



Commins Manufacturing Inc.

1. Tie-Down Systems For Wood Buildings An Overview

Function, Problems, Specification

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5-27-2025



Shearwalls and Tie-Downs

Shear walls help support buildings by controlling lateral movement and uplift. Designers obsess over system strength, nail size, penetration depth and location in order to meet drift limits, but then neglect shrinkage & settling. Shrinkage and settling are major factors in system performance. If these factors are not properly controlled system performance is compromised. This section covers critical tension items to consider with Tie-Down system design.

Design Requirements

Tie-Down Systems consist of all components that connect a structure to a base through two or more reaction points. A simple connection attaches a single shear panel to a concrete or other start through two reaction points. A complex multi-story system will have multiple reaction points distributed from the start to the top-of-structure through multiple reaction points.

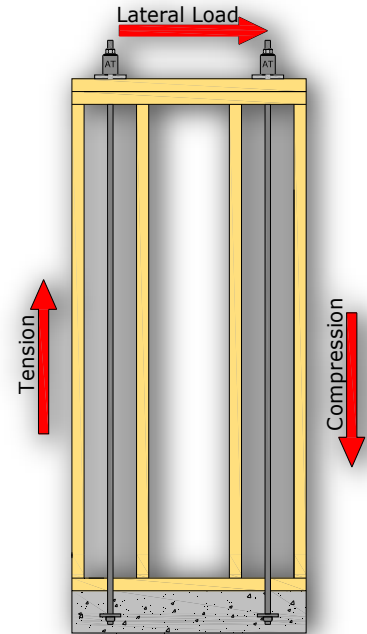
In 2021 the NDS clarified the Delta a (Δa) definition required in building uplift/drift calculations.

Δa = vertical deformation of the wall overturning anchorage system (including but not limited to fastener slip, device elongation, rod elongation and uncompensated shrinkage plus the vertical compression deformation, the effect of which are measured at the ends of the shear wall and associated with the unit shear force induced by the design load in the shear wall, in".¹

This clarification specifically requires the tie-down to include uncompensated shrinkage. Settling is usually included as a combined shrinkage/settling number. The engineers we deal with usually specify 1/4" per story for kiln dried/manufactured wood and 1/2" per story for solid sawn wood.

¹SDPWS 2021, American Wood Council, 222 Catoclin Circle SE, Suite 201, Leesburg, VA 20175. www.awc.org

Figure 1. Typical shear resisting elements use studs and plates as a structure and attach structural plywood or OSB as the shear resisting element. The shear wall is then restrained by the building weight. Tie-down systems are a combination of the two.



System Strength shall be limited by the lesser of: threaded rod tensile strength, bearing plate compressive strength, hold-down strength and Take-Up-Device (TUD) strength.

System elongation, shall include all elements in tension including: shrinkage, shrinkage compensation, rod(s), bearing plate(s), hold-down(s), and TUD ($\Delta_R + \Delta_A$).

Couplers, nuts and washers are grade compatible and are not rated for strength or elongation. However, if long couplers are used their elongation must also be added.

System Δ = \sum shrinkage-TUD compensated shrinkage (If used), $+\Delta_{Rod 1} + \Delta_{Rod 2} + \Delta_{Rod 3}$ etc. $+\Delta_{Plate}$ (or HD(s)+ TUD, $\Delta_T = (\Delta_R + \Delta_A(P_D/P_A))$).² (see ICC ES AC316 for TUD details)

Note: Without a shrinkage compensator (TUD, estimated shrinkage is used in full. With a TUD estimated shrinkage = 0.000" but TUD movements ($\Delta_R + \Delta_A$) must be added back into the equation.

Note: Shrinkage for each floor is cumulative.

² ICC ES AC316 TUD details



EVALUATION

The IBC, NDS and ICC Evaluation Service have standards for evaluating components and systems. This section introduces tie-downs in shear walls and shows common problems.

It suggests a comprehensive specification that helps designers meet strength, elongation, shrinkage and reliability specifications with precision and speed.

The analysis requires defining components and sequentially evaluating those components for:

- Strength: Rod(s) plate(s) and TUD(s)
- Selecting a TUD, for shrinkage, if required.
- Evaluating the combined system elongation: Shrinkage, rod(s), plate(s), and TUD(s).
- Adjusting material to meet selected system elongation.

LATERAL RESISTANCE

Shear walls are tied to foundations to resist uplift and lateral shear loads through tie-downs and into an anchorage. Tie-down systems are designed to meet cumulative uplift loads, elongation and shrinkage from all floors.

SHEARWALL DRIFT

$$\delta_{sw} = \frac{8vh^3}{EAb} + \frac{vh}{1000G_a} + \frac{h\Delta_a}{b}$$

*Figure 3
Equation 4.3-1*

Equation 4.3-1³ is used to determine shear wall deflection. Tiedown elongations, Δ_a , includes wood shrinkage/settling, hold down deformation, rod elongations, and wood crushing.

Common elongation errors: Rod area miscalculation (Use net tensile area), miscalculating expected shrinkage, forgetting to include one or more TUD Δ_R + Δ_A deflection elements.. Ignoring TUD movement is a common error. In building construction, the

³SDPWS, American Wood Council 2021

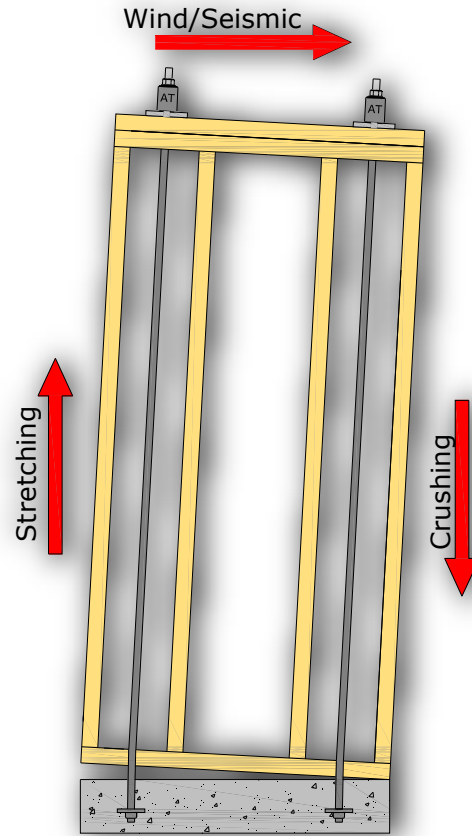


Figure 2 Wall displacement from lateral loading.

vertical shrinkage is cumulative. If a TUD is used, looseness due to shrinkage-settling is eliminated, but TUD looseness is added back.

The NDS specifies an uplift limit of 0.185" for CLT shear walls but does not specify a limit for standard shear walls. ICC-ES specifies an uplift limit, Δ_a , of 0.200" for shear walls resisting seismic forces. (ICC ES AC 316), and 0.250" for walls resisting wind (ICC ES AC 391).

If no uplift is specified, we use 0.200" as standard. We often see designers specify system elongation limits of 0.125" to 0.180" depending on wall length. In addition, if a designer needs an elongation limit to suit each wall the Commins System allows the designer to "Tune" the system.



Shrinkage and Settling: Wood shrinks!

For design, shrinkage should be considered as "**elongation without load**". Shrinkage is either included as elongation, with an assigned value or a shrinkage compensator, called a Take-up Device (TUD), is used to compensate for **system** shrinkage.



Figure 3. Standard HD in a solid sawn building.

Figure 3 is from a building on the coast of California. The building was about 12 years old. Of 12 holdowns observed, all were loose from 5/8" to 3/4".

Figure 4 is from a 5-story building in Seattle. The floor system consists of wood "I" Joists and solid sawn plates. The walls were opened because of a moisture problem. When the tie-down system was investigated every floor demonstrated 1/4" to 3/8" of looseness due to shrinkage/settling.

Under uplift loading this looseness is transferred to all floors connected above. For example, should the top floor lift, all floors below will contribute to the looseness. We could see four floors x 3/8" looseness or 1-1/2" of movement before the wall even begins to be restrained.



Figure 4. Five Stories – Ave. shrinkage 5/16" per floor.

Based on testing observations of over 300 cyclic tests, this movement would destroy the lateral capacity of the building.

If a shrinkage compensator is used between the hold down and the nut the shrinkage compensator can expand and eliminate shrinkage effects. Note shrinkage compensators are usually called Take-Up-Devices or TUDs.



Steel Straps

Metal straps are used extensively for vertical connections in light frame construction. The buckling shown was due to the drying and settling of the building. The buckling telegraphed through the exterior wall covering. It was removed and replaced at the request of the building owner.



Figure 5. How do Straps handle shrinkage. They don't!

Straps vs. TUDs.

Some companies suggest combining straps with self-adjusting TUDs. We recommend against the use of vertical metal straps with any self-adjusting system. To validate this theory a test specimen was built that combined a wood "floor-to-floor" system with a pair of straps. We then "shrank" the floor by 1/4". The strap buckling is obvious. We could have nailed to the rim joist. But this would only have (mostly) hidden the buckle, but it can't eliminate it.



Figure 6. An experiment gone wrong?

How to solve the shrinkage problem?

1. Estimate shrinkage 1/4" for mfg. wood and 1/2" to 3/4" for solid sawn lumber. This shrinkage is cumulative floor-by-floor.
2. Specify a TUD (Take-Up Device) that has the required expansion capacity.
3. Add the movement contributed by the TUD (Δ_R and Δ_A) to the system.

Note: For a 1" dia. rod a screw TUD may add 0.010", while ratchets may add 0.090" to elongation!



A Model Tie-Down Specification – For Engineers

Tie-Down systems may include: threaded rod, bearing plates, Take-Up Devices (TUDs), hold-downs and multiple types and sizes of wood. Each material has different: strengths, elongation properties, and geometry. Additionally, the wood may shrink and the building will settle over time.

AutoTight® designs systems for strength, elongation, shrinkage, settling and reliability. If required, AutoTight® can “Tune” systems to meet precise elongation specifications using the Commins AutoTight® screw type TUD. This allows us to hold a tight elongation limit and to reliability calculate elongation on all connections to just a few percent.

The Tie-Down specification here is an example of what we prefer. Modify this specification as needed for your application. If a particular item is not needed the supplier can prepare a more competitive bid that meets requirements.



ALL THREAD SYSTEM (ATS) SPECIFICATION, A SUGGESTION

The suggested specification is shown as a starting point for any Tie-Down system. Use it to help define the system needed.

Tie-Down Specification

The Tie-Down system shall be designed per the 2021 IBC for strength, elongation and shrinkage and shall follow applicable ICC-ES Acceptance Criteria and other appropriate code specifications as follows:

AC155 Acceptance Criteria for Hold-Downs (Tie-Downs) Attached to Wood Members, Dec. 2020.

AC316 Acceptance Criteria for Shrinkage Compensating Devices. 2021.

AC391 Acceptance Criteria for Continuous Rod Tie-Down Systems used to resist Wind Uplift. Jan. 2021.

Uplift forces are as shown in the hold-down schedule. Reaction loads are transferred floor-by-floor into the tension rod system. Rod Loads are cumulative reaction loads from all floors above.

Material Strengths shall follow ANSI/AISC 360. Allowable Strength Design (ASD), or Load and Resistance Force Design (LRFD) shall be followed. (**Specify one**). Specify ASD or LRFD in **full** to eliminate questions.

System Strength shall be limited by the lesser of: threaded rod tensile strength, bearing plate compressive strength, hold-down strength or Take-Up-Device (TUD) strength.



A MODEL ATS SPECIFICATION (CONT)

System elongation, shall include all elements affecting elongation including: shrinkage, rod(s), bearing plate, hold-down(s), and TUD ($\Delta_R + \Delta_A$). Couplers, nuts and washers are typically not included.

System Δ = Σ shrinkage (Calculated less compensated shrinkage), Δ Rod 1 + Δ Rod 2 + Δ Rod 3 etc. + Δ Plate + Long Coupler(s) + TUD $\Delta_T = (\Delta_R + \Delta_A(P_D/P_A))$. (ICC ES AC316)

4.3.5.5 Shear Walls in a Line. The provisions of this section are limited to shear distribution to individual shears walls in a shear wall line where the individual shear walls have the same sheathing material.

4.3.5.5.1 Shear distribution to individual shear walls in a shear wall line shall provide the same calculated deflection, δ_{sw} , in each shear wall.⁴

A System Elongation limit of 0.200" for seismic and 0.250" for high wind is

most typical. State elongation limit. (0.200" for seismic, Per AC 316 and 0.250" for wind, per AC 391 Or NDS). Elongation can be reliability controlled by run and by floor as requested, but only if screw type TUDs are used.

Elongation. Per ICC-ES AC 316 the total, per floor, elongation of the tie-Down system should not exceed 0.200". Per the National Design Specification (NDS) total elongation between reaction points shall be limited to 0.185" or less for CLT (Cross Laminated Timber) or specified by designer. See the NDS (SDPWS-2021, B.3.4). Designers often specify different elongation limits on different floors or runs to control drift. Example: System elongation is 0.180" per floor, except runs with * are 0.125" per floor. See Tie Down Table below.

Elongations are a function of loading. Exceptions: Shrinkage is added in full. (Consider shrinkage as "elongation without load". If a TUD is used and sized for the expected shrinkage, shrinkage is eliminated and is considered as 0.000". TUD deflections (both per ICC ES AC316) are then included. TUD Δ_R is always added in full. TUD Δ_A is adjusted based on % of rated capacity.

Rod elongation is per ICC ES AC391 $=\Delta L = PL/A_n$ 29,000,000. Note. Cable has an effective modulus of 10,000,000.

A code accepted screw type shrinkage compensator (TUD) shall be used at each reaction point. TUDs shall accommodate cumulative shrinkage of: 1/4", (or 3/8) per floor (Specify). Straps shall not be used with vertical connections except when the straps have a current ICC-ES report defining strength and shrinkage capacity.

Specify wall widths. 4X, 6X or 8X. Rod systems require rod and wood (and wiring and plumbing) to compete for the same location at the end of the walls. Six-inch (5-1/2") walls are required for (W) wide (5.5") steel bearing plates. Consider 8" (7-1/2") walls for heavy reactions. State the minimum number of studs between the end of the wall and the first tension rod. (Detail section shows alternate suggestions.)

Traditional bracket Holdowns may be combined with continuous tie-down systems, but TUDs should be used in all holdowns. Drift compatibility from traditional HD's must be considered when mixing traditional and continuous tie-down systems. All traditional HD's, if used, shall have TUDs installed.

Mudsill Bearing Plates shall be provided on the first-floor wood plate. (If not required specify: "Mudsill plates are not required.")

⁴ SDPWS 2021, American Wood Council, 222 Catoctin Circle SE, Suite 201, Leesburg, VA 20175. www.awc.org



A MODEL ATS SPECIFICATION

Tie Down Schedule

**Denotes tie-down with 0.125" elongation limit. WBS = Wood Beam Start*

Run Type	4A		4B		4B*		4C		2A ^{WBS}		HIEGHTS		CUMULATIVE SHRINKAGE	
Loads	T	C	T	C	T	C	T	C	T	C	FEET	INCHES		
# Runs	43		25		10		30		3					
LEVEL	4	2.0	5.0	3.0	6.0	3.0	6.0	2.0	6.0	0.0	0.0	11	6	1"
	3	4.0	8.0	7.0	10.0	7.0	10.0	10.0	14.0	3.0	6.0	10	7	3/4"
	2	9.0	15.0	16.0	20.0	16.0	20.0	22.0	25.0	12.0	15.0	10	7	1/2"
	1	15.0	23.0	25.0	33.0	25.0	33.0	37.0	38.0	-	-	11	6	1/4"

Note: Tension loads shown were derived by supplied reaction loads. Either rod tension or reactions are required. Floor heights (carpet-to-carpet) or architectural drawings are required.

Compression Posts shall be designed per the EOR.

System Strength. Designs use AISC 360-16 for rod strength. Either **ASD** or **LRFD** may be used, but not both.

System Strength is limited by the **weakest item** in series for any given floor segment

Rod Strength is rated to meet the uplift load of all floors acting through the rod.

Bearing plates and **TUDs** are rated for the reaction load at each floor..

AutoTight™ Strong, Tight, Precise™

The building can move as one!