Designing Rod Tie-Down Systems

Part 4

By Al Commins

*Part 1 (Hold Down Systems) of this series can be found in the August 2007 issue of STRUCTURE® magazine. Part 2 (Strap and Tie-Down Systems) – November 2007; Part 3 (Continuous Tie-Down Systems) – March 2008. Visit **www.STRUCTUREmag.org/archives** to download prior articles.*

The goal of any tie-down system is to provide connections that maximize the capacity of the attached shear panels. This goal is achieved only if four design elements: strength, stretch, shrinkage, and reliability are met. If any element is missing, the shear walls and the tie-down system will fail. Designing a Rod Tie-Down system can be fast and accurate if organized in a structured manner. This article details a quick, accurate and reliable design method for rod systems that maximizes shear wall capacities.

The following steps are used in the system design:

One – Organize Load and System Requirements.
Two – Design runs for strength, adjust for stretch and shrinkage.
Three – Apply to Detail Drawings.

This article covers the design of tension elements only. Shear panels, compression wood, concrete embedments, etc., are beyond the scope of this article.

Step One – Organize Load Requirements

Figure 1, details the required input information organized in a comprehensive table. Typical projects use 2 to 23 or more runs. A large number of different runs may be necessary, but most jobs are smoother with 5 different runs or less.

Required Information

The matrix lays out load requirements floor-by-floor for each run. Both tension (T) or compression (C) loads can be shown. Unless separate compression loads are shown, the tension load is also used for compression. Plate and stud material are also specified.

Columns list cumulative tension requirements, floor-by-floor, for each run. Story height (carpet to carpet) is listed in feet and inches.

The far right column is estimated wood shrinkage. Use your own estimate or *Table 1*. Shrinkage is stretch without load. Just as we have a safety factor for strength, overestimating floor shrinkage is preferred so shear panels are never loose and can perform to their potential. For critical strength-slack information, see the side bar in this article, titled *Loose Shear Walls Don't Perform*.

Run Identification

Identify runs clearly. An identification convention that names the run by the number of floors with a letter works well (see example Run 4A). For beam starts, add a suffix of WBS for a wood beam start or SBS for steel. We suggest that a number follow this to indicate the floor where the beam start begins. For example a 2A (WBS) 2 would be a 2 story run attaching to a wood beam that begins on the second floor. This helps to quickly and accurately identify the runs and the system.

Run		4A	4B	2A (WBS)	IBC 2006		
Tension =	T	Required Loads per level			Story Heights		Cumulative Shrinkage Total (in.)
Comp. =	*C*						
Level		(kips)			ft	in	
4th Floor	T	4.50	8.00		9	11	1½
3rd Floor	T	8.00	8.00	7.00	9	11	1⅛
2nd Floor	T	15.00	15.00	12.00	9	11	¾
1st Floor	T	24.00	24.00		9	11	⅜

Anchor Rod
Plate Material DFL Stud Material DFL

Figure 1: To properly design a system, the required load information is collected in one place. Required information includes uplift, story heights, shrinkage and stretch requirements.

Building Grade	**"S"**	**"A"**	**"B"**
	Steel Stud or Wood with MC 12%	**Mfg. Wood**	**Solid Sawn**
Floor	**Cumulative Shrinkage**		
5	⅝	1⅞	3¾
4	½	1½	3
3	⅜	1⅛	2¼
2	¼	¾	1½
1	⅛	⅜	¾
Per Floor	⅛	⅜	¾

Shrinkage compensators required with MC exceeding12% at time of enclosure.
Cumulative "S" Steel Stud Buildings with misalignment potential.
"A" Mfg wood materials. Supplied and kept dry.
"B" Solid Sawn materials with minimal drying.
Dimensions are in inches.

Table 1: The shrinkage-settling table provides a guide for estimating building settling. The table over estimates shrinkage in most cases on the theory that extra shrinkage compensation is better than a loose building.

ROD						Shrinkage Compensator			
						AT 75	AT 75-2.5	AT 100	AT 125
					AT Expansion >	1.1”	2.5”	1.1”	1.1”
					Max. Defl. >	0.0240	0.0200	0.0320	0.0160
Allowable Load (lbs.) per Code			**Threaded Rod**			¾”Ø	¾”Ø	1”Ø	1¼”Ø
2006 IBC	**2003 IBC**	**1997 UBC**	**Rod #**	**Dia. & Thread**	**Material[1]**	16,450 lbs	15,183 lbs	25,300 lbs	34,500 lbs
6,342	6,136	8,173	R5	⅝” - 11 NC	A307	X	X		
9,324	8,836	11,781	R6	¾” - 10 NC		X	X		
16,783	15,708	20,944	R8	1” - 8 NC				X	
26,698	24,540	32,720	R10	1¼” - 7 NC					X
0.078”	0.073”	0.097”	Stretch 10’ Rod at Design Load						
20,709	18,408	24,544	R6HS	¾” - 10 NC	A193-B7	X*	X*		
28,187	25,054	33,405	R7HS	⅞” - 9 NC				X	
0.170”	0.157”	0.202”	Stretch 10’ Rod at Design Load						
									X* – Verify AT Capacity

Bearing Plate (0.040” design load defl.)			Allowable Bearing	Notes:
Part #	**Plate Dim. T x W x L**	**Hole Dia.**	**Doug Fir-Larch (DFL)**	Capacity limited by plate area. F_c = 625 psi (DFL).
S8	⅜” x 3¼” x 4”	1”	8,125	
S10	½” x 3¼” x 5”		10,156	
S12	⅝” x 3¼” x 6”		12,188	
S8L	⅜” x 3¼” x 4”	1¼”	8,125	
S10L	½” x 3¼” x 5”		10,156	
S12L	⅝” x 3¼” x 6”		12,188	

Table 2. Typical Rod, Plate, and Shrinkage Compensator Table. This table combines rod, plate, and shrinkage compensator allowable load and stretch capacities.

Step Two – Design Runs for Strength and Adjust for Stretch

First, design runs for strength floor-by-floor. A table listing pre-calculated rod, plate, and shrinkage compensator strength and stretch information is extremely useful. *Table 2* is typical. For rod length, the stretch of a 10-foot segment at the design limit is provided. Stretch based on rod length and strength is computed based on ratios.

Bearing plates are pre-calculated for one of the four wood species groups and assigned an allowable load. Plates use a deflection of 0.040 inches at the design load. A simple ratio of actual vs. maximum capacity adjusts the deflection for each reaction point.

The last element to consider is the shrinkage compensator. Select shrinkage compensators based on: rod diameter, strength capacity, and expansion. Shrinkage compensators used with this system compensate for 1⅛ inches and are used of floors 1-3. On the top story, a device that handles at least 1½ inches must be used.

continued on next page

Run		4A				4B				2A WBS				IBC 2006		
Tension = / Comp. =	T / C	Reqd Loads Per level (kips)	Allowable Load (k) Rod ∅ - Type	Differential Load (k) AT Plate	Stretch Load (k) Rod (in) Limit (in)	Reqd Loads Per Level (kips)	Allowable Load (k) Rod ∅ - Type	Differential Load (k) AT Plate	Stretch Load (k) Rod (in) Limit (in)	Reqd Loads Per Level (kips)	Allowable Load (k) Rod ∅ - Type	Differential Load (k) AT Plate	Stretch Load (k) Rod (in) Limit (in)	Story Heights (Carpet to Carpet) ft	in	Cumulative Est. Wood Shrinkage Total (in)
Level																
4th Floor	T	4.50	6.34	4.50	4.50	8.00	9.32	8.00	8.00							
			R5	AT 75 - 2.5	0.083		R6	AT 75 - 2.5	**0.175**					9	0	1½
	C		⅝" - A307	S8	0.125		¾" - A307	S8	0.125							
3rd Floor	T	8.00	9.32	3.50	8.00	8.00	9.32		8.00	7.00	9.32	7.00	7.00			
			R6	AT 75	0.089		R6		0.000		R6	AT 75	0.074	9	11	1⅛
	C		¾" - A307	S8	0.125		¾" - A307				¾" - A307	S8	0.125			
2nd Floor	T	15.00	16.78	7.00	15.00	15.00	20.71	7.00	15.00	12.00	12.81	5.00	12.00			
			R8	AT 100	0.112		R6HS	AT 75	**0.167**		R7	AT 100	0.103	9	11	¾
	C		1" - A307	S8	0.125		¾" - B7	S8	0.125		⅞"-A307	S8	0.125			
1st Floor	T	24.00	26.70	9.00	24.00	24.00	28.19	9.00	24.00			S12				
			R10	AT 125	0.109		R7HS	AT 100	**0.190**					9	11	⅜
	C		1-¼" - A307	S10L	0.125		⅞" - B7	S10	0.125							

Anchor rod	1-¼" - A307	⅞" - B7		
Plate Material	DFL	Stud Material	DFL	

Figure 2: Required rod, bearing plates, shrinkage compensators and system stretch is computed and displayed in the load justification table.

In this example, a single AT75-2-1/2 device can be used or devices can be stacked to accommodate required settling.

Run 4A Design

Strength – The run begins with a 24 kip tension requirement on the first floor. A table look-up (*Table 2, page 27*) shows an R10 rod (1¼ inch, A307) will satisfy the tension requirement. The differential load at this reaction point is 9.0 kips. An S10L plate with a capacity of 10,156 pounds satisfies the reaction. (Note S10 and S10L plates are identical except for hole sizes). Calculations for run 4A are shown in *Table 3*.

Repeat calculations floor-by-floor for each run and each reaction point. The design can be done on a simple spread sheet with look-up tables. Performed this way, each run may take 5 minutes to design. If the process is automated, the entire building can be designed in the time it takes to enter the data. *Figure 2* shows a typical load justification.

The calculations above include system stretch, not just rod stretch. Building departments typically ask for system strength and assume stretch is low. In many cases they are right. But if you want the full capacity of the shear panel, additional sources of stretch such as plate crush, shrinkage compensator compression, and backlash must also be considered.

Table 3: 1st Floor Requirements - Strength (kips) and Stretch (inches)

	Demand	Supply	Stretch	
Rod	24.0	26.698	= 0.078 * (119/120) * (24,000/26,698)	= 0.070 inches
Plate	9.0	10.156	= 0.040 * (9,000/10,156)	= 0.035 inches
Take-Up	9.0	34.50	= 0.016 * (9,000/34,500)	= 0.004 inches
			Total Deflection	= 0.109 inches

Table 4: Run 4B -1st Floor Requirements - Strength (kips) and Stretch (inches)

	Demand	Supply	Stretch	
Rod	24.0	28.187	= 0.176 * (119/120) * (24,000/28,187)	= 0.149 inches
Plate	9.0	10.156	= 0.040 * (9,000/10,156))	= 0.035 inches
Take-Up	9.0	25.30	= 0.032 * (9,000/25,300)	= 0.011 inches
			Total Deflection	= 0.195 inches

Run 4B-High Strength Rod

Systems sometimes use high strength rods as shown in run 4B. Using the same process, run strength is figured first, then run stretch is calculated as shown in *Table 4*.

If extra stretch can be tolerated, then run 4B could be substituted for 4A, and a less expensive system designed. However, while this system has the strength to connect the shear panel, the extra stretch can reduce shear panel capacity. Bottom line: keep system stretch under ⅛ inch. See side bar to the right titled *System Backlash* for more information.

Loose Shear Walls Don't Perform

There has been some question as to whether shear panels designed to code values perform as expected. A series of independent tests demonstrated shear panels can perform as expected, but with important limits. The tests demonstrated loosely connected shear panels (0.200 inches loose, slightly more than 3/16 inches) lost 40% of their lateral capacity. This looseness was introduced by backing off the anchor bolt nut. Equivalent looseness can result from wood shrinkage, a flexible tie-down system, or backlash in ratchet shrinkage compensators. Testing was on 8-Foot x 8-foot panels. The results may be worse on narrow panels. (**www.icbolabc.org/graphics/pdf/cola-rpt.pdf** Go to page 3-17 (page 51 of 93) for loose wall lateral performance information.)

Reference: *Report of a Testing Program of Light-Framed Walls with Wood-Sheathed Shear Panels*. Structural Engineers Association of Southern California, COLA-UCI Light Frame Test Committee Subcommittee of Research Committee and Department of Civil and Environmental Engineering, University of California, Irvine, December 2001.

Skipping Floors

Skipping a floor is a design tool that can save money. Depending on the circumstances, it may be a useful alternative to having a shrinkage compensator on every floor. Typically, the best place is to skip a floor at the top. Two factors favor this approach: low loads and short runs. For example, the top floor uplift load requirement in our illustration, run 4A, is 4.5 kips. If we skip a floor, as in run 4B, the total 8 kip load will be required for both floors.

If the designer chooses to skip a floor, then several things must be done. The full load is carried through both floors. In this case it is 8 kips. Deflection for both floors must be added together. Compression studs must carry the entire load for both floors. This low load illustration shows that this is a prime candidate for floor skipping. The eight kip load is relatively low, and the height between reaction points is 15-feet, so stretch is relatively low. In this case, we increased the upper rod from R5 to R6 and recalculated the stretch. At 0.149 inches, the stretch is in line with the other run segments below, but is over the ⅛-inch limit.

Step Three – Shop Drawings

The design covers key components, but ignores couplers, nuts, washers, and compression studs. Shop drawings provide the detail needed for the contractor to select and arrange components. *Figure 3* shows a shop drawing for Run 4A. This lists all components and special connections required for the installation.

This article provides insight into the design of multi-level rod tie-down systems. For more information contact your Rod System Supplier.▪

System Backlash - Screw vs. Ratchet

The text example used a screw type shrinkage compensator. For comparison, how do ratcheting shrinkage compensators perform? Ratchet type shrinkage compensators have additional sources of backlash, such as thread pitch and ratchet motion. Using a ratcheting shrinkage compensator changes the level 1 stretch analysis is shown below.

Ratchet backlash includes thread pitch plus measured ratchet play. A system with a 1¼-inch-7NC rod adds 0.213 inches to system stretch (0.143 inches thread pitch + 0.070 inches ratchet play). Bottom line: a ratchet shrinkage compensator with high strength rod can allow a wall to move almost 4 times farther than standard strength rod and a screw-type device. The result will be markedly reduced wall strength.

The conclusion is clear and compelling, to achieve the full shear wall capacity two points must be considered:

1) Use standard strength rod or derate the high strength rod to compensate for stretch.
2) Use screw type shrinkage compensators only.

Rod Stretch	= 0.176 * (119/120) * (24,000/28,187)	= 0.173 inches
Plate compression	= 0.040 * (9,000/10,156)	= 0.036 inches
Shrinkage Compensator	= 0.030 * (7,500/25,300)	= 0.011 inches
Thread pitch and ratchet motion	= 0.143 + .070	= 0.213 inches
	Total Deflection	= 0.433 inches

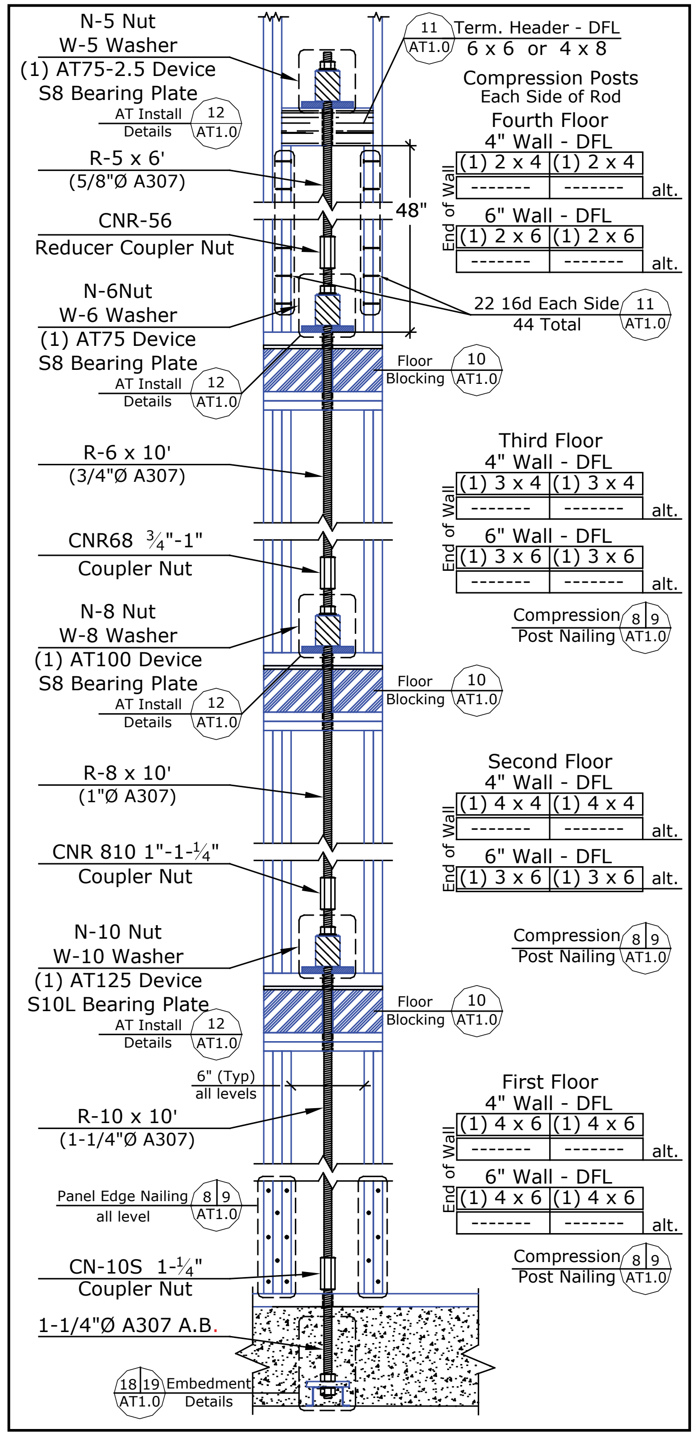

Figure 3: The shop drawing includes all elements needed to build the required run. To the rod, bearing plates and shrinkage compensators are added coupler nuts, compression wood (trimmers) and termination headers as needed.

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