Continuous Tie-Down Systems

Part 3 - A Critical Evaluation

By Alfred D. Commins

Previous articles reviewed basic holdown requirements, (*STRUCTURE® Magazine*, August 2007), and Strap and Tie-Down Systems (*STRUCTURE® Magazine*, November 2007). Visit **www.STRUCTREmag.org/archives**.

Multi-floor Tie-down systems perform in harsh environments. Connections must accommodate settling and repeated reversed loading without failing or releasing while offset 2" or more per floor. In addition, reliability of a system must be maintained while the system is hidden away in a debris filled building structure for 50 years or longer. This article surveys and evaluates Tie-Down systems based on strength, stretch, shrinkage and reliability. Opinions in this article are the sole responsibility of the author. Photos show actual or simulated installation problems.

Tie-Down Systems

Tie-down systems combine rods, plates, cages and shrinkage compensators in various ways. *Figure 1a* on *Table 1* is a plain rod system run without shrinkage compensators; *Figure 1b* on *Table 1* is the same system run with shrinkage compensators. *Figure 1b* is a parallel system. The rod carries the cumulative tensile load for all floors above, while the shrinkage compensator carries only the uplift load for that floor.

The chart on *Table 1* for *Figures 1a* and *1b* illustrates cumulative floor shrinkage with parallel systems. The chart assumes shrinkage/settling of ½-inch per floor. The *System 1a* run will result in cumulative shrinkage and system looseness of ½, 1, and 1½ inches on the first, second and third floors respectively. In the *System 1b* run, with shrinkage compensators added, the Take-Up devices work independently to compensate for building shrinkage. In this illustration, shrinkage compensators would require an expansion capacity of ½, 1 and 1½ inches for the first, second and third floors respectively.

With parallel systems, the rod carries the cumulative load of all floors connected above, but the shrinkage compensator requires strength only for the floor it is restraining. In *Figures 1a* and *1b* the rod will require 25, 10 and 3 Kips capacity at the first, second and third floors respectively, while the shrinkage compensators shown in System 1b require 15, 7 and 3 Kips per floor respectively for the same three floors. Parallel continuous rod systems with independent Take-Up devices are redundant. Each device is independent. The performance of one device does not affect the performance of the others. A more detailed performance review of these systems is set forth on *Table 2 (page 22)*, System types 1-4.

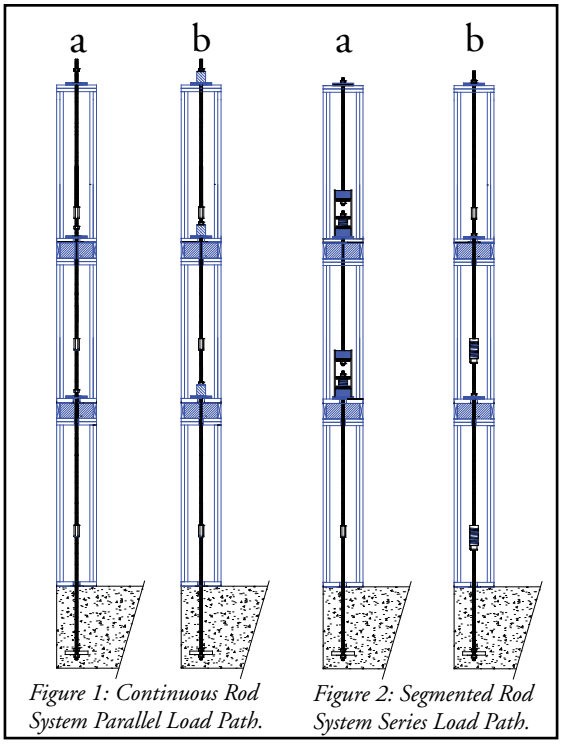

Figure 1: Continuous Rod System Parallel Load Path.

Figure 2: Segmented Rod System Series Load Path.

Continuous Rod				Segmented Rod			
Load (Kips)		Shrinkage		Load (Kips)		Shrinkage	
Rod	TU	Floor	Total	Rod	TU	Floor	Total
3	3	½	1-½	3	3	½	½
10	7	½	1	10	10	½	½
25	15	½	½	25	25	½	½

Table 1: Continuous and Segmented Rod Systems.

Figures 2a and *2b* on *Table 1* show segmented rod systems. The run shown in 2a is a cage system while run shown in 2b is a combined coupler-Take-Up device. Segmented systems are also known as linked rod or broken rod systems. Segmented systems have a break and a Take-Up device between each rod. This arrangement puts the shrinkage compensators in series, providing both an advantage and disadvantage. Segmented systems use shrinkage compensators that need only compensate for the shrinkage of the floor they connect, since compensation is cumulative. The disadvantage is that each shrinkage compensator and each cage must carry the entire tensile load of all floors above. The failure of a cage or a shrinkage compensator will affect all floors above. A more detailed performance review of these systems is set forth on *Table 2*, System types 5-6.

Figure 3: Out-Of-Square Installation.

A third type system is the cable system. While not illustrated on *Table 1*, a performance review of the system is set forth in *Table 2 (page 22)*, system type 7.

System Comparisons- Strength, Stretch, Shrinkage & Reliability

Historically, systems have been rated solely on strength. This review compares and evaluates systems based on strength, stretch, shrinkage and reliability. *Table 2, System Stretch Continuous Systems (page 22)* all assume 1-inch diameter, standard strength (A307) rod. (Note: some systems are not available in 1-inch rod. Adjustments were made to normalize systems for comparison.) Cable systems typically use high strength stranded cable. Based on strength, a ½-inch diameter cable was selected as a comparable size. For more information see Part 1 of this series of articles (August 2007).

Table 2 (page 22), System Stretch Continuous Systems, compares seven common systems based on strength, shrinkage and stretch.

continued on next page

System Type Take-Up	1	2	3	4	5	6	7
	Rod						Cable
	None	Jack Screw	Sleeve Ratchet	Cage & Jack Screw	Rod Ratchet	Coupler Jack Screw	Bellville Washers
Rod or Cable	1" - 8 NC Rod A36/A307						0.5" dia.
Design Load-Rod Only (IBC)	15,708	15,708	15,708	15,708	15,708	15,708	24,050
Rod or Cable Stretch (10')	0.080	0.080	0.080	0.080	0.080	0.080	0.960
Plate Compression	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Take-Up Backlash	0.000	0.000	0.070	0.000	0.190	0.000	?
Take-Up Deflection	0.000	0.012	0.012	0.012	0.012	0.012	?
Cage	0	0	0	0.010	0	0	?
Total Movement @ (15,708 lbs.) (Design Load Deflection)	0.120	0.132	0.202	0.142	0.322	0.132	1.000
Shrinkage Best Case	0.250	0.250	0.250	0.250	0.250	0.250	0.250
Total Movement	0.370	0.132	0.202	0.142	0.322	0.132	1.250
Adjusted Capacity @ ⅛"	N.A.	14,875	9,720	13,837	6,098	14,875	3,006
Elongation		=PL/AE	P	L	A	E	
Retrofit Only	Cable	0.9600	15708	120	0.196349	10000000	
Recommended	Rod	0.0828	15708	120	0.785398	29000000	
Not Recommended	Units	inches	pounds	inches	sq inches	Young's modulus	

Table 2: System Stretch Continuous Systems.

Shear wall performance is a function of tie-down stretch. Stretch includes all items that resist or contribute to uplift including, shrinkage, rod stretch, plate compression, take-up backlash, rod pitch and cage deformation. Systems that perform close to the target ⅛-inch value include all jack-screw devices, System 2, and a sleeve ratchet, System 3. Minor adjustments might be needed but these systems can meet the ⅛-inch elongation target and, in the opinion of this author, would be acceptable. Three systems that this author believes don't make the cut are: the rod system without shrinkage compensators (System 1): the Rod Ratchet System with an elongation of $^{5}/_{16}$ inch (System 4): and the cable system, (System 7) with stretch in excess of 1 inch.

Nearly all light frame buildings shrink and/or settle. Systems that compensate for settling use moving parts for adjustment. In time, all moving parts always stop moving. The most important criterion with continuous holdown systems is system performance with component freeze-up. While device freeze-up may be inevitable, no device should ever freeze-up *and release* its load. *Table 3*, *Continuous Tie-Down System Recommendations*, summarizes the strengths and weakness of current systems based on stretch and reliability. Each system performs differently depending on components and installation conditions. While some systems perform reliably even when the shrinkage compensator is frozen, others may release at low loads. A single item such as the out-of-square installation (*Figure 3*) can cripple some systems while others will perform well. Ratchet systems may partly advance and then catch only the tips of the rod striping the threads (*Figure 4*).

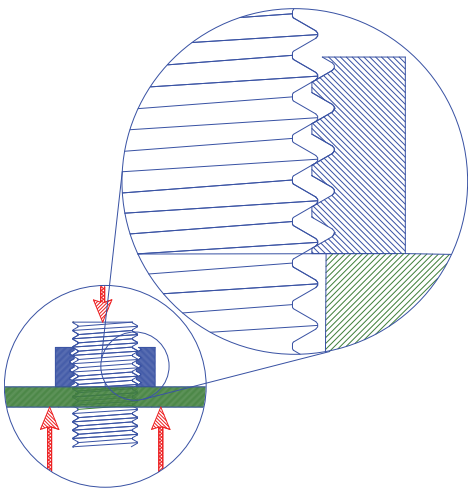

Figure 4: Rod Ratchet, Segments-thread tip loading.

Mixed Systems

To save money, some suppliers combine rod systems with straps. This is a poor idea. *Figure 5* shows a mock-up of a top floor termination that spans a floor and uses a strap for the top floor connection. With ¼-inch of simulated shrinkage, the strap just buckled. Even though the shrinkage compensation connection part may work, straps spanning floors should not be used.

Conclusion

Hold downs and continuous rod systems are an important step forward in properly securing buildings and shear walls, but they have significant limits. A code acceptance number doesn't mean a system will work under all conditions. When selecting a system, design for strength, keep system stretch under ⅛ inch, accommodate all shrinkage/settling, and, most importantly, choose a reliable system.

Part 4 - Designing Continuous Tie-Down Systems is the next installment in this series and will provide a quick, simple approach to designing a multi-story tie-down system that meets all criteria for proper shear wall attachment.▪

Figure 5: Top Floor Strap Termination. Rod Systems with straps spanning floors are not compatible. Demonstration shows the result of ¼" floor shrinkage.

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Retrofit Only		Recommended	Not Recommended
System	Use	Advantages/Disadvantages	
#1 Rod without Shrinkage Compensators		**Advantages:** Low Cost. **Disadvantages:** Loose connections with loss of lateral capacity. Appropriate for retrofit only. **Common Problems:** Loose connection due to shrinkage.	
#2 Rod and Independent Jack Screw		**Advantages:** Lowest stretch system (0.132" per floor). Fast installation. Will expand when out-of-square. Fail safe design, never releases when expanding. **Disadvantages:** Requires shrinkage estimate. **Possible Problem:** No expansion headroom.	
#3 Rod and Independent Sleeve Ratchet		**Advantages:** Moderate stretch - 0.202" per floor. **Disadvantages:** Highly stressed Internal components. Requires shrinkage estimate. Can freeze up. Sensitive to dust and dirt. Slow installation. **Possible Problem:** Dirt freeze-up.	
#4 Rod, Cage and Jack Screw		**Advantages:** Strong, stretch 0.142". **Disadvantages:** Many parts. Requires precision rod cutting, shrinkage compensator must lift rod from floor below. All load is carried by shrinkage compensator and by cage. Lacks shrinkage compensation on top floor. Slow installation. **Possible Problem:** Rod ends hitting in cages.	
#5 Rod and Independent Rod Ratchet		**Advantages:** Low Cost, Infinite expansion. **Disadvantages:** High stretch approx. 0.322". Tilt sensitive-jamming. Total release potential. Device can jam in the open position leaving no connection. Partial advance will strip threads. **Possible Problem**: Jammed elements.	
#6 Rod with Coupler Jack Screw		**Advantages:** Cumulative expansion capacity. **Disadvantages:** Each coupler jack screw carries the entire load of building above. Tilt Sensitive: devices cannot expand when out of plumb (offset can bind rotating devices). **Possible Problem:** Freezes with rod offset.	
#7 Cable System		**Advantages:** Fast installation. Low Cost. **Disadvantages:** Excessive stretch. System loosens after shrinkage. **Common Problem:** Slack cable.	Photo not available: Most common problem excess system stretch.

Table 3: Continuous Tie-Down Systems - Recommendations.