Tie-Down Systems an Overview

Shear walls perform to the code only when the tie-downs have both the required strength and tightness. ICC ES recently determined that tie-downs systems must limit deflection to 0.200" at the design load and some engineers require deflection as low as 0.125" (⅛").

This catalog defines the new tie-down requirement and helps specify required components to meet those design requirements.

If you are new to self-adjusting tie-down systems begin with "Tie-Down Systems-Designing to the Code" (pg 20). This section covers the IBC, expected movement and wood shrinkage. Follow up with the section on Tie-Down Specifications starting on page 4. If you start with clear and precise specifications a turn key system can be designed by AutoTight in as little as 2 days.

Thank you for considering AutoTight.

Alfred Commins, President

Commins Manufacturing Inc.

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ICC ES 2013 Requirements

Effective April 1, 2013 per (ICC ES AC316) Tie-Down systems must meet a maximum elongation limit of 0.200". AutoTight designs systems to 0.200" or less every day. We make it look easy.

AutoTight is up to 61% Tighter!

When identical systems were compared, AutoTight was 61% tighter compared to a system using a leading ratchet. These systems used identical rod and identical bearing plates, the only difference is the Shrinkage Compensator. This comparison was made at a design elongation limit of 0.125". A similar comparison at the ICC ES 0.200" limit demonstrated the AutoTight system was 36% tighter. To view a side-by-side comparison of AutoTight versus a leading ratchet. Go to www.youtube.com/ Search for AutoTight

TIe-Down Design Per the IBC

As of April 1, 2013 Tie-Down Systems complying with the IBC must be designed for system strength and must limit system elongation to 0.200". Many designers believe even tighter design limit limits should be used and routinely require an elongation limit of 0.125". Tight elongation limits can be a design challenge. Using the AutoTight system with a screw type shrinkage compensator solves the problem.

We routinely design multistory systems using a proprietary algorithm. The following paragraph provides an overview of how to design a tie-down system that meets code strength and elongation limits using ICC AC 316, AC 391 and the IBC. The table below describes each component to be considered and shows how to determine both system strength and elongation.

Tie-Down Components: Strength and Elongation Summary

Component	Model #	Description	Length	Strength Limit	Elongation		Comment
Rod	Rod ID	Diameter/Material/Length		AISC 360	From Table	Adjusted	Follow AISC 360 13th ed!
Bearing Plate	Bearing or HD	Size: Width X Length X Thickness		AISC 360 and AF&PA 2005	0.040"	Per Actual Load	Double HD Elongation across a floor
Shrinkage Compensator	Model Number	Diameter, Expansion etc		Per ES Report	Per ES Report	Δ_A	Adjusted per Actual Load
				Per ES Report	Per ES Report	Δ_R	Full Value (No Adjustment)
Shrinkage	1/4" or ?	Calculate per code		Est. Cat. Pg 26		Estimated	Elongation is Cumulative
		Lowest of above		Strength Limit	Elongation	SUM	

As shown in the previous table, systems are designed floor by floor.

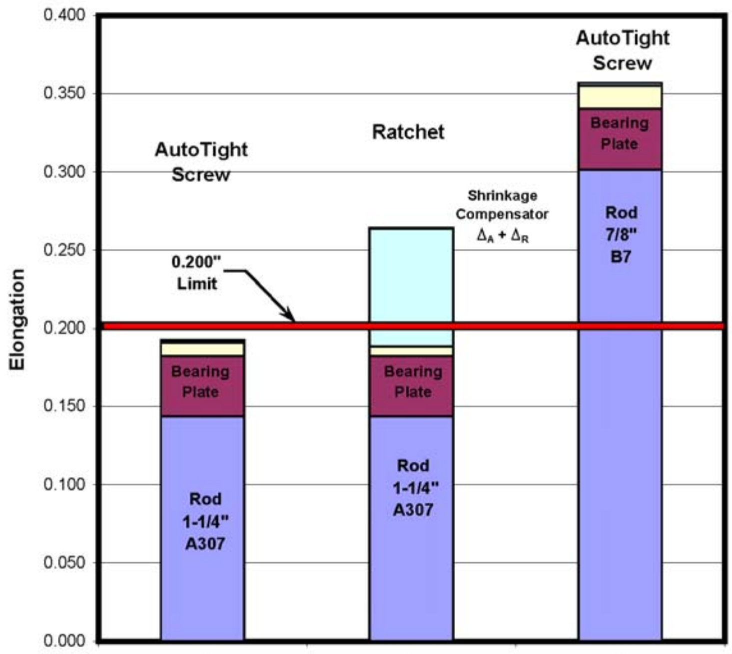
1. Design the system for strength and evaluate for system elongation (Sum the elongations).
2. Adjust elongation to specified limits by changing the rod size and/or the bearing plate. Commins Manufacturing Inc. designs systems for both strength and elongation using a custom algorithm. With this code change the AutoTight catalog now includes detailed design information on both strength and elongation.

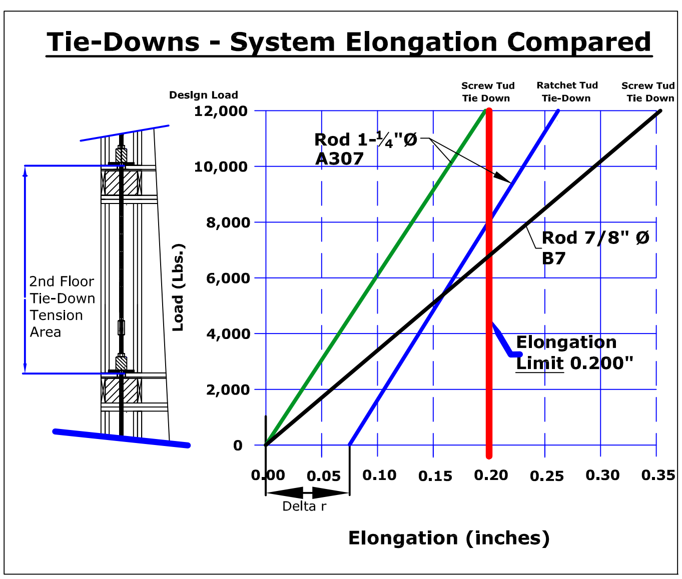
Identical Strength Systems Compared

For comparison three Identical strength systems are shown side-by-side. All systems are designed to the same strength (12,000 pounds), but because the components vary (rod, bearing plates or shrinkage compensators), system elongation ranges from 0.193" to 0.360".

The graph to the right shows the contribution to elongation that rod diameter makes and shows the contribution to elongation for a Screw Take-Up vs. a Ratchet.

AutoTight is tighter. We always uses a screw type shrinkage compensator. Code elongation limits are met by changing rod diameter, rod material or bearing plate size.





Changing the "Stacked Bar" to a load/deflection line a clear comparison emerges. All three systems have the same ultimate strength but the one with large diameter rod and a screw Tud meets system elongation limits, the others do not.

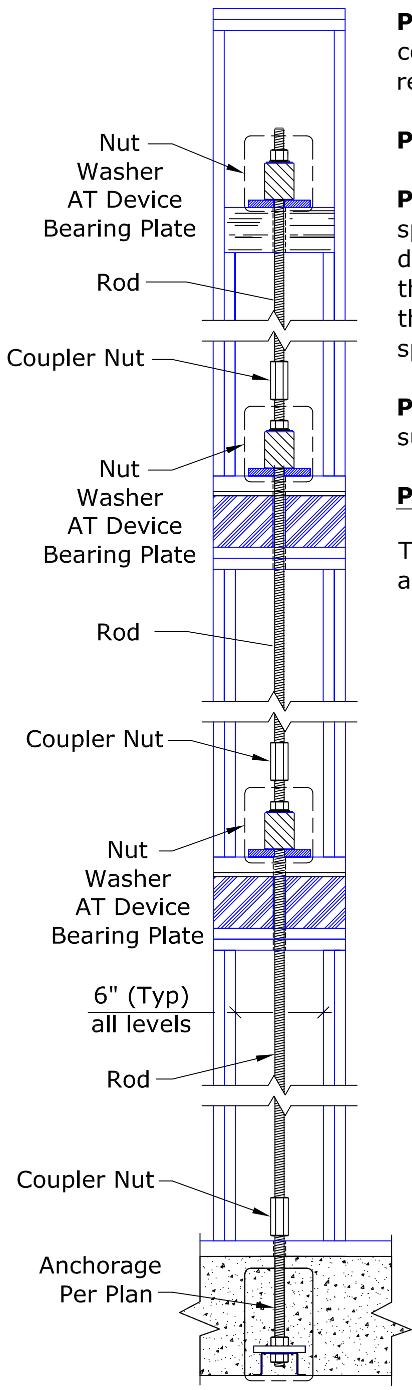
High strength rod with a screw Tud can only restrain 6,800 lbs. at the 0.200" design elongation limit (too much rod stretch.)

Large diameter (1-¼") rod coupled with a ratchet Tud can only restrain 8,000 lbs at the 0.200" elongation limit. (too much compensator looseness,)

Bottom Line: If you need a tightest system with the lowest elongation, AutoTight is the System of Choice.

A PDF that demonstrates the math required to meet a 0.200" limit or a 0.125" limit is available. Click here

Typical System



Tie-Down Specifications

Tie-Down systems perform to code capacity only when every component is properly selected.

Part 1 - Tie-Down System Specification provides a template to assist specifying components. The performance objective must meet the intent of the code and specific job requirements. Systems are designed for: strength, elongation, shrinkage and reliability.

Part 2 Is a **Commentary** on key specifications.

Part 3 demonstrates a manual method of designing a tie-down system to meet specifications. Designing for strength, elongation and shrinkage is complicated. Most designers use a computer program to maximize performance and minimize cost. I suggest that you review the method and steps even though you may rely on a manufacturer to do the design. Because these systems are complex you may find discrepancies between what is specified and what is supplied.

Plan check examiners should especially look at the engineering associated with the submittal to ensure it meets the stated code. Use a manual method to check calculations.

Part 1 - Tie-Down System Specification

The Tie-Down system shall be designed per the 2009 IBC for system strength and elongation and shall include applicable ICC-ES Acceptance Criteria as follows:

AC155 (June 2010, Hold Downs),
AC316 (June 2012 Shrinkage Compensators)
AC391 (June 2010 Tie-Down Systems)

1. The Tie-Down system shall have a current ICC-ES Evaluation Report and/or City of Los Angeles report.

2. Uplift forces and floor heights (carpet-to-carpet) are as shown in the Holdown Schedule. Forces shown are cumulative rod tensile load ASD (preferred) or LRFD in kips.

3. System Strength shall be limited by the lesser of: threaded rod tensile strength, bearing plate compressive strength or shrinkage compensator strength. Strength assessment shall be per AISC 360 equation J3-1 (Rod), AF&PA NDS (Bearing Plates) and/or applicable code Acceptance Criteria.

4. Elongation (between reaction points) shall be limited to 0.200". Short walls, (i.e. 10' or less) specified with an (*) shall be limited to an elongation not-to-exceed 0.125".

5. Elongation shall include all 5 tension elements including: rod elongation, bearing plate compression or hold down deflection, shrinkage and shrinkage compensator, delta A (ΔA) and delta R (ΔR). (See table page 2)

6. Only screw type shrinkage compensators shall be used.

7. The system shall accommodate an out-of-plumb condition not-to-exceed 2" per 10' floor.

8. Shrinkage compensators shall accommodate cumulative shrinkage of ¼" per floor (manufactured wood), or ½" per floor (solid sawn) (Select one).

9. Each reaction point shall be attached through a separate shrinkage compensator.

10. Straps may not be used with vertical connections. (See page 23.)

Note: Designing the lowest cost system that meets both **Strength** and **Elongation** can only be achieved if **uplift loads** (not rod size) are provided.

Tie-Down Specification (cont.)

Append a tie down schedule. Include Tension and compression loads, floor heights, floor levels, and cumulative shrinkage. We can show you a simple method of combining and sorting individual loads into a series of Tie-Down runs. Sorting runs will allow you to minimize and simplify the tie-down runs. Call AutoTight and ask for technical assistance.

Tie-Down Schedule

Net Tension (T) & Compression (C) Loads, Loads in Kips ASD

Run Type	4A		4B		4B*		4C		2A WBS		Floor Height		Shrinkage
	T	C	T	C	T	C	T	C	T	C	Ft	In	Cumulative
Count	43		25		10		30		3				
Level 4	2	5	3	6	3	6	4	6			11	6	1
Level 3	4	8	7	10	7	10	10	14	3	6	10	7	3/4
Level 2	9	15	16	20	16	20	21	25	12	15	10	7	1/2
Level 1	15	23	25	33	25	33	32	38			11	4	1/4
Embedments	15K		25K		25K		32K						

Suggestions

Run Type ID: List runs by # of floors then A, B, etc. WBS is a wood beam start. SBS is a steel beam start.

T/C Tension/Compression requirements in pounds or kips. **Identify Loads** as ASD or LRFD

Run Count (Optional): If a run count is supplied, contractors will receive a more accurate and competitive bid.

Elongation Limit: 0.200" **Code:** IBC 2009 **Wood:** DFL

Floor Height: (Carpet-to-carpet) Total distance between floors including floor and wall heights. Note: Grade compatible nuts, couplers and washers made to commercial standards exceed the strength of the attaching components. The supplier will specify, but not engineer, these components.

Part 2 - Tie-Down Specification Commentary.

The governing code, including the date, is the first item that should be referenced. Adding ICC-ES references helps narrow the specification scope in a rapidly evolving area. Including the latest AC (ICC ES **A**acceptance **C**riteria) and Date is suggested.

Item 1 specifies the tie-down shall have a current ICC ES report. It may be desirable to spell out acceptable Tie-Down manufacturers. My favorite:

> The Tie Down system shall be the AutoTight® Tie-Down System as manufactured by Commins Manufacturing Inc. under ICC ESR 1344, September 1, 2012 or later. (Systems and code are changing rapidly. Old listings don't necessarily meet the current code.) Other systems may be used provided they have a current ICC-ES report number and each and every item in the specification are satisfied.

Item 2 refers to the load table that completes system specifications. Except for run count (number of runs) every item in this table is needed for design. Floor heights are carpet-to-carpet and while found on architectural drawings it is best shown on a table.

Item 3 spells out specific components that must be investigated for strength. The threaded rod must comply with AISC 360 J3-1, 13th ed., bearing plates must comply with AISC 360 13th ed., for bending and the NDS 2005 for wood bearing. Shrinkage compensators must comply with ICC ES Acceptance Criteria 316 and have a current code listing.

Special Quality Note: Some suppliers are using rod strength derived from sources other than AISC 360. All suppliers source the same rod, only the rod strength derivation is different. Non-traditional calculations provide a calculated rod strength that is up to 11% higher than AISC 360 and may lead to rod overstress. IBC 2009 & ICC-ES require using AISC 360-13th ed.

Item 4 specifies the allowable system elongation, between reaction points, as 0.200". The system elongation limit is per AC 316 section 6.9. (Note: Some jurisdictions limit elongation to 0.179 (San Francisco, San Diego). Some engineers limit system elongation to 0.125". Both limits are superior but may increase system cost. But regardless of the source, the specific system elongation limit must be spelled out. To complicate this further, some jurisdictions add a "Rod Only" limit of 0.125" in addition to the system limit. The 0.125" rod-only limit doesn't make sense with a system limit of 0.200" now in place. Some jurisdictions are dropping this alternate limit. I expect that most will drop the rod only alternate 0.125" limit in the near future. Also note some jurisdictions specify a limit of 0.2". This is often interpreted as 0.249" and rounded to 0.2". If you want 0.200" state the limit clearly.)

Short wall complications:

The goal is to limit shear wall drift. Using the shear wall drift eq.:

$$\delta_{sw} = \frac{8vh3}{EAb} + \frac{vh}{1000G_a} + \frac{h\Delta_a}{b}$$

may allow short walls to drift excessively unless Δ**a** is tightly controlled. Tie-downs may contribute as much as 90% of the shear wall drift (per h/b in the last component of the drift equation). A short wall exacerbates shear wall drift. To compensate many designers use a tighter elongation specification on the short walls.

Bottom Line: keep shear walls as long as possible. When using short walls consider an elongation of 0.125" for tie-downs. A "short wall" note and (*) in the table will assist the designer in reducing the wall drift.

Item 5 specifies the tension elements (all 5) that must be considered. These are:

1. Threaded rod: Calculate: strength and elongation,
2. Bearing plate (or HD): Calculate: strength and deflection, Note the 0.040" limit.
3. Shrinkage: To help select the best model shrinkage compensator.
4 Shrinkage compensator: Determine Strength and Elongation at load:
   Add ΔA load adjusted + ΔR Device average travel and seating increment, added in full.

   System strength is limited by the weakest element in series.
   System Elongation sums elongation for: Rod + Bearing plate+ expected Shrinkage or Tud ΔA +ΔR
   The elongation of all items is adjusted to actual load, except for ΔR which is added in full.

Item 6 Specify only screw type shrinkage compensators. AutoTight has less than 10% of the deflection of ratchets.

Item 7 Identifies the out-of-plumb that the system will accept. It is best to keep the rods vertical with a minimum floor-to-floor offset. Sometimes it is necessary to move the rod over as the rod system climbs floor-to-floor. (Note: rod systems must be kept in the wall cavity, they can't "wander" outside the wall.)

Item 8 Specifies the amount of "per floor" shrinkage. This is shrinkage is cumulative. We normally see specified shrinkage of manufactured wood joists at ¼" per floor and solid sawn at ½" per floor. Wet climates may add another 1/8" per floor. See section on wood shrinkage starting on page 23.

Item 9 specifies that every item be connected through a shrinkage compensator. Some systems leave the shrinkage compensator off the top floor and/or use a strap to connect the top floors. The photo shows a building assembly before and after ¼" shrinkage. Straps don't work with shrinking wood! I recommend that you avoid straps and use a shrinkage compensator on every floor.

Item 10 The Tie-down schedule is a huge plus for the tie-down system designer. Provide it if you can. If you also provide a "run count" the bids will be more accurate and more competitive.

Part 3 Designing Tie-Down Systems (A Manual Method)

The following demonstrates a step-by-step manual design process used on tie-downs for strength and elongation. Designing a tie-down is much faster if a computer program is used. However, to understand design variables or if a design check is needed, this system will help you calculate system strength and elongation.

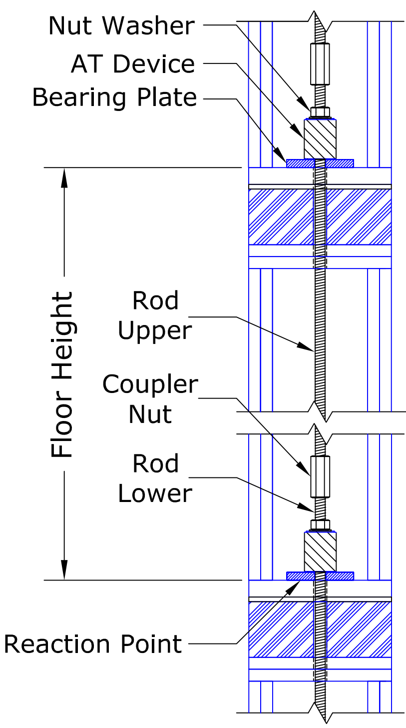
Designing a tie-down system manually requires selecting strength and elongation properties from component tables.

Step 1 Define Requirements

List demand floor-by-floor (See example, right)
Floor Heights are "Carpet-To-Carpet".
Uplift load is the cumulative rod load (kips) floor-by-floor.
Distributed Load is the (bearing plate) reaction load at each floor in kips.
Elongation is usually the global limit at 0.200" or 0.179". Adjust for short walls.
Wall width is included to assist with bearing plate fit.
Shrinkage is shown per floor and totaled (cumulative).

Run 4B

Level	Demand		
	Tie-Down Requirements		
4	Height (ft-in)	11	6
	Uplift Load (rod)	3	
	Dist Load (BP)		3
	Elongation	0.200"	
	Wall Width	6"	
	Shrinkage(fl/total)	1/4	1
	Tie-Down Requirements		
3	Height (ft-in)	10	7
	Uplift Load (rod)	6.9	
	Dist Load (BP)		4
	Elongation	0.200"	
	Wall Width	6"	
	Shrinkage(fl/total)	1/4	3/4
	Tie-Down Requirements		
2	Height (ft-in)	10	7
	Uplift Load (rod)	16	
	Dist Load (BP)		6
	Elongation	0.200"	
	Wall Width	6"	
	Shrinkage(fl/total)	1/4	1/2
	Tie-Down Requirements		
1	Height (ft-in)	11	4
	Uplift Load (rod k)	25	
	Dist Load (BP)		9
	Elongation	0.200"	
	Wall Width	6"	
	Shrinkage(fl/total)	1/4	1/4



System components are usually evaluated in the following order:

Lower Rod-	Strength and Elongation
Upper Rod-	Strength and Elongation
Bearing Plate-	Strength and Deflection
Shrinkage	
Compensator-	Strength + two Deflection
components	

Delta A (ΔA) Elongation (load adjusted).
Delta R (ΔR) Device average travel and seating increment, added in full.

The analysis that follows looks at a single floor and demonstrates a step-by-step analysis for strength. Elongation is also evaluated and compared with code limits.

The analysis is for the first floor of run 4B.

Select rod, bearing plates and shrinkage compensator using catalog tables.
Design for strength. Evaluate for total deflection.
Adjust components to minimize elongation. The template shown is run 4B, first floor.
Tie-Down Requirements provided by the EOR are shown on the left as demand.
The Tie-Down System is shown on the right. Place holders (blank cells) define required input and calculations.

Demand				Supply									
	Tie-Down Requirements			Component		Model	Size-Description		Strength Capacity		Elongation Contributions		
	Height (ft-in)	11	4			#			Rated	D/C Ratio	@ Capacity		Final
1	Uplift Load (rod k)	25		Shrinkage									
	Dist Load (BP)		9	Compensator									
	Elongation	0.200"		Bearing Plate									
	Wall Width	6"		Rod	Upper								
	Shrinkage(fl/total)	1/4	1/4		Lower								
						D/C Limit (Highest of the above 4 items)					Elongation ∑		
	Embedment			Rod		R9	1-1/8" NC B7	6"					

Embedments must match rod strength and size.

Tie Down System Design Run 4B

Threaded Rod

Rod is often the governing factor in system elongation. We typically select the least expensive rod. This is often the smallest diameter high strength rod available. The lowest floor is evaluated first. On the first floor the **lower** rod is usually the concrete embedment rod. This rod usually projects 6" from the slab. The specified rod is R9B7, a 1-⅛" NC B7 Rod. AutoTight (AISC) rates this for 46.6 kips. The elongation of 120" (10 feet) of rod is 0.253" at the design load (46.6 kips.). The 0.253" elongation is adjusted per the actual load and length. Final elongation is (25/46.6)*(6/120)*0.253" = 0.007"

The **upper** rod elongaton length =floor height - rod lower =(11'-4")(-6") = 134". Elongation =(25/28.19)(132/120)*0.253" = 0.243". The two rods attaching the first floor will contribute an elongation of 0.250". This exceeds the elongation limit and will be adjusted later.

Bearing Plate

The bearing plate is selected next. The threaded rod carries the entire uplift load for all floors, but the bearing plate distributes the local reaction load, in this case 9 kips. An S10 bearing plate is rated at 10.006 k on Douglas fir (625 psi.) Deflection is a straight line function with full load at 0.040" deflection. The deflection contributed by the bearing plate is (9/10.006) * 0.040" = 0.036".

Shrinkage Compensator

The shrinkage compensator is the last item to select. We select an AT100 to fit over the ⅞" rod. The AT deflects 0.032" at the rated load of 25.3K. The AT deflection contribution (Δa) is (9/25.3) * 0.032" = 0.011". The Delta R(ΔR) in the table is added to the deflection without modification.

	Tie-Down Requirements			Component		Model	Size-Description		Strength Capacity		Elongation Contributions		
	Height (ft-in)	11	4			#			Rated	D/C Ratio	@ Capacity		Final
1	Uplift Load (rod k)	25		Shrinkage Compensator		AT100	1" Dia X 1.1" Exp		25.3	0.36	TUD Δ_A	0.032	0.011
	Dist Load (BP)		9								TUD Δ_R	0.002	0.002
	Elongation	0.200"		Bearing Plate		S10	1/2" X 3-1/4 X 5	DFL	10.006	0.90	10.006	0.040	0.036
	Wall Width	6"		Rod	Upper	R7B7	7/8"-9 NC B7 X	144	28.19	0.89	120	0.253	0.243
	Shrinkage(fl/total)	1/4	1/4	Rod	Lower	R9B7	1-1/8"-7 NC B7 X	6	46.6	0.54	120	0.253	0.007
						D/C Limit (Highest of the above 4 items)				0.90	Elongation ∑		0.299

Exceeds Elongation Limit

Adjust Components

The total system deflection is **0.299** with selected components. If we switch the rod from an R7B7 to an R10A307 and use size compatible components (bearing plate and TUD) system elongation drops to 0.172. This elongation complies with both the ICC ES 0.200" deflection limit as well as the San Diego 0.179 elongation limit.

	Tie-Down Requirements			Component		Model	Size-Description		Strength Capacity		Elongation Contributions		
	Height (ft-in)	11	4			#			Rated	D/C Ratio	@ Capacity		Final
1	Uplift Load (rod k)	25		Shrinkage Compensator		AT100	1" Dia X 1.1" Exp		25.3	0.36	TUD Δ_A	0.032	0.011
	Dist Load (BP)		9								TUD Δ_R	0.002	0.002
	Elongation	0.200"		Bearing Plate		S10	1/2" X 3-1/4 X 5	DFL	10.006	0.90	10.006	0.040	0.036
	Wall Width	6"		Rod	Upper	R10A307	1-1/8"-7 NC A307 X	144	27.61	0.91	120	0.118	0.116
	Shrinkage(fl/total)	1/4	1/4	Rod	Lower	R9B7	1-1/8"-7 NC B7 X	6	46.6	0.54	120	0.253	0.007
						D/C Limit (Highest of the above 4 items)				0.91	Elongation ∑		0.172

OK **Elongation OK**

The first floor of run 4B is now complete. Required system strength is met and elongation is under 0.200"
The AutoTight web site will soon have a complete analysis of this run listed under Technical Notes.

Notes: