1430 Q, The HR Group Architects, Buehler Engineering, Greg Folkins Photography

Designing Light-Frame Wood Structures over Podiums: Seismic Considerations

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Course Description

This course highlights seismic design considerations for mid-rise light-frame wood buildings over concrete podiums, a common structural configuration in urban residential development. Through an abbreviated design example, participants will explore the application of the two-stage seismic analysis procedure, development of lateral forces, and the design and deflection calculation of a sample shear wall in a high seismic region, based on ASCE 7-22 and the 2024 IBC. This course highlights critical nuances of code interpretation, common design pitfalls, and real-world considerations to ensure safe and code-compliant design.

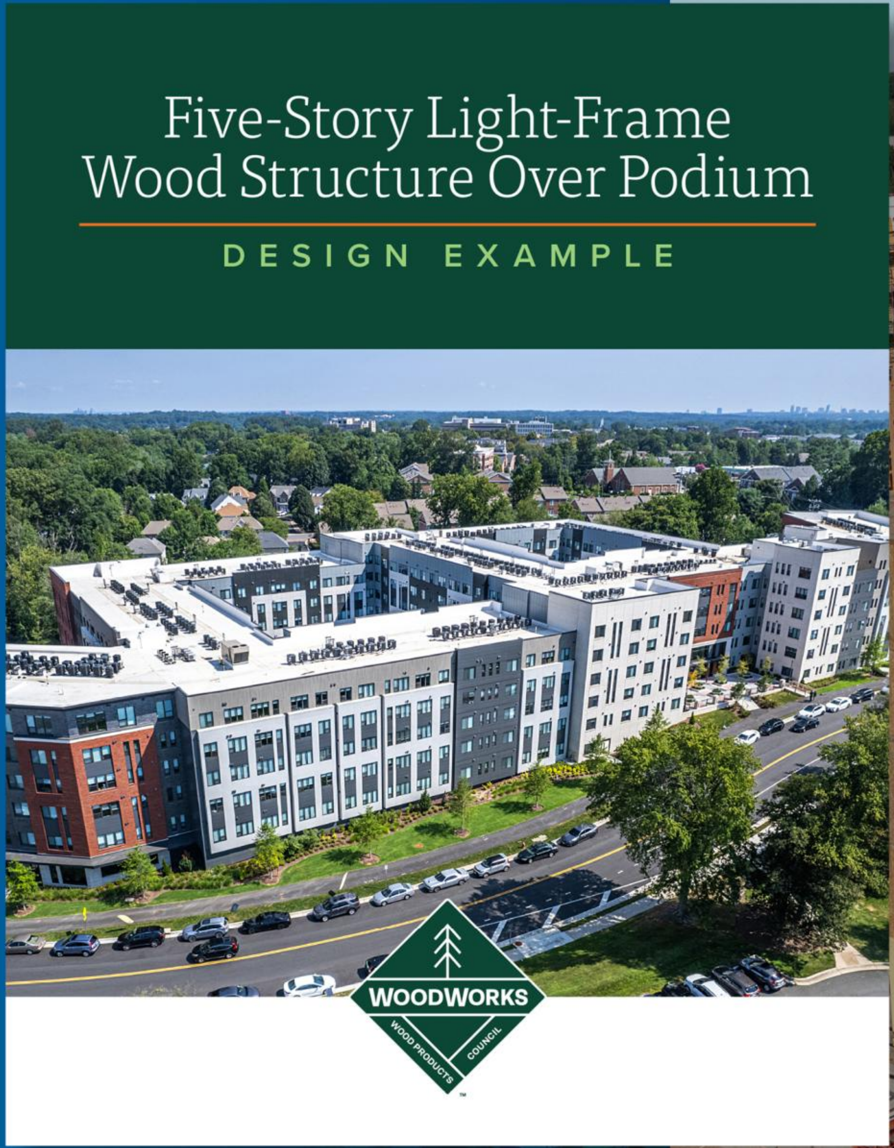
This webinar will serve as both a primer and a bridge to more comprehensive guidance. A newly published design example, which complements this presentation, will also be shared with attendees.

Learning Objectives

1. Explain the code provisions of the 2024 IBC and ASCE 7-22 that allow wood-over-podium building configurations, including fire and life safety provisions and seismic structural performance.
2. Understand how to develop the appropriate lateral loads in compliance with modern building codes and perform sample shear wall design and deflection calculations for a high-seismic zone.
3. Evaluate key updates in ASCE 7-22 that affect the seismic design of mid-rise, light-frame wood on concrete podium buildings.
4. Recognize critical design considerations, code interpretations, and potential pitfalls specific to podium construction—such as load transfer from wood to concrete systems—affecting structural integrity and ensuring occupant welfare.

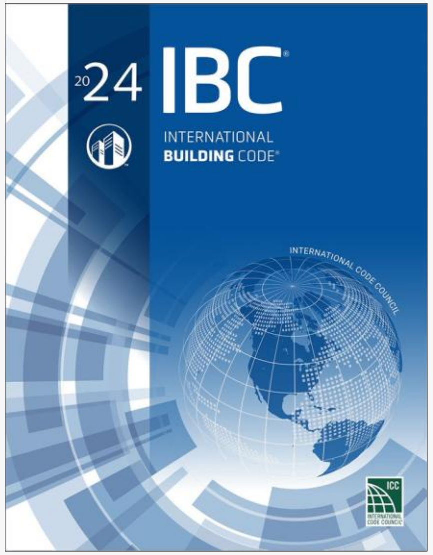
Outline

- IBC code provisions including heights and areas
- ASCE code provisions for Two-Stage Analysis
- 5-story wood-sheathed light-frame shear wall design example
- Podium design considerations

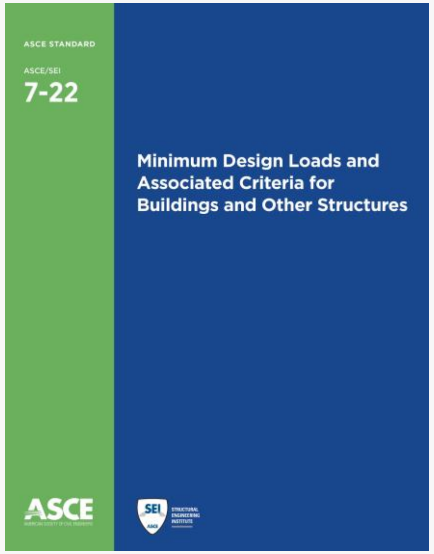


Broadstone Saratoga / Boise, Idaho
Urbal Architecture / Axiom Engineering
Photo: Chad Case Photography

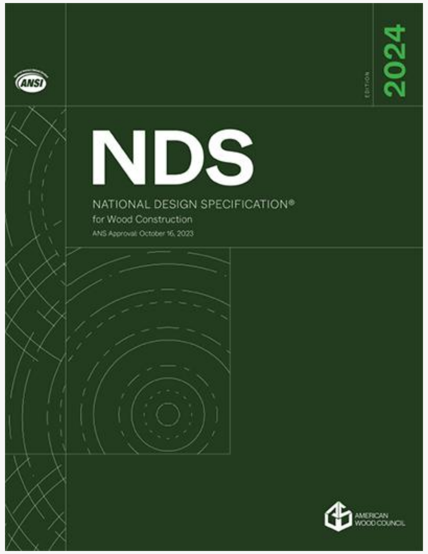
2024 IBC



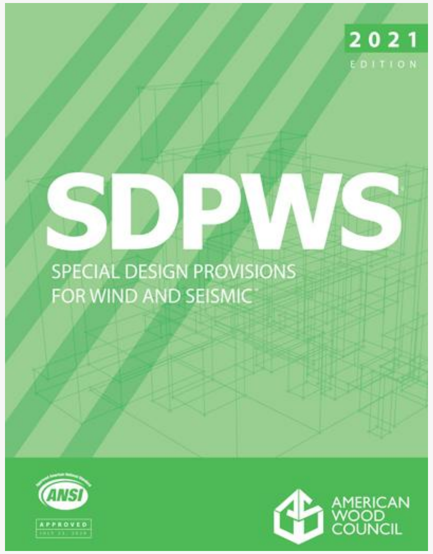
ASCE 7-22
(2022)



2024 NDS



2021 SDPWS



What are podium structures?

Marselle Condominiums / PB Architects / Yu & Trochalakis / Matt Todd Photography

Fire and Life Safety

The building code defines:

- Building size (area, height, stories)
- Allowable materials
- Fire protection requirements

Allowable building size based on:

- Building use (occupancy)
- Construction type
- Sprinklers & fire department access

IBC Light-Frame Construction Type Differences

	TYPE III		TYPE V	
	A	B	A	B
Exterior Wall Material (Chapter 6)	Non-combustible, FRTW (LF, MT)	Non-combustible, FRTW (LF, MT)	Any materials permitted by code	Any materials permitted by code
Interior Elements (Chapter 6)	Any materials permitted by code	Any materials permitted by code	Any materials permitted by code	Any materials permitted by code
Allowable Stories (Table 504.4)	5	5	4	3
Allowable Height (Table 504.3)	85’	75’	70’	60’
Allowable Area per Story (Table 506.2)	72,000 ft^2	48,000 ft^2	36,000 ft^2	21,000 ft^2
Allowable Total Building Area*	216,000 ft^2	144,000 ft^2	108,000 ft^2	63,000 ft^2
Exterior Bearing Wall Rating (Table 601)	2-hour	2-hour	1-hour	0-hour
All Other Fire Ratings (Table 601)	1-hour	0-hour	1-hour	0-hour

Residential (R-2) occupancy with NFPA 13 sprinklers without further increases. *Assuming max stories built.

Special Provisions
Horizontal Building Separation

- IBC 602.1 requires that each building be classified as one of five construction types.

- IBC 510 contains special provisions that allow different construction types in the same building or multiple "buildings" stacked on top of each other

Anaheim Stadium Apartments / Withee Malcolm Architects
Arden Photography

Horizontal Building Separation – 510.2

Considered separate buildings above and below
for purposes of area & number of stories calculations if:

- » Overall height is still limited to max of either building
- » 3hr rated horizontal assembly
- » Building below is Type I-A with sprinklers
- » Enclosures penetrating horizontal assembly are 2hr rated
- » Occupancy above is A (occupant load <300), B, M, R or S
- » Occupancy below is any except H

The Flats at ISU, Normal, IL
OKW Architects
Precision Builders & Associates

Design Example: Section 2.1

Special Provisions
Horizontal Building Separation

"Separate and distinct buildings" for:

» Area determination

» Number of stories

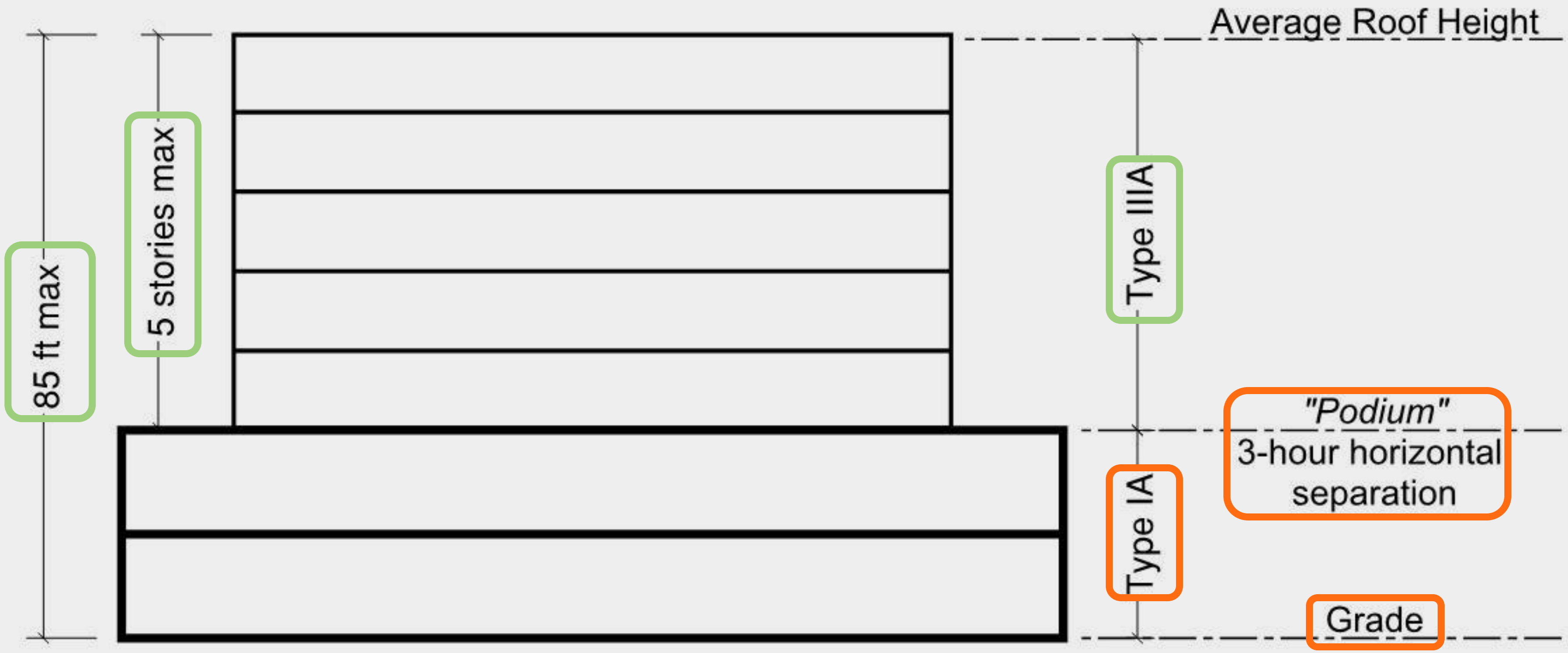
» Construction type

Building <u>height</u>…

still measured from grade

Broadway Plaza / Studio T Square / The Sobrato Organization
Photo: IMEG

Height and Story Limits



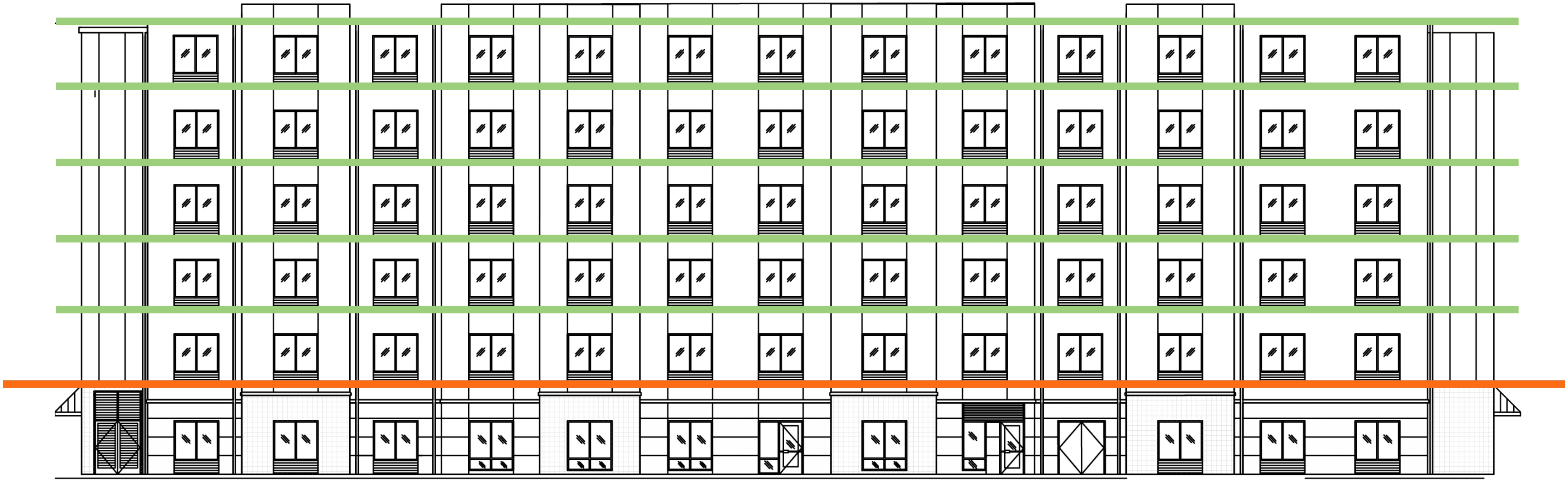
Seismic System Height Limits

ASCE 7 Table 12.2-1: Wood Shear Walls

- Seismic Design Categories D, E, F
- 65-foot maximum, measured from the “base”
- Base is the level at which horizontal seismic ground motions are imparted
- Base = top of podium (see ASCE 7 Section 12.2.3.2 item f)

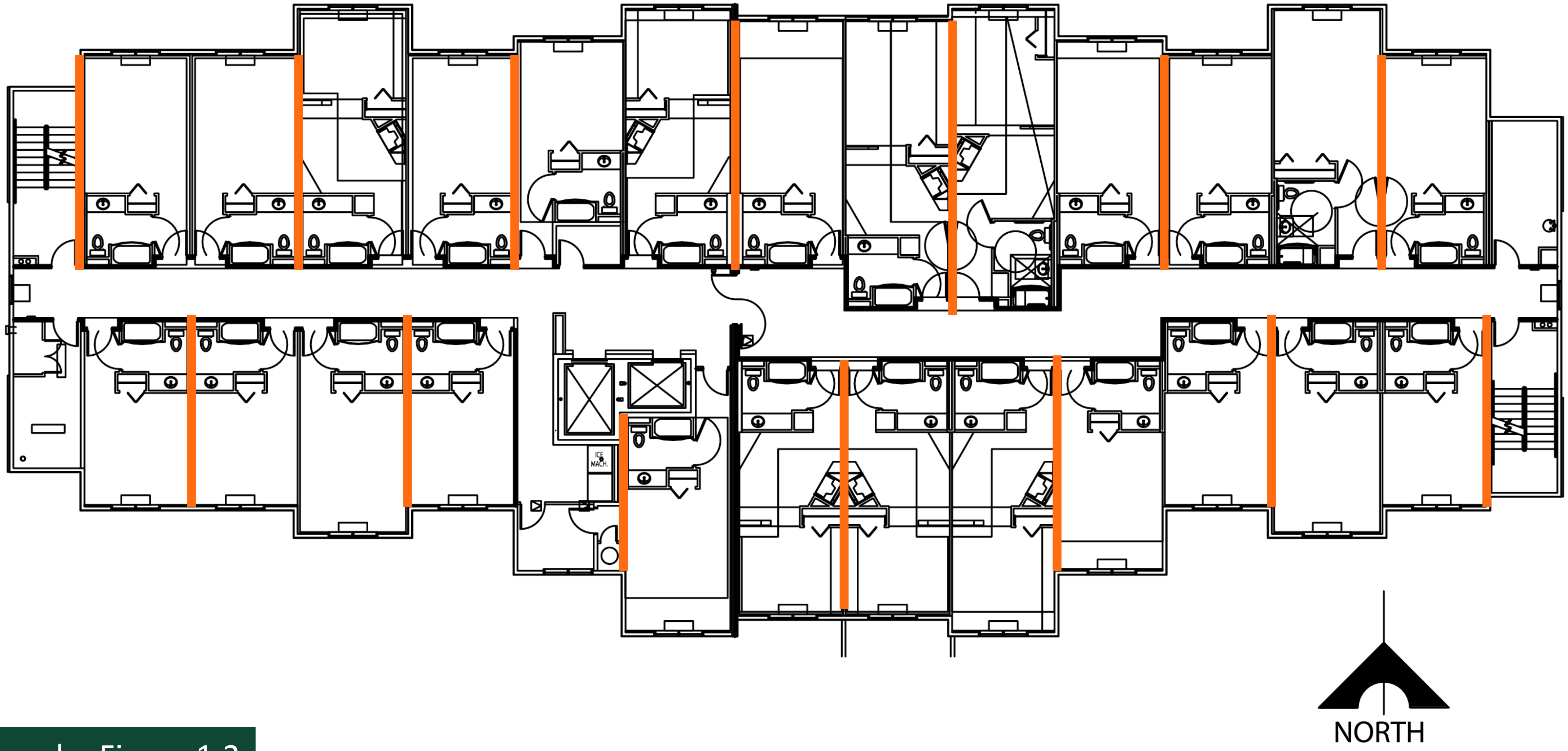
Seismic System Height Limits (SDC D-F)

Design Example: Building Elevation



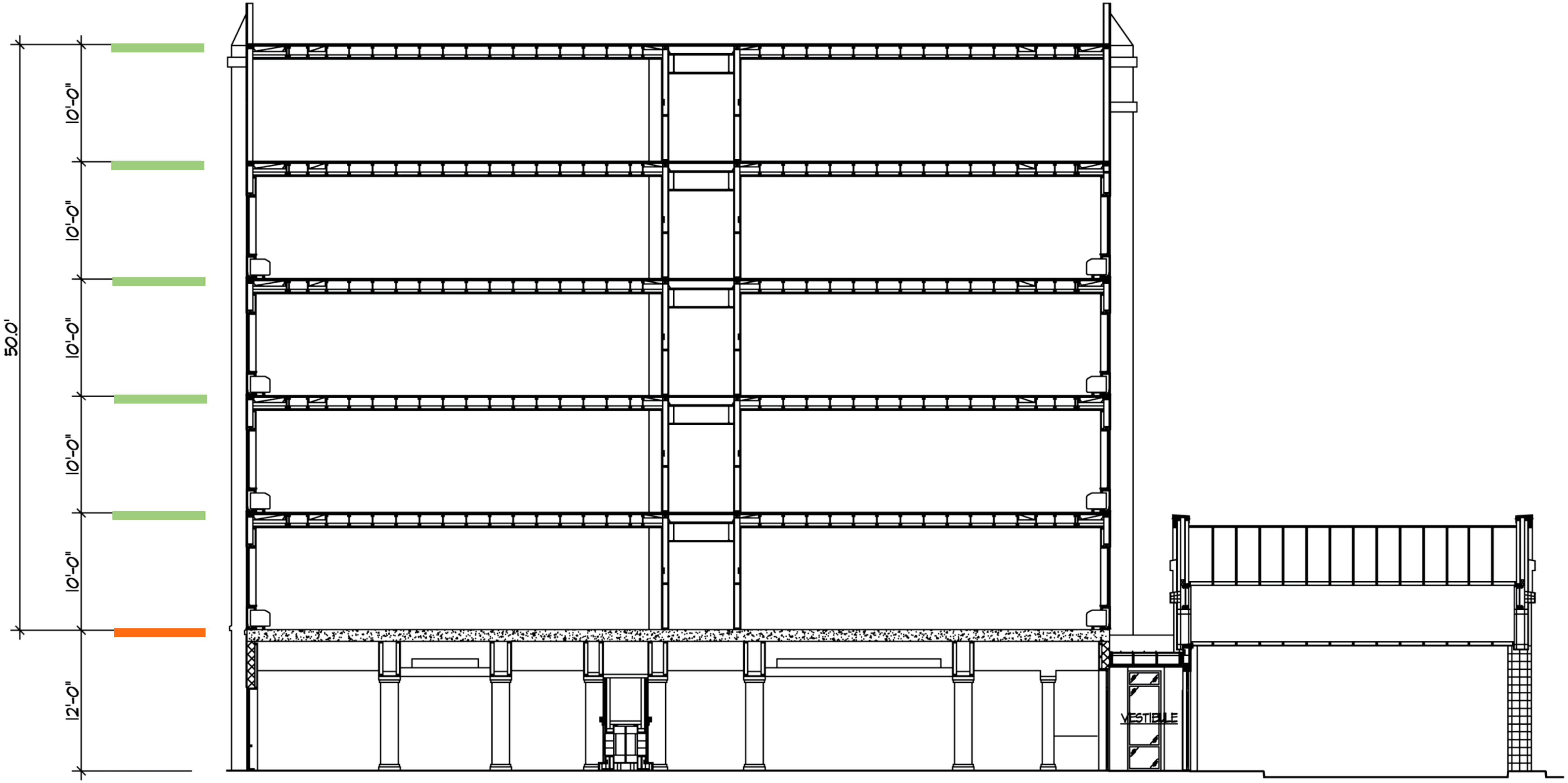
Design Example: Figure 1.1

Design Example: Plan View



Design Example: Figure 1.2

Design Example: Building Section



Design Example: Figure 1.3

Design Example: Gravity Loads

Roof Weights (psf)	
Roofing	5.0
Sheathing	3.0
Trusses + blocking	2.0
Insulation + sprinklers	2.0
Ceiling + misc.	15.0
Beams	1.0
Dead load	**28.0**
Live load	**20.0**

Floor Weights (psf)	
Flooring	1.0
Lightweight concrete	14.0
Sheathing	2.5
I-joist + blocking	4.0
Ceiling + misc.	7.0
Beams	1.5
Dead load	**30.0**
Live load	**40.0**

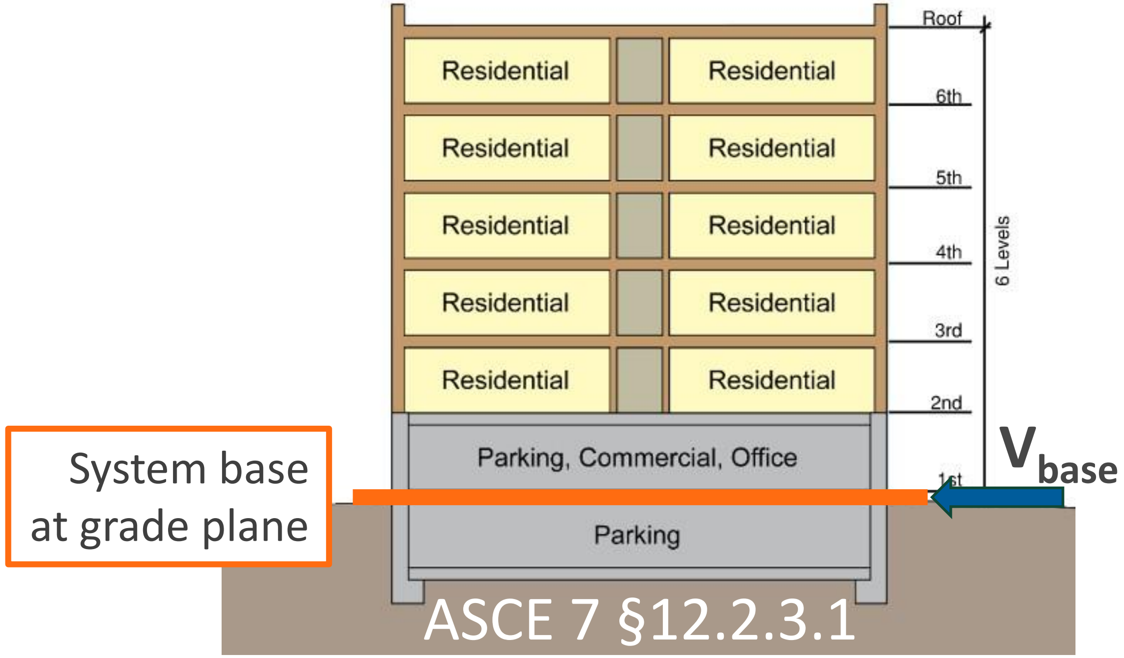
Design Example: Table 1.1

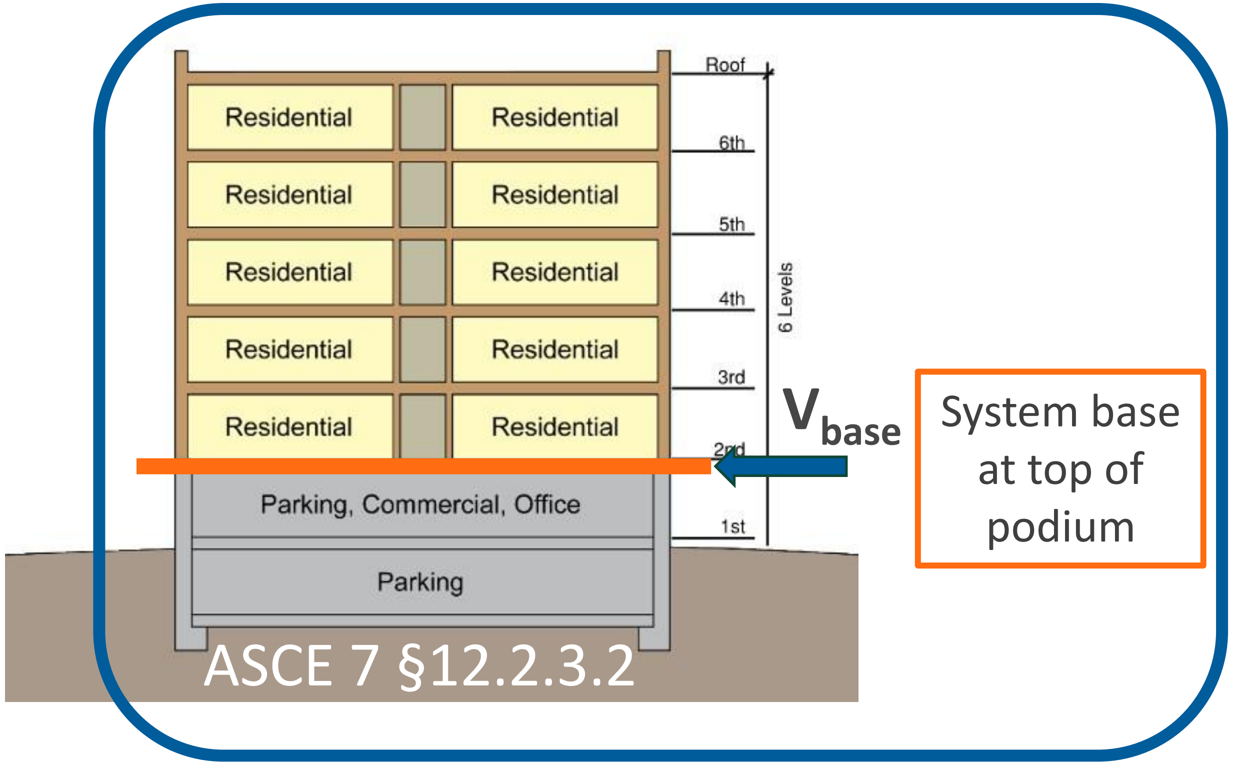
Two-Stage Seismic Analysis

- Several options for vertical combination of seismic force-resisting systems (SFRS)
- Occurs when there are different R factors for the upper/lower portions
- Section 12.2.3.1 lets you design upper/lower separately, but have to treat entire building as one mass
- **Section 12.2.3.2** lets you design upper/lower separately *and* define the base of the upper structure as the top of the lower structure
  - Prevents the mass of the concrete podium from being inverted into the upper wood portion of the building

Seismic Base

- Base is the level at which horizontal seismic ground motions are imparted
- Base = top of podium (see ASCE 7 Section 12.2.3.2 item f)





Two-Stage Seismic Analysis

"Flexible upper portion above a rigid lower portion"

- Stiffness of lower ≥ 10x Stiffness of upper
- Period of structure ≤ 1.1x Period of upper
- Upper designed using R_{upper} and ρ_{upper}
- Lower designed using R_{lower} and ρ_{lower}
- Reactions from upper amplified by $(R/\rho)_{upper} / (R/\rho)_{lower} \geq 1$
- Upper analyzed with ELF or modal response
- Lower analyzed with ELF
- Upper SFRS height limits measured from base of upper
- Lower portion designed for overstrength as required

Two-Stage Seismic Analysis

"Flexible upper portion above a rigid lower portion"

» **Stiffness of lower ≥ 10x Stiffness of upper**

» Stiffness, $k = F/\delta$

» Upper: for flexible diaphragms, use stiffness of a representative wall (engineering judgement) based on shear wall loads & deflections

» Lower: for rigid, use stiffness from 3-D analysis

Flexible vs Rigid Diaphragms

- Idealized as **flexible** per ASCE 7-22 Section 12.3.1.1
- Calculated as **flexible** per ASCE 7-22 Section 12.3.1.3

- Calculated as **rigid** per SDPWS Section 4.1.7.2

- If none of the above, assume **semi-rigid**

Save the Date:

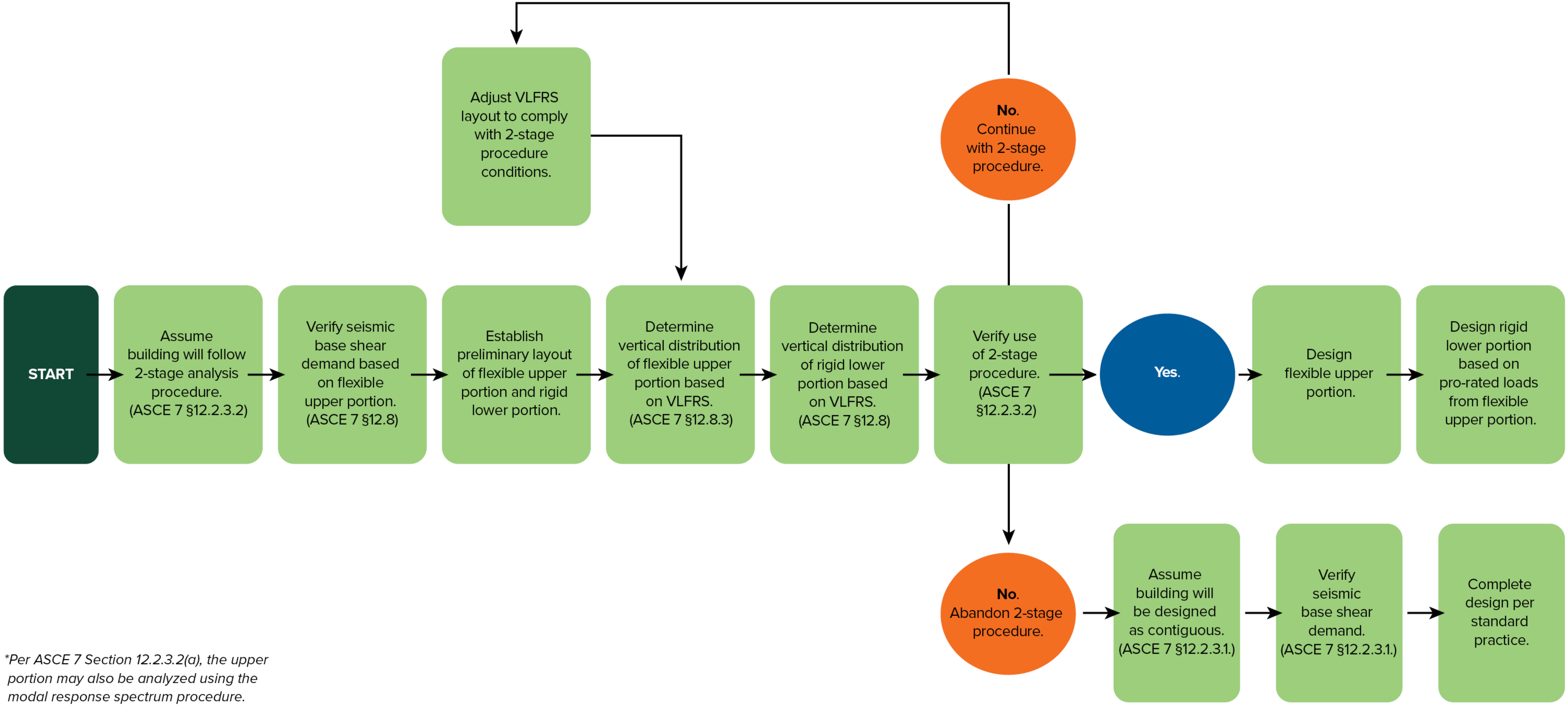
Our December 10, 2025 webinar will cover this topic in more detail!

Two-Stage Seismic Analysis

"Flexible upper portion above a rigid lower portion"

- **Period of structure ≤ 1.1x Period of upper**
- ASCE 7 Eq. 12.8-8:
  - $T_a = C_t (h_n)^x$
  - Often doesn't meet criteria
- Rayleigh's Method (ASCE 41):
  - $T = 2\pi \sqrt{\left(\sum_{i=1}^{n} w_i \delta_i^2\right) / \left(g \sum_{i=1}^{n} f_i \delta_i\right)}$

Seismic Design Workflow



Per ASCE 7 Section 12.2.3.2(a), the upper portion may also be analyzed using the modal response spectrum procedure.

Design Example: Figure 3.1

Seismic Design Criteria

ASCE 7 Table 12.2-1

Light-frame wood walls sheathed with wood structural panels rated for shear resistance

» $R = 6.5$

» $\Omega_0 = 3.0$*

» $C_d = 4.0$

Special reinforced concrete shear walls

» $R = 5.0$

» $\Omega_0 = 2.5$

» $C_d = 5.0$

* Reduced to 2.5 for flexible diaphragms

Seismic & Site Data

- Site Class: D
- S_S = 1.808 g
- S_1 = 0.692 g
- S_{DS} = 1.206 g
- S_{D1} = 0.692 g

- Risk Category: II
- Seismic Importance Factor: 1.0
- **Seismic Design Category: D**

- Seismic Response Coefficient,
  C_S = 0.186
- Seismic weight, W = 2,460 k
- Base Shear,
  V = 0.186(2,460) = **458 k**

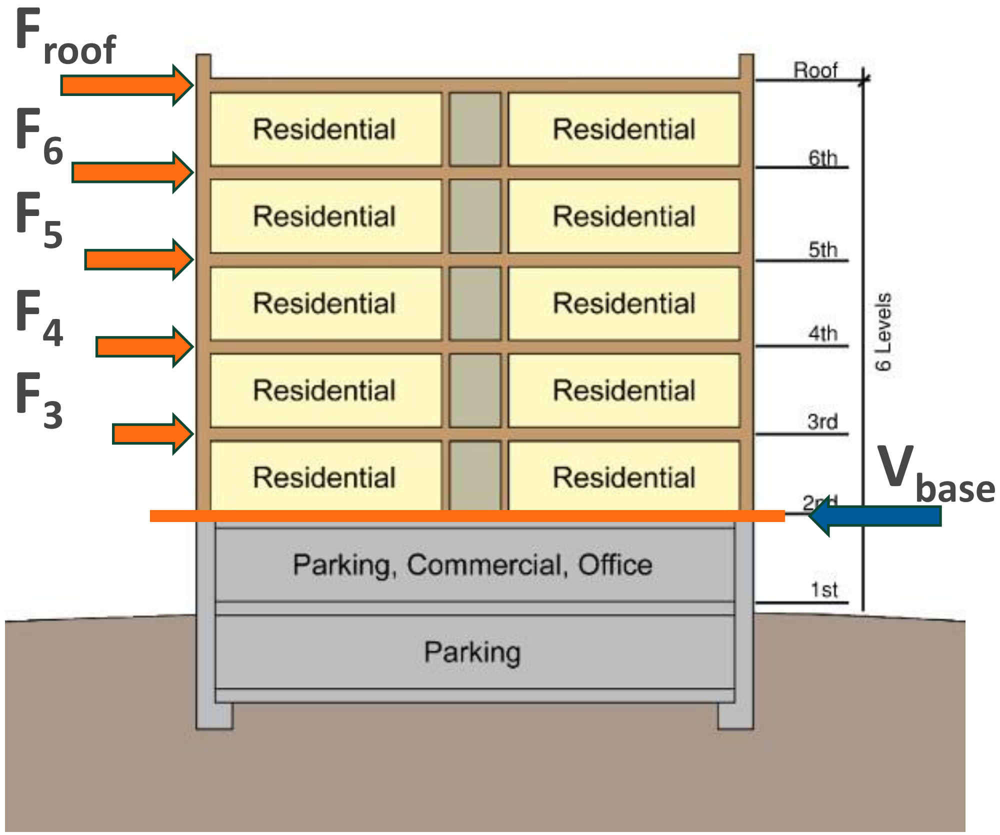
Seismic Story Forces

» Story Force, $F_x = C_{vx} * V$

Table 3.1: Vertical distribution of seismic forces

Level	W_x (kips)	C_{vx}	F_x (kips)	F_x/A (psf)
Roof	420	29%	133.5	11.12
6th	510	28%	129.6	10.80
5th	510	21%	97.2	8.10
4th	510	14%	64.8	5.40
3rd	510	7%	32.4	2.70
Sum	2,460	100%	458	

A = area of the floor plate, which is 12,000 ft^2



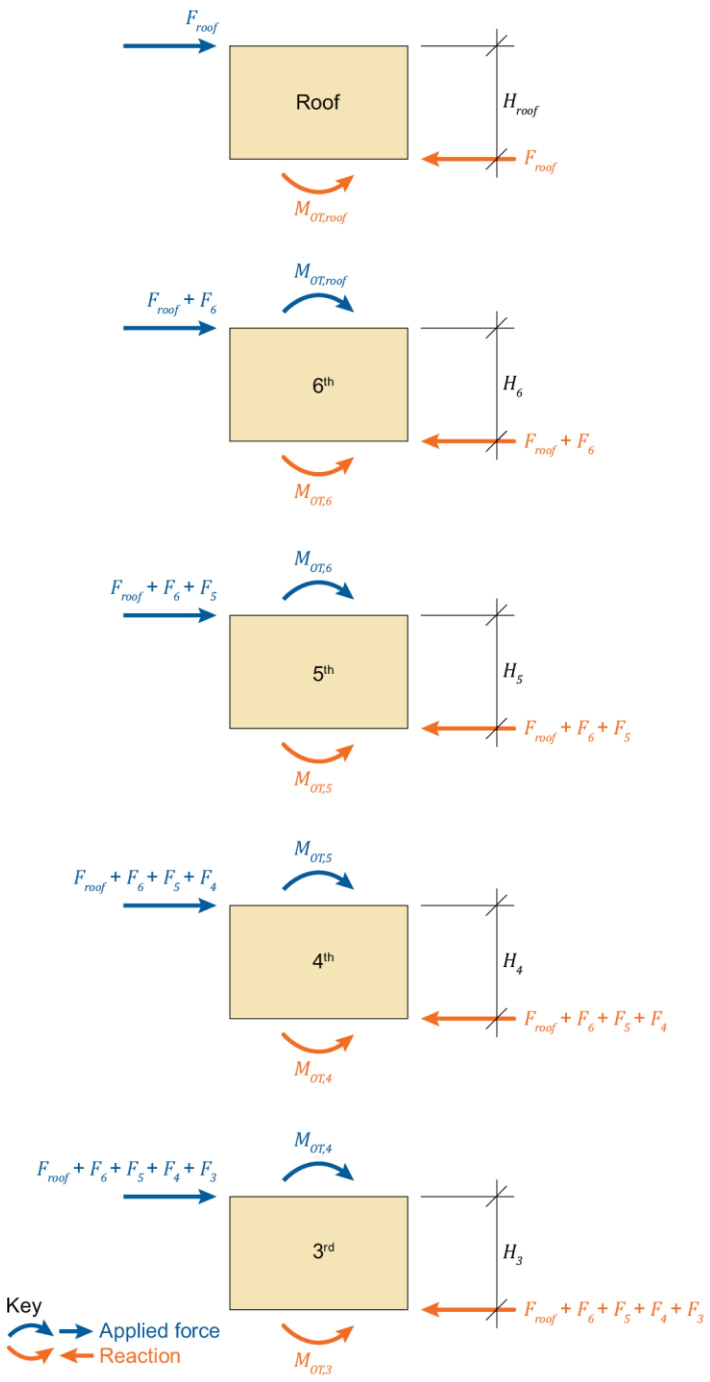
Design Example: Section 3.1.1 & Table 3.1

Seismic Forces to Typical Shear Wall

Table 3.4: Seismic forces to shear wall

Level	Story-Level Force, F (lb)	Cumulative Force, F_{total} (lb)
Roof	9,397	9,397
6th	9,129	18,526
5th	6,847	25,373
4th	4,564	29,938
3rd	2,282	32,220

Tributary Area from example is 845 sq ft.



Design Example: Table 3.4 & Figure 3.5

Shear Wall Design

Single Table for Wind and Seismic

Sheathing

Fastener Spacing

Fasteners

Table 4.3A Nominal Unit Shear Capacities for Sheathed Wood-Frame Shear Walls [1,3,6]

Wood-based Panels [4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimum Nail Bearing Length in Framing Member or Blocking, ℓ_m (in.)	Nail Type & Size [9] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Panel Edge Nail Spacing (in.) 6 v_n (plf)	6 G_a (kips/in.) OSB	6 G_a PLY	4 v_n (plf)	4 G_a (kips/in.) OSB	4 G_a PLY	3 v_n (plf)	3 G_a (kips/in.) OSB	3 G_a PLY	2 v_n (plf)	2 G_a (kips/in.) OSB	2 G_a PLY
Wood Structural Panels - Structural I [4,5]	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	560	13	10	840	18	13	1090	23	16	1430	35	22
	3/8 [2]	1-3/8	8d common nail (2-1/2 x 0.131 x 0.281) [8]	645	19	14	1010	24	17	1290	30	20	1710	43	24
	7/16 [2]			715	16	13	1105	21	16	1415	27	19	1875	40	24
	15/32			785	14	11	1205	18	14	1540	24	17	2045	37	23
	15/32	1-1/2	10d common nail (3 x 0.148 x 0.312) [8,10]	950	22	16	1430	29	20	1860	36	22	2435	51	28
Wood Structural Panels - Sheathing [4,5]	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	505	13	9.5	755	18	12	980	24	14	1260	37	18
	3/8			560	11	8.5	840	15	11	1090	20	13	1430	32	17
	3/8 [2]	1-3/8	8d common nail (2-1/2 x 0.131 x 0.281) [8]	615	17	12	895	25	15	1150	31	17	1485	45	20
	7/16 [2]			670	15	11	980	22	14	1260	28	17	1640	42	21
	15/32			730	13	10	1065	19	13	1370	25	15	1790	39	20
	15/32	1-1/2	10d common nail (3 x 0.148 x 0.312) [8,10]	870	22	14	1290	30	17	1680	37	19	2155	52	23
	19/32			950	19	13	1430	26	16	1860	33	18	2435	48	22
Plywood Siding	5/16	1-1/4	6d galv.[7] casing nail (2 x 0.099 x 0.142)	390	13		590	16		770	17		1010	21	
	3/8	1-3/8	8d galv.[7] casing nail (2-1/2 x 0.113 x 0.155)	450	16		670	18		870	20		1150	22	
Particleboard Sheathing - (M-S "Exterior Glue" and M-2 "Exterior Glue")	3/8		6d common nail (2 x 0.113 x 0.266) [8]	335	15		505	17		645	19		840	22	
	3/8		8d common nail (2-1/2 x 0.131 x 0.281) [8]	365	18		530	20		670	21		880	23	
	1/2			390	18		590	20		755	22		980	24	
	1/2		10d common nail (3 x 0.148 x 0.312) [8]	520	21		770	23		1010	24		1290	25	
	5/8			560	21		855	23		1105	24		1455	26	
Structural Fiberboard Sheathing	1/2		11 ga. galv.[7] roofing nail (1-1/2 x 0.120 x 7/16)				475	4.0		645	5.0		730	5.5	
	25/32		11 ga. galv.[7] roofing nail (1-3/4 x 0.120 x 3/8)				475	4.0		645	5.0		730	5.5	

2021 AWC SDPWS

Shear Wall Design

- SDPWS 2021:
  - ASD, seismic: $v_{ASD} = v_{nom}/2.8$
  - ASD, wind: $v_{ASD} = v_{nom}/2.0$
  - LRFD, seismic: $v_{LRFD} = v_{nom} * 0.50$
  - LRFD, wind: $v_{LRFD} = v_{nom} * 0.80$

Read the footnotes!

- Reduce capacities if not Douglas-Fir-Larch or Southern Pine

Shear Wall Design

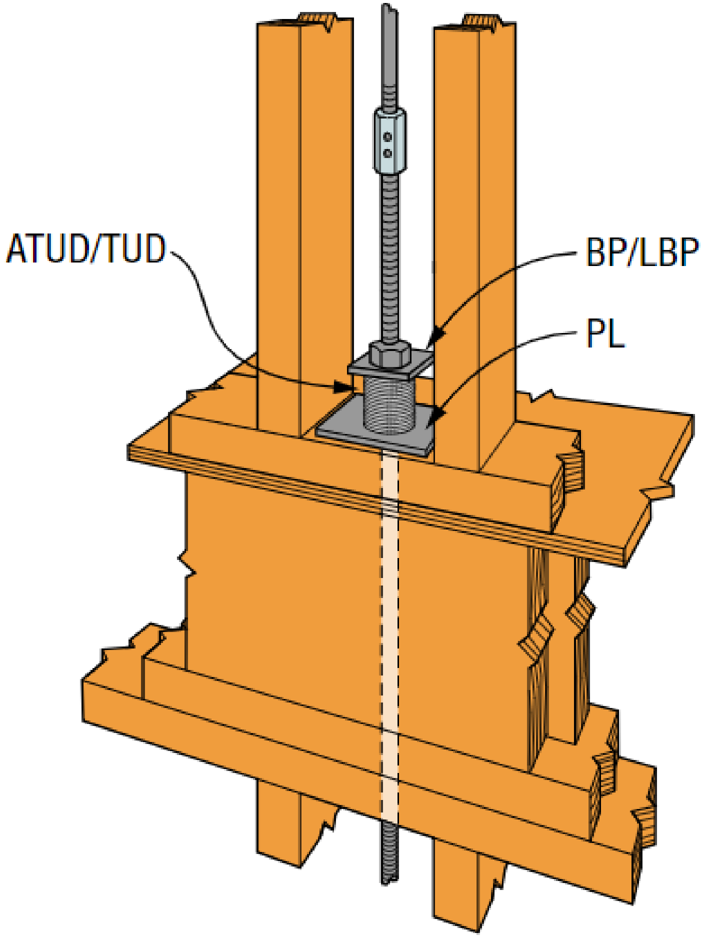
Sheathing and Nailing

Level	F_{total} (lb)	Wall Length (ft)	ASD Design Shear (plf)	Wall Sheathed 1 or 2 sides	Edge Nailing (in. o.c.)	Allowable Shear (plf)
Roof	9,397	29	227	1	6	310
6th	18,526	29	447	1	4	460
5th	25,373	29	612	1	2	770
4th	29,938	29	723	1	2	770
3rd	32,220	29	778	2	4	920

Design Example: Table 3.5

Shear Wall Design

Continuous Tiedown System



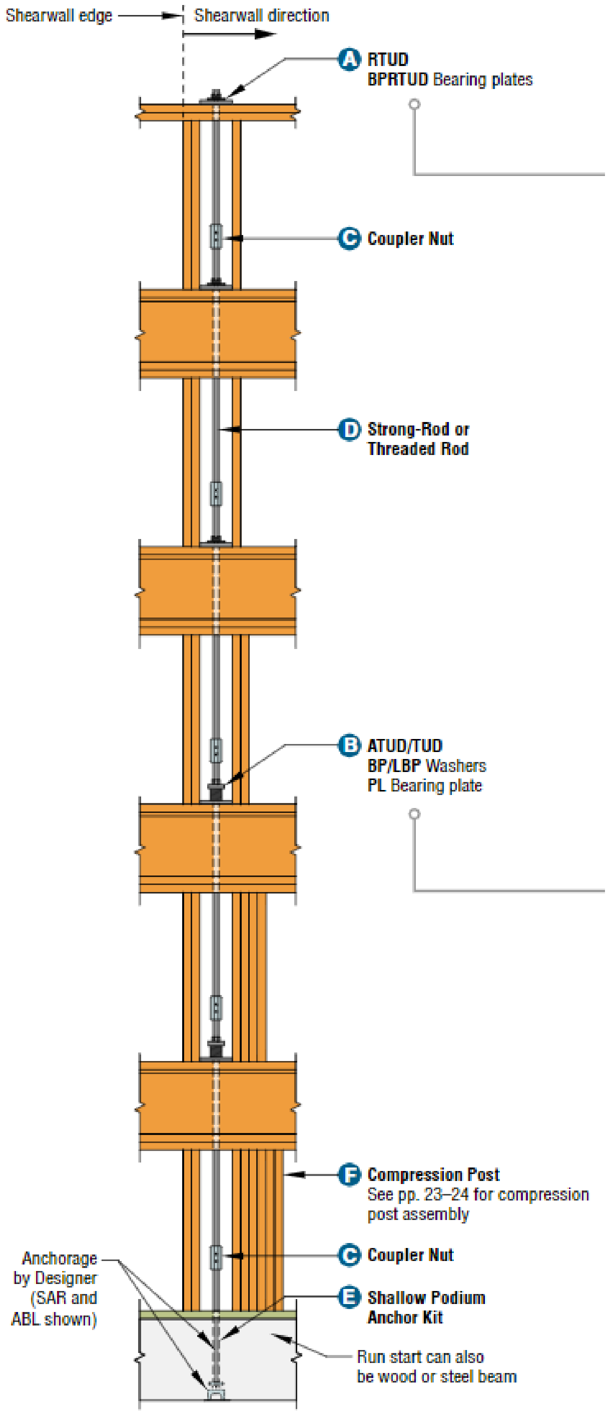
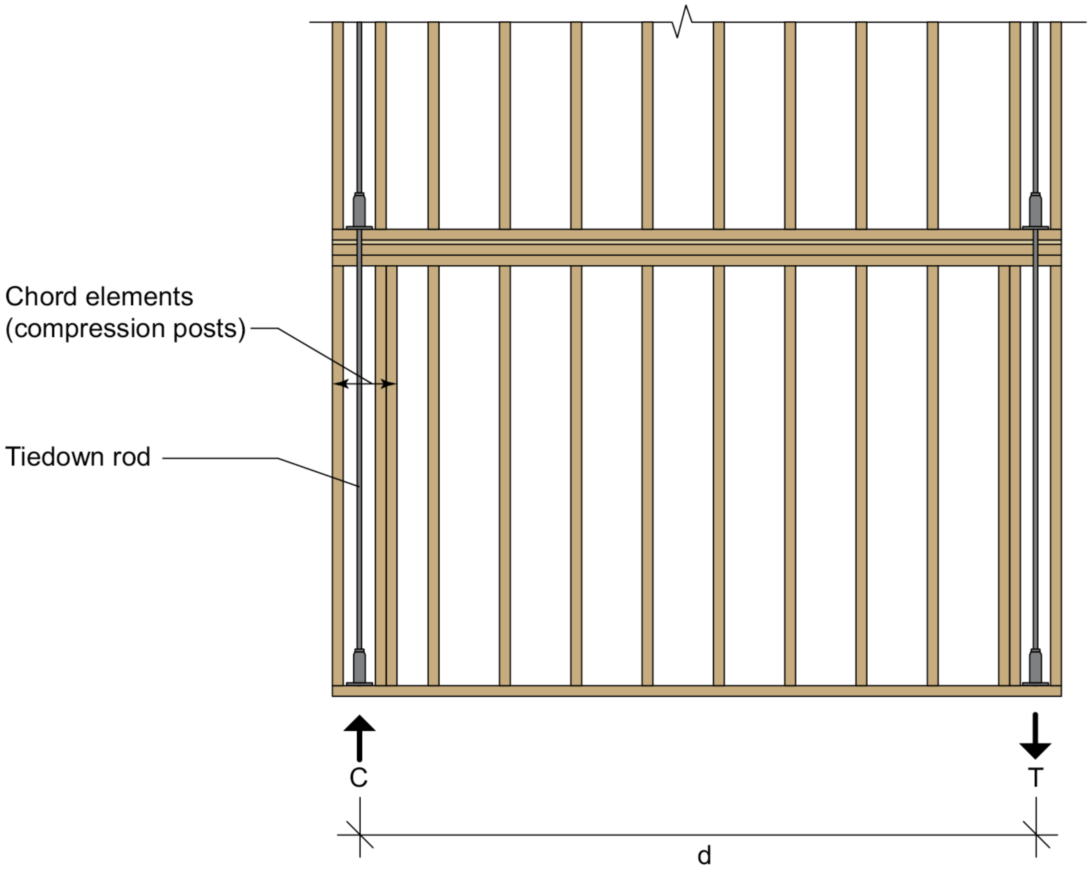
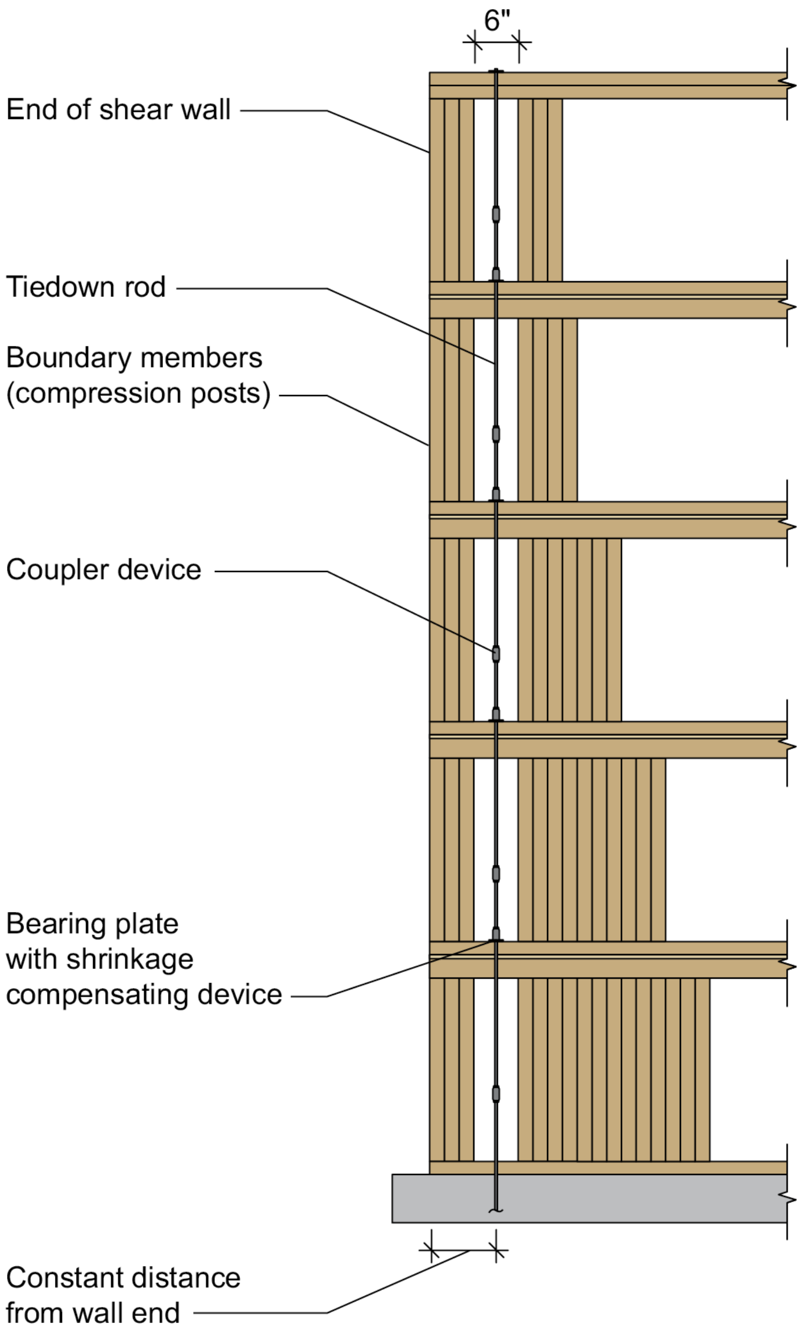


Image: Simpson Strong-Tie

Shear Wall Design

Compression Chord





Design Example: Section 3.3.5 and Figures 3.6 & 3.8

Shear Wall Design
Compression Chord

$F'_c = 450 \text{ psi}$ $F'_{c\perp} = 625 \text{ psi}$

Level	Chord Posts	Area (in.^{2})	P_{allow} (k)	Compression Demand (k)	D-C Ratio
Roof	(6) 2x4	31.5	14.19	2.60	18%
6th	(7) 2x4	36.8	16.55	8.11	49%
5th	(10) 2x4	52.5	23.65	15.94	67%
4th	(13) 2x4	68.3	30.74	25.48	83%
3rd	(16) 2x4	84.0	37.84	36.15	96%

Shear Wall Design
Tension Rod

$F_u = 58 \text{ ksi}$ $F_{nt} = 43.5 \text{ ksi}$

Level	Rod Diameter (in.)	A_g (in.^{2})	P_{allow} (k)	Tension Demand (k)	D-C Ratio
Roof	5/8	0.307	14.19	1.351	20%
6th	5/8	0.307	16.55	2.833	42%
5th	3/4	0.442	23.65	6.099	63%
4th	1	0.785	30.74	10.591	62%
3rd	1 1/8	0.994	37.84	15.742	73%

Shear Wall Design
Bearing Plate

- Check bearing capacity
- Check plate bending (not shown)

Level	Bearing Plate Size (in.)	A_{Brg} (in.^{2})	Bearing Capacity (k)	Bearing Demand (k)	D-C Ratio
Roof	3 x 3 x 3/8	8.48	14.19	1.351	23%
6th	3 x 3 x 3/8	8.48	16.55	1.482	25%
5th	3 x 3 ½ x 1/2	9.81	23.65	3.266	48%
4th	3 x 4 x 5/8	10.89	30.74	4.492	60%
3rd	3 x 4 x 5/8	10.65	37.84	5.151	71%

Shear Wall Deflection

$$\delta_{sw} = \frac{8vh^3}{EAb} + \frac{vh}{1{,}000G_a} + \frac{h\Delta_a}{b}$$ (SPDWS Equation 4.3-1)

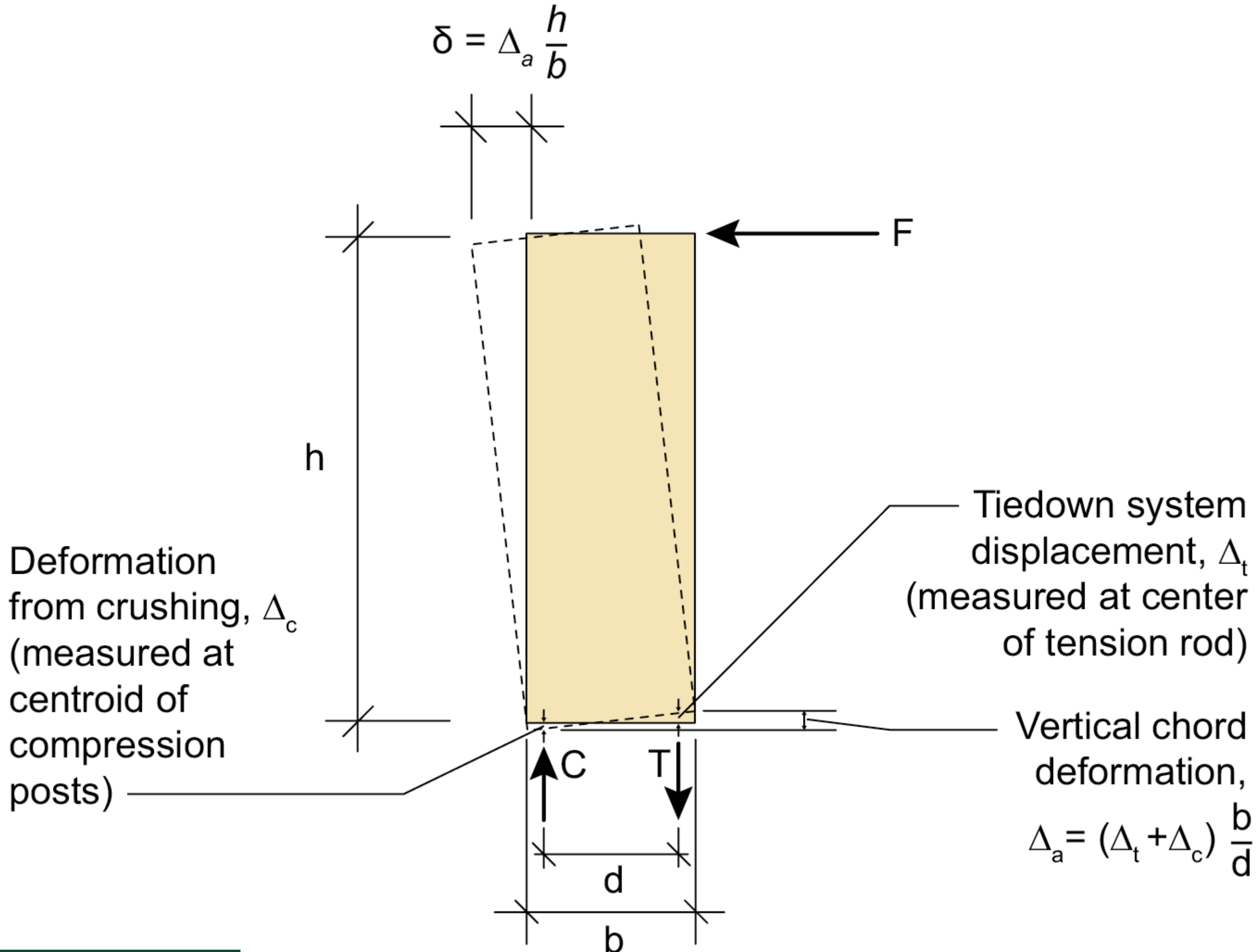
Bending deformation

Shear deformation + nail slip

Rigid body rotation

- $v =$ unit shear
- $E =$ modulus of elasticity of end posts
- $A =$ cross sectional area of end posts
- $G_a =$ apparent shear stiffness
- $b =$ shear wall length
- $h =$ shear wall height
- $\Delta_a =$ vertical deformation of wall anchorage system

Vertical Chord Deformation, Δ_a



Design Example: Section 3.4.3 & Figure 3.9

Vertical Chord Deformation, Δ_a

Level	Rod Elongation (in.)	Take-Up Device Slack (in.)	Take-Up Device Elongation (in.)	Crushing Under Post (in.)	Bearing Plate Crushing (in.)	Δ_a (in.)
Roof	0.033	0.031	0.030	0.021	0.009	0.131
6th	0.066	0.031	0.030	0.052	0.009	0.199
5th	0.099	0.031	0.030	0.078	0.019	0.272
4th	0.096	0.031	0.030	0.100	0.032	0.309
3rd	0.114	0.031	0.030	0.046	0.047	0.289

Shear Wall Deflection (3-terms)

$$\delta_{sw} = \frac{8vh^3}{EAb} + \frac{vh}{1{,}000G_a} + \frac{h\Delta_a}{b}$$

Level	Shear Force (plf)	Chord Post Area (in.^{2})	Edge Nailing	G_a (k/in.)	Δ_a (in.)	1st Term (in.)	2nd Term (in.)	3rd Term (in.)	δ_e (in.)
Roof	324	31.5	6” o.c.	22	0.131	0.002	0.147	0.045	0.194
6th	639	36.8	4” o.c.	30	0.199	0.003	0.213	0.069	0.284
5th	875	52.5	2” o.c.	52	0.272	0.003	0.168	0.094	0.265
4th	1,032	68.3	2” o.c.	52	0.309	0.002	0.199	0.107	0.307
3rd	1,111	84.0	2 x 4” o.c.	60	0.289	0.002	0.185	0.100	0.287

Design Example: Section 3.4.4 & Table 3.18

Story Drift

$$\delta_{DE} = \frac{C_d \delta_e}{I_e} + \cancel{\delta_{di}}, \qquad C_d = 4.0$$

$$\Delta_{allow} = 0.020 h_{sx}$$

Level	δ_e (in.)	δ_{DE} (in.)	Story Height (ft)	Δ_{allow} (in.)
Roof	0.194	0.78	10	2.40
6th	0.284	1.14	10	2.40
5th	0.265	1.06	10	2.40
4th	0.307	1.23	10	2.40
3rd	0.287	1.15	10	2.40

Reactions to Podium

- Gravity reactions applied directly to podium (no scaling)
- Seismic reactions (shear and overturning) from wood scaled up and applied to podium
  - $(R/\rho)_{upper} / (R/\rho)_{lower} \geq 1$
  - Shear: often accounted for as a seismic weight included in concrete base shear calculation
  - Overturning often accounted for as point load reactions from wood shear walls

Overstrength Loads

Podium supports **discontinuous walls**

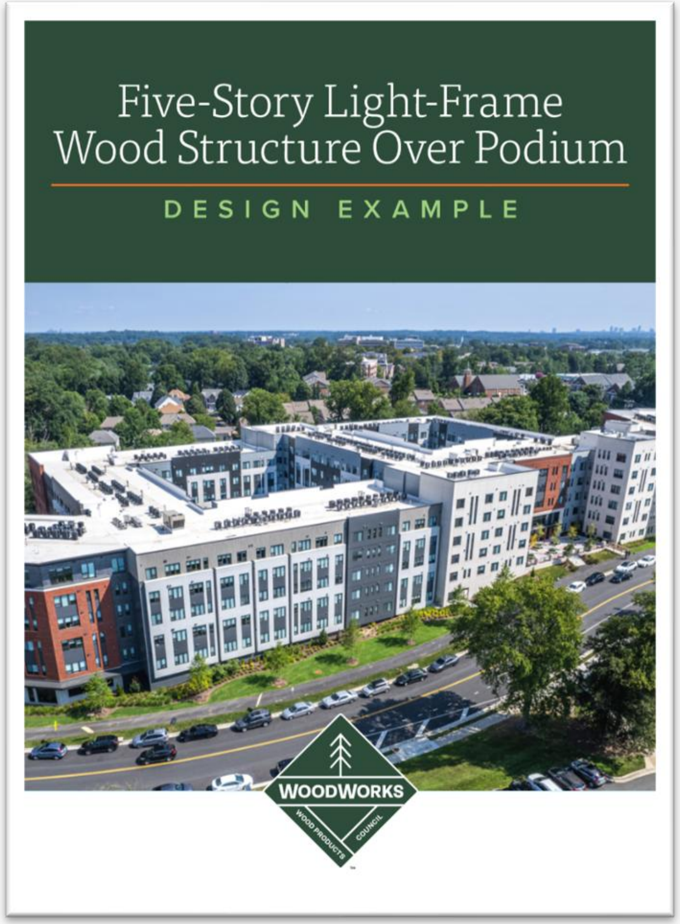
- Shear and point loads must include overstrength, Ω_0, for the design of the podium
- In ASCE 7, *connections* need not include overstrength (i.e. sill plate anchors, tiedown anchors)
- In ACI 318, anchorage to concrete *may* require overstrength

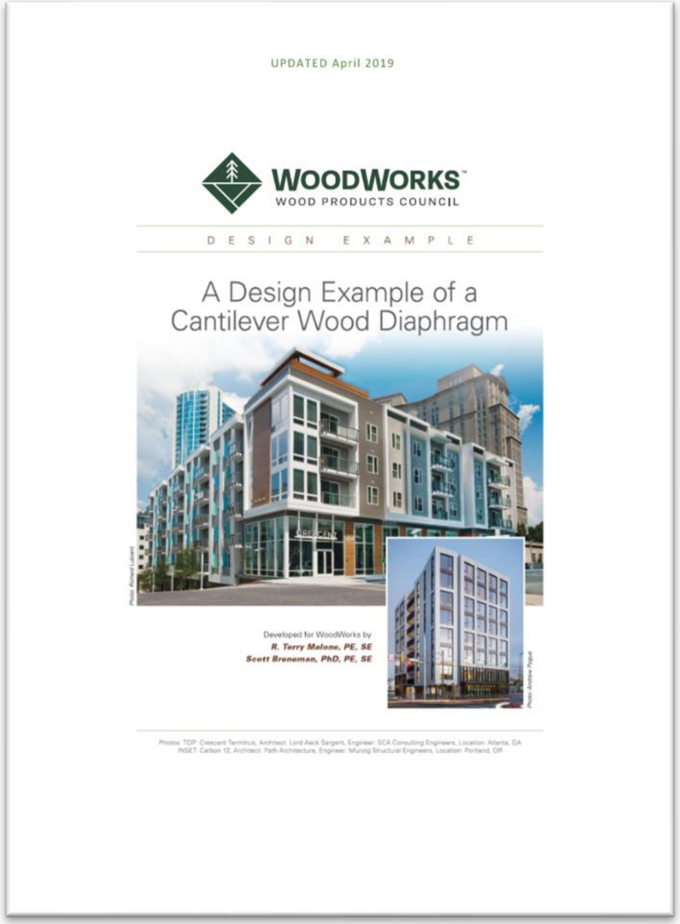
Overstrength Loads

Alternative to $\Omega_0 = 3.0$

- Seismic overstrength load "*need not be taken as larger than… the capacity-limited horizontal seismic load effect*" which is equal to *"the maximum force that can develop in the element as determined by a rational, plastic mechanism analysis."*
- Yielding of other elements limits the load that can be delivered to the system

Key Resources





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Accommodating Shrinkage in Multi-Story Wood-Frame Structures

Richard McLain, MS, PE, SE, Senior Technical Director – Tall Wood, WoodWorks • Doug Steimle, PE, Principal, Schaefer

In wood-frame buildings of three or more stories, cumulative shrinkage can be significant and have an impact on the function and performance of finishes, openings, mechanical/electrical/plumbing (MEP) systems, and structural connections. However, as more designers look to wood-frame construction to improve the cost and sustainability of their mid-rise projects, many have learned that accommodating wood shrinkage is actually very straightforward.

Wood is hygroscopic, meaning it has the ability to absorb and release moisture. As this occurs, it also has the potential to change dimensionally. Knowing how and where wood shrinks and swells helps designers detail their buildings to minimize related effects.

Wood shrinkage occurs perpendicular to grain, meaning that a solid sawn wood stud or floor joist will shrink in its cross-section dimensions (width and depth). Longitudinal shrinkage is negligible, meaning the length of a stud or floor joist will essentially remain unchanged. In multi-story buildings, wood shrinkage is therefore concentrated at the wall plates, floor and roof joists, and rim boards. Depending on the materials and details used at floor-to-wall and roof-to-wall intersections, shrinkage in light-frame wood construction can range from 0.05 inches to 0.5 inches per level.

This publication will describe procedures for estimating wood shrinkage and provide detailing options that minimize its effects on building performance.

The Brooklyn Riverside
Jacksonville, Florida
Architect: Dwell Design Studio
Structural Engineer: M2 Structural Engineering

Photo: Pollack Shores, Matrix Residential

Wood Science & Shrinkage

Understanding the cellular structure of wood allows us to understand how moisture and wood interact and identify the paths that moisture typically travels. Within wood, moisture is present in two forms: (1) free water in cell cavities, and (2) bound water in cell walls. Simplistically, wood's cellular structure can be imagined as a bundle of drinking straws held together with a rubber band, with each straw representing a longitudinal cell in the wood. Water can be free water stored in the straw cavity or bound water absorbed by the straw walls. At high moisture contents, water exists in both locations. As the wood dries, the free water is released from the cell cavities before the bound water is released from the cell walls. When wood has no free water and yet the cell wall is still saturated, it is said to be at its fiber saturation point (FSP). Imagine a sponge that has just been taken out of a bucket filled with water. As the sponge is lifted from the bucket, water comes out of the pores. When the sponge is squeezed, more water comes out of the pores. The moment when no water can be squeezed out of the sponge but yet it still feels damp is analogous to the FSP. The moisture retained in the sponge is the bound water and water that has been squeezed out is the free water.

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

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