CONTINUOUS TIEDOWN SYSTEMS FOR SHEAR WALLS: ALL-FLOORS-TIED-OFF vs. SKIPPED FLOORS

Patent Pending

OVERVIEW

In multi-story, light-frame structures, site-built shear walls may be required to resist extremely high overturning forces. These shear walls often require an alternative system to conventional holdowns. Continuous tie-down systems have emerged as a solution to resist these loads.

At times, plans may include continuous tie-down systems that skip floors as a means of reducing project costs. Skipping a floor means that one point of restraint is expected to support more than one building level. After extensive testing and analysis Simpson Strong-Tie determined that skipping floors results in significant loss of shear wall performance when compared with shear wall performance in an all-stories-tied-off system. Moreover, skipping floors results in other issues to consider, such as increased component sizes, increased drift, reduced redundancy, shrinkage and construction stability.

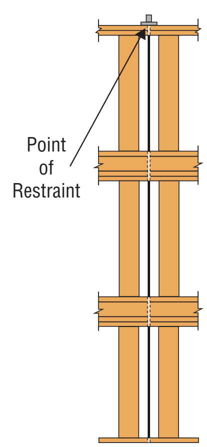
Increased Component Sizes. In a skipped-floor system, the overturning forces transfer further up the building until a restraint is reached. As a result, elements at and below the restrained point have to resist higher uplift forces necessary to constrain the unrestrained stories below. This results in increased lumber, threaded rod, and bearing plate sizes. In a tied-off system, the incremental forces at each level are transferred directly into the tie-down system at that level.

Drift. Shear walls must be designed for both strength and lateral stiffness. A skipped-floor system that is designed only for strength probably will not be sufficient to satisfy drift requirements. Test results indicate that skipping floors has the potential to substantially increase inter-story drift. Drift analysis is important for all shear walls, but it is particularly critical in skipped-floor systems.

Redundancy. Even when they are appropriately designed, structural elements can perform unexpectedly during major seismic and high-wind events. In a skipped-floor system, multiple floors rely on a single component for their performance. If that element fails, the entire uplift resistance for all non-restrained floors below may be compromised. With an all-floors-tied-off system, the lower floors do not rely on the stability of the upper floors for their performance.

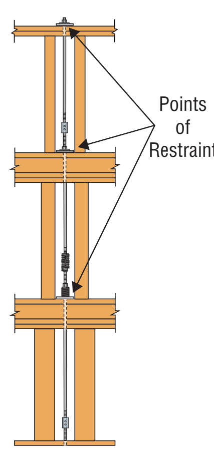
Construction Stability. When a system is designed to be tied off at each story, it allows the contractor to laterally restrain the building as construction progresses. In a skipped-floor system, the Designer or builder should consider a temporary bracing method during construction until the tie-down system is fully engaged, to prevent collapse or damage during a seismic or wind event.

SKIPPED-FLOOR SYSTEM
(Not Recommended)



A single point of restraint for multiple levels

ALL-FLOORS-TIED-OFF SYSTEM
(Recommended)



Overturning restraint provided at each level

 T-SKIPFLOORS11 2/11 exp. 6/13

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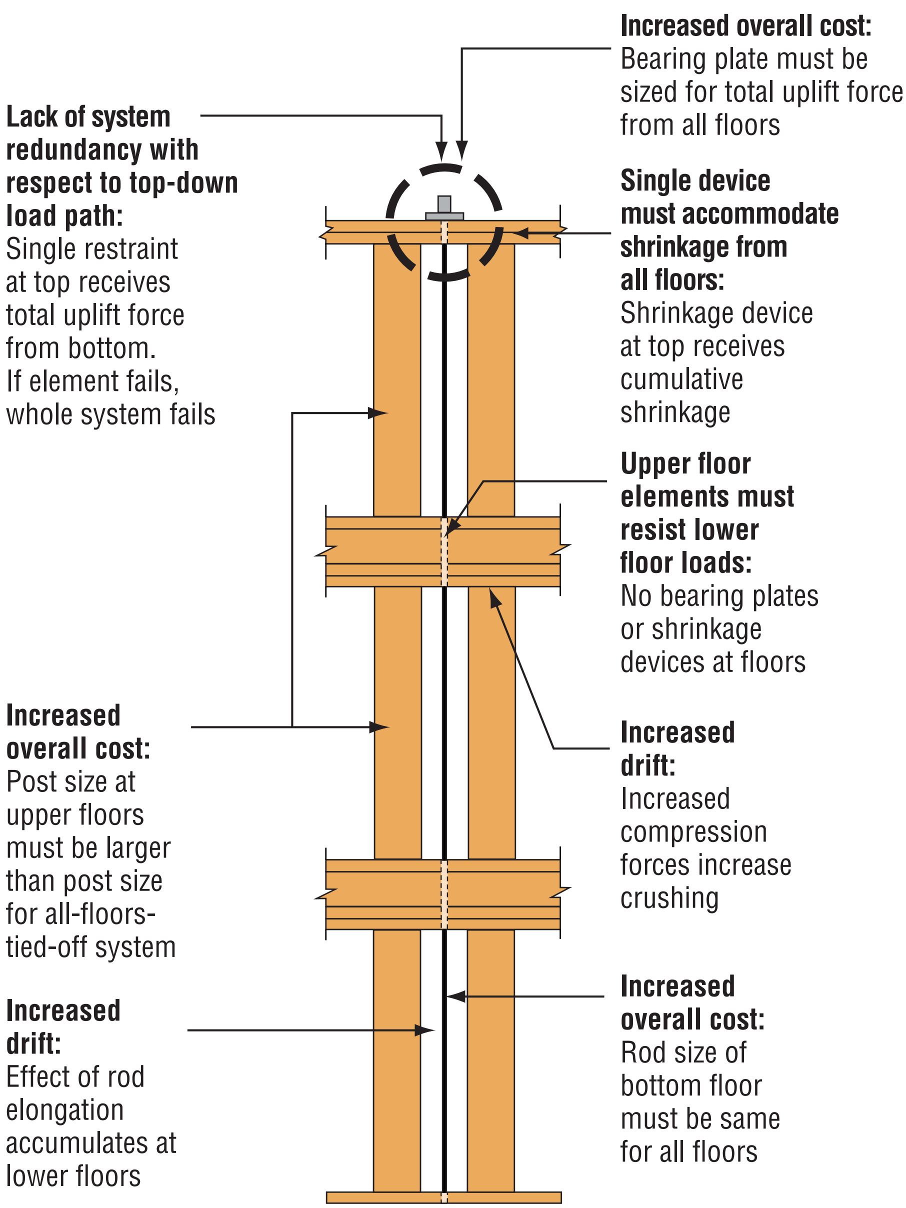
SKIPPED-FLOOR SYSTEMS

The illustration below shows an example of a skipped-floor system in a three-story structure – second- and third-floor restraints are not provided (skipped). A single bearing plate at the top level is the sole point of restraint.



SUMMARY:

- Increased cost for posts, rods and bearing plates
- Increased drift
- Lack of system redundancy
- Shrinkage not accommodated at each floor
- Inefficient load path
- Lack of construction stability

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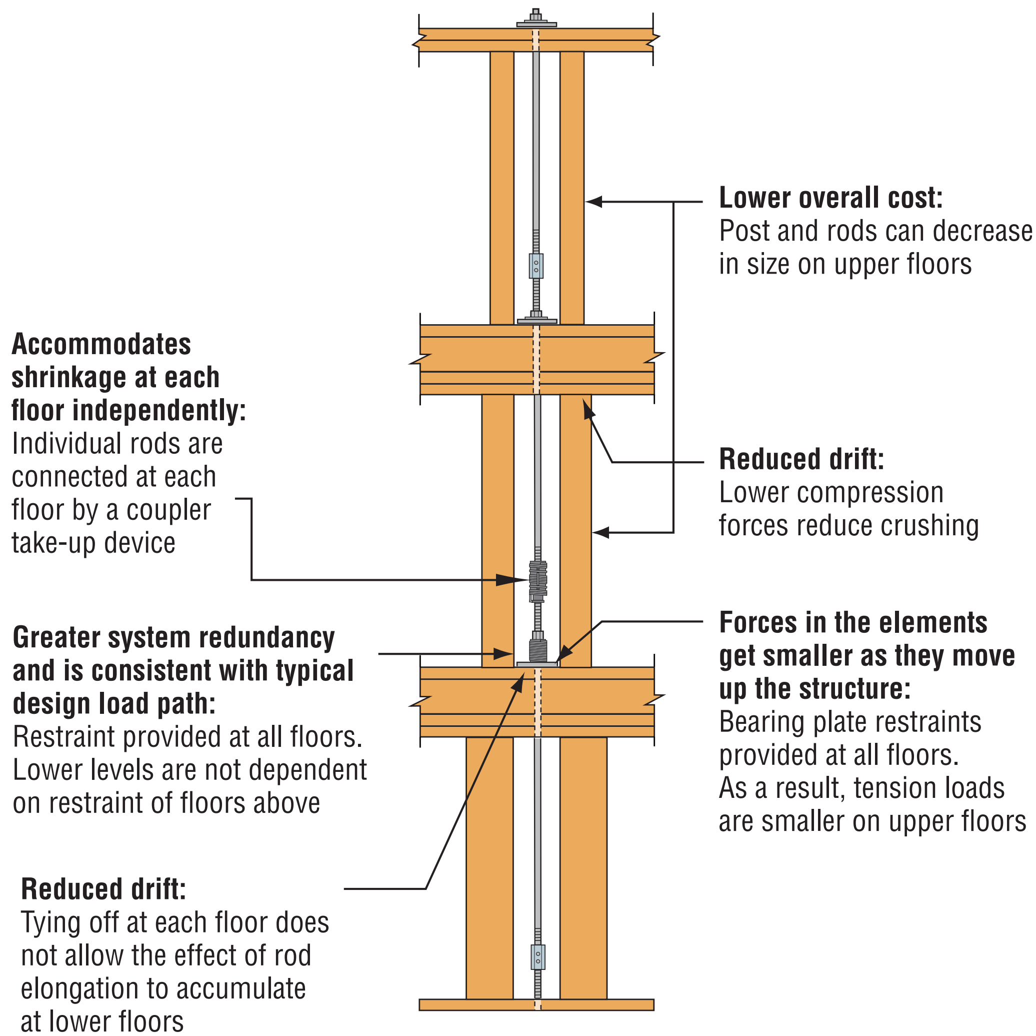
SIMPSON Strong-Tie®

ALL-FLOORS-TIED-OFF SYSTEMS

The illustration below shows an example of an all-floors-tied-off system. Each floor is restrained with a bearing plate and nut.



SUMMARY:

- Cost savings on posts, rods and bearing plates
- Shrinkage accommodated at each floor
- Reduced drift
- Efficient load path
- System redundancy
- Construction stability

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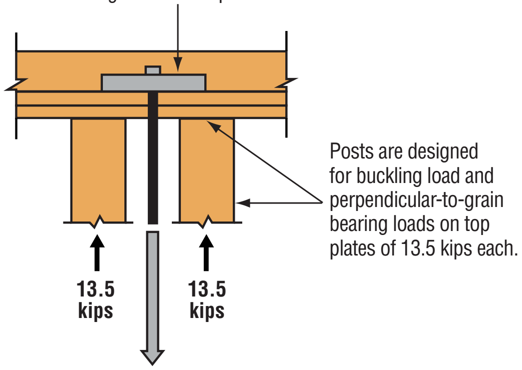
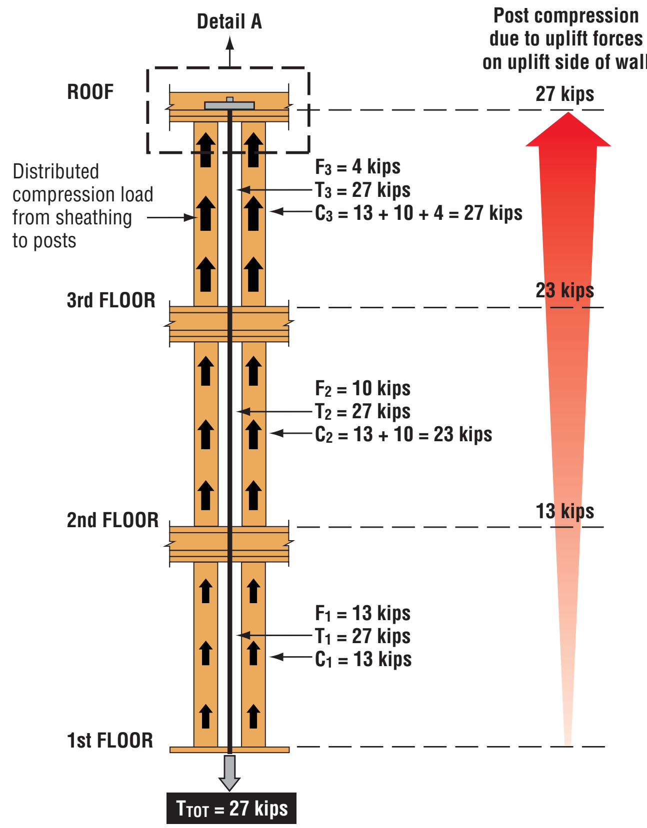
UPLIFT LOAD PATH OF A SKIPPED-FLOOR SYSTEM





Note: F_1, F_2 and F_3 are inter-story uplift forces.
T_1, T_2 and T_3 are rod tension loads.
C_1, C_2 and C_3 are the post compression loads due to uplift forces.
Example does not include gravity loads.

Axial Load Diagram of Posts on Uplift Side of Wall

LOAD PATH:

- Load path is from bottom to top and then back to bottom – not efficient.
- Overturning loads are transferred to posts through boundary nailing and travel upward through compression until finding a point of restraint at the top of the building.
- The whole system is restrained at the upper most top plate by a large steel bearing plate.
- Bearing plate transfers the load to the nut and then the rod.
- The free body-diagram shows that top floor tension force is a result of all of the lower posts transferring the cumulative uplift load upward to the top floor before coming back down. In order for this to happen, the posts in the lower floors must carry that force up in compression. Therefore, posts in the top floor must resist the uplift force from bottom floor.

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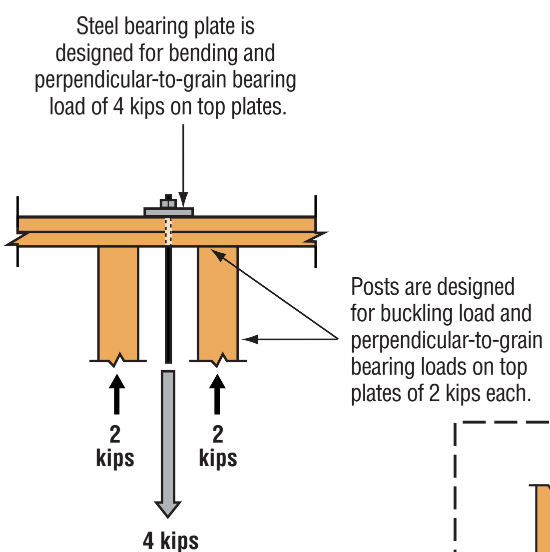
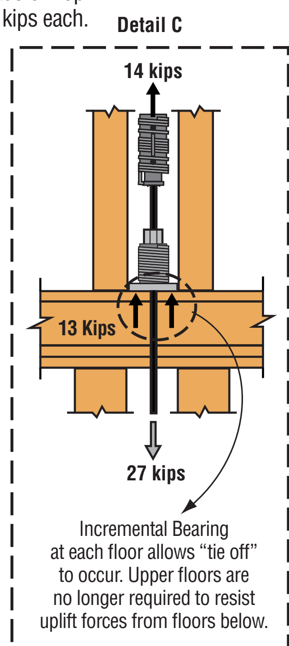
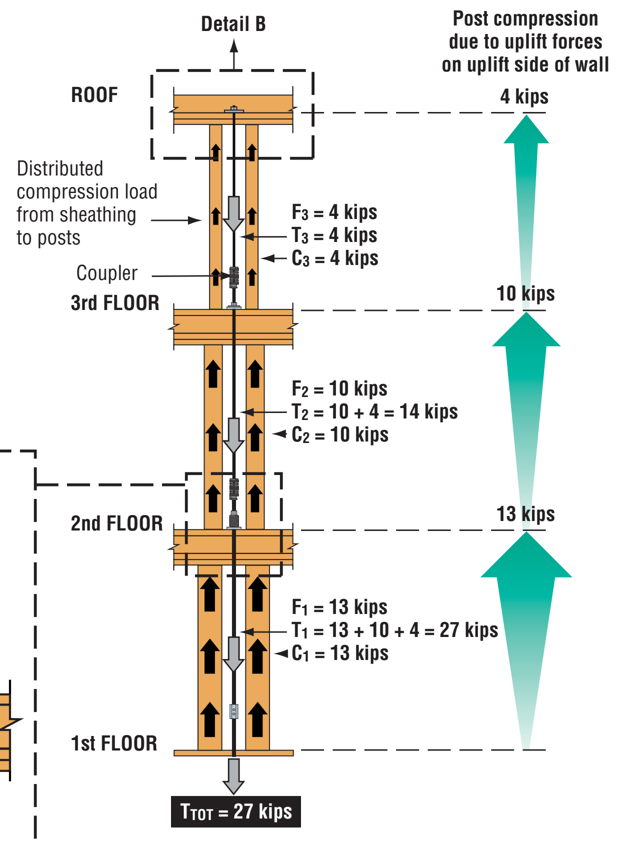
UPLIFT LOAD PATH OF AN ALL-FLOORS-TIED-OFF SYSTEM

Detail B







Note: F_1, F_2 and F_3 are inter-story uplift forces.
T_1, T_2 and T_3 are rod tension loads.
C_1, C_2 and C_3 are the post compression loads due to uplift forces.
Example does not include gravity loads.

Axial Load Diagram of Posts on Uplift Side of Wall

LOAD PATH:

- Overturning loads are transferred to posts through boundary nailing and travel upward through the floor system until finding a point of restraint at each story.
- Floor system or roof top plates resist the post uplift from each floor below. The posts are engaged in compression because of uplift from the inter-story load.
- Floor system or roof top plates are held down by the bearing plate on the sole plate or roof top plates. The bearing plates resist inter-story uplift load at each floor.
- Bearing plates transfer the incremental load to the nut and then the rod.
- The free-body diagram shows that posts on top floor resist the uplift force from the top floor only.

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Full-scale test set up for a three-story skipped-floor system.

TEST RESULTS MEASURING INTER-STORY DRIFT

Simpson Strong-Tie conducted a series of tests to compare the differences between skipped-floor and tied-off systems. Four types of three-story shearwall systems were tested on a shake table at the state-of-the-art Simpson Strong-Tie Tyrell Gilb research laboratory in Stockton, California. The four systems included:

- All floors tied off
- All floors skipped
- Second floor skipped
- Third floor skipped

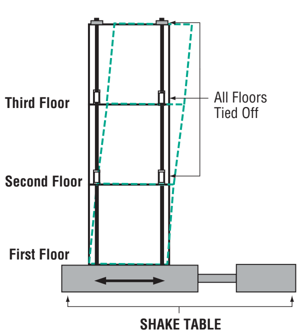
The testing simulated a 6.7 magnitude earthquake ground motion to compare the drift for each story *(inter-story drift)* of each system. Building codes require the inter-story drift to be less than 2.5% of the story height. In this case, the tested shearwall systems measured 96" in height for each story, resulting in a 2.4" allowable inter-story drift.

The test results concluded that skipping floors has the potential to significantly increase inter-story drift and reduce shearwall performance. The three skipped-floor systems did not perform as well as the all-floors-tied-off system and in this case, did not meet code drift limitations on the lowest floor of the set of skipped floors.

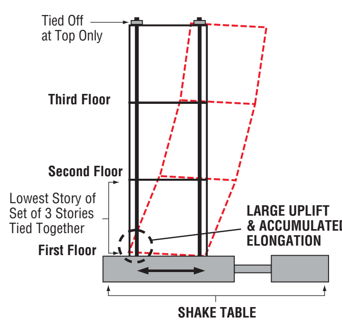
The significant increase in the drift can be mainly attributed to:

- Effect of rod elongation accumulated at the lowest floor of a set of skipped-floors
- Accumulated elastic compression of the floor systems on the uplifting side of the wall
- Accumulated compression *(perpendicular-to-grain deformation)* of top plates and sill plates on the uplifting side of the wall

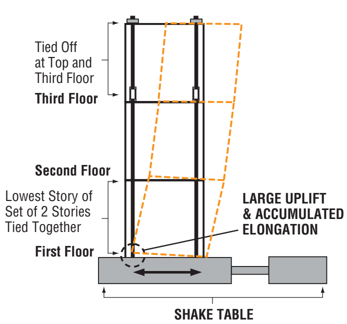
TIED OFF



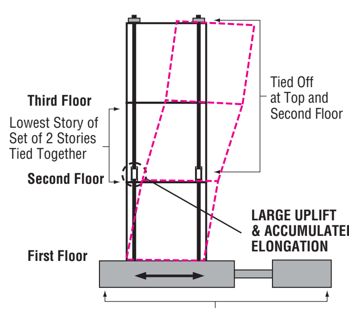
ALL FLOORS SKIPPED



SECOND FLOOR SKIPPED



THIRD FLOOR SKIPPED



NOTE: Deflected shapes are exaggerated for illustration clarity.

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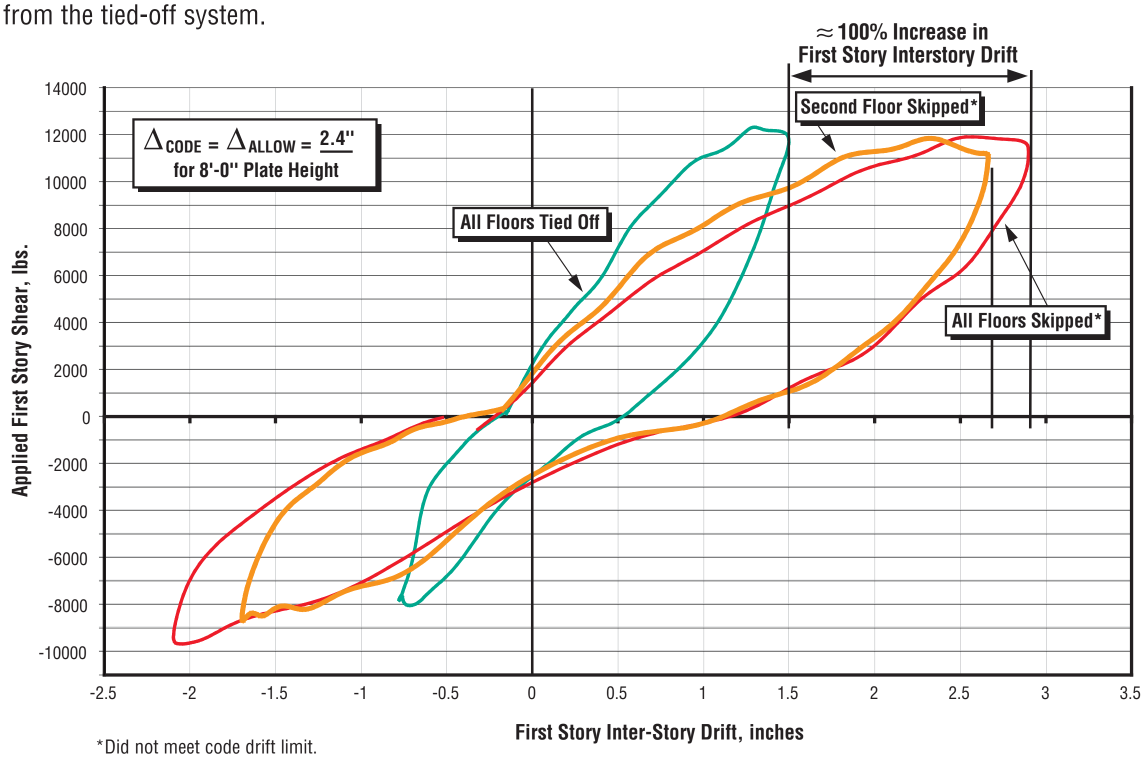
FIRST STORY INTER-STORY DRIFT COMPARISON

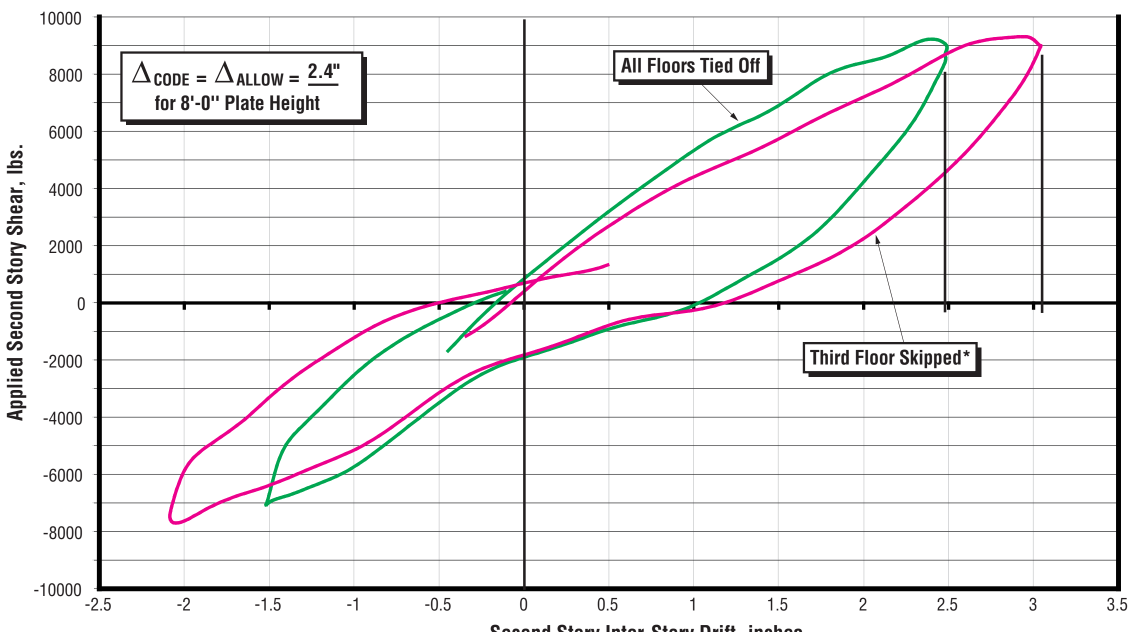
For the all-floors-skipped and the second-floor-skipped configurations, the first story is the bottom story of the group of stories tied together (see system illustrations on page 6). This story experiences the greatest increase in inter-story drift. The graph below compares this drift with that from the tied-off system.



*Did not meet code drift limit.

SECOND STORY INTER-STORY DRIFT COMPARISON

For the third-floor-skipped configuration, the second story is the bottom story of the group of stories tied together (see system illustrations at right). This story experiences the greatest increase in inter-story drift. The graph below compares this drift with the second story drift of the tied-off system.



*Did not meet code drift limit.

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Four Methods for Specifying ATS

We recognize that specifying Simpson Strong-Tie® ATS is unlike choosing any other product we offer. You must first address several design questions and considerations to ensure that the system will be configured to meet the design intent. These considerations might include whether to use ATS, or conventional holdowns and strapping; determining the project's incremental and cumulative loads; or, specification of elongation limits, for example. For more on these issues and many others, please visit **www.strongtie.com/ats**. We currently offer the following four methods of specifying ATS:

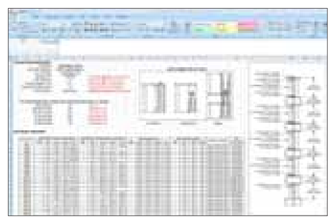
ATS Selector Software

1. Use our ATS Selector software for customized runs

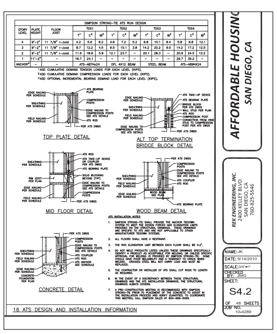
Many Designers find it convenient to use our free ATS Selector software to design custom runs to meet their exact demand loads. With this method of specification the ATS Selector software creates drawings of the custom runs for placement in the construction documents. Since the runs are customized, they are less expensive than comparable catalog runs. The current ATS Selector software does not yet optimize the runs with the latest improvements in the ATS product line, but Simpson Strong-Tie can review these jobs to ensure the most cost-effective solutions are specified on the construction documents; this service is provided at no additional cost. For this review, the Designer need only e-mail the ATS design file to **engineeringservices@strongtie.com**. Our team will optimize the runs to include the most cost-effective ATS products, and quickly return installation drawings and calculations to the Designer.

2. Send us your loads and we'll optimize the runs

Designers who do not use the ATS Selector software can also receive customized run drawings that incorporate the cost-savings from the expanded ATS product line. After sending us your project loads and criteria in a spreadsheet, we will customize the runs and quickly return installation drawings and calculations. To utilize this free service, please download a copy of the spreadsheet at www.strongtie.com/ats. E-mail the completed spreadsheet to **engineeringservices@strongtie.com**. Our team will optimize the runs to include the most cost-effective ATS products, and quickly return installation drawings and calculations to the Designer.



ATS Design Load Spreadsheet



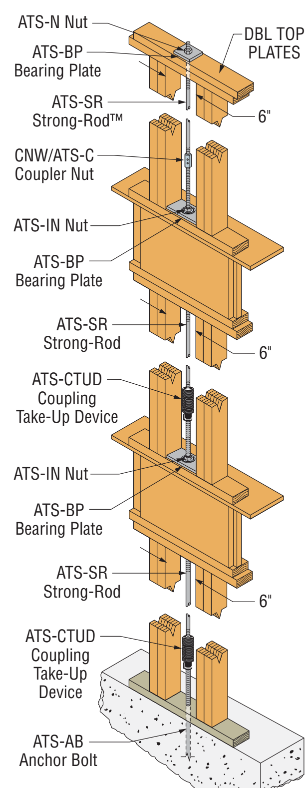
Generic Installation Details

3. Provide loads and generic specifications on drawings

Simpson Strong-Tie can also provide customized runs for Designers who prefer to include only design loads and generic specifications on their construction drawings. This works well, provided that all the design information is clearly specified, including: cumulative tension and compression loads, anchorage requirements, elongation limits, run locations, etc. All this information is critical to specifying a system that meets the Designer's intent. To assist Designers who prefer this method of specification we have created recommended installation drawings and notes. These details contain the critical information needed to design the runs properly. Download them at **www.strongtie.com/ats**. Our team will optimize the runs to include the most cost-effective ATS products and provide installation drawings and calculations for review and approval.

4. Specify catalog runs from the ATS catalog

For years, Simpson Strong-Tie has listed model numbers for catalog ATS runs in the *Anchor Tiedown System for Multi-Story Overturning Restraint* catalog. This enables Designers to easily specify ATS without having to provide ATS run details and installation drawings on their construction documents. While this specification method does not offer the same customized, cost-saving features as other methods, Simpson Strong-Tie does provide support for jobs specified with catalog runs. During the design review phase of the project, our team will optimize the runs to include the most cost-effective ATS products and provide installation drawings and calculations for review and approval as a cost-effective alternative to the catalog runs.



Catalog ATS Run

This technical bulletin is effective until June 30, 2013, and reflects information available as of February 1, 2011. This information is updated periodically and should not be relied upon after June 30, 2013; contact Simpson Strong-Tie for current information and limited warranty or see www.strongtie.com.

800-999-5099
www.strongtie.com