Detailing and Best Practices of Developing the Lateral Load Paths

Light-Framed Multi-Story Wood Structures

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Disclaimer: This presentation was developed by a third party and is not funded by WoodWorks or the Softwood Lumber Board.

Summary of Topics to be covered:

1. Development of Lateral Load Resistance Systems
2. General Detailing Discussions & Load Paths
3. Shear Wall Sheathing
4. General Shear Wall Fastening
5. Shear Wall Hardware: Traditional Hold-Down & Strap System
6. Shear Wall Hardware: Continuous Rod System
7. Anchorage to Podium or Foundation

Development of Lateral Loads

- International Building Code (IBC) 2018
- ASCE 7-16

Resistance of Lateral Loads

- AWC: Special Design Provisions of Wind and Seismic, 2015 Edition (SDPWS)

Continuous Load Path

Primary System Components

- Horizontal Diaphragms: Floor and Roof Sheathing
- Vertical Shear Walls: Sheathed Wood Walls

Connectors Between Components

- Fasteners: Nails, staples, screws
- Hardware: Hold-Downs, Straps, Continuous Threaded Rods
- Anchorage to Foundation/Podium: Embedded plates, rods, post-installed anchors


Photo: Sandman Structural Engineers

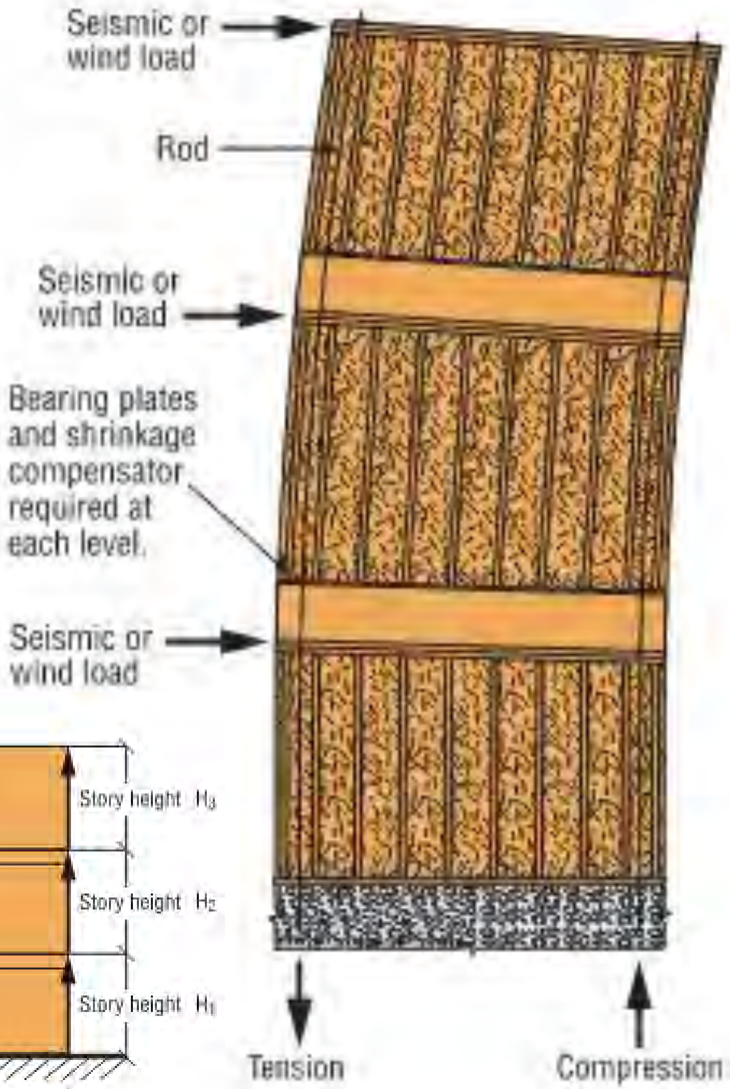
Detailing can be a major controlling factor for the selection of lateral systems layouts

- **Is the Wall Sheathing in this area compatible with the following?**
  - Architectural finishes (Interior and Exterior)
  - STC Ratings
  - Fire Ratings / UL Listings
  - Sequencing: MEP installation
  - Wall Panelizing preferences
  - Thermal requirements
  - Sound channel locations

- **Is the Hardware and Connecters compatible with the following?**
  - Architectural finishes
  - MEP interferences
  - Adjacent Window/Door Jamb Framing
  - Substrate available for anchorage at foundation or podium
  - It may be typical for the plumbing stacks to be located at walls ends, overlapping with locations of hold-downs and threaded rods

Lateral Load Path Basics:

- Lateral Loads collected in horizontal diaphragms (floor and roof sheathing) are transferred into vertical Shear Wall components
- Shear Wall stacks collect this diaphragm load at each level, accumulating force to the base level
- Shear Wall sheathing resists these in-plane shear forces with capacity based on fastener spacing and sheathing type.
- When shear forces exceed the dead load in the wall, net overturning is introduced
- These overturning forces are resisted by hardware at the ends of the Shear Wall
- The hardware must be designed to be anchored into foundation or podium structure.



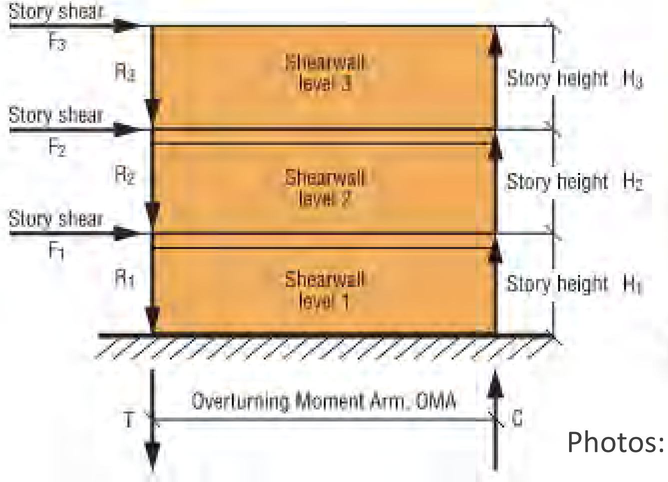


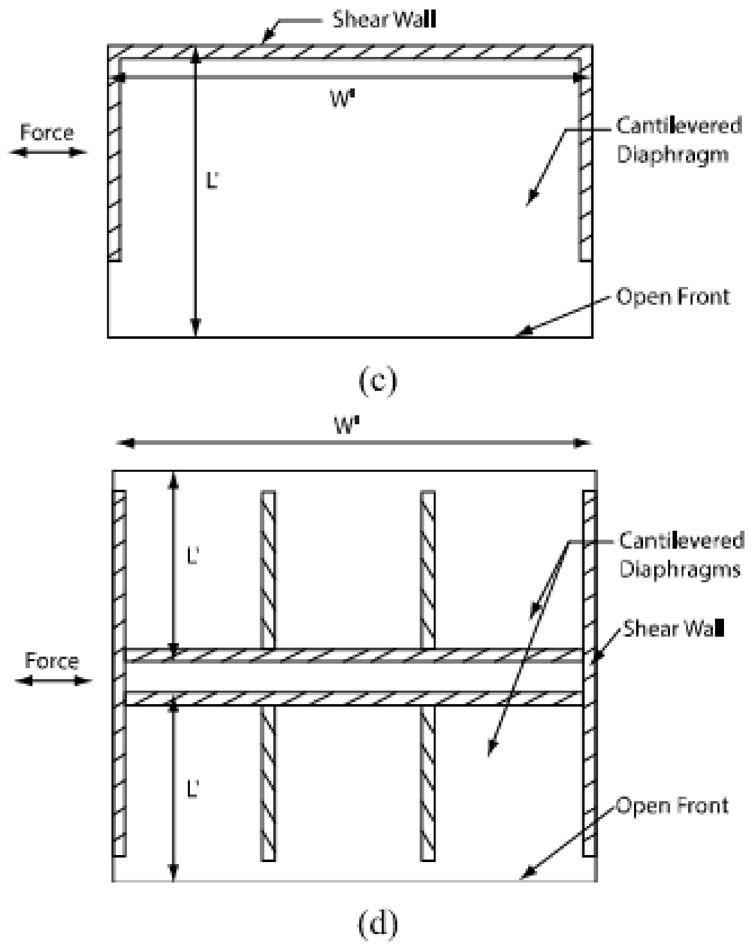
Figure 1

Shearwall Free Body Diagram Example

Photos: Simpson Strong-Tie

Selecting Shear Wall Locations and Defining Diaphragms

- All buildings will present a unique challenge for layout of Shear Wall elements and definition of diaphragms
- Simplest load path to follow in-plane shear and overturning forces is for the Shear Wall segments to stack on all wood levels and maintain the same length
    - If first level Shear Walls are not present due to differing floor plans, alternate systems need to be evaluated, such as steel braced frames or moment frames
- Shear Walls that are staggered laterally on plan between levels will result in a concentrated force being added to diaphragm.
- Common challenge in multi-story housing projects is exterior walls being too perforated to develop shear resistance. Open Front Diaphragms can be evaluated as a solution.



Open Front Structure Examples SDPWS Section 4.2.5

Photos: AWC: SDPWS

Shear Wall Types: SDPWS 4.3.5

- Individual Full-Height, Force Transfer, & Perforated
- Each type introduces different level of detailing and installation complexity
  - Examples: Strapping around openings or sill plate uplift

Figure 4D **Typical Individual Full-Height Wall Segments Height-to-Width Ratio**

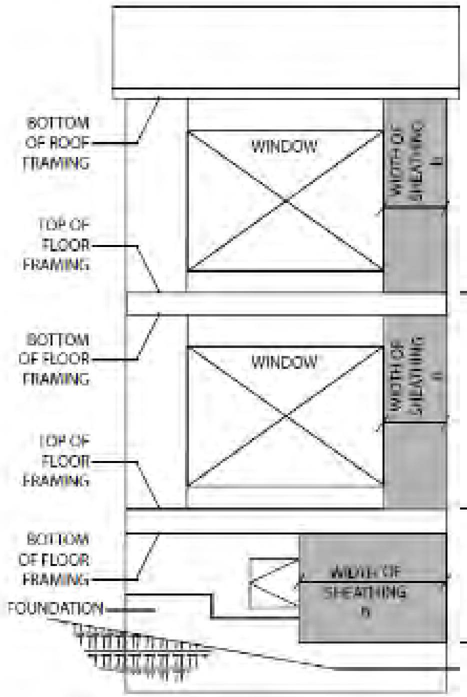


Figure 4E **Typical Shear Wall Height-to-Width Ratio for Shear Walls Designed for Force Transfer Around Openings**

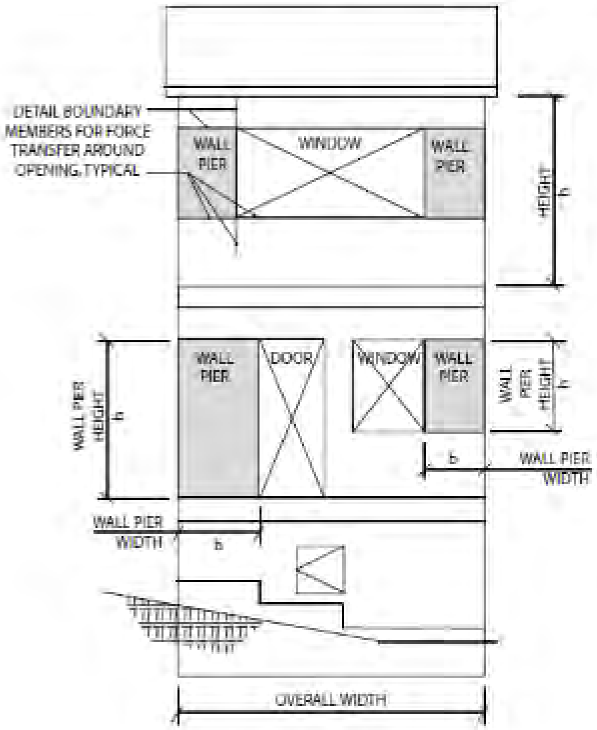
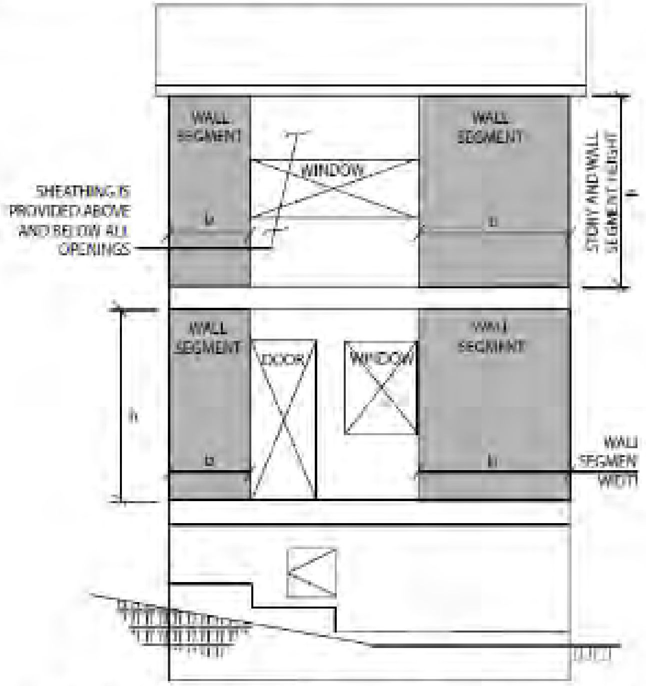


Figure 4C **Typical Shear Wall Height-to-Width Ratio for Perforated Shear Walls**



Note: b_s is the minimum shear wall segment length, b, in the perforated shear wall.

Photos: AWC: SDPWS

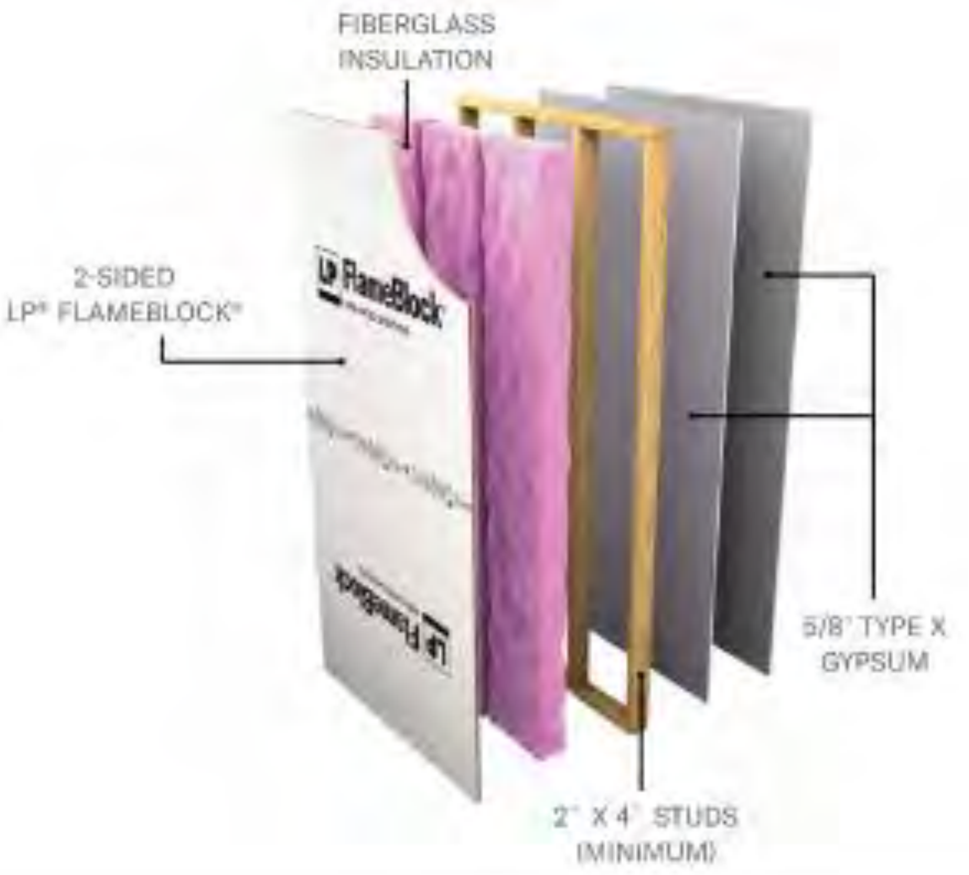
Shear Wall Systems: SDPWS 4.3.7: Tables 4.3A, 4.3B, & 4.3C

Typical Options for Sheathing

- **Wood Structural Panels**: Interior & Exterior
    - Plywood or OSB sheathing
    - Typical Preference is 7/16", APA Rated, Exposure 1
    - Structural 1 grade or thicker panels for high load applications
    - High Shear Values
    - Allows for narrower aspect ratios
    - Reduces double sided sheathing applications seen with weaker sheathing

Options for Type 3 Construction: Exterior FRT Walls

- Wood Based Sheathing Products
- High Shear Values
- Satisfies FRT Requirements



EXTERIOR LOAD-BEARING WALL – UL DESIGN NO. U349

(2-Hour Wall; fire-rated from inside)

- Commonly used in Type III load-bearing exterior walls

Photo: Louisiana-Pacific Corporation

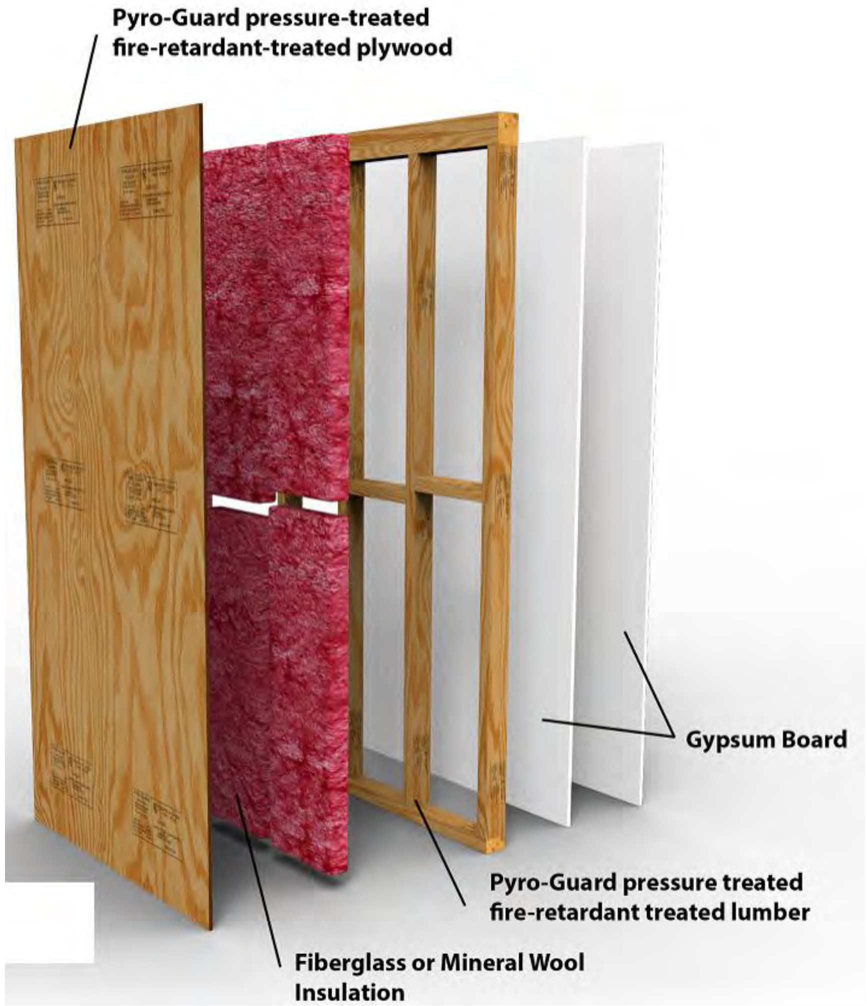


Photo: Hoover Treated Wood Products

- **Gypsum Sheathing Board** (Exterior)
  Gypsum Wallboard (Interior)
  - Lower Shear Capacity compared to wood sheathing
  - High Load applications may involve multiple layers or faces of wall to be sheathed
  - Compatible with gypsum wallboard already specified for interior finish or fire assembly requirements
  - Meets Type 3 Exterior Wall assemblies for sheathing
  - Tends to be installed late in project after MEP and insulation in walls is completed
    - This leads to reduced lateral stability during construction wind or seismic events. Temporary bracing is possible

Photo: Sandman Structural Engineers

- SDPWS Shear Capacity tables provide screw and nail fastener values. Verify with contractor for fastener preference

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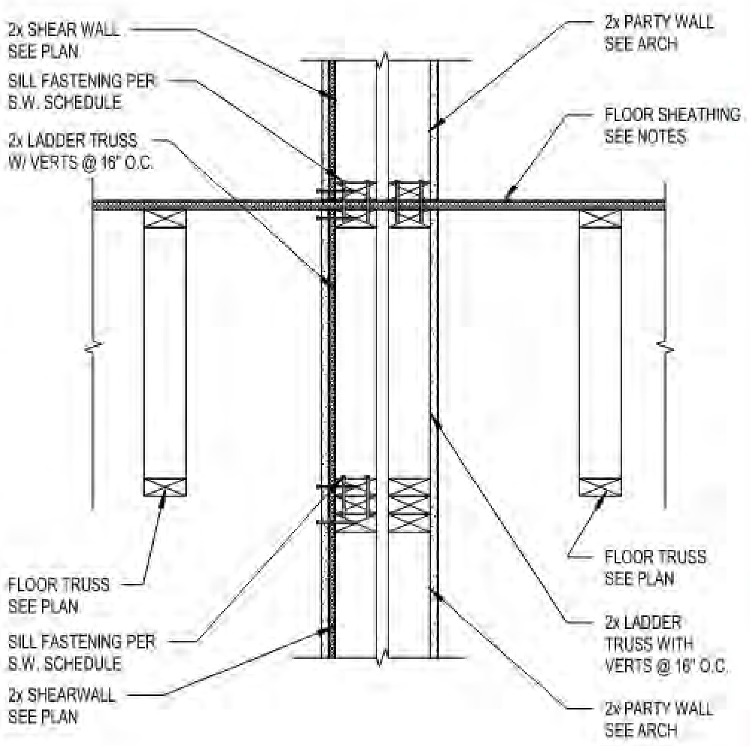
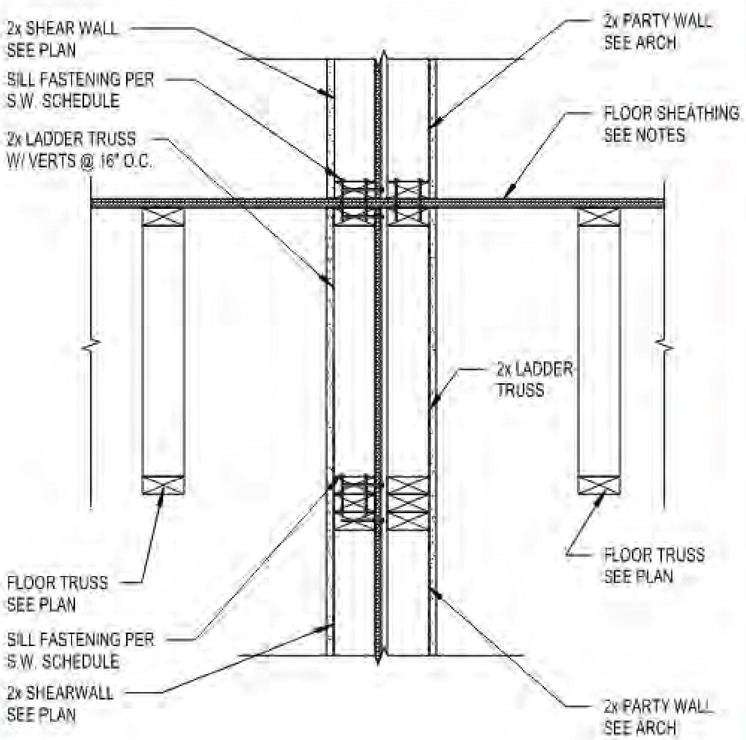
- **Proprietary Sheathing Systems**
    - Wood sheathing with built-in rigid insulation
        - See manufacturer's ESR Report for allowable shear values reduced due to rigid insulation
        - Works well with new energy codes
        - Allowable shear values may vary with each manufacturer
- Tables 4.3A, 4.3B, & 4.3C also include other sheathing materials that may be more prevalent in certain geographical regions

Shear Wall Sheathing Placement: Double Party Wall Condition



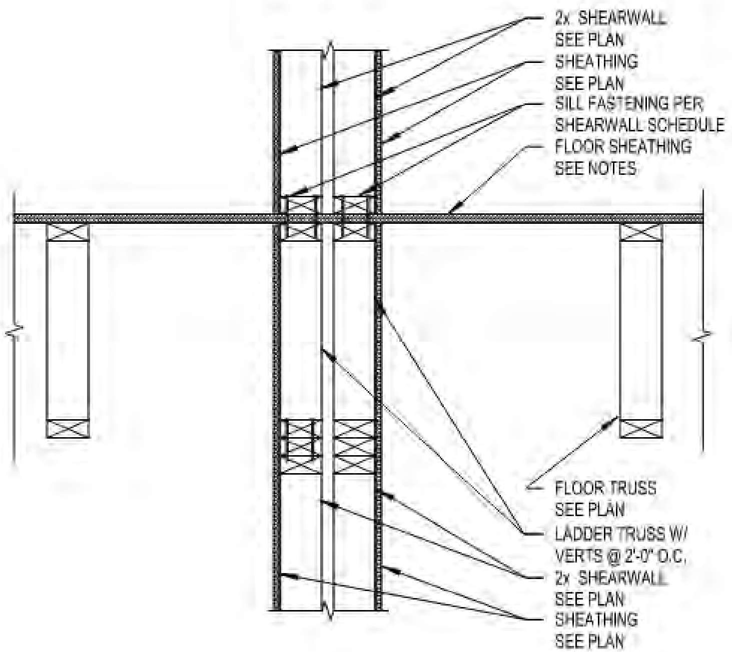
Wood SW Sheathing on Unit Face

- Leaves Full Air Space between Sheathing to capture highest STC rating
- Wood Sheathing blocks left side to access wall cavity for insulation & MEP install
- All installs to happen from right side
- Overall wall assembly is thicker



Wood SW Sheathing Between Walls

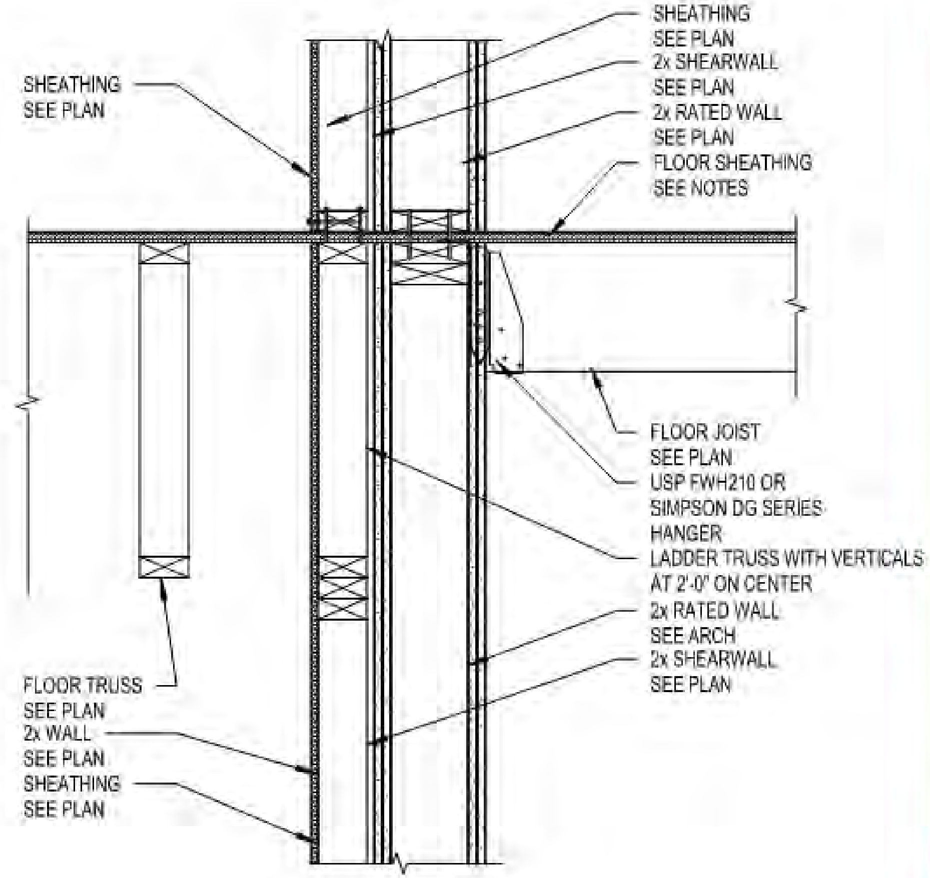
- Reduces STC rating of wall assembly
- Allows for easy access from both sides for insulation and MEP installs
- Overall wall assembly is minimum thickness
- SW Sheathing doesn't need to jog if 2x wall stud sizes differ along wall length



Double Sheathing – Both Walls SW

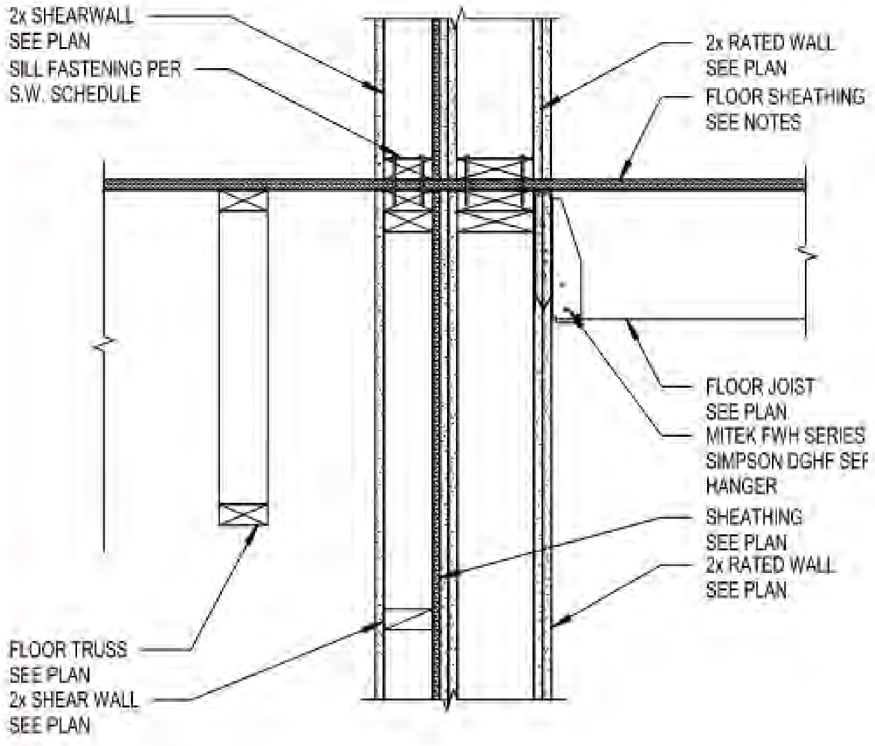
- Leaves Full Air Space between sheathing to capture highest STC rating
- Both walls are used for shear, resulting in potential hardware in both walls
- If both layers are gypsum board, SW sheathing will not be installed until drywall trades are complete

Shear Wall Sheathing Placement: Stair Fire Barrier with Shear Wall Adjacent



Wood SW Sheathing on Unit Face

- Allows SW sheathing to be install in field conventionally
- Wood SW sheathing must be installed after insulation and MEP installs. Delay in lateral building capacity
- Wall assembly is thicker due to unit side gyp cover layer (not shown on detail)



Wood SW Sheathing on Fire Barrier Side

- SW sheathing must be installed before wall is tipped into place
- Wall assembly is minimum wide
- Unit side is open for installation of MEP and insulating

Alt. Option:

- Utilize Fire Barrier wall as SW by adding wood sheathing on stud face
- Verify with jurisdiction that wood sheathing is permitted within barrier assembly
- All SW sheathing and hardware will need to be inspected prior to installation of gypsum sheathing

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Shear Wall Fasteners

Considerations:

- Builder Preference
- Wall Panel manufacture’s preference
- Shear capacity requirements

Nails:

- AWC NDS 2015: Table L4 provides industry designations based on type, length, & diameter, equating to a Pennyweight
- Local construction industry may prefer nail diameter specs compatible with their preferred nail gun manufacturer
- Nail gun preferred nails may have smaller diameters, reducing the Shear Wall capacity, and resulting in tighter nail spacing

Table L4 Standard Common, Box, and Sinker Steel Wire Nails[1,2]

Common or Box Sinker

D = diameter
L = length
H = head diameter

Type		Pennyweight										
		6d	7d	8d	10d	12d	16d	20d	30d	40d	50d	60d
Common	L	2"	2-1/4"	2-1/2"	3"	3-1/4"	3-1/2"	4"	4-1/2"	5"	5-1/2"	6"
	D	0.113"	0.113"	0.131"	0.148"	0.148"	0.162"	0.192"	0.207"	0.225"	0.244"	0.263"
	H	0.266"	0.266"	0.281"	0.312"	0.312"	0.344"	0.406"	0.438"	0.469"	0.5"	0.531"
Box	L	2"	2-1/4"	2-1/2"	3"	3-1/4"	3-1/2"	4"	4-1/2"	5"		
	D	0.099"	0.099"	0.113"	0.128"	0.128"	0.135"	0.148"	0.148"	0.162"		
	H	0.266"	0.266"	0.297"	0.312"	0.312"	0.344"	0.375"	0.375"	0.406"		
Sinker	L	1-7/8"	2-1/8"	2-3/8"	2-7/8"	3-1/8"	3-1/4"	3-3/4"	4-1/4"	4-3/4"		5-3/4"
	D	0.092"	0.099"	0.113"	0.12"	0.135"	0.148"	0.177"	0.192"	0.207"		0.244"
	H	0.234"	0.250"	0.266"	0.281"	0.312"	0.344"	0.375"	0.406"	0.438"		0.5"

1. Tolerances are specified in ASTM F1667. Typical shape of common, box, and sinker steel wire nails shown. See ASTM F 1667 for other nail types.
2. It is permitted to assume the length of the tapered tip is 2D.

Photos: AWC: SDPWS

Screws:

- May be the contractor preferred fastener for gypsum sheathing and wallboard applications
- Screw values not equal to nail values in gypsum capacity tables

Staples:

- If preferred by builder, see ESR reports for shear values

Field Fastening

- Field framed walls vs Offsite panelized walls
- Wall Panels constructed off-site
    - Additional field fastening between panels to create continuity of Shear Wall
    - Field splicing of chord elements, such as double top plates
    - Offsite installation of shear wall components: double end studs, compression studs, etc
    - Will shear wall sheathing be offsite installed or onsite installed?

Shear Wall Overturning Hardware

- Typically, two general types
- Multiple Manufacturers available


Photo: Sandman Structural Engineers

- Continuous Rod Systems

- Traditional Hold-Down & Strap Systems


Photo: Sandman Structural Engineers


Photo: Sandman Structural Engineers

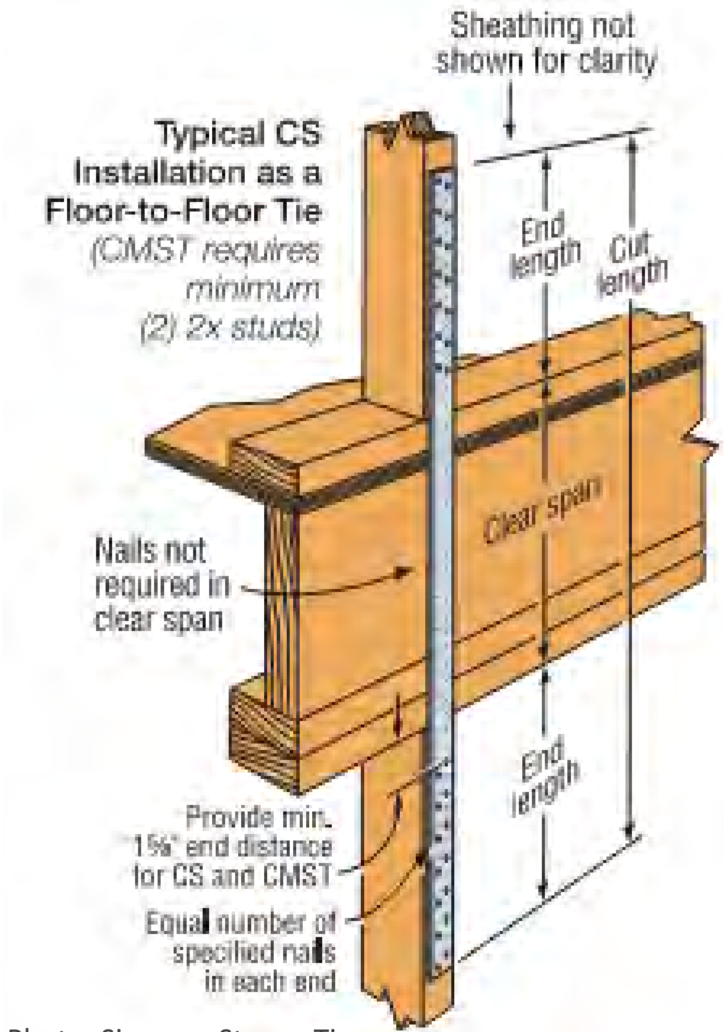

Photo: Simpson Strong-Tie

Traditional Strap & Hold-Down System:

Independent Hardware used to transfer tension loads

- Shear Wall end posts are sized to be the tension wood member at shear wall ends, spliced by steel straps or hold-down pairs at floor level transitions
- In high load applications, end posts may need to be engineered lumber in order to develop fasteners strengths in hardware

Photo: Sandman Structural Engineers

Strap at Floor Level

- **Metal Straps at Floor Levels:**
  - Strap systems lack shrinkage compensating devices and will potentially “bow” as the building shrinks and compresses during construction
  - Sequencing of strap nailing may need to be adjusted to allow for shrinkage before final install and completion of nailing

Strap at Floor Level

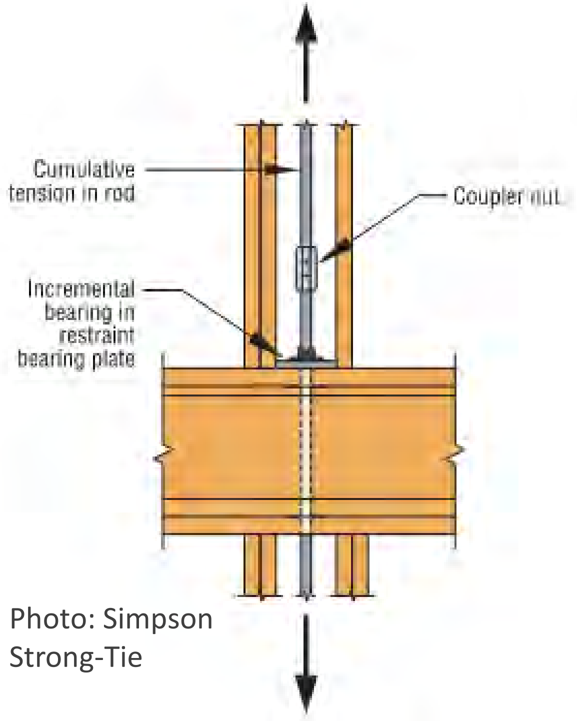

Photo: Simpson Strong-Tie


Photo: Sandman Structural Engineers

- **Continuous Rod System:**
- Series of threaded rod and hardware field assembled as one system to resist tension force in Shear Wall ends
  - Wood framed tension posts are no longer necessary
  - Overturning tension force is resisted by continuous steel rod assembly
  - Compression posts are specified to resist opposing overturning compression

- **Continuous Rod System:**
  - Rods are installed per floor using coupler nuts for splicing
  - Shrinkage compensating devices are installed at each floor
  - System is capable of transferring higher overturning loads when compared to traditional strap and hold-down system
    - Tension force is not limited by wood post capacity or strap fastener capacity

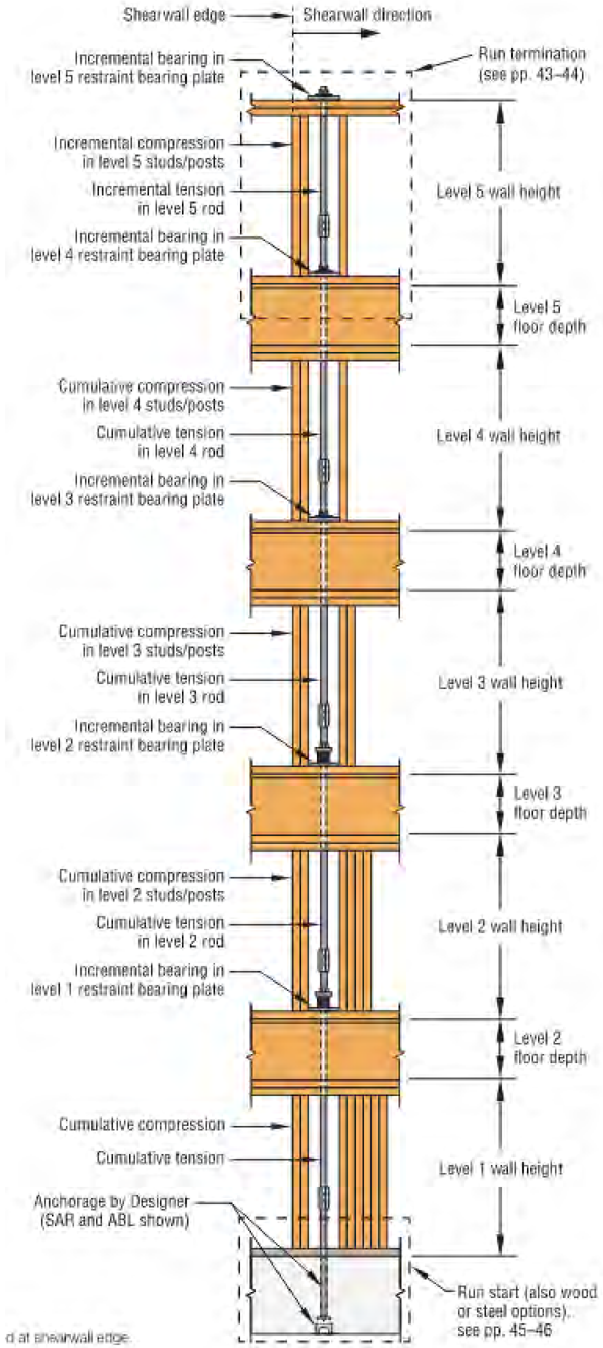

Photo: Simpson Strong-Tie

- **Continuous Rod System:**
- **Specification of System**
  - System can be fully designed by SEOR and specified on Construction Documents
  - Lateral Loads can be provided by SEOR on Construction Documents. Hardware vendor's engineer will design and detail system
    - Both systems result in fully detailed shop drawings from vendor with part labels
    - System is colored coded and labeled for field installation
- Substitutions of specified hardware to another qualified vendor is possible prior to construction

Traditional Hold-Down & Strap vs. Continuous Thread Rod

- **Comparing Both Systems:**
  - Driven by load capacity needed
  - Best solution for expected shrinkage
  - Installers experience with system
  - Material cost evaluation and labor cost evaluation
  - Which system presents the most feasible anchorage solution

Anchorage to Foundation or Podium Structure:

- To complete the load path, the base level wood Shear Wall will require anchorage to the foundation or podium structure.
  - Sill Plate Anchorage
    - Uniform shear & potentially uplift
  - Hardware anchorage from overturning forces at Shear Wall ends (Continuous Rods, hold-downs)
    - Tension and compression load cases
- These forces can accumulate to very high loads, superimposed onto a wide variety of foundation and podium conditions.

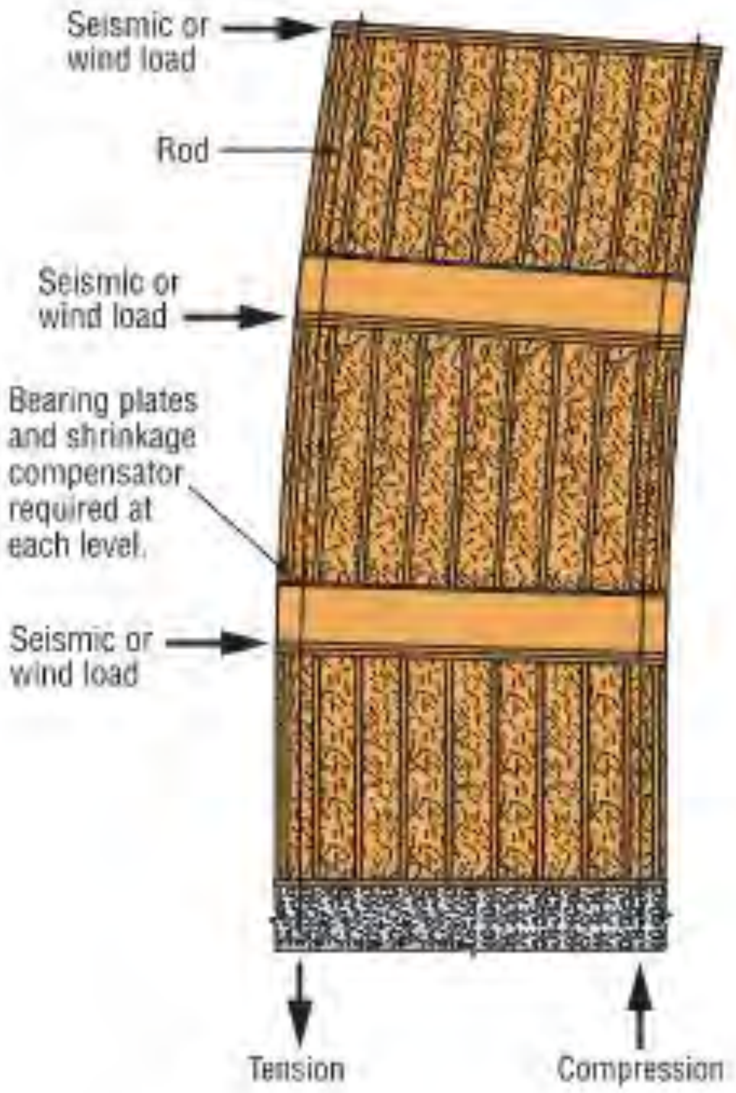

Photo: Simpson Strong-Tie

Anchorage to Foundation or Podium Structure:

- Typical types of Foundations to consider
  - Narrow stem walls (CMU or CIP concrete)
  - Thicken edge monolithic cast slabs
- Typical types of Podiums to consider
  - Post-Tensioned Concrete
  - Precast Concrete
  - Structural Steel transfer beams

Photo: Sandman Structural Engineers

Photo: Sandman Structural Engineers

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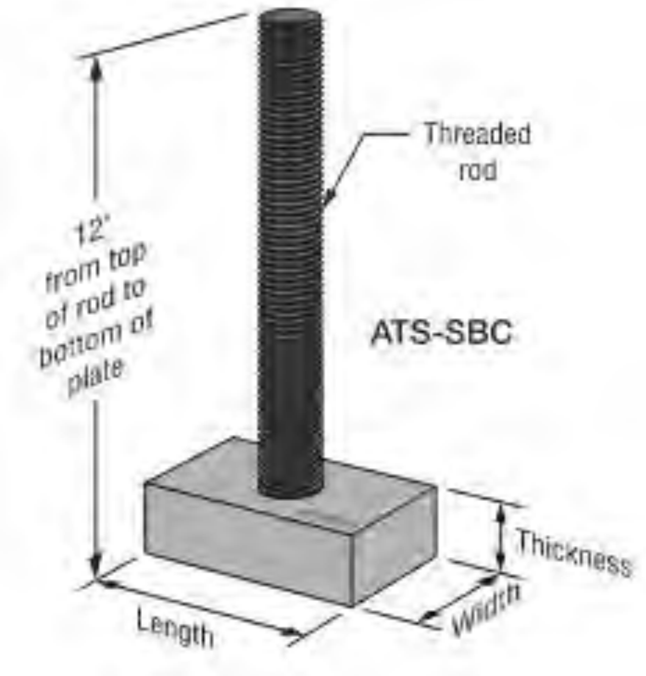
Anchorage to Foundation or Podium Structure:

- Sill Plate Anchorage
  - Typically cast-in-place (CIP) anchor bolts or post installed mechanical anchors
    - Sequencing of construction and type of foundation/podium will drive if CIP anchors are feasible for the project
    - Post-Tension podium slabs are limited for post-installed anchors. Alternate CIP anchors, embeds, or x-ray imaging of the slab may be necessary.
    - Precast concrete podiums may allow for post-installed anchor, but local areas of grouting may be required to develop anchor strength at hollow cores.

Photo: Sandman Structural Engineers

Anchorage to Foundation or Podium Structure:

- Shear Wall End Anchorage for Overturning Forces
    - These superimposed loads to the podium and foundation can reach high values (Some cases upwards to 40 kips ultimate)
    - Development into foundation/podium substrate must be thoroughly detailed.
        - Are post-installed anchors feasible with substrate material and edge distances?
        - If CIP anchors or embeds are specified, does foundation trades have enough information to place properly



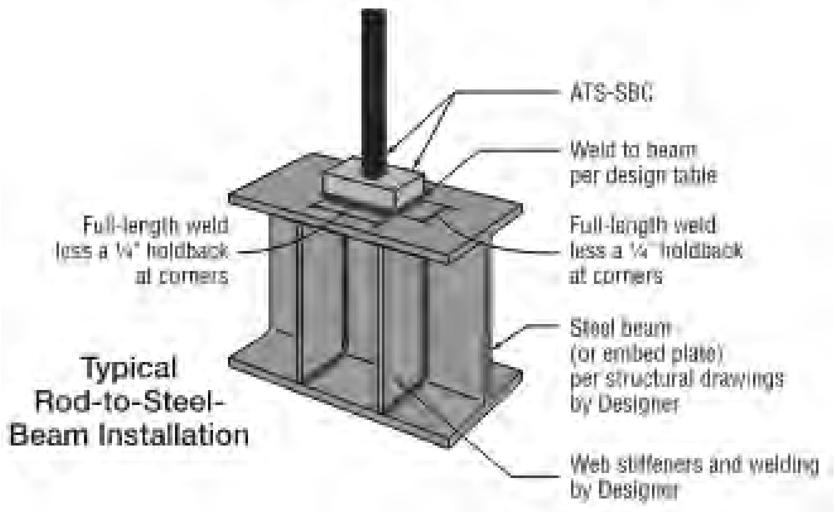


Photo: Simpson Strong-Tie

Examples of tension rod connections to podium & foundations

- Threaded Rod starter base welded to embed plate cast into CMU foundation wall

- Threaded rod thru bolted precast podium with oversized washer plate (view from below)

- Threaded rod bolted to pre-fab bracket that is welded to CIP foundation embed

- **Additional Lessons Learned & Best Practices**
  - Complete site visits to observe installation & gather contractor feedback
  - Always consider simplicity when designing lateral systems
  - Give proper design and detailing attention to anchoring Shear Wall systems to the podium and foundation
  - Understand how MEP systems are being routed through structural walls
  - Take the time to discuss/explain the lateral load paths to your design partners and field crews

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

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