not permitted

Selecting a timber shear wall system is closely linked to the selection of construction type, as the latter will determine allowable structural materials and provide fire-resistance requirements not discussed in this document. Table 2 summarizes the maximum height limit for each construction type and where timber wall systems can be used. All of the CLT shear wall options have similar material requirements. CLT walls can be used in most locations in Type IV construction provided they meet the minimum size requirements of heavy timber construction. They can also be used in Type III and V construction. However, they are not permitted in the exterior walls of Type III buildings when fire-retardant-treated wood (FRTW) is required, as FRTW CLT is not currently available. For jurisdictions that do not require FRTW in the exterior walls of Type III construction, CLT walls may be used. Light-frame wood walls can be used in construction Types III and V, and in Type IV-HT if they have a minimum 1-hour fire-resistance rating.

TABLE 2 – Timber shear walls in IBC construction types

Construction type	III-A	III-B	IV-A	IV-B	IV-C	IV-HT	V-A	V-B
Maximum height (ft)	85	75	270	180	85	85	70	60
CLT shear walls	Yes, interior		Yes, meeting HT sizes				Yes	
Light-frame wood walls sheathed with WSPs	Yes, FRTW in exterior walls		No			Yes, with 1-hr FRR	Yes	

Low-rise and mid-rise residential – For these projects, designers typically consider Type III, IV-HT, and V construction. Where allowable based on size, there is a strong trend toward the use of Type V-A and V-B. For larger mid-rise buildings, Type III (A or B) requirements are more compatible with residential occupancies (i.e., economically efficient) than IV-HT. For SDC A or B, the team may want to consider SDPWS Section 4.6.3 Exception CLT shear walls with large wall panels, or light-frame wood shear walls. An effective combination may be to use light-frame wood walls for the typical interior and exterior walls combined with balloon-framed SDPWS Exception shear walls in the stair and elevator shafts. In SDC C or higher projects, options include SDPWS Appendix B, Oregon SAM path 2, or light-frame wood shear walls, with cost considerations often nudging the design toward light-frame wood.

Office, educational, and institutional – If a project meets the size limits for Type V construction, the team may want to consider SDPWS Exception, Oregon SAM path 2, or SDPWS Appendix B CLT shear walls, or light-frame wood shear walls. In larger Type III or IV-HT buildings, the higher lateral loading and greater spacing between walls relative to residential construction tends to bring innovative systems like the mass timber rocking shear wall or steel and concrete lateral systems into consideration. In modern mid-rise mass timber office, educational, and institutional projects larger than the Type V limits, but not large enough to require Type IV-A, IV-B, or IV-C, U.S. projects are split between Type III and Type IV-HT, each having their own design considerations.

Industrial – In projects such warehouses, light manufacturing, and datacenters, exterior CLT shear walls can be a natural structural fit. If the exterior walls are framed with vertically oriented CLT wall panels resting on the foundations, the SDPWS Exception, Oregon SAM path 2, and SDPWS Appendix B shear walls are all potential options depending on the SDC and jurisdiction. For horizontally oriented CLT wall panels spanning between columns, the SDPWS Exception and Oregon SAM path 2 shear walls are potential options.

Tall timber – In Type IV-A, IV-B, or IV-C buildings over 65 ft tall, the currently standardized CLT shear wall systems are not permitted, except in SDC A. A project team could consider a mass timber rocking wall system via an alternative means approach or non-timber lateral system.

This summary is a starting point for evaluating a variety of CLT shear wall lateral systems. As always, the lateral requirements and appropriate lateral system should be determined based on the specific building and applicable version of the building code. Suggested next steps for reading are:

- *Key Design Considerations For Mass Timber Projects*
- *Exterior Walls In Mass Timber Buildings – Code Requirements*

- *Creating Efficient Structural Grids in Mass Timber Buildings*
- *Tall Mass Timber Resources*

If you have a U.S. building project in development and would like assistance navigating the complexities of which lateral system meets your needs, please reach out to us here at WoodWorks for project support.

[1]CLT diaphragm requirements are found in SDPWS Section 4.5. For more information, see WoodWorks' *CLT Diaphragm Design Guide*.

[2]Federal Emergency Management Agency (FEMA). (2008). *FEMA P-695, Quantification of Building Seismic Performance Factors*.

*Figures in this article are adapted from *The Analysis of Irregular Shaped Structures: Wood Diaphragms and Shear Walls, 2nd Edition by Terry R. Malone, Scott E. Breneman, and Robert, W. Rice.*