Codes and Standards for Mid-rise Construction – An All Wood Solution

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Description

Mid-rise construction, with multiple stories of wood framing over a concrete first story, has been popular for many years as a way to take advantage of wood’s cost effectiveness for the superstructure while maintaining a more traditional construction type below. Recently, some designers have chosen to forego concrete altogether and build the entire structure in wood, including the transfer floor framing level between R-2 and S-2 occupancies—further decreasing their costs while speeding construction and creating less massive, more uniform buildings. This course will examine two very different projects, a luxury apartment complex and a senior housing/mixed use project. Design considerations for durability, fire protection, sound transmission, seismic loads, and other provisions in the International Building Code (IBC) and the AWC Special Design Provisions for Wind and Seismic (AWC-SDPWWS) will be addressed.

Learning Objectives

• At the end of this program, participants will:

1. Understand the opportunities and challenges for wood use in mid-rise construction and be able to use that knowledge to specify this type of system in the future.
2. Learn the motivational drivers associated with the use of wood for midrise construction and why to consider it on future projects vs. typically specified systems.
3. Discover the structural challenges associated with transfer floor framing (level between R-2 and S-2) and gain a better understanding of the collaboration necessary with the structural engineer.
4. Understand how a transfer floor framing (level between R-2 and S-2) is designed for durability and longevity using non-traditional systems and methods.
Outline

- Podium Construction Defined
- Project Overviews
- Design Challenges and Solutions
- Features and Benefits
Podium Construction Defined

- Traditional Podium Construction
- All wood Construction

Residential + Nonresidential wood construction

Podium Construction Defined

Residential + Nonresidential concrete podium (transfer slab)

Residential + Nonresidential wood transfer floor
History

2-story wood office building over subterranean parking

Outline

- Podium Construction Defined
- Project Overviews
- Design Challenges and Solutions
- Features and Benefits
Project Overview

**Oceano at Warner Center:**
- Luxury apartments, 244 units
- 4 stories above grade, one story below, 55’
- 2008 LABC based on 2007 CBC
  based on 2006 IBC

**Galt Place:**
- Affordable seniors’ housing, 88 units
- 3 stories, 47’
- 2007 CBC based on 2006 IBC

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**Project Overview-Oceano at Warner Center**

**Project Team:**
- Owner: TDI California Construction & Oceano Partners
- General Contractor: TDI California Construction
- Architect: RC Alley III, NCARB, Architects Orange
- Structural Engineer: Tom VanDorpe, SE, VanDorpe Chou Associates, Inc. (VCA)
- Framer: Brian Larrabure, Larrabure Framing

**Construction Timeline:**
- January 2011 to occupancy in July 2012
Project Overview-Oceano at Warner Center

- Architectural Components:
  - Construction Type: VA
  - Occupancies:
    - Below Grade: S-2 Enclosed semi-subterranean parking below grade
    - Levels 1-4: R-2 Building 1 – 116 units (146,847 sf) and Building 2 – 128 units (163,468 sf)
  - Sprinklers: NFPA 13 sprinkler system.
Project Overview – Galt

- Project Team:
  - Owner: City of Galt and CFY Development Inc.
  - General Contractor: CFY Development Inc.
  - Structural Engineer: Mike Baker, SE, Baker Guptil Structural Designs, Inc.
  - Framer: Becker General Contractors
- Construction Timeline:
  - March 2011 to occupancy in June 2012

Project Overview – Galt

- Architectural Components:
  - Construction Type: VA
  - Areas & Occupancies:
    - Level 1: S-2 (24,633 sf) Enclosed, A2, M and B—Retail/Restaurant/Office and Residential Administration (14,356 sf)
    - Levels 2 and 3: R-2—88 Units (62,480 sf)
  - Sprinklers: NFPA 13 sprinkler system.
Project Overview – Galt

Structural Components

- Structural Specifications
  - Light-framed shear walls all levels
  - Wood Transfer Floor: Engineered Wood System
    - Wood Structural Panels with gypcrete topping
    - I-joists
    - Glued laminated Beams (Glulams)
Structural Components

- Engineered Wood System
  - Wood Structural Panels
    - Oriented Strand Board (OSB)
    - Plywood for balconies
  - I-joists and Sawn Lumber

Structural Components

- Light-framed shear walls
  - Superstructure
    - Shear wall design methods
    - Architectural Gingerbread
Structural Components

- Light-framed shear walls
  - Wood Transfer Floor
    - Focus on Continuity
    - Detailing

Structural Components

- Glulam Beams
  - 2 Stress Classes
    - Bending Stress, Modulus of Elasticity
    - 24F-1.8E (2400 psi, 1.8x10⁶ psi)
    - 30F-2.1E (3000 psi, 2.1x10⁶ psi)
  - Variety Sizes
    - 5-1/8 inches to 12-1/4 inches wide
    - 10-3/4 inches to 45 inches deep

LVL Laminations
Structural Components

- Structural Steel
  - Steel Columns & Connections
  - Price Steel Beams > Glulams

Outline

- Podium Construction Defined
- Project Overviews
- Design Challenges and Solutions
- Features and Benefits
Design Challenges and Solutions

Governing Codes for Engineered Wood Design

2007 California Building Code (CBC)
Design Challenges and Solutions

2008 City of Los Angeles Building Code

Design Challenges and Solutions

2010 California Building Code (CBC)
Design Challenges and Solutions

Heights and Areas

• What factors into determining allowable heights and areas?
  • Occupancy
  • Construction Types
  • Protected or Unprotected
  • Open Frontage
  • Sprinklers
  • Fire Walls/Barriers
Design Challenges and Solutions

IBC 2009 Special Provisions – 509

- 509.1 General. The provisions in this section shall permit the use of special conditions that are exempt from, or modify, the specific requirements of this chapter regarding the allowable heights and areas of buildings based on the occupancy classification and type of construction, provided the special condition complies with the provisions specified in this section for such condition and other applicable requirements of this code. The provisions of Sections 509.2 through 509.8 are to be considered independent and separate from each other.

Design Challenges and Solutions

IBC 2009 Special Provisions – 509

- 509.2 Horizontal building separation allowance.
- considered separate buildings above and below for purposes of area calculations if:
  - 3hr horizontal assembly
  - one story above grade of Type 1A with sprinklers below separation
  - occupancy above is A, B, M, R or S
  - occupancy below is A, B, M, R or S-2
  - overall height is still limited
**Design Challenges and Solutions**

**IBC 2009 Special Provisions – 509**

- 509.4 Parking beneath Group R.
- Possibility of a Type IV podium where number of stories starts above parking:
  - 1 hr horizontal assembly
  - one story above grade of Type IV open with sprinklers below separation
  - occupancy above is R
  - occupancy below is S-2
  - overall height is still limited

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**Design Challenges and Solutions**

**Considering a Conventional Code “Podium”**

**Will the parking work?**

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For SI: 1 ft = 304.8 mm, 1 square ft = 0.093 m².

- A = building area per story, S = stories above grade plane, UL = Unlimited, NF = Not permitted.
- a. See the following sections for general exceptions in Table 509:
  1. Section 501.2: Allowable building height and story increase due to automatic sprinkler system installation.
  2. Section 506.2: Allowable building area increase due to street frontage.
  3. Section 506.3: Allowable building area increase due to automatic sprinkler system installation.
  4. Section 507: Unlimited area buildings.
- b. For open parking structures, see Section 406.3.
- c. For private garages, see Section 406.1.
- d. See Section 115.5 for limitations.

Sec. 406.3.3 states _Open parking garages shall be of Type I, II or IV construction._
Design Challenges and Solutions

Considering a Conventional Code “Podium”
Will the parking work?

Enclosed Garages:  406.4
Height and area as per table 503 as modified by sections 504, 506, and 507

Type V is OK for S2 Occupancy per table 503 Parking Garage is OK in Type VA construction IF it is enclosed

Enclosed Parking Garage

- Ventilation Systems required for Enclosed Garages
- Mech Code: 403.8 Exhaust Ventilation for Enclosed Parking Garages. Exhaust airflow for enclosed parking garages shall be provided in accordance with the requirements in Table 4-4 and this Section. Exhaust makeup air shall be permitted to be any combination of outdoor air or transfer air.

  Table 4-4  Parking garages  0.75 cfm / sq ft

- 403.8.2 Alternative Exhaust Ventilation for Enclosed Parking Garages. Mechanical ventilation systems used for enclosed parking garages shall be permitted to operate intermittently where the system is arranged to operate automatically upon detection of vehicle operation or the presence of occupants by approved automatic detection devices.

- Part natural and part mechanical ventilation permitted by code
  - Final result: 10,000 cfm system ...cost 10K
Design Challenges and Solutions

**IBC 2009 Special Provisions**

- 508 Mixed Use & Occupancy
- Separated Occupancies 508.3.3 (06 IBC) 508.4 (09 IBC)
- Separation of Occupancies Table 508.3.3 (06 IBC) 508.4 (09 IBC) – 1-hour fire resistive rating
- References Section 711 (06 IBC) 712 (09 IBC) Construction – Horizontal Assemblies
- 711.2 (06 IBC) 712.2 (09 IBC) Materials. The floor and roof assemblies shall be of material permitted by the building type of construction.

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Design Challenges and Solutions

**Oceano at Warner Center**

- Architectural Components:
  - Construction Type: VA
- Areas & Occupancies:
  - Below Grade: S-2 Enclosed semi-subterranean parking below grade with 353 parking stalls (78,650 square feet)
  - Levels 1-4: R-2 with a total of 244 units (310,195 square feet) Building 1 has – 116 units (146,847 square feet) and Building 2 has – 128 units (163,468 square feet)
- Sprinklers: NFPA 13 sprinkler system.
Design Challenges and Solutions

Oceano Wood Transfer Floor

- R-2 & S-2 Enclosed Occupancies
- Type V Construction
- CBC 508.3.3 – Mixed Use Occupancy
  - Section 712.3 for the requirements of the horizontal assembly states the floor and roof assemblies shall be of materials permitted by the building type of construction.
  - Table 508.4 specifies a fire separation between occupancies to have a 1-hour fire resistive rating.

Design Challenges and Solutions

Galt Place

- Architectural Components:
- Construction Type: VA
- Areas & Occupancies:
  - Level 1: S-2 70 covered and open air parking stalls (24,633 square feet), A2, M and B– Retail/Restaurant/Office and Residential Administration (14,356 sf)
  - Levels 2 and 3: R-2– 88 Units (62,480 square feet)
  - Separated Occupancies: 1 hour maximum fire resistive rating per Table 508.3.3
- Sprinklers: NFPA 13 sprinkler system.
Design Challenges and Solutions

Galt Wood Transfer Floor

- R-2 & S-2 Enclosed Occupancies
- Type V Construction
- CBC 508.3.3 – Mixed Use Occupancy
  - Section 712.3 for the requirements of the horizontal assembly states the floor and roof assemblies shall be of materials permitted by the building type of construction.
  - Table 508.4 specifies a fire separation between occupancies to have a 1-hour fire resistive rating.

Code Check Resources

- Building Height and Area Limitations
  - "Check Height & Area" Calculator for 2006/2009 IBC and 2006/2010 CBC
  - For mixed-use projects, you can use these applications to calculate the interior area and the grade plane elevation.
- Plumbing Fixtures
  - "Plumbing Fixtures" Calculator

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Design Challenges and Solutions

- Durability:
  - Protected building envelope
  - Different approaches
    - Oceano
    - Galt

Design Challenges and Solutions

- Two accepted fire resistance rating methods recognized in the U.S.
  - IBC Empirical Method
  - NDS Mechanics Based Model

FRT
Chapter 16 – Fire (ASD)

- **Fire resistance up to two hours**
  - Columns
  - Beams
  - Tension Members
  - ASD only

- **Products**
  - Lumber
  - Glulam
  - SCL
  - Decking

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**SECTION 721**

**CALCULATED FIRE RESISTANCE**

721.1 General. The provisions of this section contain procedures by which the fire resistance of specific materials or combinations of materials is established by calculations. These procedures apply only to the fire resistance of steel and wood members and shall not be otherwise used. The calculated fire resistance of concrete, concrete masonry, and clay masonry elements shall be permitted in accordance with A61.17/MS 217/MS. The calculated fire resistance of all assemblies shall be permitted in accordance with Chapter 5 of ASCE 29. The calculated fire resistance of exposed wood members and wood deckings shall be permitted in accordance with Chapter 16 of ANSI/ASME/NAI National Design Specifications for Wood Construction (NDS).

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**Design Challenges and Solutions**

Calculating Fire Resistance of Glulam Beams and Columns, Technical Note Y245

**FIGURE 5**

**SIMPLE SPAN UNBALANCED LAYOUT**

- Standard Beam Layout
  - Compression tensile at top
  - Core tensile in center
  - Tension tensile at bottom

- One Hour Rated Beam Layout
  - One core tensile removed from center
  - One tensile tensile added at bottom
Performance of Wood vs. Steel

![Comparative Strength Loss of Wood versus Steel](image)

Horyu-ji temple, Ikaruga, Nara Prefecture, Japan, (c. 711)
Urnes stave church, Sogn og Fjordane County, Norway (c. 1150)
Government Buildings Historic Reserve in Wellington, NZ (c. 1870)
Design Challenges and Solutions

• Communication:
  • Project team
    • Subconsultants
    • Single Engineering Firm
  • BIM
  • Glulam Manufacturers
  • Emphasis on Stacking

Design Challenges and Solutions

• Field Modifications:
  • BIM
  • Hole cutting
  • Field Notching and Drilling of Glulam
  • (APA Form S560)
Moisture Changes In Wood
Causes dimensional changes perpendicular to grain

Growing tree is filled with water

As wood dries, it shrinks perp. to grain

Design Challenges and Solutions

Moisture Changes In Wood
Causes dimensional changes perpendicular to grain

Growing tree is filled with water

As wood dries, it shrinks perp. to grain

Design Challenges and Solutions

**IBC 2009 & 2012 Shrinkage**

- 2304.3.3 Shrinkage. Wood walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the building official shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems, or other equipment installed therein due to excessive shrinkage or differential movements caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equipment will not be adversely affected or, as an alternative, such systems shall be designed to accommodate the differential shrinkage or movements.
Design Challenges and Solutions

Wood Shrinks

- Wood mainly shrinks perpendicular to grain. (Shrinkage parallel to grain is approximately 1/40 of the shrinkage perpendicular to grain and can be neglected.)
- The amount of shrinkage (or expansion) in wood is directly proportional to the change in moisture content.
- The higher the moisture content at time of construction, the more shrinkage that can occur in the structure.
Shrinkage occurs primarily in horizontal members such as wall plates and floor joists.
Design Challenges and Solutions

http://www2.wwpa.org/Portals/9/docs/PDF/TN10.pdf

Calculating Shrinkage

Shrinkage of a softwood lumber member can be estimated using the following equation:

\[
S = D \times M \times C
\]

Where:
- \( S \) = Shrinkage, inches
- \( D \) = Dimension, inches
- \( M \) = Change in moisture content, percent
- \( C \) = Shrinkage coefficient, 0.0020 for Western softwood species (including Redwood) except 0.0017 for Western Red Cedar.

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<th>Thickness</th>
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<th>Shrinkage (from EXP)</th>
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<table>
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*6" thickness S-GRN size is for unseasoned timbers.
Design Challenges and Solutions

Tips:
- Rule of thumb: 4% change MC approx. equals 1% dimensional change
- Prefabrication
- Joist hangers
- Load floors asap
- Accommodate movement in plumbing and electrical (vertical slip joints, vertical slot holes at horiz. runs, etc.)
- Limit or avoid dissimilar materials.

Outline

- Podium Construction Defined
- Project Overviews
- Design Challenges and Solutions
- Features and Benefits
Benefits

- Enhanced constructability:
  - Fewer trades on job
  - Less mobilization time
  - Fewer construction delays

Benefits

- Enhanced constructability:
  - Improved framing efficiency
  - Large pool experienced and competitive labor
  - Easier field modifications
Benefits

• Structural:
  • Decreased mass for lateral design
  • Continuity of lateral system
  • Fewer design team members

Benefits

• Improved sustainability:
  • Wood as a building material
  • Renewable sustainable forestry
  • LEED-HMR Silver (Oceano)
  • LCA
Comparing CO₂ emissions of different materials

- Sawn lumber products have a negative net CO₂ contribution
- Wood industry often contributes biomass energy to the grid

Wood Structures = Long Term Storage

2,400 sf home = 32 m³ structural = 29 metric tons CO₂ = 5.7 passenger annual emissions

Source: FP Innovations
Features and Benefits

- Galt Place is a great example of Smart Growth
- Mixed Use
- Infill and Urban
- Encourages transportation choice - car, bus, walk, bicycle
- High in Resource Efficiency - low energy and land use
- supports existing infrastructure
- Quality Design that creates a sense of place
Features and Benefits

- More economical building:
  - Motivating factor to build wood transfer floors for both projects
  - Oceano - wood transfer floor estimated to be 2/3 cost of concrete podium
  - Galt – one change order - received $2 million credit primarily due to use of wood

Public Partner Perspective

Affordable housing requires public-Private Partnerships

- C.F.Y. Development financed this $20 million project with a combination of partnership equity, conventional mortgage, deferred profit and a loan from the City of Galt Redevelopment Agency

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Resources

- SEAOC Convention Proceedings:
  http://seaoc.org/bookstore/conventionproceedings.html
Resources

- APA Case Study, Form No. N110
- www.apawood.org
- www.woodworks.org

Questions?

www.awc.org
info@awc.org