Evaluating Tie-Downs – a Systems Approach

Part 6

By Alfred D. Commins

The online version of this article contains detailed references. Bracketed numbers herein refer to those references. Visit ***www.STRUCTUREmag.org****.*

Evaluating Tie-Downs is a general review of commercially available tie-down systems. This article describes system evaluation and suggests appropriate system design limits so shear walls used in light frame buildings can reliably perform at rated loads. Discussion is limited to the vertical hold-down system only, and does not discuss embedment design or the shear wall proper.

Wood shear walls are efficient, cost effective solutions for resisting wind and seismic loads. The building codes provide capacities for combinations of sheathing, studs, nails, nailing patterns, etc, per the following:

IBC Section 2306.4.1 Shear walls are permitted to be calculated by principles of mechanics with limitations by using values for nail strength given in the AF&PA NDS and wood structural panel design properties given in the APA Panel Design Specification.[1]

But, a key section is missing in the above directive. How should the system be tied down? How does system *stretch* affect shear wall performance? Some engineers assume that the weight of the building or the tensile capacities of the restraining members is all that is required for a proper connection. Wood shrinkage, system stretch and building settling may not be properly considered, and may result in connections that are loose or designed with excessive deflection. Many designers know these items need addressing, but others are not fully briefed in what it takes to allow the shear wall to perform at full capacity.

In 2001, a test series looked at some of the factors affecting shear wall performance. The test series by The City of Los Angeles-University of California at Irvine (COLA-UCI) revealed a 40% reduction in lateral capacity when a 0.200-inch gap (just over 3/16 inch) was introduced into the system. The gap simulated building shrinkage-settling[2]. The testing demonstrated that loosely connected shear panels lost 40% of their lateral capacity and strongly suggested code level shear values are only obtained if the connection is tight and stiff, as well as strong.

Evaluating shear wall tie-down connections is especially difficult, since loads may reverse direction and system looseness can introduce backlash. The "backlash" term wasn't used in the COLA-UCI testing and should be introduced to system designers. Backlash is most commonly used by mechanical engineers and may not be familiar to structural engineers. Backlash is the play resulting from loose connections between gears or other mechanical elements, especially those that reverse direction. Most shear wall testing is performed with tight-stiff connections. If the shear wall system is loose due to shrinkage and/or hardware looseness, the system capacity is reduced. As shown by the COLA-UCI testing, a 40% reduction in lateral capacity may result from a gap of just 0.200 inches.

Who Should Evaluate Systems?

It would seem logical for the code to establish a standard for tie-down systems. The International Code Council Evaluation Service (ICC ES) rates straps, hold downs, tie-downs, shrinkage compensators, etc. The International Building Code (IBC) provides lateral capacities for shear walls based on extensive testing, but little guidance is provided concerning the sum-of-the-parts. Because there is no guidance, the building designer must ferret out the necessary information. Until an Evaluation Service provides a comprehensive evaluation method, the building designers must establish their own evaluation limits and methods. ICC ES has requested input

Table 1: Rod System Tie-Downs – Current System Evaluations.

Jurisdiction	Best Practice (Proposed)	City of San Diego	City of San Jose	City of San Francisco	City of Los Angeles
Reference		B-16-1	PCN #13	AB-084	Cont. Tie-Down System
Deflection Limit ASD (inches)					
Rod (Only)		0.125	0.125	0.132	0.200
Total	0.125	0.125	0.200	0.132	0.325
Items Included	Rod, Take-Up Device (Compression + Backlash) Bearing plate Couplers Hold Down (Tie-Down)	Rod Only	All Items	Rod, Take-Up Device, Couplers, Bearing plate	Plates, couplers and Take-Up Devices are not specifically addressed
Rod Stretch based on	Net Section			Nominal section	
Skipping Floors	Acceptable: IF Total deflection between reaction points = 0.125 or less	OK on Case by Case Basis		Prohibited	
Mixing of different hold-down systems (Rod and HD's)	Permitted if all Systems are Evaluated Equally	Not Permitted	Not Addressed	Prohibited	Not Addressed
Wood Shrinkage analysis	Required		CBC Sec. 2304		
Shrinkage Compensators	Required per AC 316 unless specifically removed per EOR	Every Floor	Implied (Sec. 4)	Required	

Note: The term Shrinkage Compensator and Take-Up Device are used interchangeably in this article.

in this area but until an Acceptance Criteria is established, each engineer must use their own best judgment.

The Cities of San Diego[3], San Francisco[4], San Jose[5] and Los Angeles[6] have noted the lack of a codified approach, and have established their own requirements. These requirements are summarized in *Table 1*. A column labeled "Best Practice" lists items a designer should evaluate along with suggested performance limits.

Required Tie-Down Elements

Table 1 details the current requirements of four California jurisdictions and suggests required design specifications that will allow code referenced shear walls to perform at full capacity. The following summarizes required tie-down performance elements so the installed wall can perform per the code.

1) **Strength:** The strength of all components in series shall be evaluated. The lowest strength component shall govern system capacity.
2) **Stretch:** The system elongation for all components shall be evaluated. Items to be evaluated shall include rod, bearing plates, shrinkage compensators (both backlash and deflection) and hold downs (two if spanning a floor). Not all items are used on all connections. Less deflection is always better. For the shear walls to perform at their code rated value, all items must sum to 0.125 inches or less.
3) **Shrinkage:** Shrinkage-settling of the building shall be evaluated. Shrinkage-settling shall be considered "stretch without load". Shrinkage is added to stretch, and shall be evaluated as part of the total system elongation.
4) **Serviceability:** Systems shall be evaluated for reliability. Any device or system that can exhibit flexing under settling or reversed loading shall be further evaluated for suitability. Any device or system that has an inconsistent or catastrophic failure load shall not be allowed.

An inconsistent or catastrophic failure load may be difficult to characterize. An example would be a strap subject to compression loading. Compression loading may be due to building settling, shrinkage or reversed loading. Straps do not work well with reversed loading. They may flex, buckle and fail after just a few cycles. Embedded straps are often installed out-of-plumb. The installation location, close to dirt, may allow chemical reactions to rust the connection. Serviceability may be the most difficult item to evaluate.

Evaluating Typical Systems

The performance of properly installed shear walls tested under laboratory conditions is well documented, but there is a caveat. Most testing has been on properly installed and supported shear walls, with all systems tight and with a stiff, reliable connection. In other words, the evaluation has been under perfect laboratory conditions. The question every designer must ask is, "will the installed system perform as designed?" when installed by contractors who may introduce gaps, less than perfect details and out-of-plumb connections.

Table 2 (page 10) compares six commercial systems for strength, deflection, shrinkage capacity and reliability. Systems include standard hold downs, straps, a rod system without a take-up device, a rod system with a ratchet take-up device, and a rod system with a screw type take-up device. Finally, a Hybrid Rod & Tie-Down system with a screw type take-up device is evaluated. For this analysis all systems are two stories. (*Note: the comparison is for complete systems attaching the second floor to the floor below, and with an assumed ¼-inch shrinkage-settlement.*)

Standard Hold Down, System #1, is a commercially available, good quality, hold down attached with special screws. Standard hold downs are normally installed without shrinkage

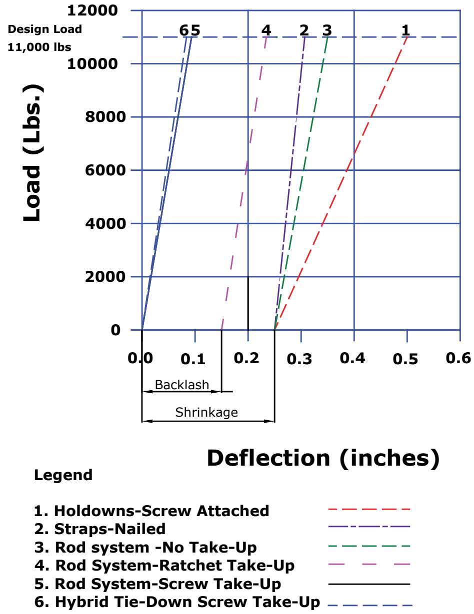

Figure 1: System comparisons, Load vs. Deflection (shrinkage and backlash included).

compensators. When a floor settles, the system doesn't begin restraint until uplift reaches the settled amount (in this case ¼ inch). This illustrates system backlash introduced by system settling. Stretch combined with shrinkage results in a design load elongation of 0.555 inches. *Table 2* and *Figure 1* provide numerical and graphic information for each system.

To achieve the required design load for strap Hold Down #2, two straps are used side-by-side. Straps are unable to restrain the wall until the strap straightens a full ¼ inch. Straps may have a reliability problem, since a buckled strap may only flex a few times before a fatigue failure and total release.

Rod System-No Take-Up, System #3, is a rod system without a shrinkage compensator. Uplift restraint begins only when the wall lifts ¼ inch.

For retrofit systems, where shrinkage-settling is not a factor, Systems #1, #2 and #3 may be appropriate. However, if lateral loading can induce buckling, straps may not be appropriate.

System #4 is a rod system with a ratchet take-up. Ratchets have a backlash or "dead zone" with no uplift resistance until the ratchet "clicks" into the next thread. Backlash is always present with ratchet systems. Backlash can be as much as 0.190, depending on the thread pitch and the internal working parts. Some ratchet systems may "Point Load" the thread and overstress the working elements at ¼ or less of the working load. *Figure 1* shows backlash for a ratchet tie-down. The displaced starting point for Systems #1-#4 is shown as a deflection offset.

System #5 is a rod system with a screw shrinkage mechanism. The mechanism has little backlash and begins uplift restraint without lost motion.

System #6 is a Hybrid Rod & Tie-Down System. The Tie-Down nails to the vertical studs and doesn't span a floor system. Located in this position, one Take-Up device can connect two floors.

Figure 1 shows six identical systems. Identical systems based on required strength, but when stretch, shrinkage, backlash and reversed loading are considered none of the systems are identical. Only walls connected with systems 5 and 6 will yield code predicted performance. Expect other walls to perform poorly.

Shear walls have been used for over 50 years. These shear walls perform well when properly connected. But the "Devil is in the Details". We now have the means to properly connect shear walls to achieve the performance promised in the code. Systems properly designed and detailed for Strength, Stretch, Shrinkage and Serviceability can meet that promise. Are you up to the challenge?

Shrinkage compensators are relatively new devices. They must be designed for walls that will not be opened for 50 years or more. And, some will be installed out-of-plumb up to 2 inches per floor or more. For those who truly understand the conflicting requirements, shrinkage compensating devices are marvelous devices.▪

Mixing Systems

To save money some engineers mix rod systems with straps and standard hold downs. They forget to connect the top floor with a shrinkage compensator, or argue that shrinkage from two top plates is inconsequential. The resulting mixed-system yields systems where some shear walls are tight as the building shrinks while others are loose. Unless you use Magic Straps and Magic Hold Downs that self-adjust for shrinkage, the two don't mix. The clear and simple answers are: 1) Never use vertical straps, and 2) All reaction points must have a clear, unrestricted connection through a shrinkage compensator.

Why Tie-Down System Design is Difficult

There is controversy about Tie-Down System design. Unless all critical factors are met, the system and building will not perform at the expected level. Systems must be designed for strength, stretch, shrinkage and reliability. Additionally, settling and movement can be slow or fast, and will reverse direction. Buildings shrink and settle over several years. When loaded, these same connections must accommodate reversed loading. The reversed loading may be rapid or slow, but the connection must always perform. Finally, shear walls are sensitive to deflection.

*Alfred Commins has been designing structural hardware since 1979. Mr. Commins currently heads Commins Manufacturing Inc. He can be contacted via email at **al@comminsmfg.com**.*

Table 2: Tie-Down Systems – A Comparison.

Deflection Summary Second Story	Standard HD	Strap HD	Rod Systems			Hybrid
	Screw Attached (#1)	Nailed (#2)	No Take-Up (#3)	Ratchet Take-Up (#4)	Screw Take-Up (#5)	Rod & Tie-Down (#6)
Rod	0.031	NA	0.068	0.038	0.038	0.069
Bearing Plates	NA	NA	0.036	0.036	0.036	0.000
Tie-Downs, HD's, Straps	0.274	0.062	–	0.000	0.000	0.012
Take-Up Device- Deflection	NA	NA	–	0.013	0.013	0.013
Backlash	–	–	–	0.145	0.000	0.000
Shrinkage (Effective)	0.250	0.250	0.250	0.000	0.000	0.000
Total Elongation	0.555	0.312	0.354	0.237	0.087	0.094
Capacity Limit	11,175 2 Standard HDs	11,720 2 Strap HDs	12,360	12,360	12,360	12,360

Note: Systems based on: 11,000 pound design load, 1″ Dia. Rod, Estimated Shrinkage ¼″.

References

[1] 2006 International Building Code Section 2306.4.1
[2] *Report of a Testing Program of Light-Framed Walls with Wood-Sheathed Shear Panels,* Structural Engineers Association of Southern [2]California. COLA-UCI Light Frame Test Committee, Subcommittee of Research Committee and Department of Civil and Environmental Engineering, University of California, Irvine, December 2001.
[3] City of San Diego, Technical Policy B-16-1, February 26, 2003
[4] City of San Francisco, Administrative Bulletin, AB 084 Draft #4, October 2, 2007.
[5] City of San Jose, Wood shear wall tie-down anchoring devices, PCN #13, Date 4-28-2008.
[6] City of Los Angeles, Criteria for Determining Tension Capacity of Multistory Continuous Tie-down System with/without hold-down device. 0506r