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

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
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.
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.
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: $b_1$ is the minimum shear wall segment length, $b_2$ 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

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

Photo: Sandman Structural Engineers
• 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
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**

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

• Continuous Rod Systems

• Traditional Hold-Down & Strap Systems
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: Simpson Strong-Tie

Strap at Floor Level

Photo: Sandman Structural Engineers
• **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
• **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
• **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
• 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
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 thru bolted precast podium with oversized washer plate (view from below)

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

- 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
This concludes The American Institute of Architects Continuing Education Systems Course

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