5 over 1
High-Rise Podium Structures

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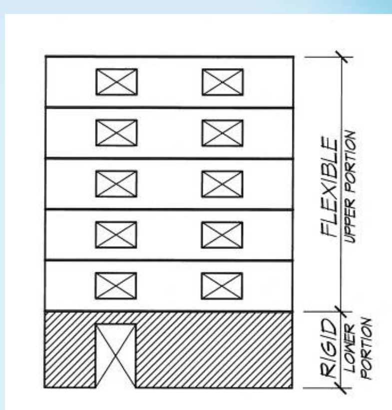
Presentation Summary

- Relevant CBC Provisions
- Structural Design Challenges
- Fire & Life Safety Overview / FRT Lumber Design
- Ask questions along the way

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

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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 ≥ 10x the stiffness of Upper Portion
  - T of entire structure ≤ 1.1 x 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 = $(R / rho)_{Upper} / (R / rho)_{Lower}$
  - CBC∮1614A1.4 adds additional criteria

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Lateral Design Challenges

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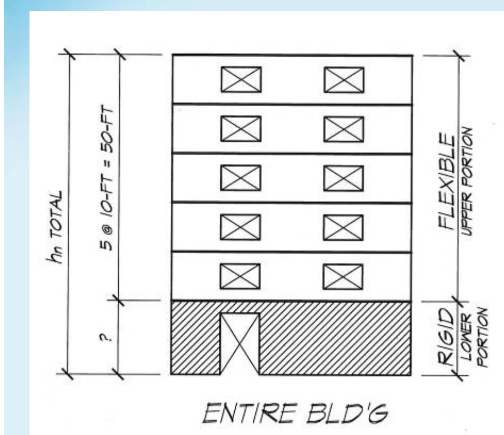
Maximum Building Height Provisions



- 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

- 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

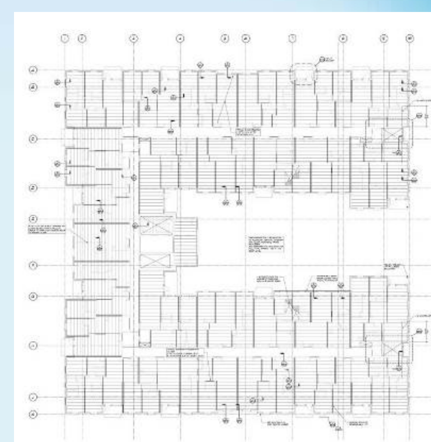
- Use of Code-Approximate fundamental period may not be appropriate when considering entire building
- Modal analysis may be required to approximate the fundamental period of the entire structure

2-Stage Analysis Criteria

- The amplification ratio applied to reactions from the upper portion can vary from $\simeq$ 1.7 to 1.0 based on R and rho values of each portion
  - Amplification ratios are <u>largest</u> when
    - Upper Portion rho = 1.0
    - Lower Portion rho ≥ 1.0
  - Amplification ratios are <u>smallest</u> when
    - Upper Portion rho ≥ 1.0
    - Lower Portion rho = 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 Ω_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

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Strength Considerations

- Shear & hold-down anchorage forces shall be designed for load combos using Ω_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

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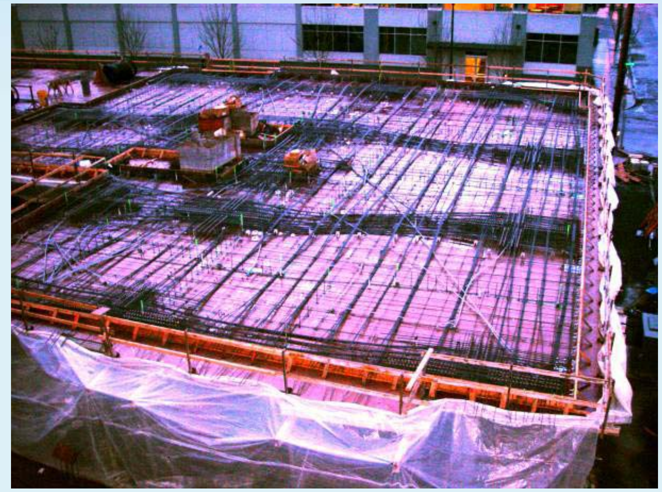
Constructability Considerations

Consider all that is going on within that podium slab



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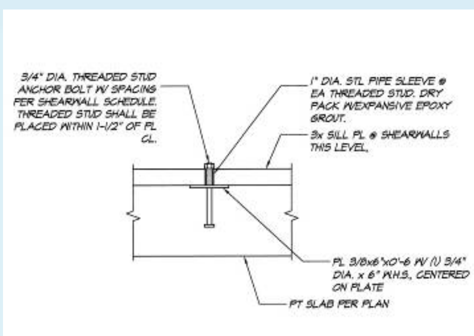
Constructability Considerations

Provide connection details that allow maximum layout tolerances and constructability



Anchor bolt detail

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Constructability Considerations

Provide connection details that allow maximum layout tolerances and constructability

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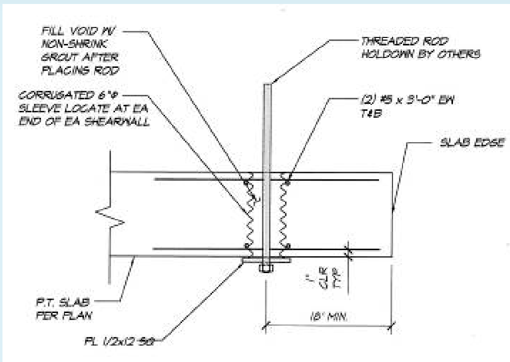
Constructability Considerations

Provide connection details that allow maximum layout tolerances and constructability



Hold-down detail

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Constructability Considerations

Consider mechanical / plumbing when locating shear walls

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Vertical Design Challenges

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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…

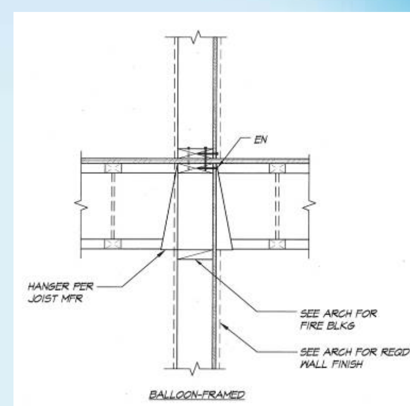
Vertical Displacement Ranges

Level	Vertical Displacement		Design Displacement
	Per Floor	Cumulative	
5	0.358” – 0.966”	1.47” – 3.94”	1-1/2” – 4”
4	0.358” – 0.966”	1.11” – 2.98”	1-1/8” – 3”
3	0.358” – 0.966”	0.75” – 2.01”	3/4” – 2”
2	0.394” – 1.046”	0.394” – 1.05”	3/8” – 1”

A free ‘shrinkage calculator’ can be downloaded from the western wood products association webpage (www2.wwpa.org)

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



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Methods to Account for Vertical Displacement

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

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Methods to Account for Vertical Displacement

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

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Methods to Account for Vertical Displacement

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

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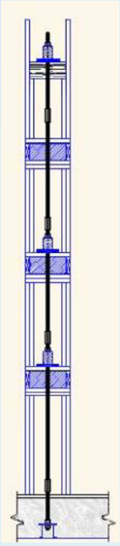
Methods to Account for Vertical Displacement

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

Fire and Life Safety Overview

- 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

FRT Adjustment Factor Ranges (For Douglas Fir)	
Property	Adjustment Factor
Comp Parallel to Grain	1.00 – 0.99
Comp Perpendicular to Grain	0.95 – 0.90
Horizontal Shear	0.96 – 0.95
Tension Parallel to Grain	0.95 – 0.80
Bending (E)	1.05 – 0.96
Bending (F_b)	0.99 – 0.96
Fasteners / Connectors	0.90 – 0.85

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

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