

StiffWall® Shear Wall System

# Technical Note

StiffWall® Strap Bracing Shear Wall System

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# STIFFWALL<sup>®</sup> STRAP BRACING SHEAR WALL SYSTEM

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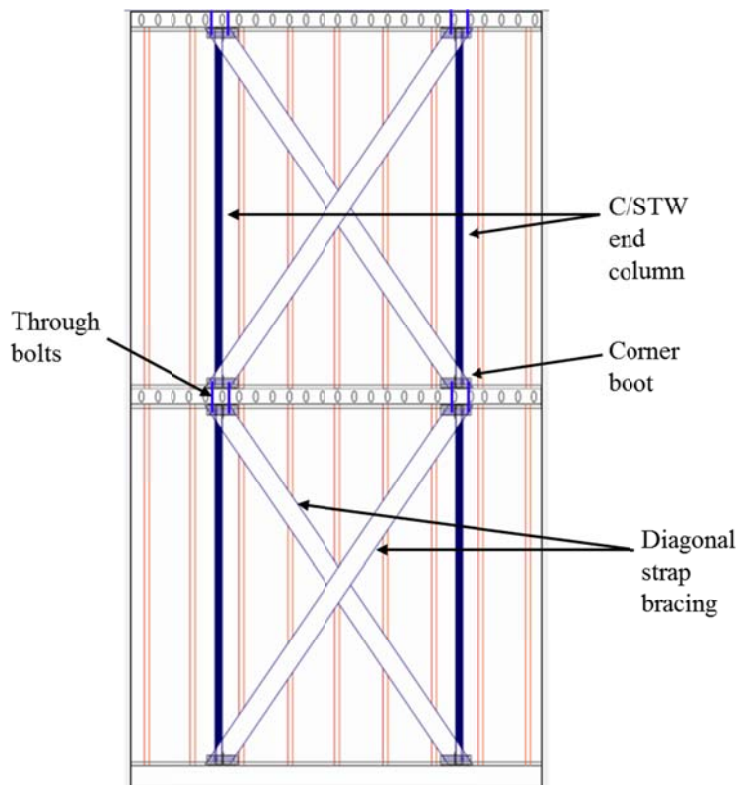
## **Introduction**

Buildings require a vertical load resisting system to provide lateral stiffness and to transfer acting lateral loads from wind or seismic forces down to the foundation. Lateral stiffness is required to prevent the floors and roof from excessive side sway. In addition, buildings with sufficient lateral stiffness will suffer less non-structural damage, which means less cracking in walls and finishes, less water infiltration, and increased durability. StiffWall<sup>®</sup> is a pre-engineered system intended to simplify and optimize the design and installation of strap bracing shear walls to resist wind or seismic forces and provide required lateral stiffness. The system eliminates the need for plywood, OSB, or steel sheet sheathed shear panels all of which require excessive and complex fastener schedules. The system also eliminates the need for corner gusset plates traditionally used in strap bracing shear walls. In the StiffWall, the load path for shear forces through floor slabs is simplified by using corner “Boot” connection and through bolts. StiffWall has been effectively used in residential and commercial low and mid-rise cold-formed steel applications. The product is designed and manufactured to meet the performance requirements of each project.

## **Components of StiffWall**

The StiffWall system is composed of panels where each panel connects two floors vertically. For a multi-story building, the number of panels for a single StiffWall system equals the number of stories. The panel consists of several structural components, which are the vertical end Columns (vertical chords), the diagonal strap bracing, the corner Boot connections, and the floor-to-floor through bolts. **Figure 1** shows the components of a StiffWall system.

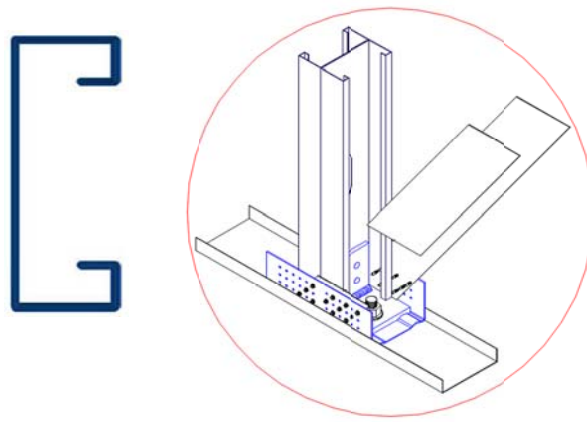
Note that the horizontal top and bottom chords of the shear wall panel consist of the floor/roof slabs or diaphragm, which are not part of the StiffWall. The top and bottom runner tracks of the wall may be engineered to act as part of the horizontal top and bottom chords. Other components that are built within the panel that are not part of the resisting strength and stiffness are the intermediate studs and any intermediate horizontal bracing.



**Figure 1: Two-panel StiffWall shear wall system**

The end Columns of the StiffWall system (labeled C/STW) are spaced at the design panel width and extend from floor slab to floor slab. The end Columns may replace typical wall studs or may fit within the stud spacing between studs. In either case, the end Columns should be engineered to have a design axial compression capacity not less than the design axial compression capacity of the typical wall stud in the same wall. This requirement is to ensure that when under floor/roof deformation, the Columns can support gravity loads equivalent to the loads supported by the typical wall stud. StiffWall Columns are manufactured with non-standard web dimension in order to fit inside the StiffWall corner Boot connection. Therefore, standard (S) sections will not fit into the corner Boot.

The diagonal strap bracing is the tension element used to transfer lateral loads diagonally between floor/roof diaphragms through the corner Boot connection. Diagonal strap bracing is recommended to be a minimum of 4 inches wide and 54 mil (16 ga) thick to achieve proper connection at the two ends. The straps can be attached at the ends to the StiffWall corner Boot connection using #12 self-drilling screws or using fillet welds. **Figure 2** shows the connection of the Column, strapping, and corner Boot.



**Figure 2: C/STW end Column and corner Boot connection**

The StiffWall corner Boot consists of a 12 inch, 97 mil strap track that sits inside the runner track of the wall and is designed to receive and secure the attachment of the diagonal strap bracing. In addition to the Strap Track, the Boot includes various sizes of cold-formed steel or structural steel uprights that attach to the StiffWall Column on one side and anchor the Boot down to the floor slab on the other side. The anchorage of Boot is achieved with through bolts for floor-to-floor connection or mechanical/adhesive anchors at the foundation level. The anchorage of Boot at a podium floor level can also be achieved via direct welding to floor steel beams or embedded plates.

### **Design Considerations**

Components of StiffWall system are designed according to the North American Specification for the Design of Cold-Formed Steel Structural Members (AISI S100) and the North American Standard for Cold-formed Steel Framing – Lateral Design (AISI S213). Section C4 in AISI S213 standard limits the aspect ratio (height/width) of a shear wall with diagonal strap bracing to not exceeding 2:1 unless a rational analysis is performed which includes joint flexibility and end moments in the design of the end chord Columns. The technical information for the StiffWall system provides design data for a range of wall aspect ratio between 0.6 and 2.

The StiffWall system is typically analyzed as a truss model with lateral and/or gravity loads applied at joints that represent the points of contact between the shear wall and the floor/roof diaphragms. Load should be factored based on the design method selected for analysis (strength design or allowable stress design) and proper load combinations should be applied per ASCE Standard for Minimum Design Loads for Buildings and Other Structures (ASCE 7-10). In any shear wall panel, only diagonal bracing acting in tension should be modeled since strap bracing is not capable of resisting compression forces.

When the StiffWall system is designed to resist lateral seismic forces, the seismic loads are to be calculated based on a seismic response modification coefficient,  $R = 4$ , as recommended in Chapter 12 of the ASCE 7-10 standard. However, attention should be given to Sections C1.1 and C5.2 in the AISI S213 standard for the consideration of special seismic requirements in the design when  $R$  is taken greater than 3. Further clarification for the use of special seismic design is given Section C1.1 of AISI S213 standard. The clarification states that for Seismic Design Category A through C, the designer has the option to use an  $R = 3$  (instead of 4) to determine the seismic loads and thereby avoid the special detailing in Section C5.2. In Seismic Design

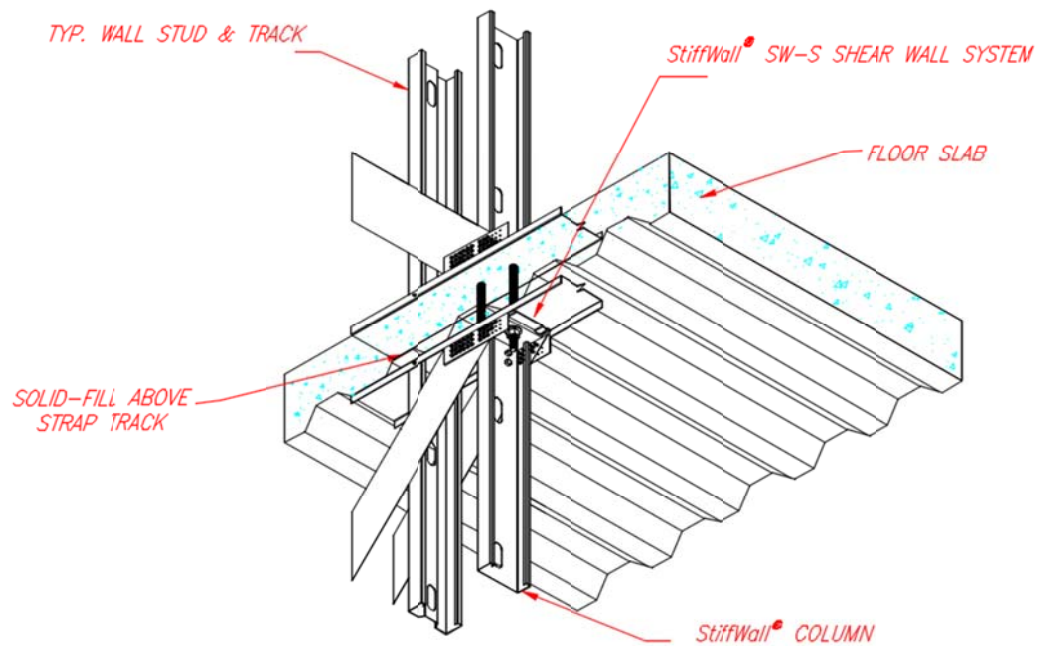
Category D through F, the designer must use  $R = 4$  and must apply special detailing in Section C5.2.

### Construction Details

This section demonstrates and discusses StiffWall construction details for several typical design conditions in multi-story steel framing construction.

#### Connection through Corrugated Metal Deck Floor Slab (Figure 3)

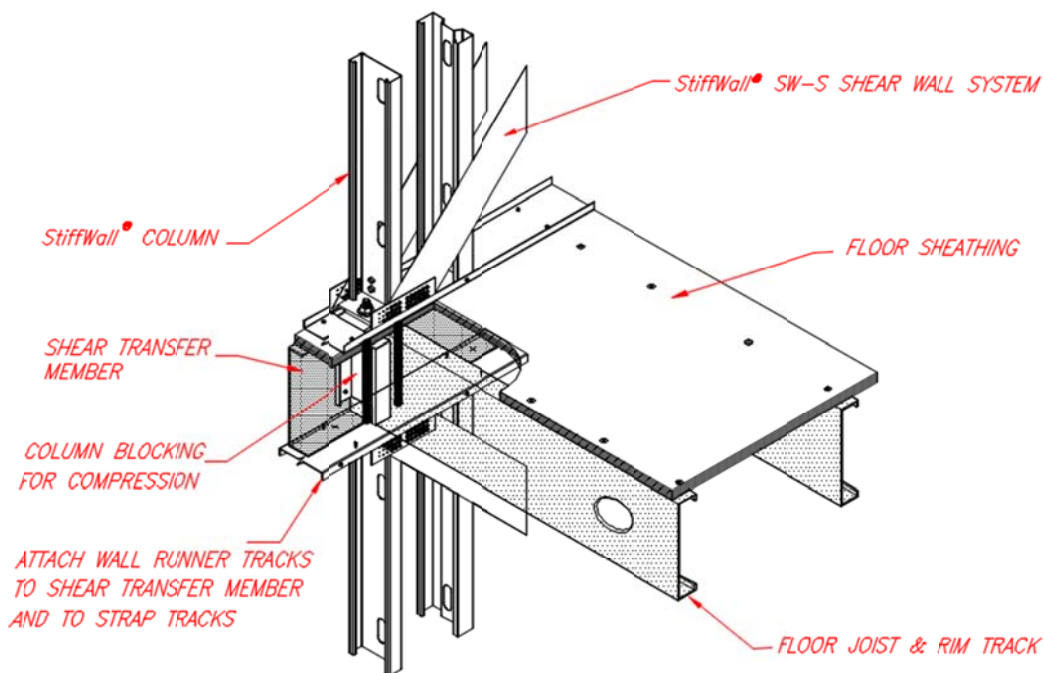
When the StiffWall system runs through corrugated metal deck floor slab, it is important to trace the load path for shear and tension forces of the Boot connection through the slab. The shear reaction from the StiffWall Boot above and the shear load from the slab diaphragm are transferred through the bolts to the StiffWall Boot below through bearing against the slab. Since the bottom face of the slab is not flat against the runner track of the Boot below, it is recommended to solid-fill the corrugation above the Strap Track area with structural grout to ensure full bearing. The tension reaction from the StiffWall Boot above is transferred directly to the Boot below through the bolts.



**Figure 3: Connection through corrugated metal deck slab**

## StiffWall Connection Through Floor Joist or Truss Framing (Figure 4)

When the StiffWall system runs through light steel floor joist or truss framing, it is important to trace the load path for shear, compression, and tension forces of the Boot connection and the end Columns through the floor space. Floor joists and floor trusses can have a depth ranging from 12 inch to 24 inches. The shear reaction from the StiffWall Boot above and the shear load from the floor diaphragm must be transferred to the StiffWall Boot below through a horizontal member in the floor space. If the floor joists or floor trusses run perpendicular to the wall, this horizontal member can be the end rim track of the joists or the solid blocking between the trusses. If the floor joists or floor trusses run parallel to the wall, this horizontal member needs to be an additional joist or additional truss installed for the full length on top of the StiffWall shear panel below. In either case, the solid blocking or the additional joist/truss must be designed to transfer the shear force. The two wall runner tracks (one above and one below the transfer member) are part of the load path at the Strap Track locations, and should be connected to the transfer member and the Strap Track with a connection capacity equivalent to the shear force. The compression reaction from the StiffWall Column above is transferred to the Column below through blocking/stiffener designed to support the compression force. The tension reaction from the StiffWall Boot above is transferred directly to the Boot below through the bolts.

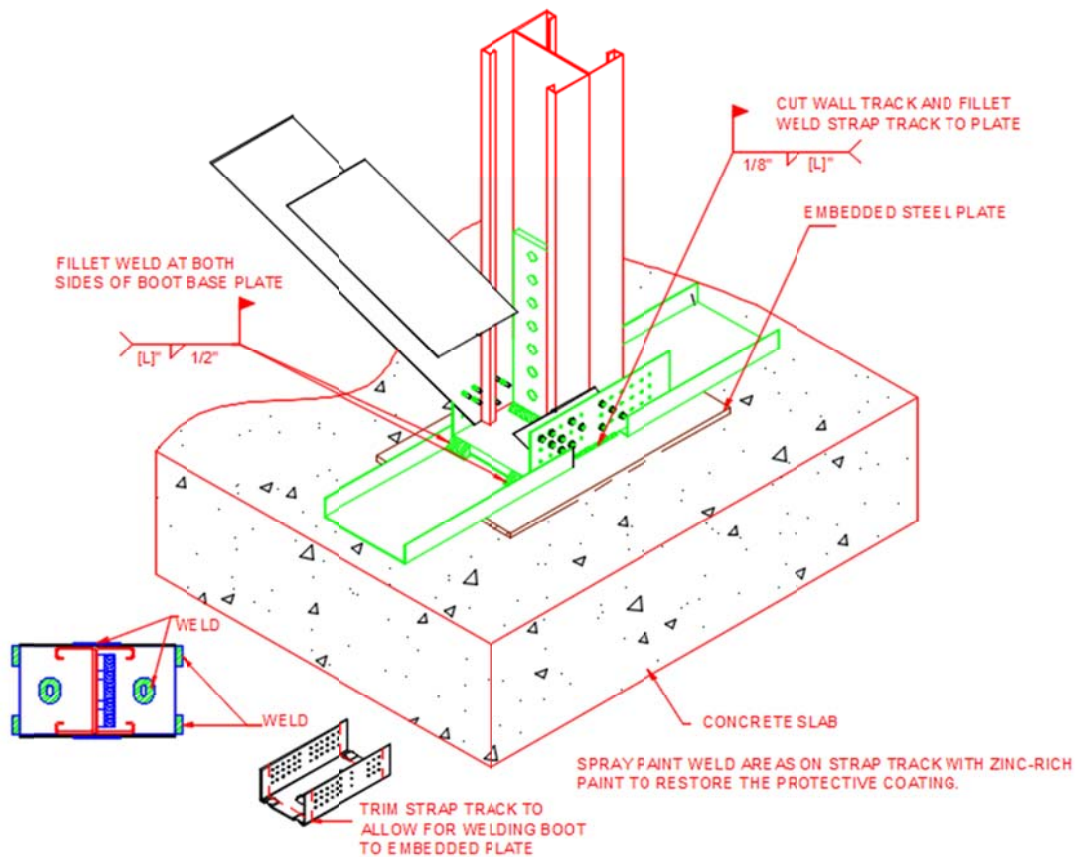


**Figure 4: Connection through floor joist or truss framing**

## Anchorage Welded Connection at Podium Level or Foundation (Figure 5)

The StiffWall system is sometimes required to be anchored to the foundation, a podium slab, or steel beam by welding instead of anchor bolts. In such cases, it is important to trace the load path for shear and uplift reactions of the Boot connection to the supporting structure. Welding can be achieved directly from the StiffWall Boot to a steel beam. However, an embedded plate is required for this connection in the case of a foundation slab or a concrete slab. The shear reaction

from the StiffWall Boot can be transferred by fillet welds between the two sides of the Strap Track and the steel beam or the embedded plate. The uplift reaction from the StiffWall Boot can be transferred by fillet welds at the two ends of the base plate of the Boot and through the bolt holes to the steel beam or the embedded plate. Notice that the ends of the Strap Track need to be trimmed one inch on each side to match the length of the base plate. The wall runner track needs to be slotted or notched at all locations of weld to allow direct access to the steel beam or the embedded plate. It is recommended to clean then spray-paint all weld areas with zinc-rich paint to restore the protective coating of the steel.



**Figure 5: Anchorage connection to embedded plate at podium or foundation**

### Installation Recommendations

This section discusses some important recommendations while installing StiffWall system in multi-story steel framing construction. Other installation recommendations are outlined in the document “Construction Guide: Load Bearing Wall Systems” by the Steel Network, Inc.

#### Diagonal Flat Straps

Diagonal flat straps in the StiffWall system must be installed tight to ensure the shear wall panel will perform as designed. It is recommended to install the straps with some pre-tension to remove any waviness or bowing and ensure tightness. A tool, TightStrap<sup>®</sup>, is provided with the StiffWall system to apply up to 50 lbs of tension into a flat strap before fastening it with screws or weld to the Strap Track. It is recommended to tighten the flat straps in the field after the

application of gravity loads on floor where the StiffWall shear wall panels exist. In the case of panelized wall panels in the fabrication shop, it is recommended to compress the wall panels, with the StiffWall included, in a jig before the flat straps are tighten and secured to the Strap Track.

Flat strap cannot be installed, then un-installed by releasing the screws to the Strap Track, and then re-installed with screws again in the same screw holes. Either a new piece of strap is required, or the exposed edge of the strap to be welded to the Strap Track with an approved weld design. It is not recommended to fasten the diagonal flat straps to the intermediate studs between the StiffWall end Columns. However, the typical or occasional attachment of sheathing and/or resilient channel to the intermediate studs through the straps is acceptable. Finally, diagonal flat straps are major elements in the lateral load resistance of the building, and therefore the straps should not be cut, punched or spliced without an approved design.

### Fitting StiffWall Columns between Wall Studs

When the end Columns of the StiffWall are designated to fit in the stud spacing between the typical wall studs, the Columns should be centered such that there is no interference between the StiffWall Strap Track and the neighboring wall studs (refer to Figure 1). The length of the Strap Track is 12 inches, and the full StiffWall Boot connection should fit in any stud spacing 16 inches or larger (center-to-center). When the stud spacing is 12 inches or less, either one stud is to be shifted to allow space for the StiffWall Boot, or the design of the StiffWall Column is to be updated to replace and accommodate the gravity load of one of the wall studs.

### Connection of StiffWall Boot to Roof Rafter or Beam at a Slope

When the StiffWall Boot is required to be connected at the top end to a roof rafter or a beam at a sloped angle, special Boot consideration is required since standard Boot fit only 90 degrees angle attachment. If the roof slope is very small, the StiffWall Boot maybe shimmed with steel sheets with bolt holes to accommodate the slope. The steel sheets must be placed between the Strap Track and the wall runner track, and must be welded together as well as welded to the Strap Track. If the roof slope is large, a special steel wedge maybe manufactured to accommodate the slope. The wedge must be placed between the Strap Track and the wall runner track, and must be welded to the Strap Track.

### Holes in Concrete Floor Slab for Through Bolts

There are several ways to provide holes in concrete floor slabs to accommodate the through-floor bolts of the StiffWall Boot. Since shear loads are transferred through the floor slab via bolt bearing against the concrete, it is important to ensure there are no gaps between the bolts and the concrete after full concrete pouring and curing. Any gaps due to the method of creating the bolt holes must be grouted with structural grout or filled with structural epoxy. The same applies to hollowcore precast concrete floor planks, where the hollow cells of the planks containing the through bolts must be broken open and filled with structural grout.

### Pre-Installed Anchors Rods in Foundation

If the anchorage of the StiffWall system into the foundation is designed with pre-installed anchor rods, it is important to maintain the alignment and the correct spacing between these anchors



while the concrete is being poured. One method to ensure proper alignment and spacing between the anchors is to install a steel template at the top surface of the foundation and secure it to the concrete forms. It is also recommended to tape the threads of the anchor rods to prevent any contamination by the concrete. If sleeves or wrappers are used around the anchors during pouring of concrete and then taken out, they will create gaps between the anchors and the StiffWall Boot. These gaps must be grouted with structural grout or filled with structural epoxy.

### **Design Example:**

The following example illustrates the design capabilities of the StiffWall system as a shear panel to resist lateral loads using hand calculations and also using SteelSmart® System software. A user guide is available for the software input data as part of the software Help menu. Certain assumptions are made within the example problem, and the analysis shown does not replace building code specific loading requirements and/or load combinations.

The example utilizes StiffWall in the construction of a 5-story building. Applied loads and reactions at each story have been provided as well as overall foundation reactions for anchorage design. It should be noted that distribution of applied loads to multiple shear walls in a building can also be performed in the SteelSmart System software.

Service wind loads and ASD design method are used. Two load cases were examined:

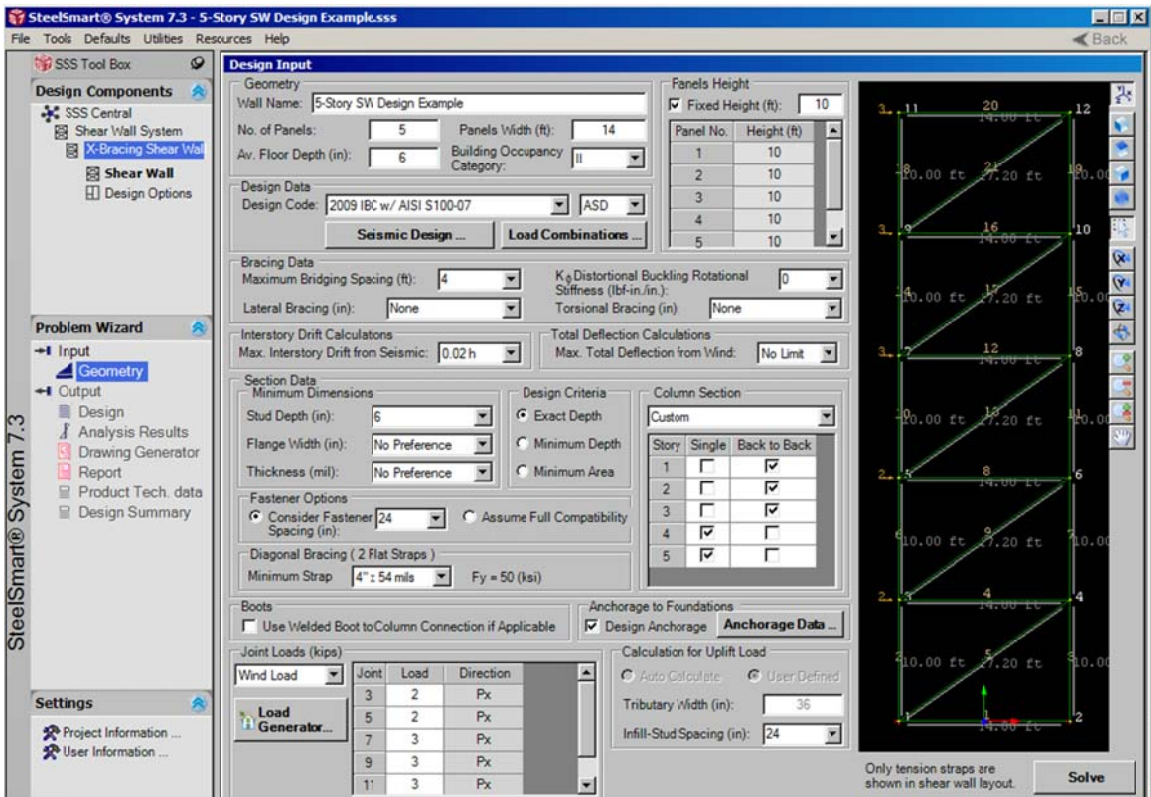
- (1) Dead + In-plane Wind, (D + W)
- (2) Dead + 0.75 Live + 0.75 In-plane, (D + 0.75L + 0.75W)

### Important Design Considerations:

- D + W load combination is the controlling combination in this example. The wall depth is chosen as 6 inch.
- Uplift and tension loads in StiffWall Columns are calculated with a tributary width from the dead load = 5 ft. (about 1/3 of panel width). Compression loads in StiffWall Columns are calculated with a tributary width from dead load equals to stud spacing = 2 ft.
- End Columns are designed as unbraced full height in the lateral and torsional directions under compression forces. Otherwise, if bracing is considered, it must be adequately designed for bracing force.
- Back-to-back end Columns are designed to be attached together @ 24 inches max. o.c.
- StiffWall does not substitute for floor rigidity. Sufficient diaphragm stiffness or an additional horizontal compression member is required to transfer the load.
- $f'_c$  of foundation concrete = 4,000 psi.

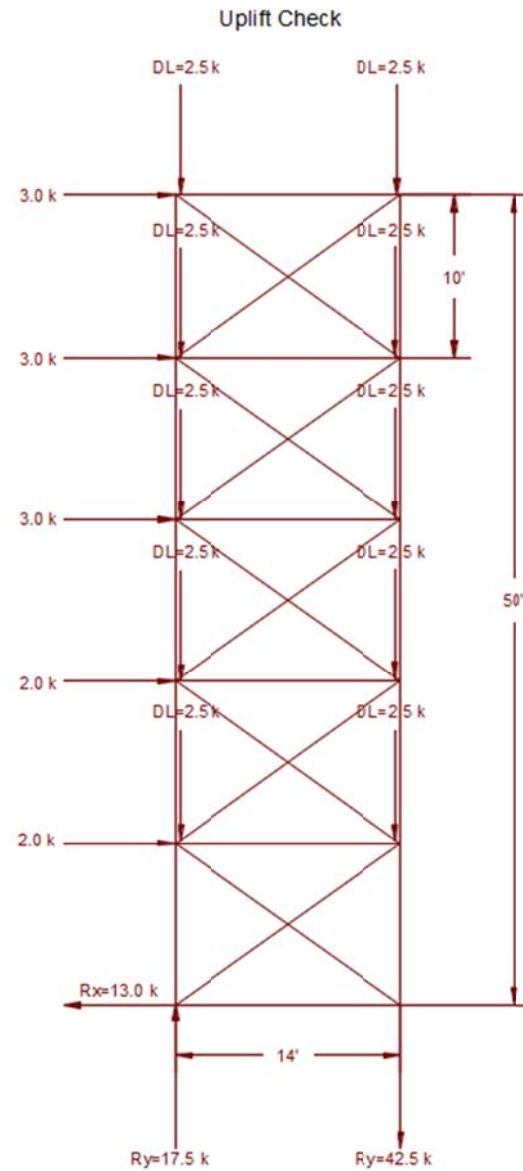
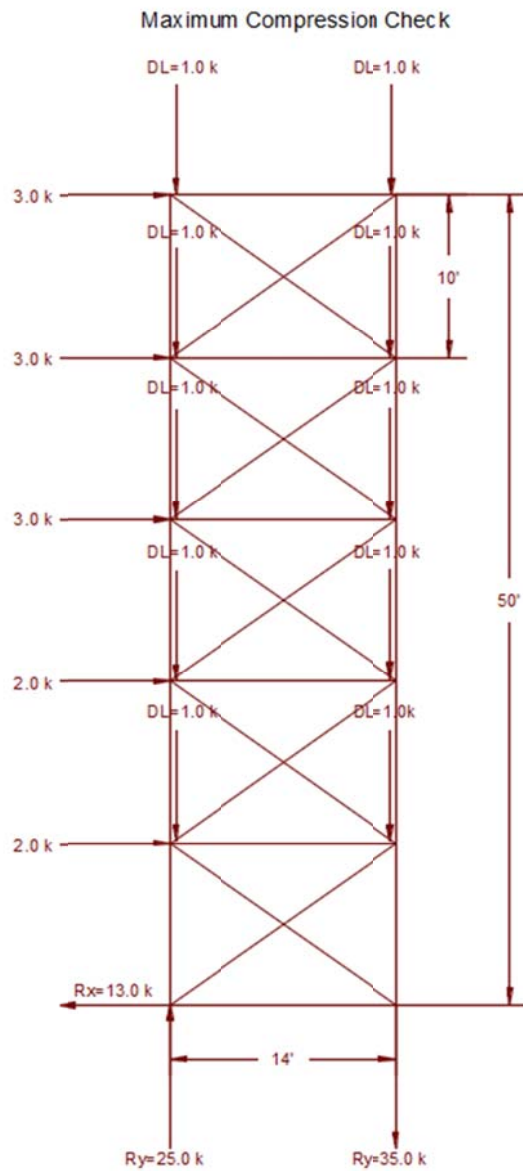
### Assumptions:

- Stud Spacing = 24 inch o.c.
- Dead Load = 0.5 kips/ft.
- Live Load = 0.75 kips/ft.
- Tributary Width = 2.0 ft. for Compression check; 5 ft. for Uplift check
- D + W load combination checked
- D + 0.75L + 0.75W load combination checked

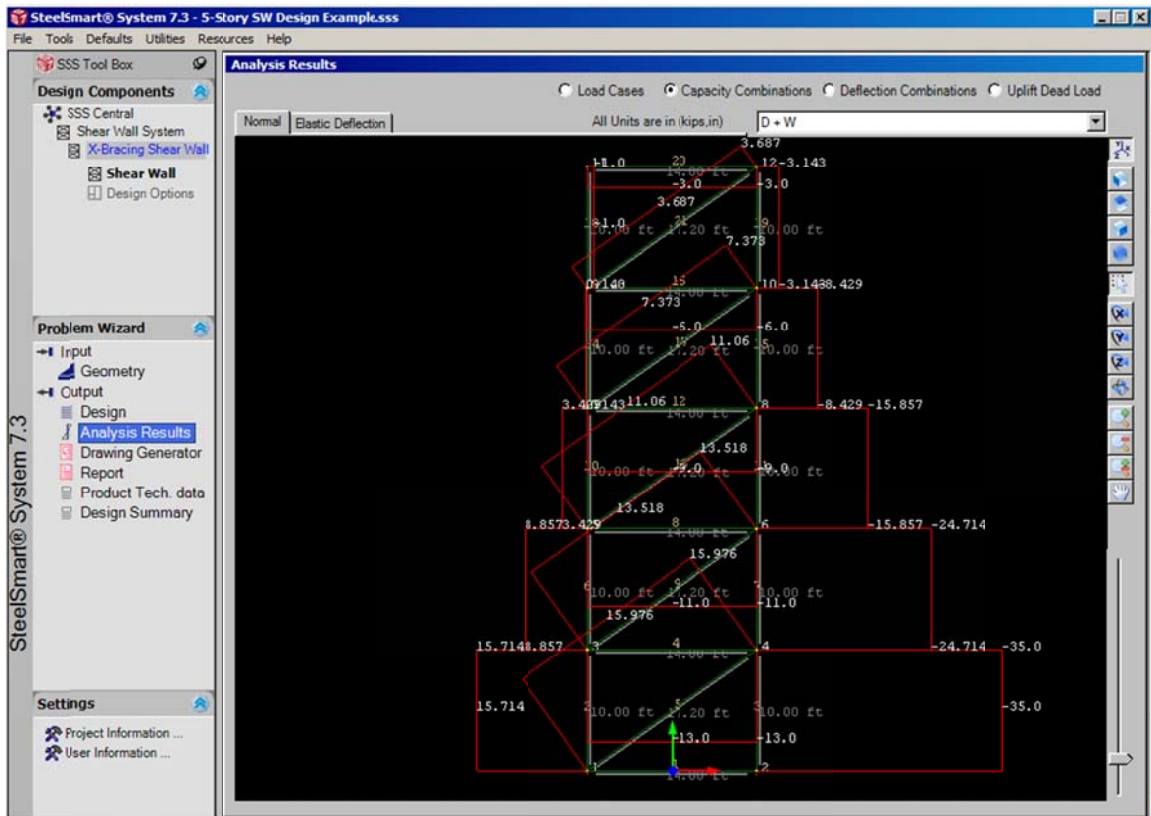


Input screen in SSS software

Analysis Results:

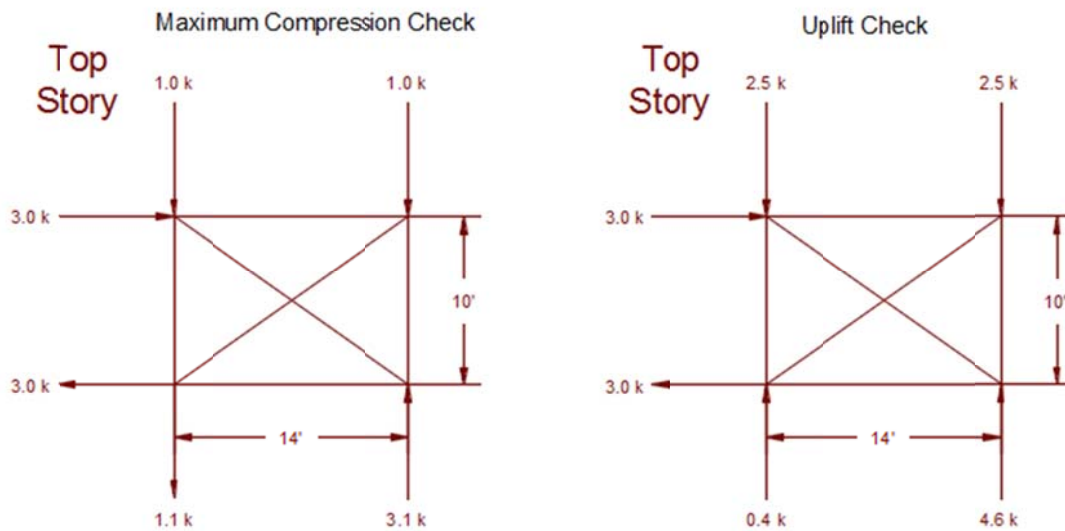


**Analysis model and reactions**



Maximum compression check results in SSS software

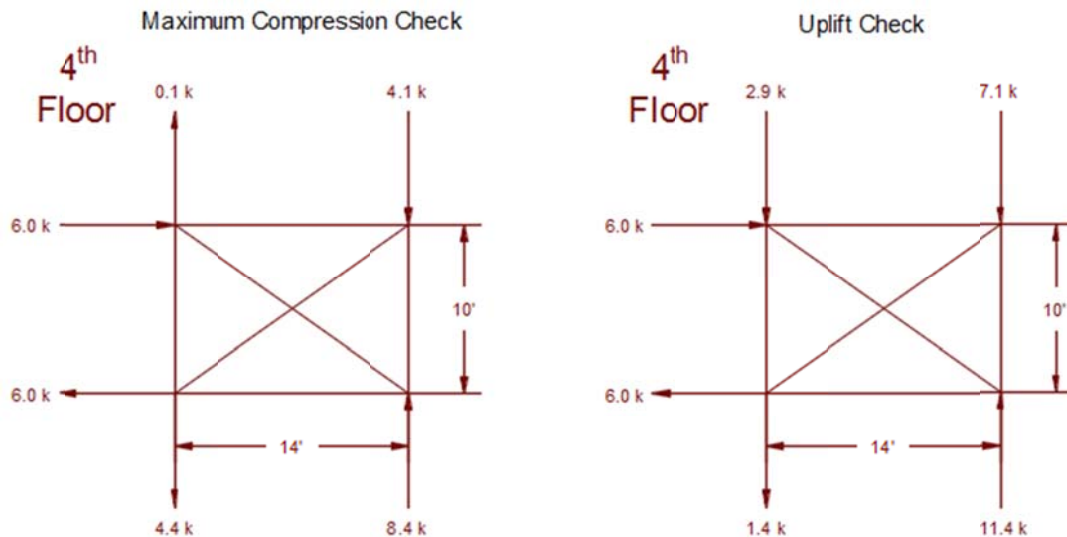
Loads on Top Floor Shear Wall (from analysis):



1. Column compression = 3.1 kips. No tension in Column
  - Use 600C/STW250-54 with allowable capacity = 3.5 kips > 3.1 kips
2. Use StiffWall Light Boot with T1 capacity = 6.5 kips
3. Attach StiffWall Light Boot to Column using (4) #12 screws

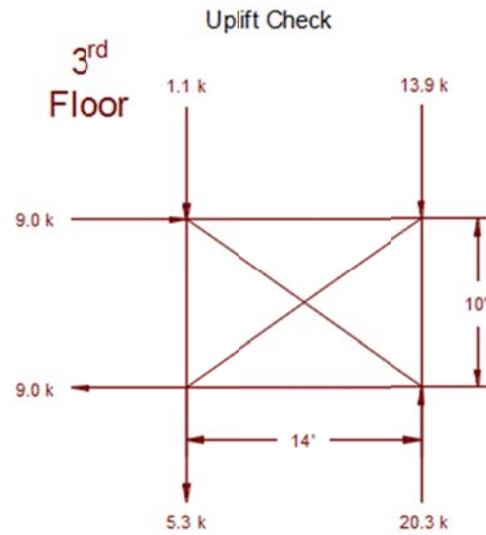
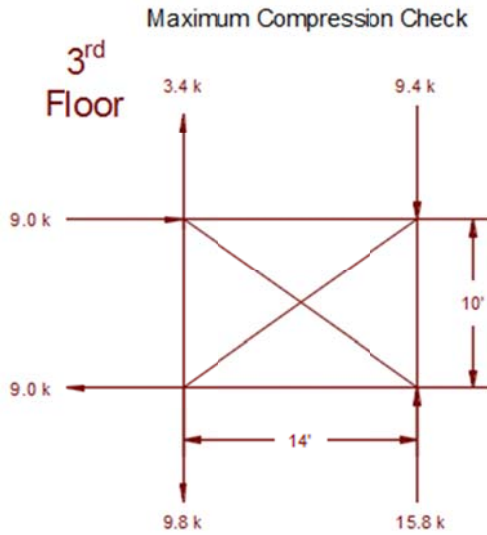
4. The tension in the flat straps is: 3.7 kips in 2 straps:
  - Use (2) 4" x 54 mil straps with capacity = 11.5 kips > 3.7 kips
  - Use (6) #12 screws each strap to Strap Track with capacity = 6.8 kips > 3.7 kips
5. No uplift in through-floor connection, shear = 3.0 kips
  - Use One 7/8" A325 bolt through floor

Loads on 4<sup>th</sup> Floor Shear Wall (from analysis):



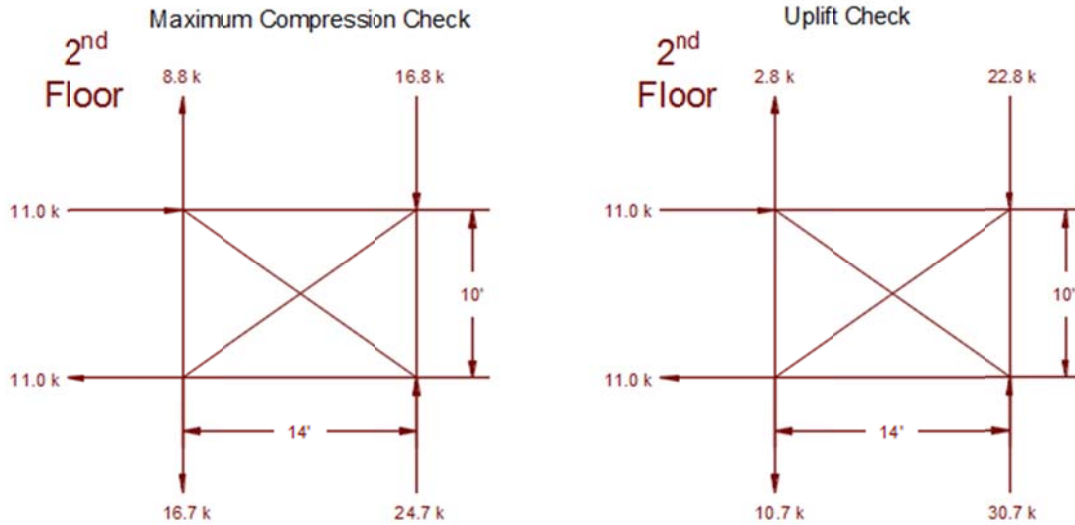
1. Column compression = 8.4 kips. No tension in Column
  - Use 600C/STW250-118 with allowable capacity = 10.7 kips > 8.4 kips
2. Use StiffWall Plus Boot with T1 capacity = 11.6 kips
3. Attach StiffWall Plus Boot to Column using (4) #12 screws
4. The tension in the flat straps is: 7.4 kips in 2 straps:
  - Use (2) 4" x 54 mil straps with capacity = 11.5 kips > 7.4 kips
  - Use (7) #12 screws each strap to Strap Track with capacity = 8.0 kips > 7.4 kips
5. Uplift in through-floor connection = 1.4 kips, shear = 6.0 kips
  - Use One 7/8" A325 bolt through floor
  - Use (2) 7/8" A325 bolts at base to connect to Small Boot below

Loads on 3<sup>rd</sup> Floor Shear Wall (from analysis):



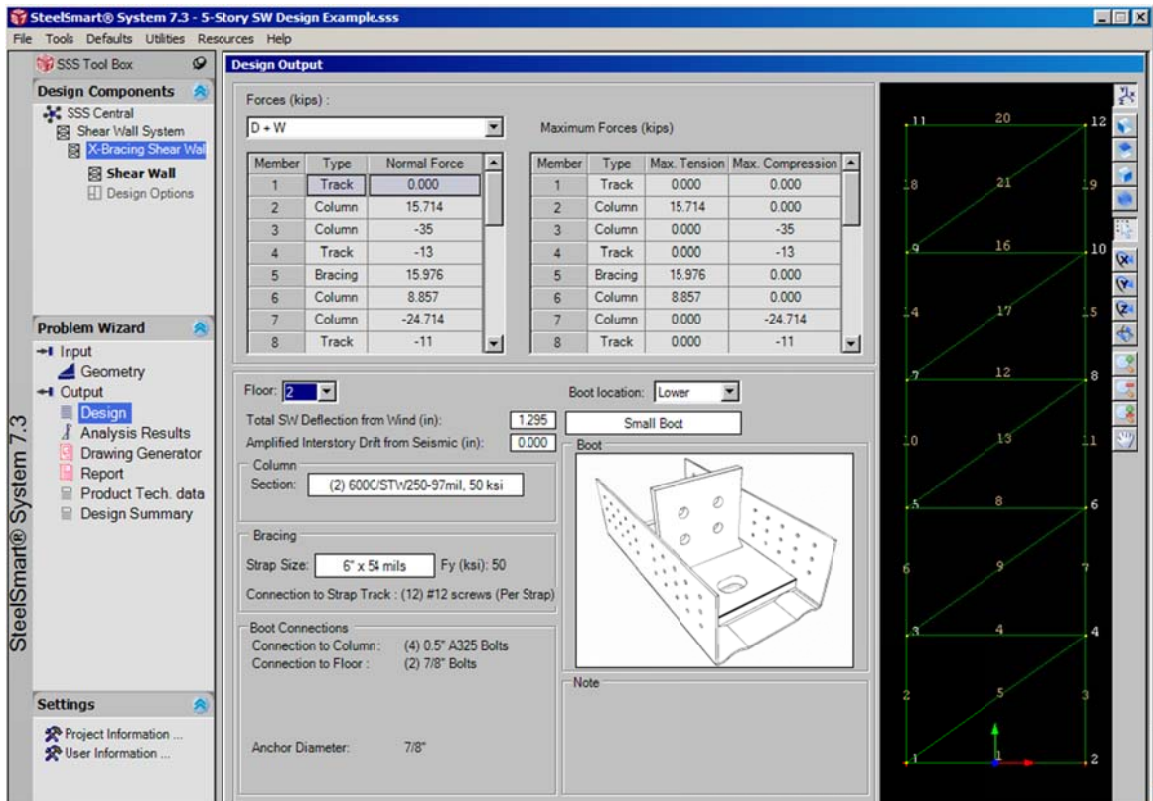
1. Column compression = 15.8 kips. No tension in Column
  - Use (2) 600C/STW250-97 with allowable capacity = 25.5 kips > 15.8 kips
2. Use StiffWall Small Boot with T1 capacity = 18.9 kips
3. Attach StiffWall Small Boot to Column using (4) 1/2" A325 bolts
4. The tension in the flat straps is: 11.1 kips in 2 straps:
  - Use (2) 4" x 54 mil straps with capacity = 11.5 kips > 11.1 kips
  - Use (10) #12 screws each strap to Strap Track with capacity = 11.4 kips > 11.1 kips
5. Uplift in through-floor connection = 5.3 kips, shear = 9.0 kips
  - Use (2) 7/8" A325 bolt through floor

Loads on 2<sup>nd</sup> Floor Shear Wall (from analysis):



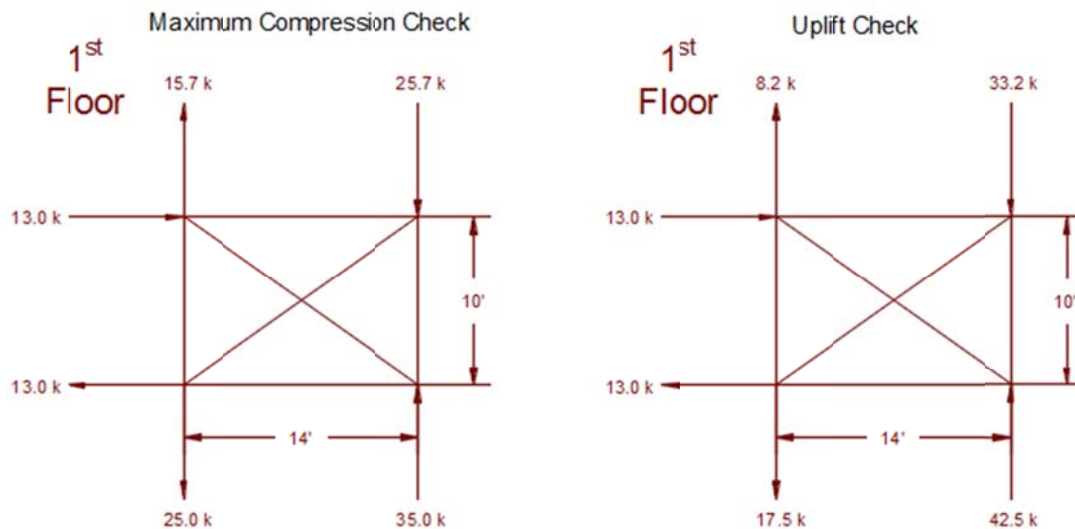
1. Column compression = 24.7 kips
  - Use (2) 600C/STW250-97 with allowable capacity = 25.5 kips > 24.7 kips
2. Column tension = 2.8 kips\*
  - Use StiffWall Small Boot with T1 capacity = 18.9 kips & T2 capacity = 15.3 kips
3. Attach StiffWall Small Boot to Column using (4) 1/2" A325 bolts
  - Capacity of (4) 1/2" A325 bolts to (2) 97 mil Columns = 21.2 kips > 2.8 kips
4. The tension in the flat straps is: 13.5 kips in 2 straps:
  - Use (2) 6" x 54 mil straps with capacity = 17.3 kips > 13.5 kips
  - Use (12) #12 screws each strap to Strap Track with capacity = 13.7 kips > 13.5 kips
5. Uplift in through-floor connection = 10.7 kips, shear = 11.0 kips
  - Use (2) 7/8" A325 bolt through floor

\*Uplift calculated using 5 ft. tributary width and dead load used to offset uplift at the tension side of the wall.



Design results for SW-2 in SSS software

Loads on 1<sup>st</sup> Floor Shear Wall (from analysis):



1. Column compression = 35.0 kips
  - Use (2) 600C/STW250-118 with allowable capacity = 34.7 kips  $\approx$  35.0 kips
2. Column tension = 8.2 kips\*
  - Use StiffWall Small Boot with T1 capacity = 18.9 kips & T2 capacity = 15.3 kips
3. Attach StiffWall Small Boot to Column using (4) 1/2" A325 bolts



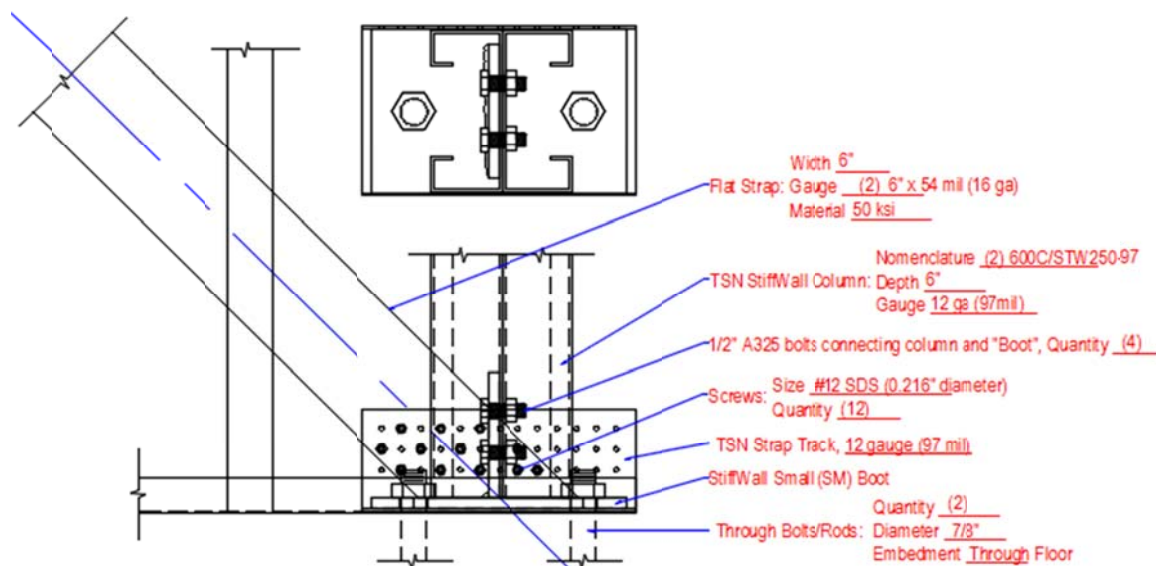
- Capacity of (4) ½” A325 bolts to (2) 118 mil Columns = 21.2 kips > 8.2 kips
4. The tension in the flat straps is: 16.0 kips in 2 straps:
- Use (2) 6” x 54 mil straps with capacity = 17.3 kips > 16.0 kips
  - Use (15) #12 screws each strap to Strap Track with capacity = 17.1 kips > 16.0 kips
- \*Uplift calculated using 5’ tributary width and dead load used to offset uplift at the tension side of the wall.
5. Anchorage uplift = 17.5 kips, shear = 13.0 kips
- Use (2) 7/8” Hilti HIT-HY 200 Adhesive Anchors, HAS Super ASTM A193 B7, Embedment depth = 10.5 inch; check additional tension from prying action.

**Final Design:**

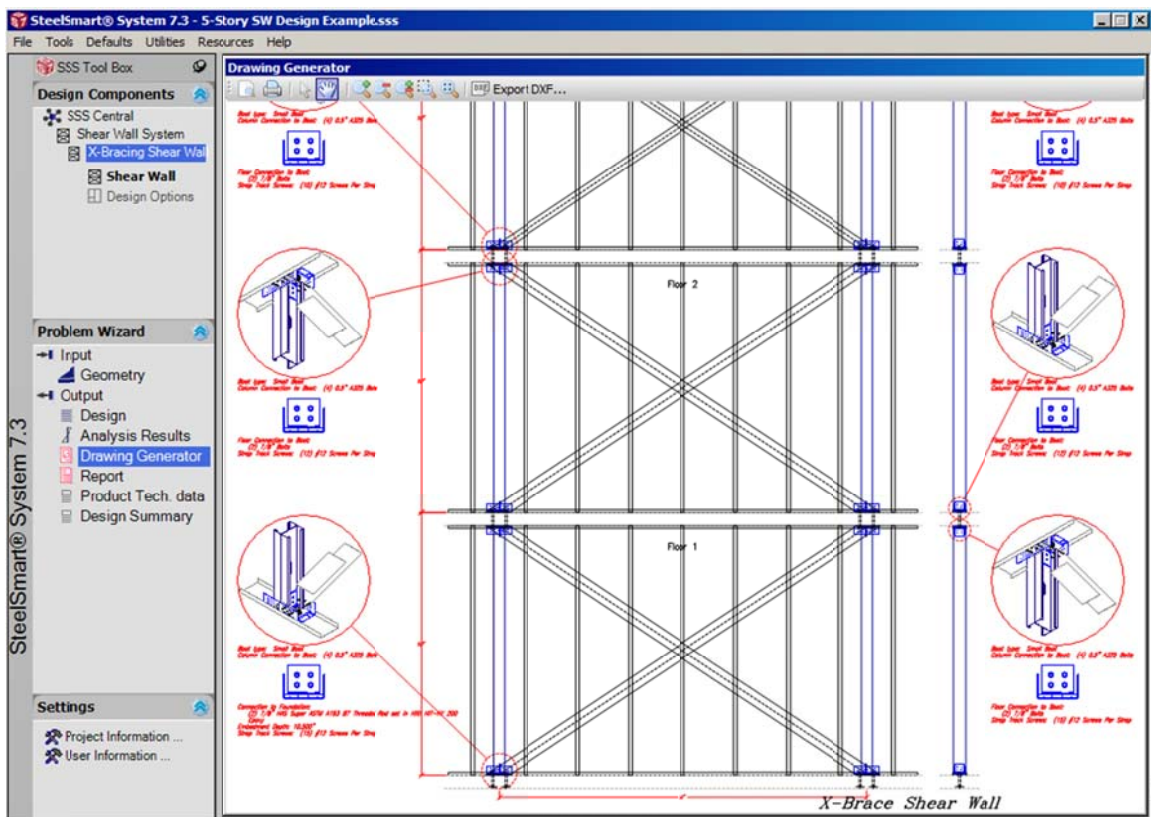
The table below presents a design summary of all part of the StiffWall system.

StiffWall® SWS Schedule					
Wall #	StiffWall® Column & Boot Section	Strap Bracing	Column Connection to Boot	Strap Track #12 Screws (Each Side)	Floor/Anchorage Connection
SW-5	600C/STW250-54-1-LT	(2) 4" x 54 mil	(4) #12 Screws	6	(1) 7/8" A325 Bolt
SW-4	600C/STW250-118-1-PL	(2) 4" x 54 mil	(4) #12 Screws	7	(1) 7/8" A325 Bolt, (2) at base
SW-3	600C/STW250-97-2-SM	(2) 4" x 54 mil	(4) ½” A325 Bolts	10	(2) 7/8" A325 Bolts
SW-2	600C/STW250-97-2-SM	(2) 6" x 54 mil	(4) ½” A325 Bolts	12	(2) 7/8" A325 Bolts
SW-1	600C/STW250-118-2-SM	(2) 6" x 54 mil	(4) ½” A325 Bolts	15	(2) 7/8” Hilti HIT-HY 200 Adhesive Anchors

The detail below shows a sample detailed Boot connection at the 2<sup>nd</sup> floor (SW-2).



**Detailed Boot connection for SW-2**



**Drawing generator in SSS software showing StiffWall elevation and details**

## References

- AISI S100-12, “North American Specification for the Design of Cold-Formed Steel Structural Members”, American Iron and Steel Institute (AISI), 2012 Edition, Washington, DC.
- AISI S213-07, “North American Standard for Cold-formed Steel Framing – Lateral Design”, American Iron and Steel Institute (AISI), 2007/2012 Edition, Washington, DC.
- ASCE 7-10, “Standard for Minimum Design Loads for Buildings and Other Structures”, American Society for Civil Engineers, VA, USA.
- ASI SSS7, “Steel Smart System Version 7.3”, Cold Formed Steel Design Software, Applied Science International, LLC, Durham, NC.