High-Rise Podium Structures

- Flexible Upper Portion
  - Generally wood or light gauge bearing wall systems for residential occupancies
- Rigid Lower Portion (Podium)
  - Generally concrete slab & shear wall systems for retail or mixed-use occupancies

Design Coefficients & Factors for Seismic Force-Resisting Systems (SFRS)

Per ASCE 7-05   Table 12.2.1

- Upper Portion
  - SFRS: Type A-13 Light Framed Walls w/ Wood Sheathing
  - $R = 6.5$
  - $\Omega_o = 3$
  - $C_d = 4.0$
  - Max Building Height
    - No limit for seismic design categories B & C
    - 65-ft for seismic design categories D, E & F
Design Coefficients & Factors for Seismic Force-Resisting Systems (SFRS)
Per ASCE 7-05 Table 12.2.1

- Lower Portion
  - SFRS: Generally A-1/A-7 Special Reinforced Concrete/Masonry Shear Walls
  - OR -
  - B-1/B-2/B-3 Steel braced frames
  - $R = 6$ to $8$
  - $\Omega_o = 2$
  - $C_d = 4.0$ to $5.0$

Seismic-Force Analysis
- Consider Upper & Lower Portions as separate structures w/ separate $R$ & $\rho$ values: 2-stage analysis
- ASCE 7-05§12.2.3.1 permits the use of a 2-stage analysis provided:
  - Stiffness of Lower Portion $\geq 10x$ the stiffness of Upper Portion
  - $T$ of entire structure $\leq 1.1 \times T$ of Upper Portion when Upper Portion is considered as a separate structure fixed at base
  - Design Lower Portion w/ amplified reactions from Upper Portion
    - Amp Ratio = \frac{(R / \rho)_{Upper}}{(R / \rho)_{Lower}}
  - CBC§1614A1.4 adds additional criteria

Lateral Design Challenges
- Maximum Building Height
  - ASCE 7-05 Table 12.2.1 lists a max building height of 65-ft for a type A-13 (light framed walls) structure in SDC D, E & F
  - Consider an Upper Portion w/ five 10-ft floors over a 15-ft retail podium
    - Total Building Height = 65-ft
    - Top floor w/ roof trusses may exceed 10-ft
    - Retail level may require heights > 15-ft for tenants

Maximum Building Height Provisions
- Provide structure with appropriate lateral resistance to seismic forces.
Maximum Building Height Provisions

- ASCE 7-05 Table 12.2.1 describes building height as measured from the base of the structure
- ASCE 7-05 § 11.2 defines ‘base’ as ‘the level at which horizontal seismic ground motions are considered to be imparted on the structure’
  - Is the ‘base’ the top of the podium or top of grade?
  - May depend on jurisdiction
  - Woodworks is working with AF&PA, AWC and ICC for ruling

2-Stage Analysis Criteria

- Use of Code-Approximate fundamental period may not be appropriate when considering entire building
- Modal analysis may be required to approximate the fundamental period of the entire structure

2-Stage Analysis Criteria

- The amplification ratio applied to reactions from the upper portion can vary from ≈ 1.7 to 1.0 based on R and ρ values of each portion
  - Amplification ratios are largest when
    - Upper Portion ρ = 1.0
    - Lower Portion ρ ≥ 1.0
  - Amplification ratios are smallest when
    - Upper Portion ρ ≥ 1.0
    - Lower Portion ρ = 1.0

Diaphragm Analysis

- Code Provision Overview
  - ASCE 7-05 § 12.3.1.1 permits diaphragms of wood structural panels in 1 & 2 family residential buildings to be idealized as flexible
    - CBC § 1613.6.1 extends this provision beyond 1 & 2 family dwellings
Diaphragm Analysis

• Code Provision Overview
  • ASCE 7-05 § 12.3.1.3 provides methodology for idealizing diaphragms as flexible based on calculated deflection
    • CBC § 2305.2.2 provides equation to calculate diaphragm deflections
    • CBC § 2305.2.5 lists design requirements for rigid diaphragms of wood construction

Flexible vs. Rigid

• Flexible Advantages
  • Straight forward analysis
  • May reduce $\Omega_o$ by 0.5 per ASCE 7-05

• Flexible Disadvantages
  • Limits flexibility in shear wall layout
  • May be unrealistic based on actual span to depth ratios

Flexible vs. Rigid

• Rigid Advantages
  • Gives more flexibility in shear wall layout

• Rigid Disadvantages
  • More complicated analysis
  • Must consider accidental torsion and irregularities

Load Transfer to Podium Slab
Strength Considerations

- Shear & hold-down anchorage forces shall be designed for load combos using $\Omega_o$ (per ASCE 7-05 § 12.3.3.3)
- Consider eliminating exterior walls as shear wall lines & hold back hold-down locations to eliminate large loads at slab edges

Constructability Considerations

Consider all that is going on within that podium slab

Constructability Considerations

Provide connection details that allow maximum layout tolerances and constructability

Anchor bolt detail
Constructability Considerations

Provide connection details that allow maximum layout tolerances and constructability

Hold-down detail

Vertical Design Challenges

High Axial Loading of Studs Require Unique Design Solutions

- Consideration of stud size v. stud spacing v. material grade
- Sill PL crushing may control stud sizing at lower levels
Long-Term Vertical Displacement

• Causes:
  • Settlement of Construction Gaps
    • May account for up to 1/8" of vertical movement per level
  • Wood Shrinkage
    • Decrease in volume as wood dries over time
    • Largest in direction tangential to grain
    • Proportional to overall decrease in moisture content ≈ 0.00267 in/in/%

Long-Term Vertical Displacement

• Causes:
  • Deformation Under Sustained Loading-Creep
    • Rates are greater for members drying under load
    • Not usually considered for wood construction but large-magnitude stud loading may warrant consideration
  • Appendix F of NDS provides commentary on creep in wood, recommends a deflection factor of 1.5 to 2.0 when computing deflection due to long-term loading

Long-Term Vertical Displacement

• CBC § 2304.3.3 states that shrinkage must be considered for wood walls supporting more than 2 floors
  • Required to provide analysis ‘satisfactory’ to the building official showing shrinkage will not have adverse effects...

<table>
<thead>
<tr>
<th>Level</th>
<th>Vertical Displacement</th>
<th>Design Displacement</th>
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<tbody>
<tr>
<td></td>
<td>Per Floor</td>
<td>Cumulative</td>
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<tr>
<td>5</td>
<td>0.358” – 0.966”</td>
<td>1.47” – 3.94”</td>
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<tr>
<td>4</td>
<td>0.358” – 0.966”</td>
<td>1.11” – 2.98”</td>
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<tr>
<td>3</td>
<td>0.358” – 0.966”</td>
<td>0.75” – 2.01”</td>
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<tr>
<td>2</td>
<td>0.394” – 1.046”</td>
<td>0.394” – 1.05”</td>
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</table>

Methods to Reduce Vertical Displacement

• Use kiln-dried plates, defined as having maximum moisture content of 19% (or consider the use of engineered lumber plates)

• Consider the use of single top plates
  • Eliminates 33% of plate shrinkage
  • Requires additional design, detailing and layout
  • Coordination for stacked construction

• (Modified) Balloon Framing
  •Eliminates shrinkage from dimensional lumber joists
  •May not have shrinkage reduction in projects w/ engineered wood joists

A free ‘shrinkage calculator’ can be downloaded from the western wood products association webpage (www2.wwpa.org)
Methods to Account for Vertical Displacement

Oversized openings in studs / rims / joists to prevent damage to rigid mechanical / plumbing assemblies such as fire stacks.

Coordinate attachments of exterior systems to accommodate building settlement, particularly important at flashing joints.

Insure compatibility when using dissimilar materials within the vertical assembly, such as steel columns, creating a ‘high spot’

Use continuous rod hold-downs w/ shrinkage compensating devices
- Loose connections in hold-down assembly can significantly reduce performance.
Fire and Life Safety Overview

• Lower Portion:
  • Type 1A Construction
  • Occupancy = S2, B, E, A2
  • Allowable Height = Unlimited
  • Allowable Stories = 1
  • Allowable Area = Unlimited

• Upper Portion:
  • Type V Construction
  • Occupancy = R2
  • Allowable Height = 55-ft
  • Allowable Stories = 4
  • Allowable Area = 16,000 SF
  • However, CBC § 504.2 allows an increase of one story and 20-ft to allowable height if an automatic sprinkler system is used
    • Modified Allowable Height = 75-ft
    • Modified Allowable Stories = 5
    • Becomes Type IIIA –or- IIIB

Type IIIB Fire Resistant Ratings
Per CBC Table 602

Structural Frame = 0-HR
Exterior Bearing Walls = 2-HR
Interior Bearing Walls = 0-HR
Floor Construction = 0-HR
Roof Construction = 0-HR

• CBC § 602.3 defines Type III Construction as those types w/ exterior walls of non-combustible materials. Therefore, the use of fire-retardent-treated (FRT) wood is required in exterior wall assemblies

Structural Design with FRT Wood

• CBC § 2303.2 lists the relevant structural provisions
  • Adjustments to design values must be used w/ FRT wood
  • These vary w/ supplier and should be based on product-specific ESR reports

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<thead>
<tr>
<th>Property</th>
<th>Adjustment Factor</th>
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<tr>
<td>Comp Parallel to Grain</td>
<td>1.00 – 0.99</td>
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<tr>
<td>Comp Perpendicular to Grain</td>
<td>0.95 – 0.90</td>
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<tr>
<td>Horizontal Shear</td>
<td>0.96 – 0.95</td>
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<tr>
<td>Tension Parallel to Grain</td>
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<tr>
<td>Bending (E)</td>
<td>1.05 – 0.96</td>
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<tr>
<td>Bending (Fb)</td>
<td>0.99 – 0.96</td>
</tr>
<tr>
<td>Fasteners / Connectors</td>
<td>0.90 – 0.85</td>
</tr>
</tbody>
</table>

• Maximum moisture content = 19% for FRT lumber (Already kiln-dried)
• CBC § 2304.9.5
  • Fasteners used in FRT wood must be hot-dipped galvanized
Contact

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