Strap and Tie-Down Systems

Part 2 – A Critical Evaluation

By Alfred D. Commins

The promised lateral capacity provided by shear walls is seldom achieved because one or more performance factors are overlooked in the tie-down system. If any factor is lacking, panels will not perform as expected. We think of these failures as shear panel failures, but the root cause is often a deficiency in the tie-down system. This article reviews and evaluates common tie-downs, hold downs and hold down systems using a wider perspective than previous reviews. The article goes on to evaluate conventional straps and tie-downs (holdowns) typically used without shrinkage compensators, and reviews continuous tie-down systems (typically rod systems with shrinkage compensators). (*Note: the terms tie-down, holdown and hold down are used interchangeably by most engineers.*)

Historically, manufacturers and code evaluators have rated hold downs and hold down systems solely on system strength. System strength is important, but is only one of several criteria that must be addressed. This review evaluates straps and holdowns based on strength, stretch, shrinkage and durability as follows:

1) **System Strength**. Strength is limited to the lowest value of any item loaded in series including the device, attaching hardware, and wood members.
2) **System Stretch**. Elongations of all elements of a given connection are added together. The limit is set at ⅛ inch, at the system design load. All elements contributing to stretch are evaluated and summed.
3) **Shrinkage and Settling**. Shrinkage and settling are considered "stretch" without load. As such, they are considered part of the system stretch. Except as specifically exempted (wood with an MC of 10% or less), all holdown connections should be self-adjusting for shrinkage/settling. Shrinkage and settling on a floor-by-floor and cumulative basis should be evaluated by the engineer. As an alternative, a shrinkage/settlement table may be used.
4) **Long Term Durability**. All components must be evaluated for long term durability. Durability includes the ability to resist aging and corrosion, and to be unaffected by reversed loading. Elements that are difficult to install properly or that have a catastrophic failure mode should not be used.

For an in-depth review of these four factors, please see *Hold Down Systems, Key to Shear Wall Performance-Part 1 Basics*, STRUCTURE® magazine, August 2007.

Figure 1: Typical buckled strap installation.

Several years ago, the Applied Technology Council tested complete shear panels in a cyclic manner attached with commercially available hardware. They concluded that narrow shear panels did not perform in a satisfactory manner when attached with standard commercially available hardware. The hardware used was installed properly, was good quality and was listed by ICBO.

ASTM E-72 is the standard used to rate sheathing material. This standard uses an 8x8-foot panel, and ties down the end with a pair of 1¼-inch diameter rods. The restraint provided a hold down with very little elongation. Additionally, no looseness, as from shrinkage, was allowed into the system. If we are to get shear panels to perform at the same level as ASTM E-72 predicts and the code expects, hold downs and hold down systems equivalent to that used in the original tests must be used.

Table 1 lists straps and holdowns reviewed in this evaluation.

Table 1: Comparaison of Straps and Hold Downs. An overview of Straps and Hold Downs for Strength, Stretch, Shrinkage Capacity and Serviceability.

		ATTRIBUTE								
		1. Cap (K)		2. Stretch		3. Shrinkage Compensation	4. Serviceability			Comments
STRAPS		Typ.	Max.				Rust	Compress	Install	
Straps	(yellow)	4	7	Low	Flex	None	Low	Intolerant	Easy	Use with KD or mfg. wood.
Embedded Straps	(red)			High Potential		None	High	Intolerant	Difficult	Alignment & corrosion. NR.
HOLD DOWN - ECCENTRIC										
Nailed	(yellow)	3-4	5	Moderate	3/16"	Accessory	Low	Tolerant	Easy	Single story, stretch.
Bolted	(red)	8	16	High	¼" +	No	Low	Tolerant	Difficult	Stretch issue. NR.
Screwed	(yellow)	3-6	15	Moderate	1/16" - ⅛"	Accessory	Low	Tolerant	Moderate	Single story only.
Stacked HD's	(red)			Double stretch numbers.			Low	Tolerant	Difficult	Excess deflection. NR.
HOLD DOWN - CONCENTRIC										
Bolted	(yellow)	10	30	Very Low	⅛"	Accessory	Low	Tolerant	Difficult	Difficult installation. NR.
Nailed	(light blue)	8	15	Very Low	Low	Accessory	Low	Tolerant	Difficult	Limited availability.

***Corrosion Potential considers device location and performance when corroded.*

(yellow) *Use in selected connections - look for stretch or installation issues.*

(light blue) *Concentric Nailed HD - the HD of the future - use with shrinkage compensator.*

(red) *NR = Not recommended*

Straps and Strap Hold Downs

Nailed Straight Straps are used widely in wood frame projects. Straps handle moderate loads (to 7 kips), have low stretch and are relatively low cost. However, straps have two serious performance limitations. First, a strap's ability to resist compression loads due to building settling or wood shrinkage is poor. Shrinkage and settlement will load a strap vertically, resulting in a bend or kink. A bulge on the side of a building is an indication of excess settlement and a potentially non-performing vertical connection. Wood shrinkage and building movement can be kept to an acceptable level *if* dry wood plates and manufactured wood joists are used, *and if* the building is kept dry during construction.

The second problem concerns lateral loading. Shear panel lateral loading translates into a strap compression load. This compression load is additive to any load induced by shrinkage. The result can be strap buckling (*Figure 1*), flexing during an event, and, after several cycles, a fatigue failure.

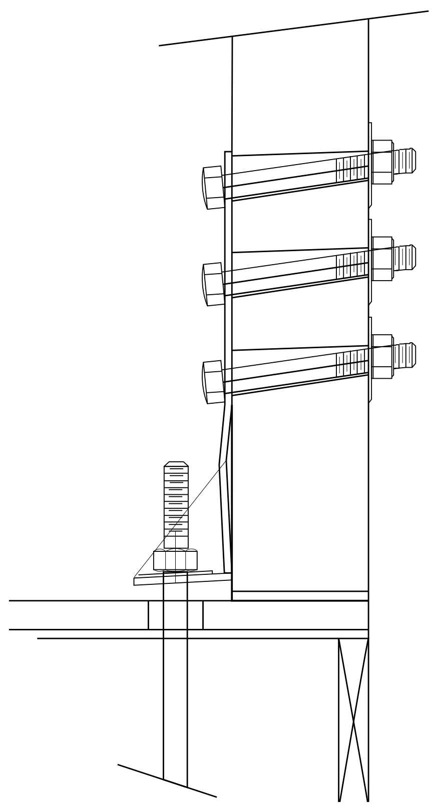

Figure 3: A typical eccentric hold down showing bolt "Drift".

Embedded Straps

Embedded Strap hold downs are used widely in one and two story wood frame buildings. Strap hold downs embed into the concrete and lap the wall. *Figure 2* details a worst-case installation with several separate problems combined into one installation.

In theory, embedded strap hold downs offer a clean, continuous connection from the concrete into the wood structure. In practice, however, straps may not be properly installed. Performance issues include: a zigzag connection from the concrete face to the outside plywood; strap not vertical or not in line with a stud resulting in nails not properly nailed to the wood; layout misalignment of the concrete and the wood frame building; and, strap flex during an event or with wood shrinkage.

The potential for a poor installation is such that some engineers and building jurisdictions will not allow the use of embedded strap hold downs. When a lateral event strikes, excessive elongation and joint fatigue may result in an unconnected shear panel.

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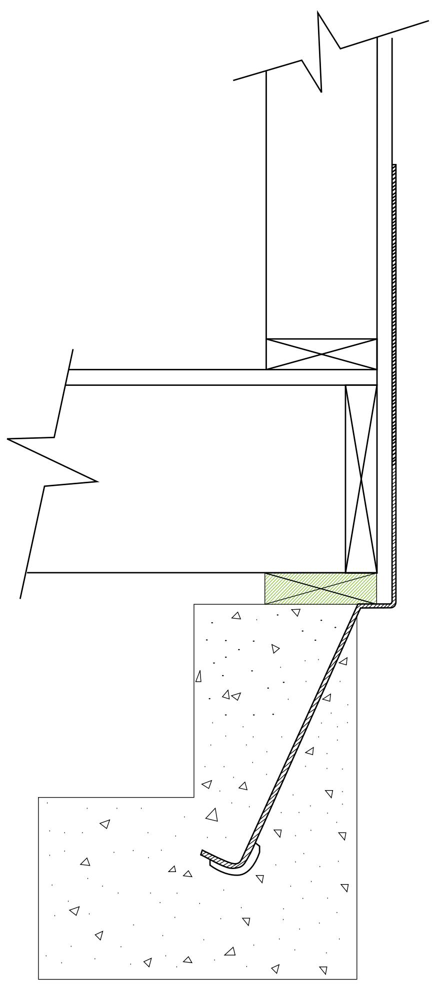

Figure 2: Embedded Strap hold down with multiple installation problems.

Durability

Even with a good installation, the lower strap portions are often exposed to moisture and may corrode to the point of uselessness. Embedded straps are often used on the building perimeter. Rain and moisture can collect on the exposed metal and may rust the steel. Combine moisture with the pressure treatments often used on mudsills, and these straps may soon corrode. When these straps are needed in 20, 30 or 40 years, will they still be connected?

With potential problems from geometry, shrinkage and durability, embedded straps should be retired from our list of connections.

Eccentric Hold Downs

Most hold downs sold today are eccentric (*Figure 3, page 17*). Eccentric hold downs mount to the side of the vertical wood member with nails, bolts or screws. A bolt extends from the holdown base to the concrete or to the floor below. Eccentric single-sided hold downs are relatively easy to install, but may have significant disadvantages, including: eccentric post loading; exaggerated deflection because of the eccentricity; and, restricted room for a shrinkage compensating device.

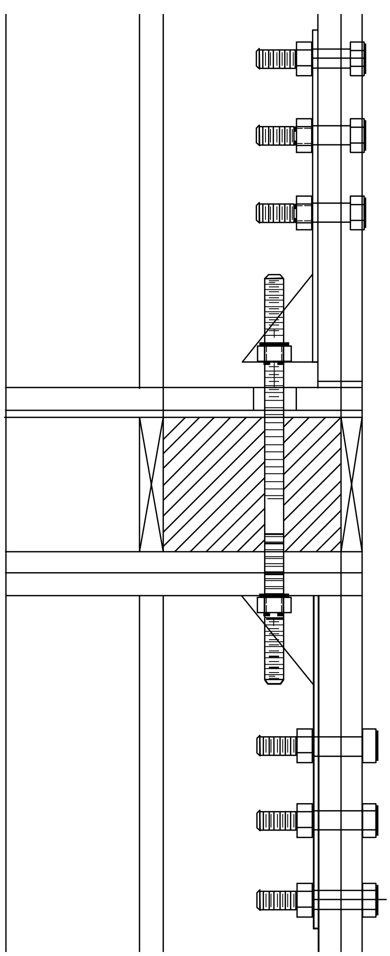

Figure 4: Stacked hold downs. All deflection numbers are doubled.

Table 2 evaluates the deflection of typical bolted, screwed and nailed hold downs. The first number after "Hold down Deflection" is the typical deflection posted in a suppliers catalog. These numbers refer only to the hold down itself. They are based on "best case" installations, and are often tested in a steel jig. Several items may change the real world performance from the catalog values. The attachment holes drilled into the wood posts are drilled oversize by 1/16 inch. In practice, this hole sometimes becomes ⅛ inch or more oversize. The fastener also bears on one side of the hole, and tends to rotate and slip. The designer must estimate and add these numbers to the catalog values. Finally, mudsill crush and shrinkage should be added. The result is Total Movement. The estimates for oversize holes, fastener rotation and mudsill crush and shrinkage are conservative. As a designer you may want to provide your own estimate. Remember this is for a single story, slab-on-grade installation.

Based on the author's analysis, single eccentric hold downs should be restricted to screw attached models only. In addition, the screwed-on models should be de-rated to one half of their current allowable load rating.

Stacked Hold Downs

The preceding example is for a single hold down and a slab-on-grade installation. Many hold downs are stacked and span a floor system (*Figure 4*). When used in series, deflection is doubled. Design load deflection (including fastener slip and rotation) can approach 1 inch. In addition, floor system shrinkage must be considered. Combined load deflection and shrinkage can result in connection deflections ranging between ½ to 1¾ inches. These large deflections will allow shear panels to fail at loads substantially lower than expected.

Figure 5: A bolted concentric hold down.

Stacked hold downs are evaluated and shown in the lower portion of *Table 2*. The total slip is doubled with stacked hold downs. Minimal (Best Case) and Maximum (Worst Case) shrinkage is then added. These numbers are based on the author's experience. Your projects and experience may differ.

Code reports provide correct numbers as stated, but these numbers don't include slip, shrinkage, installation irregularities etc. This is left to the designer; however, many designers either don't realize they should add slip and shrinkage, or don't know what to do.

Eccentric Hold Down Recommendations

If you *must* use an eccentric hold down, the author suggests that you use hold downs with a screw attachment only. Use single hold downs only; never stack hold downs. If a rod spans a substantial amount of wood (3 inches or more) across the grain, **always** use a shrinkage compensator. De-rate holdowns to 50% of catalog values.

Table 2: Eccentric Hold Downs-Deflection Performance. A comparison of typical bolted, screwed and nailed hold downs for stretch-with and without typical shrinkage.

		Bolted	**Screwed**	**Nailed**
	Load Rating (lbs.)	**9,900**	**11,275**	**5,250**
Single Hold Down	Hold Down Deflection	0.269	0.040	0.087
	Fastener Hole Oversize	0.062	0.000	0.000
	Fastener Rotation	0.125	0.062	0.062
	Total Slip (Internal)	0.456	0.102	0.149
	Mudsill Crush-Shrinkage	0.125	0.125	0.125
	Total Movement	0.581	0.227	0.274
Stacked Hold Downs	Stacked Hold Down Slip	0.912	0.204	0.298
	Shrinkage Best Case	0.250	0.250	0.250
	Total Movement Best Case	1.162	0.454	0.548
	Shrinkage Worst Case	0.625	0.625	0.625
	Total Movement Worst Case	1.787	1.079	1.173

Figure 6: A nailed-on concentric hold down.

Concentric Hold Downs

Concentric hold downs are supported by wood on both sides (*Figure 5*). Available in bolted and nailed styles, they eliminate the eccentricity of single sided connections. Eliminating eccentricity greatly increases capacity and stiffness. Concentric hold downs require a relatively precise distance between studs for proper installation. Bolted concentric hold downs are the highest capacity hold downs, but are difficult and expensive to install. If possible, framers avoid the use of concentric bolted hold downs.

The concentric nailed hold down (*Figure 6*) installs with nails. Either gun nails or apron nails may be used. This design appears to give a higher capacity, low deflection connection. It is only now being introduced.

Conclusion

Hold downs and straps can properly secure building shear walls. But shear walls can only achieve their design potential if the four criteria of strength, stretch, shrinkage and reliability are met simultaneously. Not only must the system have the required strength, but the system must limit stretch to ⅛ inch or less. This performance level can only be met when screw attached hold downs and shrinkage compensators are used at all hold down locations with 3 inches or more of wood subject to shrinkage.

This critical review on straps and hold downs may prompt designers to wonder how they can properly connect buildings in a cost effective manner. Several manufacturers are offering continuous systems that simultaneously tie the building down, control stretch and compensate for wood shrinkage and settling. The next installment, *Part 3*, *Continuous Tie-Down Systems*, will provide a critical review of strengths and weaknesses of systems currently available.▪

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Part 3 of this series will continue the critical evaluation of continuous tie-down systems typically called rod systems.

References

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