Opportunities for Wood Use in Low Rise Commercial Buildings

September 12, 2023

Presented by
John O'Donald II, PE
WoodWorks

"The Wood Products Council" is a Registered Provider with The American Institute of Architects Continuing Education Systems (AIA/CES), Provider #G516.

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

AIA Approved Continuing Education

Course Description

This course is intended for designers who want to learn more about the use of wood-frame construction for low-rise retail, office and restaurant occupancies designed under the International Building Code. Topics covered include common framing systems and details, paths to code compliance and tall wall design.

Learning Objectives

1. Review permitted applications of wood-frame construction in the International Building Code in low-rise commercial buildings, with an emphasis on retail, office and restaurant occupancies.
2. Consider detailing options for the framing of common features in low-rise commercial buildings, such as flat roofs, parapets and open front floor plans.
3. Examine code requirements pertaining to multi-occupancy buildings and different paths to compliance.
4. Evaluate opportunities for tall wall framing with wood construction and understand the design requirements for code compliance.

Outline

- Introduction
- Framing System Design and Details
  - Structural Design Compliance
  - Wall Framing
  - Wall Bracing
  - Roof Framing
- Non-Structural Requirements and Design
  - Allowable Heights and Areas
  - Multi-Tenant and Multi-Occupancy Buildings
  - Fire Resistance and Detailing
- Large Retail Project Case Study

Outline

- Introduction
  - Framing System Design and Details
    - Structural Design Compliance
    - Wall Framing
    - Wall Bracing
    - Roof Framing
  - Non-Structural Requirements and Design
    - Allowable Heights and Areas
    - Multi-Tenant and Multi-Occupancy Buildings
    - Fire Resistance and Detailing
  - Large Retail Project Case Study

Why Wood?

Using wood helps reduce environmental impact
Wood products play significant role in modern economy

- Wood Costs Less
- Wood is Versatile
- Wood Meets Code
- Wood is Durable
- Wood is Renewable

Photo courtesy OFRI

The Gibson, Hummel Architects, KPFF Consulting Engineers, photo Leo A. Geis

Carbon Benefits of Wood

- **Less energy intensive** to manufacture than steel or concrete
- **Less fossil fuel consumed** during manufacture
- **Avoid process emissions**
- Carbon **storage in forests** and **promote forest health**
- Extended carbon **storage in products**

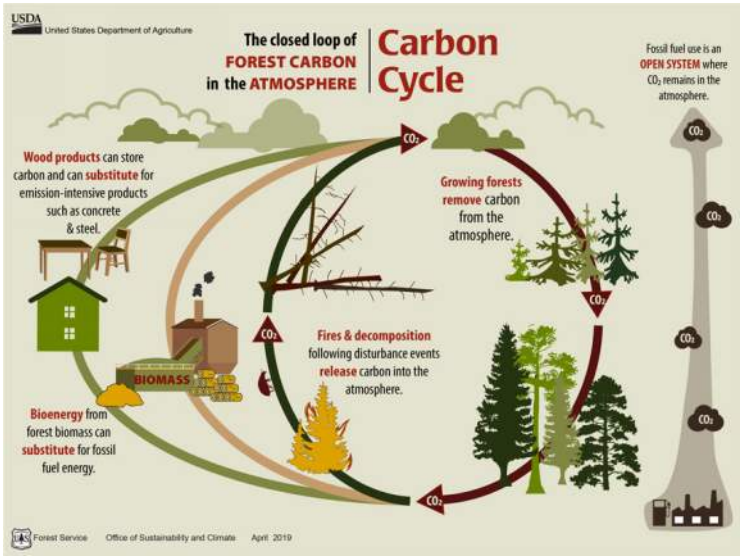


Image: USDA US Forest Service

Herrington Recovery Center – Roger's Memorial Hospital

Oconomowoc, WI

- 3 stories; 21,000 square feet, 20 bed treatment facility
- Safe, confidential facility
- Institutional building with a **residential feel**
- Serene, spiritual environment; **biophilic** properties of wood
- LEED Silver
- **Locally available** wood products

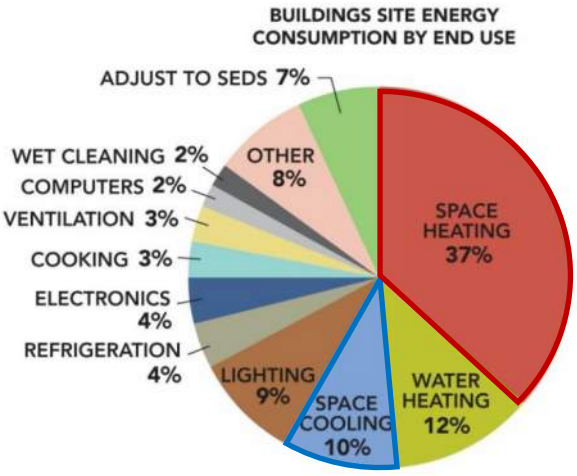
Architect: TWP Architecture
Structural Engineer: Pujara Wirth Torke, Inc.

Herrington Recovery Center – Roger's Memorial Hospital
Oconomowoc, WI

Architect: TWP Architecture
Structural Engineer: Pujara Wirth Torke, Inc.

Estimated by the Wood Carbon Calculator for Buildings, based on research by Sarthre, R. and J. O'Connor, 2010, A Synthesis of Research on Wood Products and Greenhouse Gas Impacts, FPInnovations. Note: CO_2 on this chart refers to CO_2 equivalent.

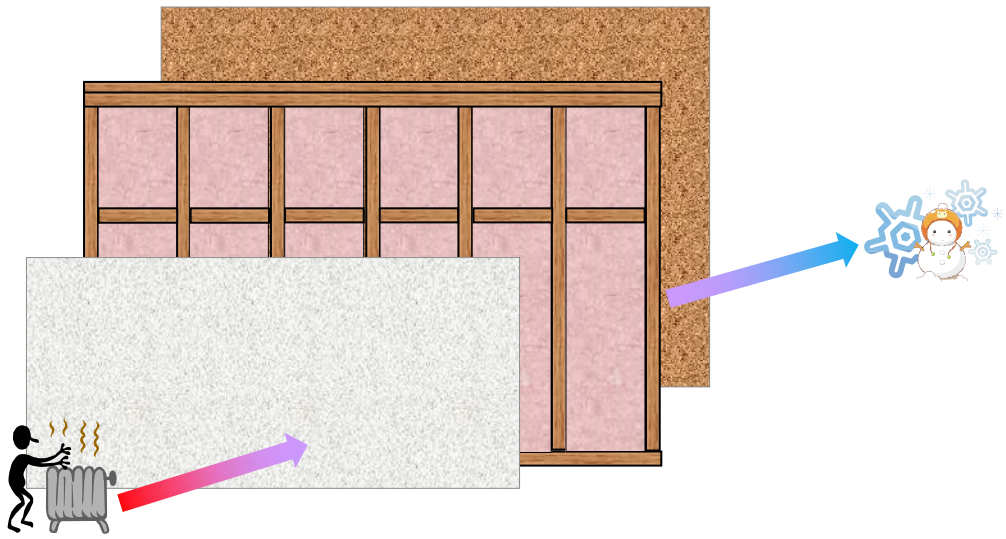
Energy Use of US Buildings



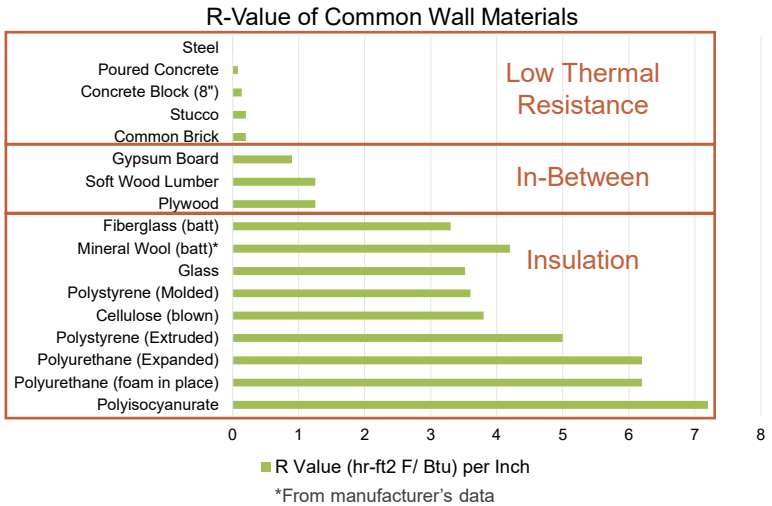
47% of energy goes to HVAC Systems

Source: US DOE Buildings Energy Data Book (2011 Data)

Thermal Performance of Walls

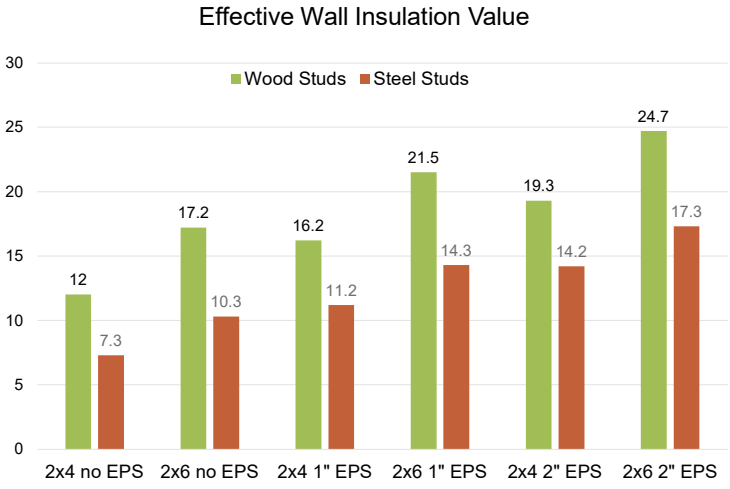


Thermal Conductivity of Materials



Data Source: "Building Construction Illustrated" 3rd Edition (2001). Ching & Adams

Wood vs Steel Framing



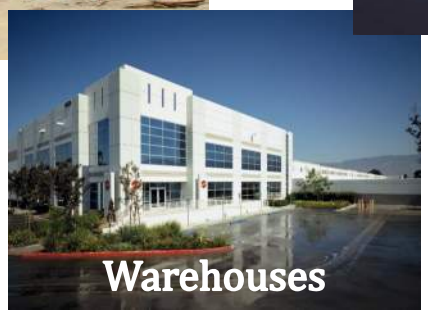
Thermal Performance of Light Frame Structures-CWC, Wood Handbook – FPL USDA

Given same amount of insulation, the wood framing walls perform better.

OR

It takes more insulation to get equivalent performance out of a steel stud wall.

Low-Rise Wood Construction

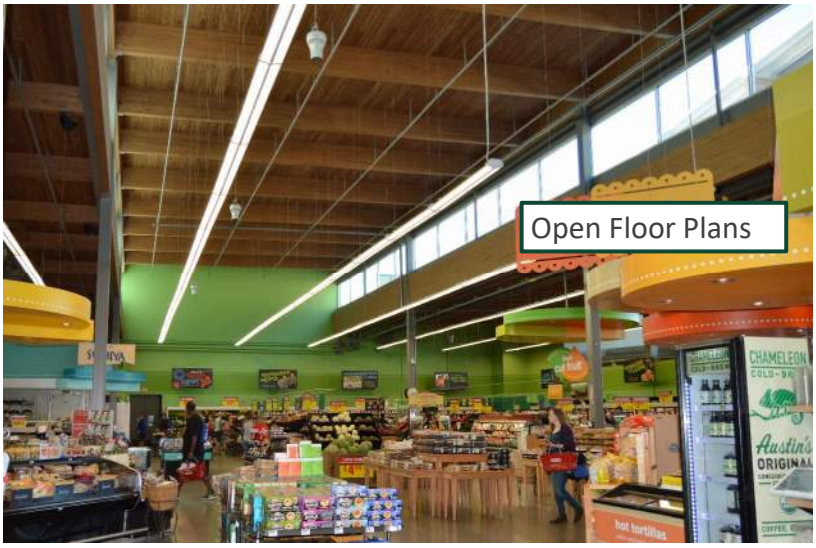


Storage Facilities
Offices
Medical Office Buildings
Schools

Wood Can Handle Common Features

Wood Can Handle Common Features

Wood Can Handle Common Features



IBC Occupancy Groups

- **A**ssembly : Groups A-1, A-2, A-3, A-4 and A-5.
- **B**usiness: Group B.
- **E**ducational: Group E.
- **F**actory and Industrial: Groups F-1 and F-2.
- **H**igh Hazard: Groups H-1, H-2, H-3, H-4 and H-5.
- **I**nstitutional: Groups I-1, I-2, I-3 and I-4.
- **M**ercantile: Group M.
- **R**esidential: Groups R-1, R-2, R-3 and R-4.
- **S**torage: Groups S-1 and S-2.
- **U**tility and Miscellaneous: Group U.

IBC Occupancy Groups

- **A**ssembly : Groups A-2
  - Nightclubs, Restaurants, Taverns and bars
- **B**usiness: Group B
  - Banks, barber and beauty shops, dry cleaning and laundries, professional services, etc.
- **M**ercantile: Group M
  - Department stores
  - Drug stores
  - Markets
  - Motor fuel-dispensing facilities
  - Retail or wholesale stores
  - Sales rooms

ICC Building Valuation Data

	Construction Type								
Occupancy Group	**IA**	**IB**	**IIA**	**IIB**	**IIIA**	**IIIB**	**IV**	**VA**	**VB**
A-2 Assembly	233	226	220	212	199	194	204	181	174
B Business	241	232	224	213	195	187	205	172	164
M Mercantile	174	167	161	153	140	136	145	121	116

Published $ / Square Foot of Building Area

Structural Wood Framing Allowed

Source August 2021, ICC Published National Building Valuation Data
https://www.iccsafe.org/products-and-services/i-codes/code-development-process/building-valuation-data/

ICC Building Valuation Data

	Construction Type		
Occupancy Group	IIA	IIIA	Difference
A-2 Assembly	220	199	$21/sf
B Business	224	195	$29/sf
M Mercantile	161	140	$21/sf

Published $ / Square Foot of Building Area

Type IIA and IIIA construction have very similar allowable heights and areas

Is this enough to matter to you or your clients?

Source August 2021, ICC Published National Building Valuation Data

ICC Building Valuation Data

	Construction Type		
Occupancy Group	IIB	VA	Difference
A-2 Assembly	212	181	$24/sf
B Business	213	172	$33/sf
M Mercantile	153	121	$24/sf

Published $ / Square Foot of Building Area

Type IIB and VA construction have very similar allowable heights and areas.

An even larger difference than IIA and IIIA

Source August 2021, ICC Published National Building Valuation Data

Outline

- Introduction
- Framing System Design and Details
  - Structural Design Compliance
  - Wall Framing
  - Wall Bracing
  - Roof Framing
- Non-Structural Requirements and Design
  - Allowable Heights and Areas
  - Multi-Tenant and Multi-Occupancy Buildings
  - Fire Resistance and Detailing
- Large Retail Project Case Study

Paths to Structural Compliance

- IBC Chapter 16 as starting point for most structural requirements
- IBC Chapter 23 for wood specific requirements and paths to compliance
- ASCE 7 Minimum Design Loads for Buildings and Other Structures referenced from IBC Chapter 16 for Wind and Earthquake Loading

	Path to Compliance	Reference	Approach
1	Convention Construction	IBC 2308	Prescriptive
2	AWC Wood Frame Construction Manual	IBC 2309	Prescriptive or Engineered
3	AWC National Design Specification for Wood Construction (NDS) AWC Special Design Provisions for Wind and Seismic (SPDWS)	IBC 2305 IBC 2306 (ASD) IBC 2307 (LRFD)	Engineered

Prescriptive Methods

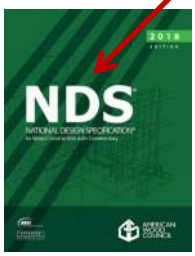
IBC Conventional Construction

AWC Wood Frame Construction Manual

Both Limited to 40 psf Live loads.
Possibly useful for 1 story Commercial Buildings

Engineered Design via AWC NDS and SDPWS

IBC



AWC NDS for Wood Members and Connections

AWC SDPWS for Wood Shear Walls and Diaphragms

General Engineered Approach:
Not limited in scope as Conventional Construction and WFCM

Outline

- Introduction
- Framing System Design and Details
  - Structural Design Compliance
  - Wall Framing
  - Wall Bracing
  - Roof Framing
- Non-Structural Requirements and Design
  - Allowable Heights and Areas
  - Multi-Tenant and Multi-Occupancy Buildings
  - Fire Resistance and Detailing
- Large Retail Project Case Study

Wall Framing Options

Solid Sawn Lumber Sizes
- 2x4 to 2x14
- 4x, 6x and greater thickness available

Different Species Groups Available
- "Southern Pine" is not a single species but a group of related species which are graded together
- Other common species groups include: Doug-Fir Larch, Hem-Fir, Spruce-Pine-Fir

Different Grades
- Visually Graded: #1, #2, etc
  - Most Common
- Machine Graded:
  - Machine Stress Rated (MSR)
  - Mechanical Evaluated Lumber (MEL)

Automatic Lumber Tester
Photo: Metriguard

Wall Framing Options

Finger-Jointed Dimensional Lumber:

- Structural end-gluing of shorter members
- Technically called “End-Jointed”
- Can be used interchangeably with solid sawn lumber of same species and grade, where approved.
  - See IBC 2303.1.1
- Look for grading and grade stamp by

Variations of Finger Jointed Lumber

- **HRA** (Heat Resistant Adhesive)
  - Only use HRA FJ Lumber in fire rated assemblies
- **Non-HRA** (or no HRA in stamp)
- **Vertical Use Only** or **Stud Use Only**
  - Bending or tension stresses only from short term loading

Wall Framing Options

Engineered Lumber Products

- Laminated Strand Lumber (LSL)
- Laminated Veneer Lumber (LVL)
- Parallel Strand Lumber (PSL)
- Glue Laminated Lumber (Glulam)

Tall Walls in Low Rise

Parameters for Engineered Stud Design

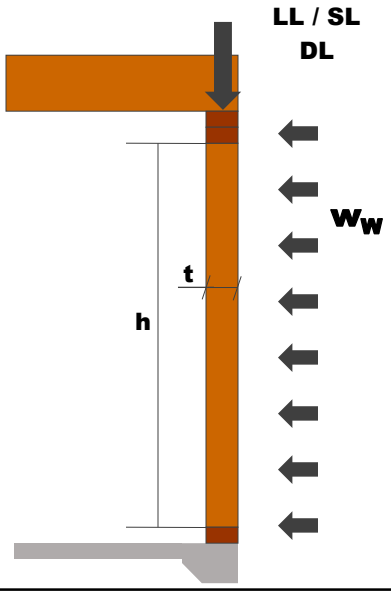
Structure Parameters

- Design height - **h**
- Stud spacing
- Wall thickness – **t**

Loading Parameters

- Dead Load - **DL**
- Live and Snow Load – **LL/SL**
- Wind Loads (C&C and MWFRS) – $\mathbf{w_w}$
- Any eccentricity

Deflection Criteria based on Finishes



Exterior Wall Design Checks

- Strength Check 1:
  Gravity + Main Lateral Force Loads
- Strength Check 2:
  Full Components and Cladding Wind Loads
- Deflection Check:
  Reduced Components and Cladding Wind Loads

Strength Check 1 for Stud Design

Strength Check as a Vertical Load Supporting element:

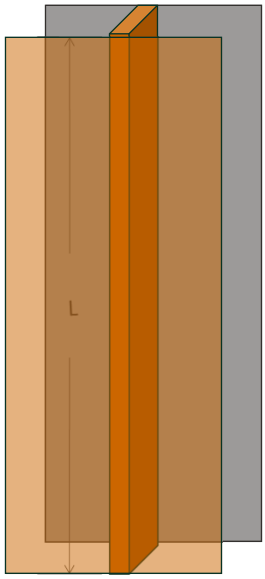
- Apply Vertical Dead, Live, Roof and/or Snow Loads
- Apply out-of-plane lateral loads
  - MWFRS wind loads (ASCE 7-15 Chapter 27 or 28)
  - Seismic wall forces (ASCE 7-15 12.11.1)
- Apply vertical MWFRS wind or Seismic force (if any)
  - For example: a hold-down post.
- Combined Bending & Axial Load Check per AWC NDS
- Use standard load combinations
  - IBC Section 1605 or
  - ASCE 7 Chapter 2

Design Tip: Bottom plate crushing may govern over Stud and Post Capacities

Wall Sheathing Provides Weak Axis Bracing

NDS Commentary:

"Experience has shown that any code allowed thickness of gypsum board, hardwood plywood, or other interior finish adequately fastened directly to studs will provide adequate lateral support of the stud across its thickness irrespective of the type or thickness of exterior sheathing and/or finish used."



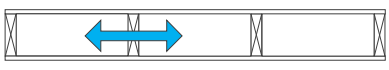
Design Considerations

Slenderness Limits (NDS 2018 3.7.1.4)

Max Effective Unbraced Length = 50d, d = depth in inches

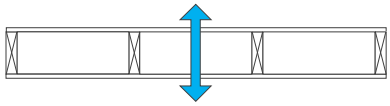
Max of 75d during construction

1½" depth
6'-3" max unbraced length.
9'-4" during construction.



Stud or column can be braced against buckling in this direction by sheathing.

3½" (2x4) Max Height: 14'-7"
5½" (2x6) Max Height: 22'-11"
7¼" (2x8) Max Height: 30'-2"



Stud or column is **not** braced against buckling in this direction by sheathing.

Intermediate Wall Stud Blocking

Strength Checks on Stud Design 2

Strength Check for Components & Cladding Winds

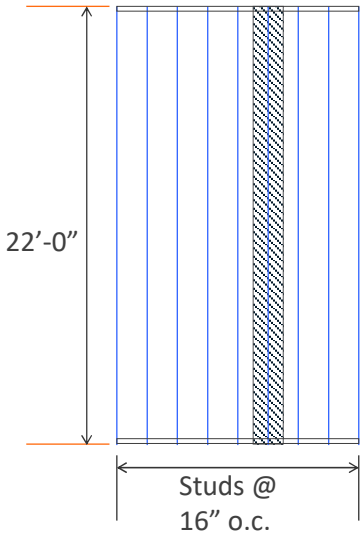
- No axial loading
- **C&C transverse Wind loads only**
- Check stud for bending and shear

Design Tip: Be aware of ASCE 7 Definition of Effective Wind Area to decrease the required C&C wind load

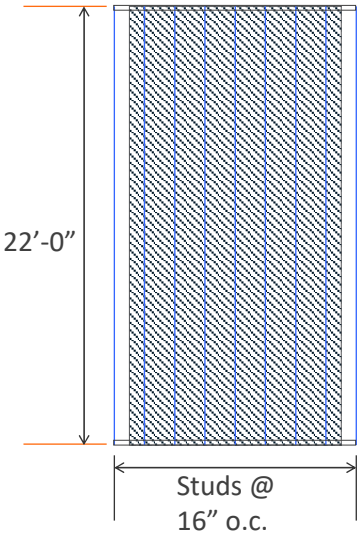
EFFECTIVE WIND AREA, *A*: The area used to determine (GC_p). For component and cladding elements, the effective wind area in Figs. 30.4-1 through 30.4-7, 30.5-1, 30.6-1, and 30.8-1 through 30.8-3 is the span length multiplied by an effective width that need not be less than one-third the span length. For cladding fasteners, the effective wind area shall not be greater than the area that is tributary to an individual fastener.

Effective Wind Area Example

Tributary Area = (22)(1.33) = 29 ft^2



Effective Wind Area = 22*22/3 = 161 ft^2



Strength Checks on Stud Design 2

Strength Check for Components & Cladding Winds

- No axial loading
- C&C transverse Wind loads only
- **Check stud bending** and shear.

Design Tip: For bending stress check, be aware of Repetitive Use factor C_r of NDS and Wall Stud Repetitive Member Factor of SDPWS 3.1.1

Table 3.1.1.1 Wall Stud Repetitive Member Factors

Stud Size	System Factor
2x4	1.50
2x6	1.35
2x8	1.25
2x10	1.20
2x12	1.15

Deflection Checks on Stud Design

Deflection Check for Components and Cladding Winds

- No Axial Loading
- C&C transverse Wind load only.
- Check out-of-plane deflection to IBC Table 1604.3 or other more stringent requirements.

Note: This check often governs tall walls

Design Tip: ASCE 7 Definition of Effective Wind Area to decrease the required C&C wind load applies here.

Deflection Checks on Stud Design

Deflection Check for Components and Cladding Winds

- No Axial Loading
- C&C transverse Wind load only.
- Check out-of-plane deflection to IBC Table 1604.3 or other more stringent requirements.

TABLE 1604.3
DEFLECTION LIMITS[a, b, c, h, i]

CONSTRUCTION	L	S or W[f]
Exterior walls:		
With plaster or stucco finishes	—	*l*/360
With other brittle finishes	—	*l*/240
With flexible finishes	—	*l*/120

Deflection Checks on Stud Design

Deflection Check for Components and Cladding Winds

- No Axial Loading
- C&C transverse Wind load only.
- Check out-of-plane deflection to IBC Table 1604.3 or other more stringent requirements.

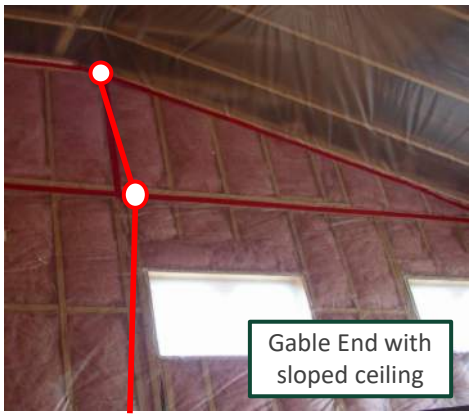
Design Tip: Change in SDPWS 2015 referenced from IBC 2015 allows application of Wall Stud Repetitive Factor to Stud STIFFNESS. See SDPWS 3.1.1

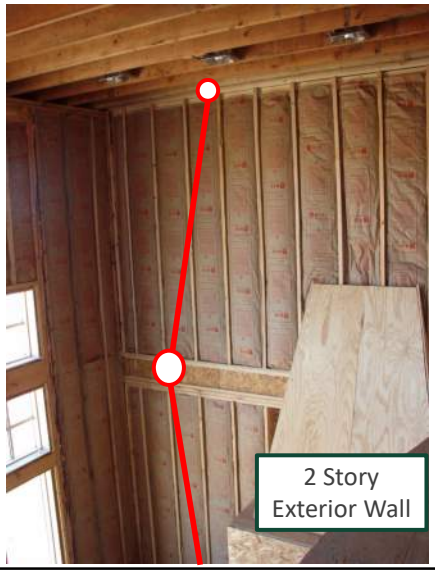
Table 3.1.1.1 Wall Stud Repetitive Member Factors

Stud Size	System Factor
2x4	1.50
2x6	1.35
2x8	1.25
2x10	1.20
2x12	1.15

Can this Exterior Wall Pass Deflection Check?

"Hinge Point" creates a structural weakness in the wall





Can this Exterior Wall Pass Deflection Check?

Solution = Continuous Studs

Tall Walls in Office

Atlanta, GA

2-Story, 12,000 sf office bldg.

≈20ft tall

2x6 SYP #2 at high entry

Tall Walls in Restaurant

Emeryville, CA
24'+ tall
2x8 Doug Fir

Tall Walls in Retail

Large Diamond Retailer
Murfreesboro, TN
22' tall 2x8 Pre-Fabricated

Small Retail Building – Northern CA

Small Retail Building – Northern CA

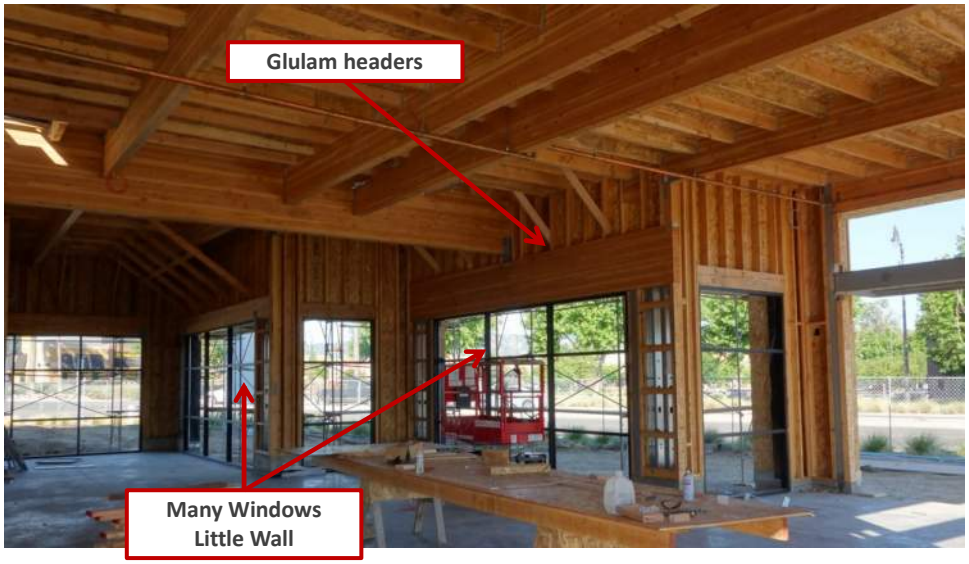
Flat Roof with:

- WSP Sheathing
- 2x Sub-Purlins
- Glulam Purlins
- Glulam Beams

20 ft 2x6 DF walls

- Interior
- Exterior

Small Retail Building – Northern CA



Small Retail Building – Northern CA

Retail Building – Berlin Vermont

4,500 sf

Retail Building – Berlin Vermont

Roof Construction:

- Metal Plate Connected Monoslope Wood Roof Trusses
- 6’ Deep at Front, 4.5’ at Back, 50’ Span, 24” o.c.
- Wood Structural Panels
- 2x6 @ 16” o.c. Bearing Walls & Shear Walls– 13’ Tall
- Structural Steel Open Front Frame

Retail Building – Berlin Vermont

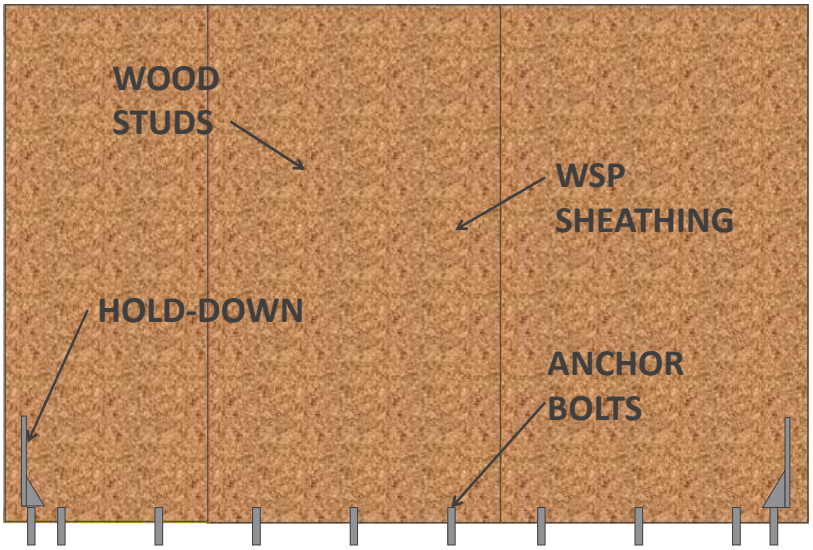
Front Canopy and Façade

Retail Building – Berlin Vermont

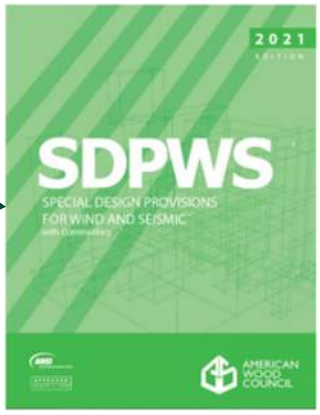
Outline

- Introduction
- Framing System Design and Details
  - Structural Design Compliance
  - Wall Framing
  - Wall Bracing
  - Roof Framing
- Non-Structural Requirements and Design
  - Allowable Heights and Areas
  - Multi-Tenant and Multi-Occupancy Buildings
  - Fire Resistance and Detailing
- Large Retail Project Case Study

Anatomy of Wood Sheathed Shear Walls



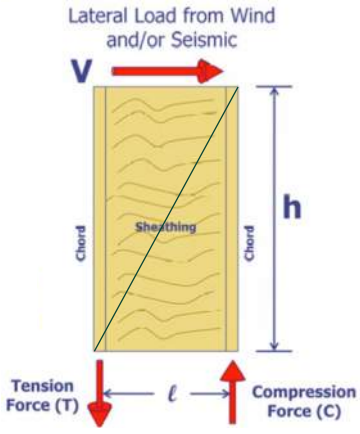
Lateral Load Capacity



Tip: Nailed Wood Shear Wall Allowable Capacities in IBC 2009 and earlier versions. Not in IBC 2012+. Nominal capacity in SDPWS

AWC SDPWS
Provides details and capacities of these types of nailed wood shear walls

Shear Wall Requirements in AWC SDPWS



Wood Education Institute

Table 4.3.4 Maximum Shear Wall Aspect Ratios

Shear Wall Sheathing Type	Maximum h/b, Ratio
Wood structural panels, unblocked	2:1
Wood structural panels, blocked	3.5:1[1]
Particleboard, blocked	2:1
Diagonal sheathing, conventional	2:1
Gypsum wallboard	2:1[2]
Portland cement plaster	2:1[2]
Structural Fiberboard	3.5:1[3]

3:5:1 max aspect ratio for blocked Wood Structural Panel Shear Wall. Reduction in Capacity when greater than 2:1

Shear Wall Requirements in AWC SDPWS

Capacities in SDPWS are **Nominal** values. Not ASD

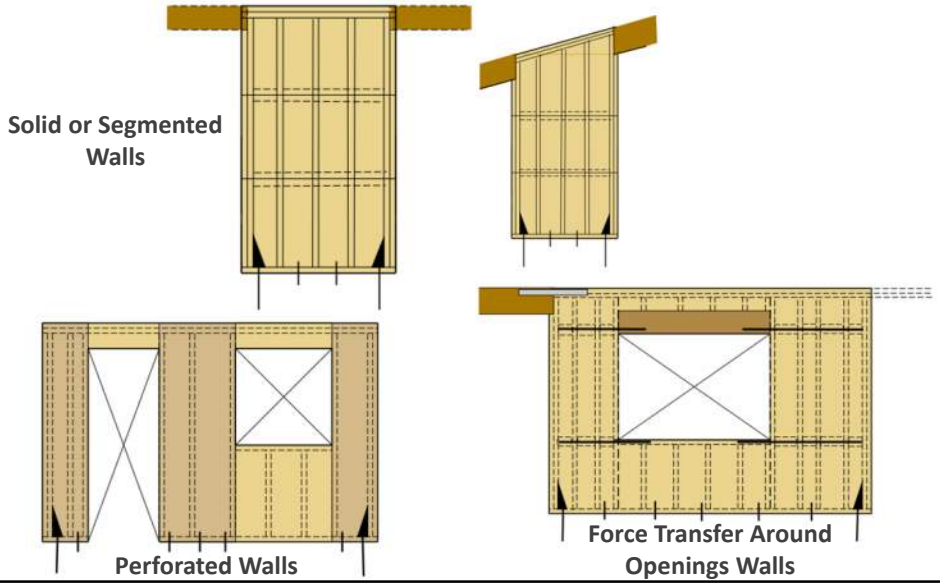
SDPWS 2021
Single Nominal Value
Divide Nominal Values by 2.0 for ASD Wind and by 2.8 for ASD Seismic
Multiply Nominal Values by 0.8 for LRFD Wind and 0.5 for ASD Seismic

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			4			3			2		
				v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)		v_n (plf)	G_a (kips/in.)	
					OSB	PLY		OSB	PLY		OSB	PLY		OSB	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
	5/16	1-1/4	6d common nail	505	13	9.5	755	18	12	980	24	14	1260	37	18

Engineered Shear Wall Types



Why Use Force Transfer Around Openings?

Why Use Force Transfer Around Openings?

Open Front & Narrow Walls

Prefabricated Shear Wall Options

Proprietary Products with Evaluation Reports

Different Material Options

Metal Panel
Hardy Frame

Metal Panel
Simpson Strong-Tie

Wood Panels
Simpson Strong-Tie

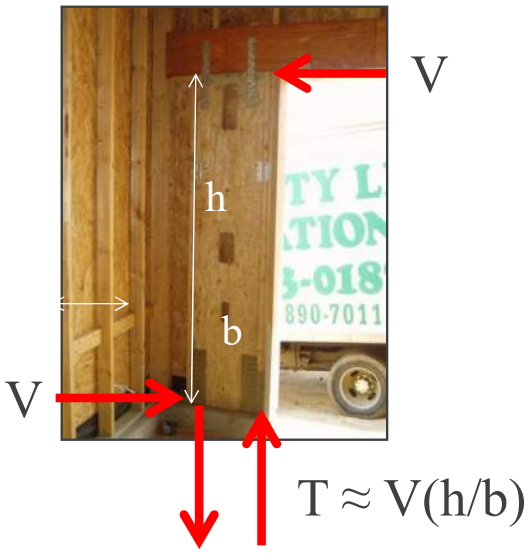
The primary benefit is to have lateral force resistance where a 3:5 to 1 aspect ratio shear wall does not fit.

Using Prefabricated Shear Walls

Considerations:

- Drift compatibility with other walls sharing load
- Large hold-down forces
- Foundation Anchorage Coordination
- Sizes range from 12”->24” wide to 6.5’->20’ tall

Tip: Cast-in-place anchorage to concrete needed. Don’t expect post-installed concrete anchors to work.

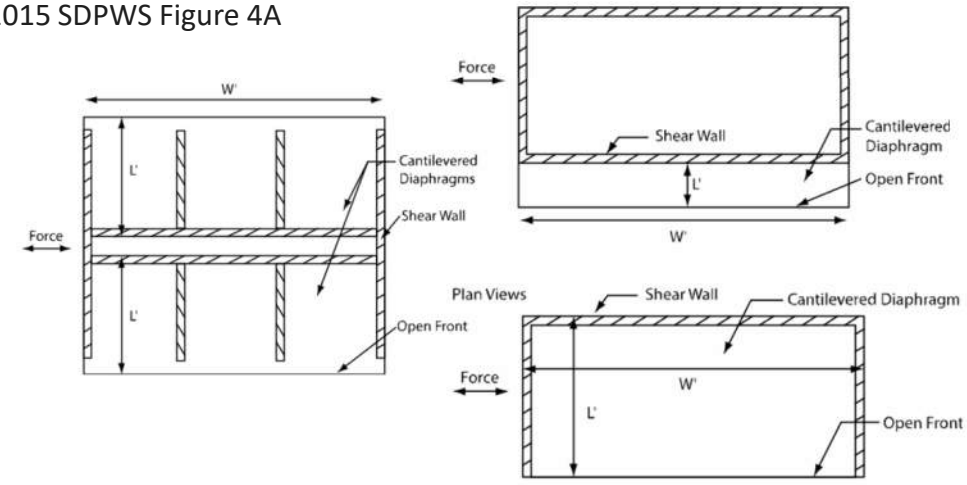


Small Retail Building – Northern CA

Open Front Structures

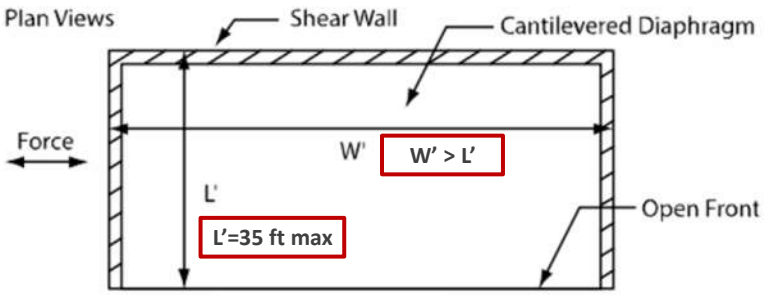
2015 SDPWS unifies Cantilever Diaphragms and Open Front Structures

2015 SDPWS Figure 4A



Open Front Structures

SDPWS allow Open Front Structures… provide certain important requirements are met.

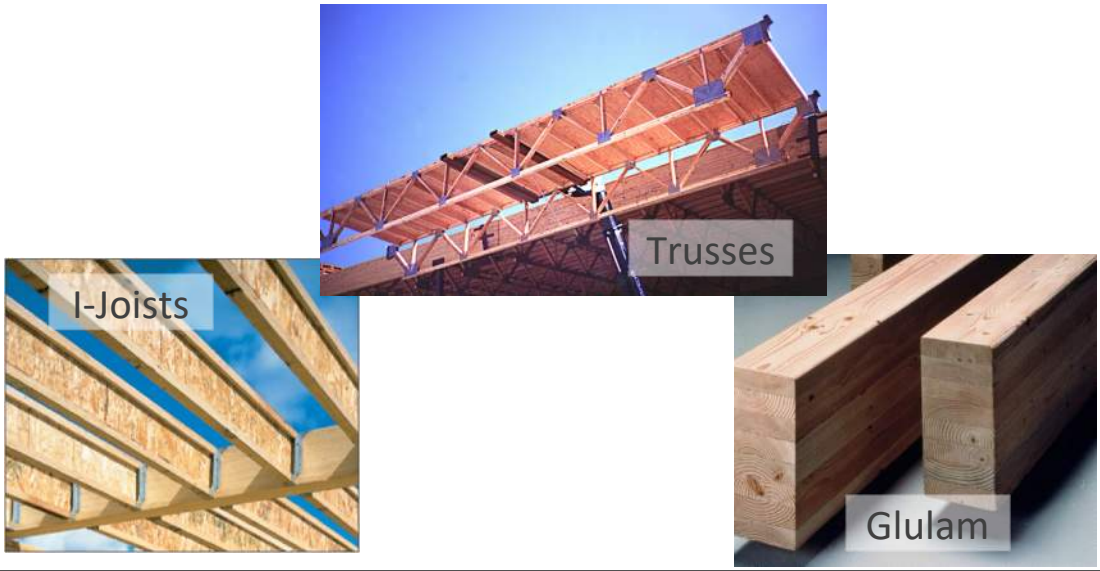


Possible **1-Story** Open-Front Structure in SDPWS 2015 & 2021

Outline

- Introduction
- Framing System Design and Details
  - Structural Design Compliance
  - Wall Framing
  - Wall Bracing
  - Roof Framing
- Non-Structural Requirements and Design
  - Allowable Heights and Areas
  - Multi-Tenant and Multi-Occupancy Buildings
  - Fire Resistance and Detailing
- Large Retail Project Case Study

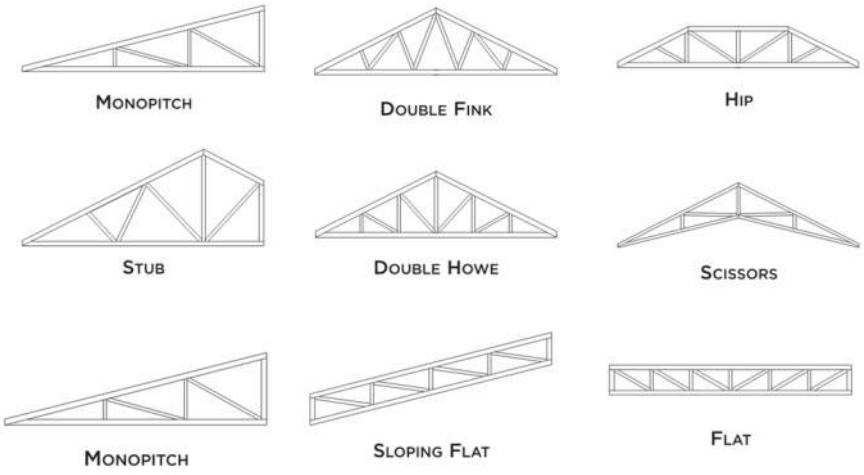
Common Roof Framing Options



Metal Plated Wood Truss

Metal Plated Wood Truss

Truss Configurations



Exposed Timber Trusses

T&G Deck over Timber Trusses

Berlin Shopping Mall, Berlin VT

Exposed Timber Trusses

90ft Span Concealed Connector Timber Truss

Exposed Timber Trusses

67’ Span Glulam Trusses

Whole Foods Market, Atlanta, GA

Metal Plated Trusses over Exposed Timber Trusses

Shenandoah Social Center Photo courtesy D. Remy & Co.

I-Joist Roof Framing

- Flat or Sloped Roofs
- Vaulted Ceiling Possibilities

Havens Elementary, Photo courtesy RedBuilt

Strip Mall Building

Large Flat Roof Systems

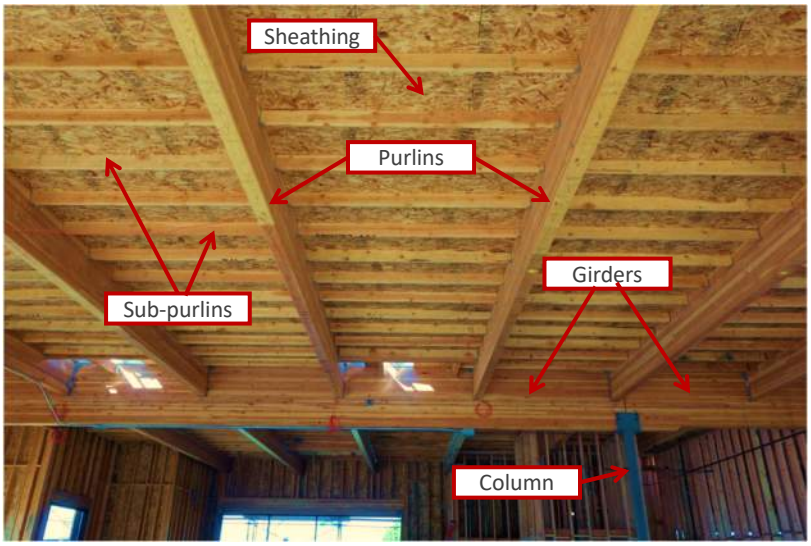
Creating Open Floor Space

Grid dimensions in low rise commercial buildings are often a deciding factor when determining structural systems. Accommodation of large, open floor plans with a minimal number of columns is required

Common Grid Dimensions: 25'x30' to 45'x50' and larger

Photo: Myers-Company.com

Anatomy of a Large Flat Roof



Different Flat Roof Framing Systems

Girder	Purlin	Sub-Purlin	Sheathing
Glulam	Glulam @ 8’ to 10’ o.c.	2x	WSP
Glulam	Trusses @ 4’ to 10’ o.c.	2x	WSP
Glulam	Trusses @ 16” to 48” o.c.	None	WSP
Glulam	I-Joists @ 16” to 48” o.c.	None	WSP
Glulam	Glulam @ 4’ to 10’ o.c.	None	T&G Decking
Glulam	Glulam @ 8’+ o.c.	None	Mass Timber Panels: Cross-Laminated Timber Nail-Laminated Timber Etc.

Architectural Grade Exposed Wood Options

Material Connection to Nature (visual)

Biophilic Pattern

- Wood is a natural material – timber is sourced from trees in our forests.
- Exposing natural materials provides a connection to nature in this biophilic pattern

Material Connection to Nature (non-visual)
Biophilic Pattern

Other sensory connections to nature:

- Soft feel of wood – might this contribute to this biophilic pattern?
- Smell of wood in offices- might this contribute to this biophilic pattern?
- Smell of wood has surprised some designers who didn't consider it in design

Albina Yard
LEVER Architecture | Photo: LEVER Architecture

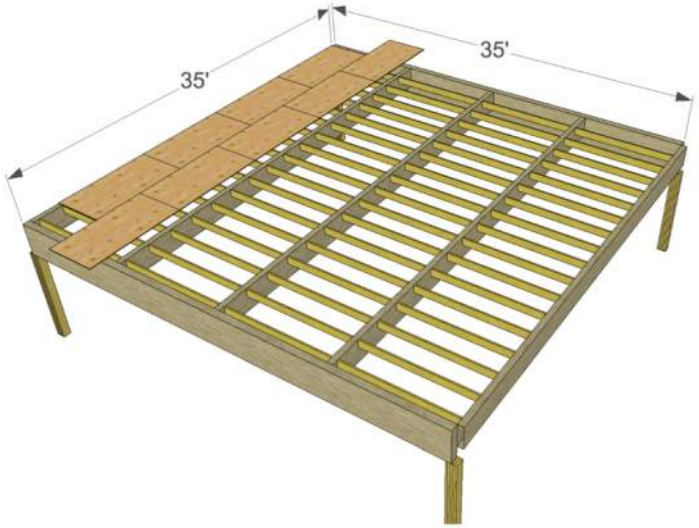
Biophilic Design Patterns
Nature in the Space

	Pattern	Stress Reduction	Cognitive Performance	Emotion, Mood & Preference
Nature in the Space	Visual Connection w/ Nature	✓	✓	✓
	Non-Visual Connection w/ Nature (smell, touch)	✓	✓	✓
	Non-Rhythmic Sensory Stimuli	✓	✓	
	Thermal & Airflow Variability	✓	✓	✓
	Presence of Water	✓	✓	✓
	Dynamic & Diffuse Light	✓		
	Connection w/ Natural Systems			✓

Source: Terrapin Bright Green: *14 Patterns of Biophilic Design*, 2014

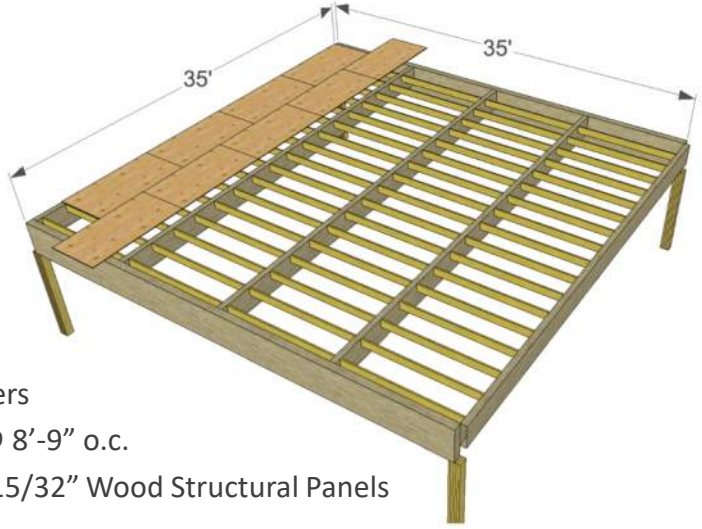
Example Roof Framing System

15 psf Roof DL
20 psf Roof Live Load



Example Roof Framing System

15 psf Roof DL
20 psf Roof Live Load

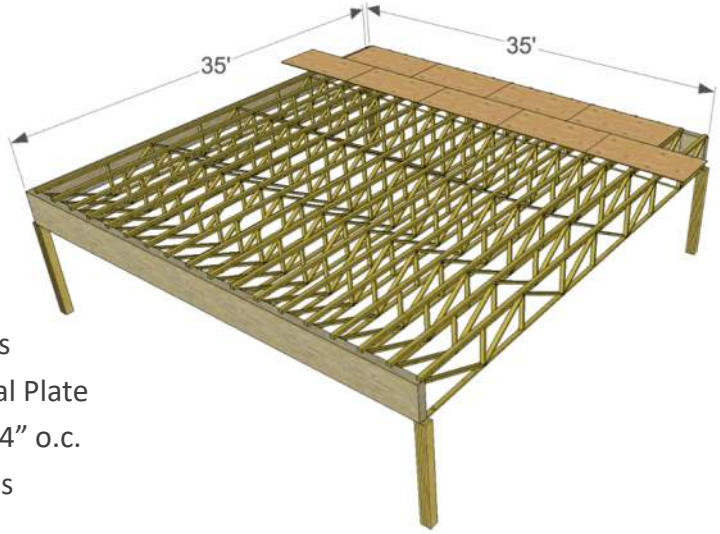


6-3/4”x31-1/2” Glulam Girders
5-1/8”x21” Glulam Purlins @ 8’-9” o.c.
2x8 @ 24” o.c. Sub-Purlins, 15/32” Wood Structural Panels

Example Roof Framing System

Example Roof Framing System

15 psf Roof DL
20 psf Roof Live Load



6-3/4”x31-1/2” Glulam Girders
3’-0” Deep Prefabricated Metal Plate Connected Wood Trusses @ 24” o.c.
15/32” Wood Structural Panels

Example Roof Framing System

15 psf Roof DL

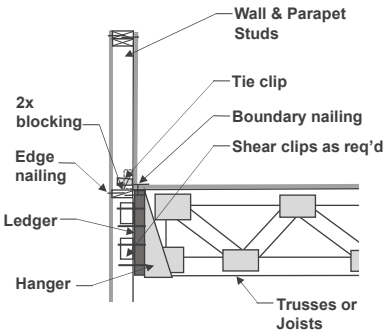
20 psf Roof Live Load

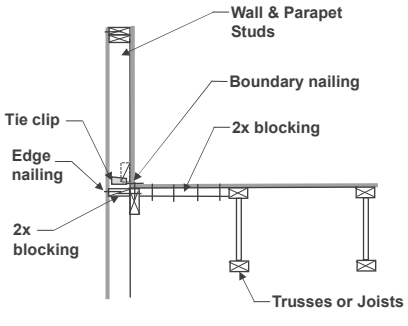
6-3/4”x31-1/2” Glulam Girders

5-1/8”x21” Glulam Purlins @ 8’-9” o.c.

HT/Mass Timber Decking Options: NLT, CLT, GLT, 3x T&G

Parapet Framing Options





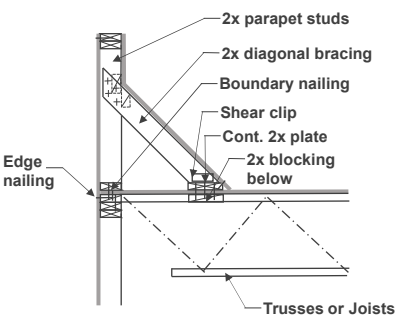
Tall Stud Parapet Style

Parapet Wall Example

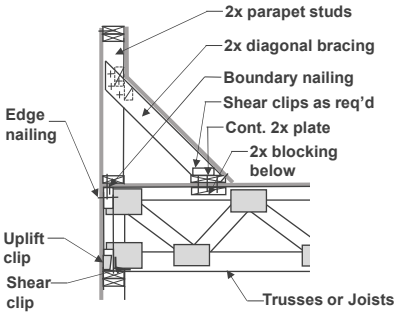
- Sporting Good Retailer
- Dinuba, CA
- 17’ to top of roof
- 22’ to top of parapet
- 2x6 DF
- Used with hybrid panelized roof

Pelton Engineering

Parapet Framing Options



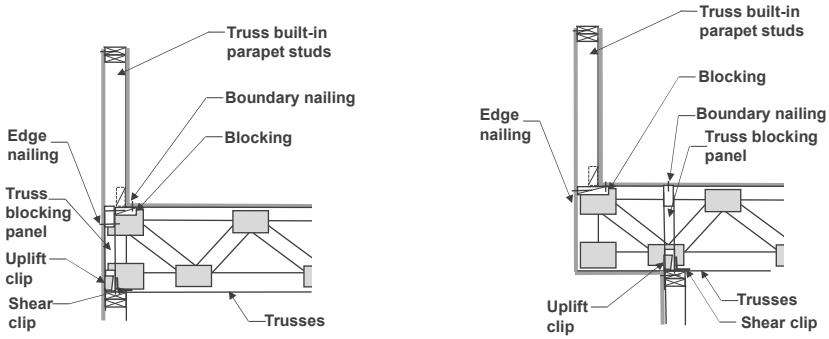
Top Flange Hanger Style



Platform Framing Style

Built-Up Parapet Style

Parapet Framing Options

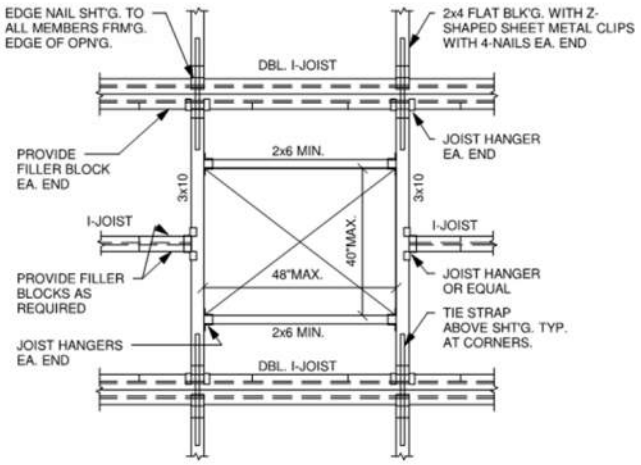


Parapet Flush with Wall

Cantilevered Truss

Parapet in Truss Style

Flexible Detailing for Roof Openings



www.woodworks.org/cad-revit/
for example details

Layton Petro Mart, Greenfield, WI

Photos by Arquitectura

Commercial Wood Design Award 2009
Arquitectura Inc. – Milwaukee, WI

Layton Petro Mart, Greenfield, WI

Photo: Arquitectura, Inc.

Fast Food Restaurant

- 2x6 wall studs
- 10’ tall walls + 3’ Parapet
- Brick and Stone Cladding

Fast Food Restaurant

Roof Construction:

- Metal Plate Connected Wood Roof Trusses
- 36” Deep, 34’ Spans, 32” o.c.

Wood in Retail Design

Restaurant

- Murfreesboro, TN
- Completed July, 2015

Restaurant – Brewery Chain

Roof Construction

- Wood Structural Panels Sheathing
- Composite Wood-Steel Open Web Trusses
- Glulam Beams
- 2x6 Bearing Walls

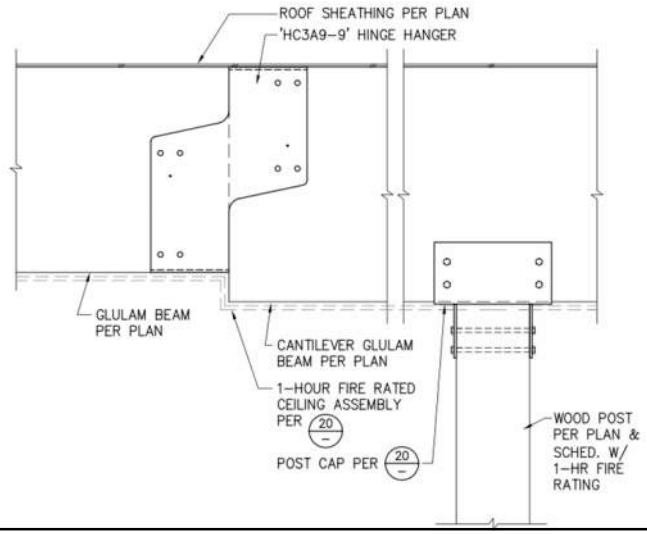
Wood in Retail Design

Restaurant – Brewery Chain

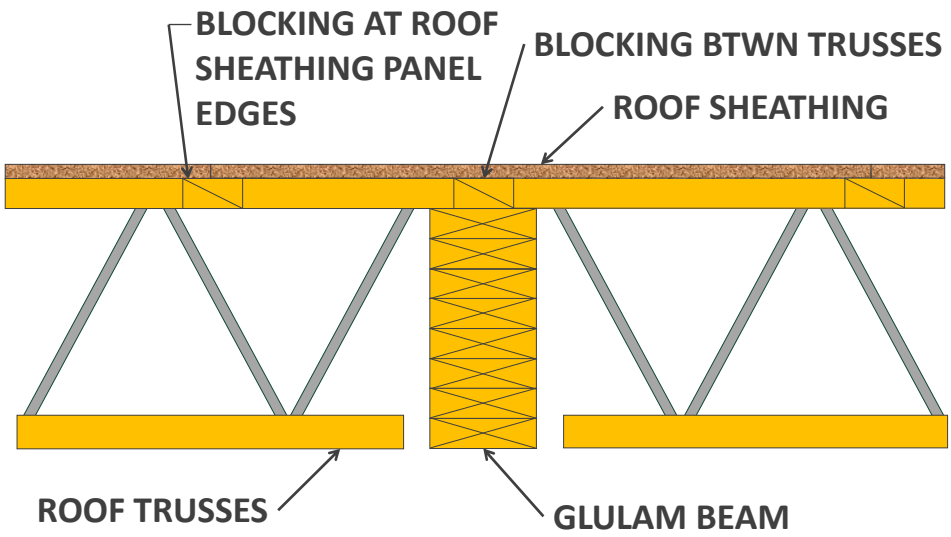
Blocked Roof Diaphragm for Higher Capacity

Retail Store: Gravity Framing System

Glulam Roof Beam Connection Details



Roof Framing Detail



Wood in Retail Design

Fast Food Restaurant in Provo, UT

Fast Food Restaurant

Building Construction

- Wood Structural Panels & T&G Decking Sheathing
- Composite Wood-Steel Open Web Roof Trusses & Solid Sawn Rafters
- Glulam Beams
- PSL & Built-Up Solid Sawn Columns
- 2x6 Bearing Walls & Shear Walls

Outline

- Introduction
- Framing System Design and Details
  - Structural Design Compliance
  - Wall Framing
  - Wall Bracing
  - Roof Framing
- Non-Structural Requirements and Design
  - Allowable Heights and Areas
  - Multi-Tenant and Multi-Occupancy Buildings
  - Fire Resistance and Detailing
- Large Retail Project Case Study

Height and Areas Code Analysis

Question:

For the building program, including occupancies and size, what Construction Types are allowed by the Building Code?

Answer:

Determined by Heights and Areas Code analysis

Heights and Areas – IBC 2018 Table 503

GROUP		TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
	HEIGHT (feet)	UL	160	65	55	65	55	65	50	40
	STORIES(S) AREA (A)									
M	S	UL	11	4	2	4	2	4	3	1
	A	UL	UL	21,500	12,500	18,500	12,500	20,500	14,000	9,000
R-1	S	UL	11	4	4	4	4	4	3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
R-2	S								3	2
	A								12,000	7,000
R-3	S								3	3
	A								UL	UL
R-4	S								3	2
	A	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
S-1	S	UL	11	4	2	3	2	4	3	1
	A	UL	48,000	26,000	17,500	26,000	17,500	25,500	14,000	9,000
S-2[b, c]	S	UL	11	5	3	4	3	5	4	2
	A	UL	79,000	39,000	26,000	39,000	26,000	38,500	21,000	13,500
U[c]	S	UL	5	4	2	3	2	4	2	1
	A	UL	35,500	19,000	8,500	14,000	8,500	18,000	9,000	5,500

Normal Calculated Allowable Heights and Area one route to an answer.
Don't overlook Unlimited Area Route

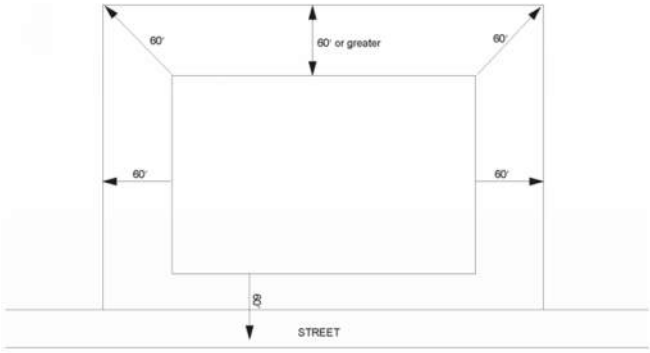
Unlimited Area Buildings

IBC Section 507 gives Unlimited Area Building routes for Type III, IV and/or V Construction for the following occupancies:

- Assembly
- Education
- Business
- Factory
- Mercantile
- Storage

Unlimited Area Buildings

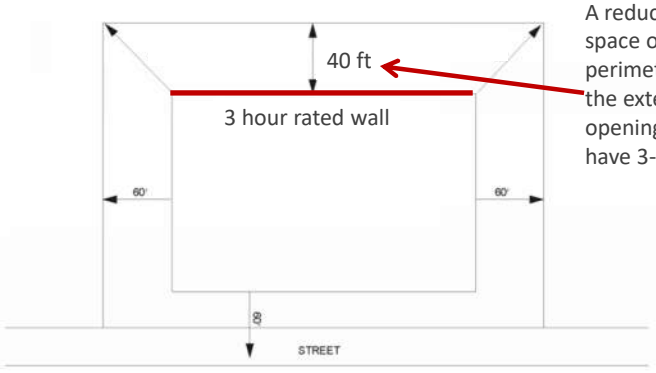
Provisions for unlimited area buildings rely on open space surrounding building (IBC 507)



REQUIRED SEPARATION FOR UNLIMITED AREA BUILDINGS

Unlimited Area Buildings

Provisions for unlimited area buildings rely on open space surrounding building (IBC 507)



A reduction to 40 feet open space of up to 75% of perimeter is allowed provided the exterior wall and openings at reduced frontage have 3-hour ratings

REQUIRED SEPARATION FOR UNLIMITED AREA BUILDINGS

Unlimited Area Building Route 1

B F M and S Occupancies can have **unlimited area** for **any construction type** provided:

- Two stories or less above grade plane
- Equipped with automatic sprinklers
- See IBC 507.4

Photo Steve Fareham- Creative Commons

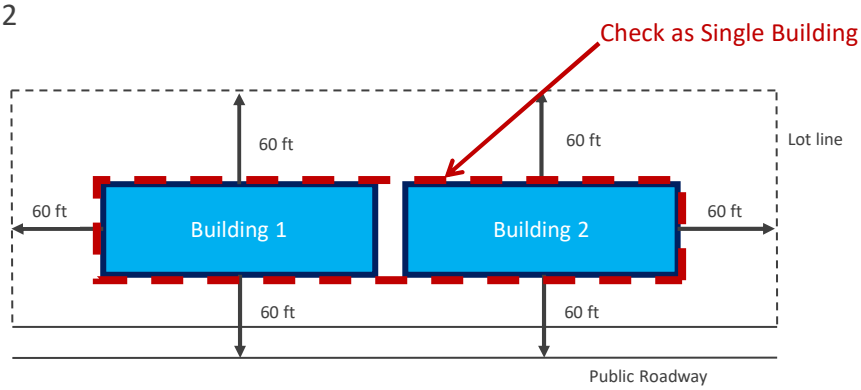
Unlimited Area Buildings

Can these buildings meet the open space provision to qualify for Unlimited Area?

Photo Steve Fareham- Creative Commons

Unlimited Area Building(s)?

IBC 507.2 Commentary: Two unlimited area buildings ***on the same lot*** must be separated by 60 feet [or 40 feet if Section 507.2.1 is used] unless they are treated as a single building under the provisions of Section 503.1.2



Construction Types

Allowable Building Area

IBC 2018 Table 506.2

TABLE 506.2
ALLOWABLE AREA FACTOR (A_t = NS, S1, S13R, S13D or SM, as applicable) IN SQUARE FEET[a, b]

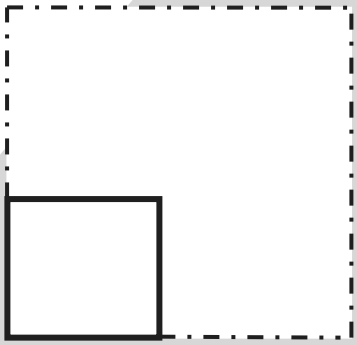
OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
A-1	NS	UL	UL	15,500	8,500	14,000	8,500	15,000	11,500	5,500
	S1	UL	UL	62,000	34,000	56,000	34,000	60,000	46,000	22,000
	SM	UL	UL	46,500	25,500	42,000	25,500	45,000	34,500	16,500
B	NS	UL	UL	37,500	23,000	28,500	19,000	36,000	18,000	9,000
	S1	UL	UL	150,000	92,000	114,000	76,000	144,000	72,000	36,000
	SM	UL	UL	112,500	69,000	85,500	57,000	108,000	54,000	27,000
E	NS	UL	UL	26,500	14,500	23,500	14,500	25,500	18,500	9,500
	S1	UL	UL	106,000	58,000	94,000	58,000	102,000	74,000	38,000
	SM	UL	UL	79,500	43,500	70,500	43,500	76,500	55,500	28,500

Allowable Story Area

IBC 2018 Table 506.2

Floor Area Increase

Buildings equipped throughout with an NFPA 13 sprinkler system can be increased **300% (single story buildings)** or **200% (multi-story buildings)** over nonsprinklered conditions



Allowable Story Area

IBC 2018 Table 506.2

Provides base (non-sprinklered) & increased areas

TABLE 506.2[a, b]
ALLOWABLE AREA FACTOR (A_t = NS, S1, S13R, or SM, as applicable) IN SQUARE FEET

OCCUPANCY CLASSIFICATION	SEE FOOTNOTES	TYPE OF CONSTRUCTION								
		TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
		A	B	A	B	A	B	HT	A	B
R-1	NS[d, h]	UL	UL	24,000	16,000	24,000	16,000	20,500	12,000	7,000
	S13R									
	S1	UL	UL	96,000	64,000	96,000	64,000	82,000	48,000	28,000
	SM	UL	UL	72,000	48,000	72,000	48,000	61,500	36,000	21,000

**Can still increase these areas by the Frontage Factor of Section 506.3

NS = Buildings not equipped throughout with an automatic sprinkler system

S1 = Buildings a maximum of one story above grade plane equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 (NFPA 13)

SM = Buildings two or more stories above grade plane equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.1 (NFPA 13)

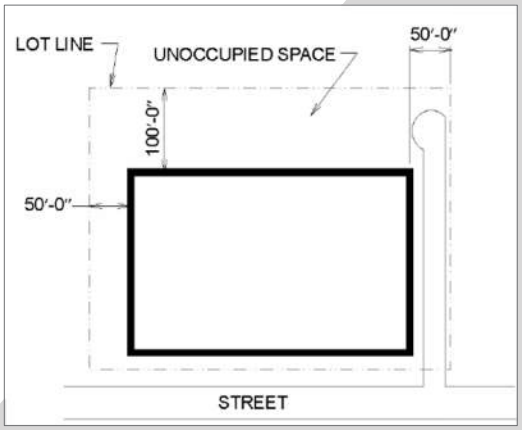
S13R = Buildings equipped throughout with an automatic sprinkler system installed in accordance with Section 903.3.1.2 (NFPA 13R)

Fire Department Access

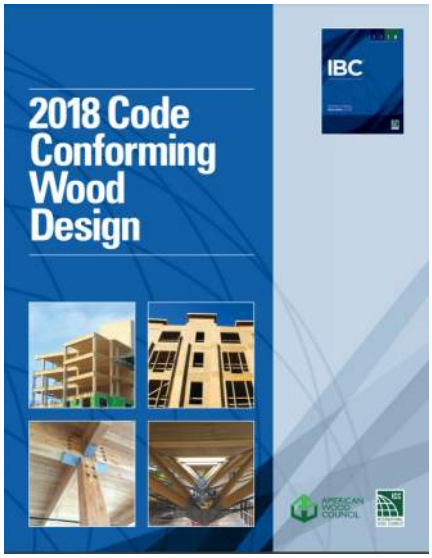
IBC 506

Frontage

Frontage provides access to the structure by fire service personnel, a temporary refuge area for occupants as they leave the building in a fire emergency and a reduced exposure to and from adjacent structures. Larger building area possible with certain amount of frontage



AWC Code Conforming Wood Design



Outline

- Introduction
- Framing System Design and Details
  - Structural Design Compliance
  - Wall Framing
  - Wall Bracing
  - Roof Framing
- Non-Structural Requirements and Design
  - Allowable Heights and Areas
  - Multi-Tenant and Multi-Occupancy Buildings
  - Fire Resistance and Detailing
- Large Retail Project Case Study

Multi-Tenant Buildings

Lead to mixed occupancy buildings

Code Sections Related to Multiple Occupancies

- Incidental Uses (509)
- Accessory occupancies (508.2)
- Non-Separated occupancies (508.3)
- Separated Occupancies (508.4)
- Separate Buildings (503.1)
- Covered and Open Malls (402)

Outside scope of presentation

Incidental Uses (IBC 509)

- Ancillary function associated with an Occupancy
- Pose GREATER risk than the Occupancy
- Examples:
  - Laundry room over 100 square feet.
  - Refrigerant machinery room
  - Incinerator room
  - Furnace room
  - Boiler room

Incidental Uses (IBC 509)

- Not more than 10% of area of story
- Have fire separation, smoke separation and/or sprinkler systems per Table 509 and Section 509.4
- **NOT classified as a different occupancy.**
- **Allowable Building Area and Height per main Occupancy**

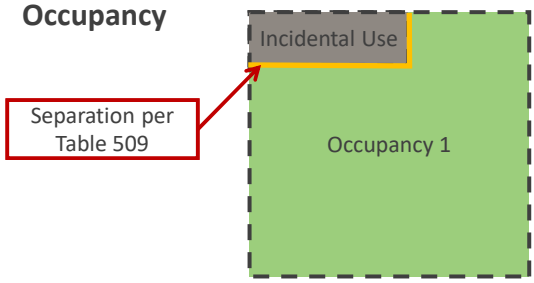


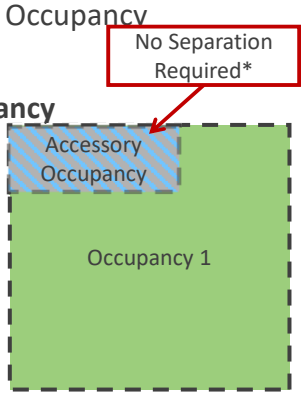
Photo Sean Hackbarth/Flickr

Accessory Occupancies (508.2)

- Ancillary to the main Occupancy
- Accessory Area not greater than:
  - 10% of the main Occupancy on same floor
  - IBC 506 “NS” Allowable Area limit of Accessory Occupancy
- No separation between occupancies required*
- **Allowable Building Area and Height per main Occupancy**

*Hazardous occupancies require separation

*Residential separations per Section 420 still apply

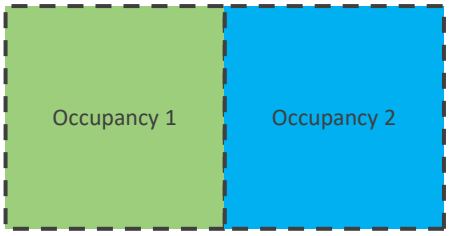


Non-Separated Occupancies (508.3)

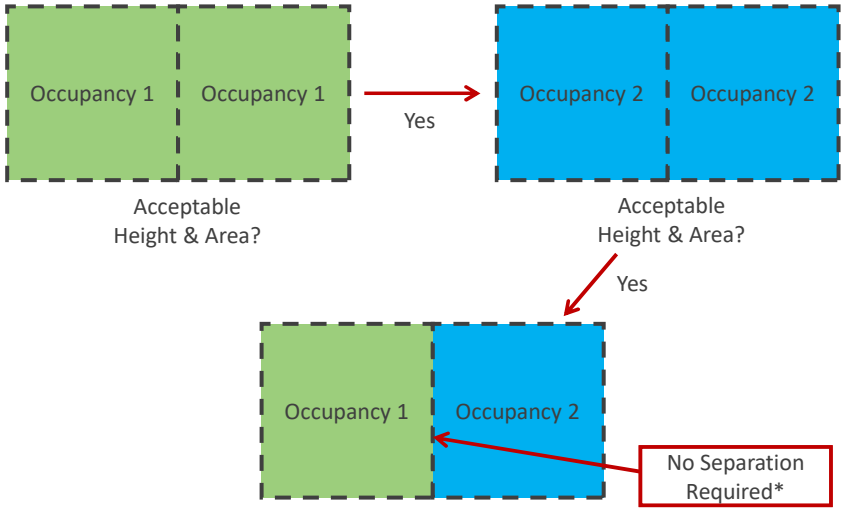
- Most restrictive requirements of all occupancies apply for:
  - Fire Protection Systems (Chapter 9)
  - Allowable Height and Area
- Other requirements for each portion based upon occupancy of that portion
- No separation between occupancies required*

*Hazardous occupancies require separation.

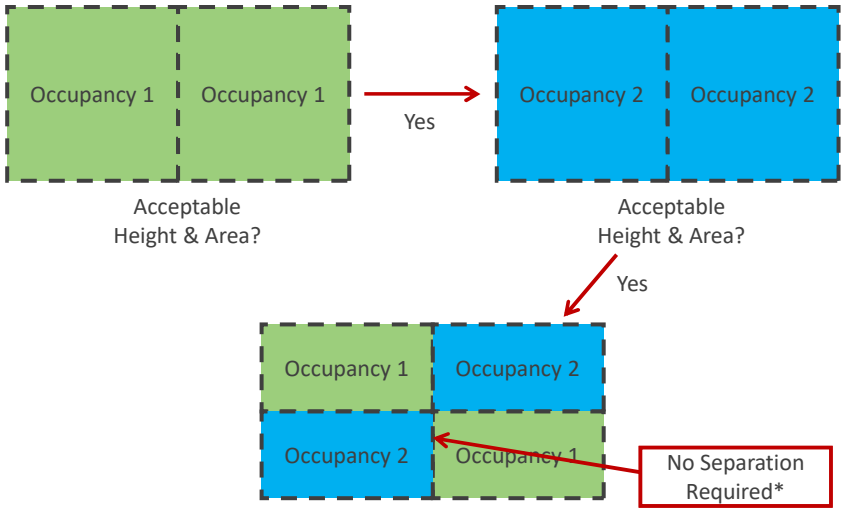
*Residential separations per Section 420 still apply



Non-Separated Occupancies (508.3)



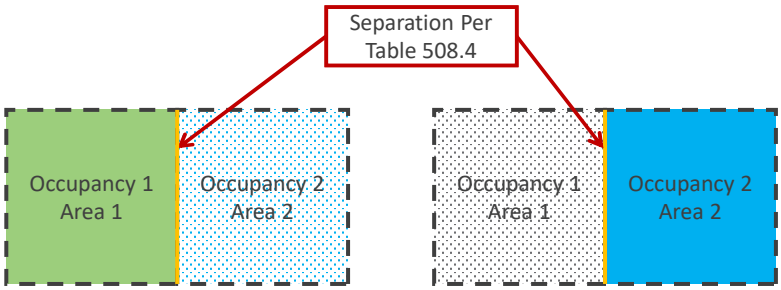
Non-Separated Occupancies (508.3)



Separated Occupancies (508.4)

- Requirements of code for each portion based upon occupancy of that portion
- Allowable Height of each occupancy based upon construction type and occupancy
- Allowable Area of each story
  - Sum of actual area over allowable area of each occupancy ≤ 1.0

Separated Occupancies (508.4)



$$\frac{A1}{\text{Allowable Area for Occupancy 1}} + \frac{A2}{\text{Allowable Area for Occupancy 2}} \leq 1.0$$

Check Performed for each Story.
Separation by Fire Barriers and Horizontal Assemblies

Separated Occupancies (508)

Separation by *Fire Barriers* and *Horizontal Assemblies* required per Table 508.4

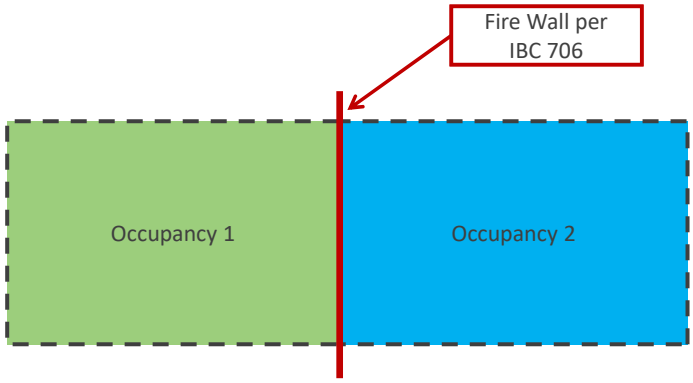
OCCUPANCY	A, E		I-1[a], I-3, I-4		I-2		R[a]		F-2, S-2[b], U		B[c], F-1, M, S-1	
	S	NS	S	NS	S	NS	S	NS	S	NS	S	NS
A, E	N	N	1	2	2	NP	1	2	N	1	1	2
I-1[a], I-3, I-4	—	—	N	N	2	NP	1	NP	1	2	1	2
I-2	—	—	—	—	N	N	2	NP	2	NP	2	NP
R[a]	—	—	—	—	—	—	N	N	1[c]	2[c]	1	2
F-2, S-2[b], U	—	—	—	—	—	—	—	—	N	N	1	2
B[c], F-1, M, S-1	—	—	—	—	—	—	—	—	—	—	N	N
H-1	—	—	—	—	—	—	—	—	—	—	—	—
H-2	—	—	—	—	—	—	—	—	—	—	—	—
H-3, H-4	—	—	—	—	—	—	—	—	—	—	—	—
H-5	—	—	—	—	—	—	—	—	—	—	—	—

Table 508.4 (Abbreviated)

NP = Not Permitted, N = No Separation Required

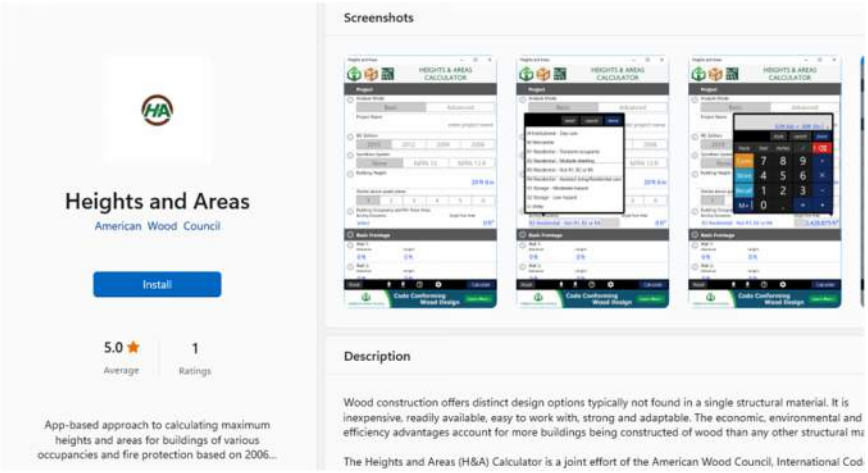
Separate Buildings

Each portion of a building separated by one or more ***fire walls*** shall be considered to be a separate building



Heights and Areas Calculator

IBC H&A Calculator available from App Stores for Windows, iOS and Android



Outline

- Introduction
- Framing System Design and Details
  - Structural Design Compliance
  - Wall Framing
  - Wall Bracing
  - Roof Framing
- Non-Structural Requirements and Design
  - Allowable Heights and Areas
  - Multi-Tenant and Multi-Occupancy Buildings
  - Fire Resistance and Detailing
- Large Retail Project Case Study

Fire Resistance Ratings – IBC Table 601

Building Element	Type III		Type IV	Type V	
	A	B	HT	A	B
Primary Structural Frame	1	0	HT	1	0
Exterior Bearing Walls*	2	2	2	1	0
Interior Bearing Walls	1	0	1/HT	1	0
Exterior Nonbearing walls*	Varies per Fire Separation Distance – See IBC Table 602				
Interior Nonbearing walls	0	0	See IBC section 602.4.6	0	0
Floors	1	0	HT	1	0
Roofs	1	0	HT	1	0

* See IBC Table 602 for Exterior wall Fire Resistance Rating modifications due to Fire Separation Distance

AC0

Fire Resistance Rating – IBC Table 601

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Roof construction and secondary members (see Section 202)	1 1/2[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

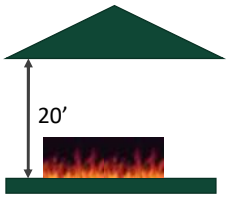
c. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.

AC0

Table 601 Footnotes – "b"

Fire protection of structural members shall not be required, where every part of the roof construction is 20 feet or more above any floor immediately below.

- FRT wood allowed in Roofs of Such Type I and II buildings



Except in group F-1, H, M, and S-1 occupancies

Slide 206

AC0 Footnotes should be updated for most current IBC provisions.
Ashley Cagle, 2023-08-18T16:42:31.280

Slide 207

AC0 Footnotes should be updated for most current IBC provisions.
Ashley Cagle, 2023-08-18T16:42:50.387

Table 601 Footnotes – "c"

Heavy Timber roof can be used where fire rating is 1hr or less

- Applies to any type of construction except Type IA

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Roof construction and secondary members (see Section 202)	1 1/2[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

Sources of Fire Rated Assemblies and Components

Commonly Approved Sources:

- American Wood Council's DCA3: Fire-Rated Wood-Frame Wall and Floor/Ceiling Assemblies
- APA's Document W305 – Fire-Rated Systems.
- SBCA's Metal Plate Connected Wood Truss Handbook – Section 17 Fire Performance of Trusses
- Underwriters Laboratory Fire Rated Listing

An "UL Assembly" listed by the Underwriters Laboratory is only ONE of MANY routes to compliance with fire ratings.

Outline

- Introduction
- Framing System Design and Details
  - Structural Design Compliance
  - Wall Framing
  - Wall Bracing
  - Roof Framing
- Non-Structural Requirements and Design
  - Allowable Heights and Areas
  - Multi-Tenant and Multi-Occupancy Buildings
  - Fire Resistance and Detailing
- Large Retail Project Case Study

Retail Store Design

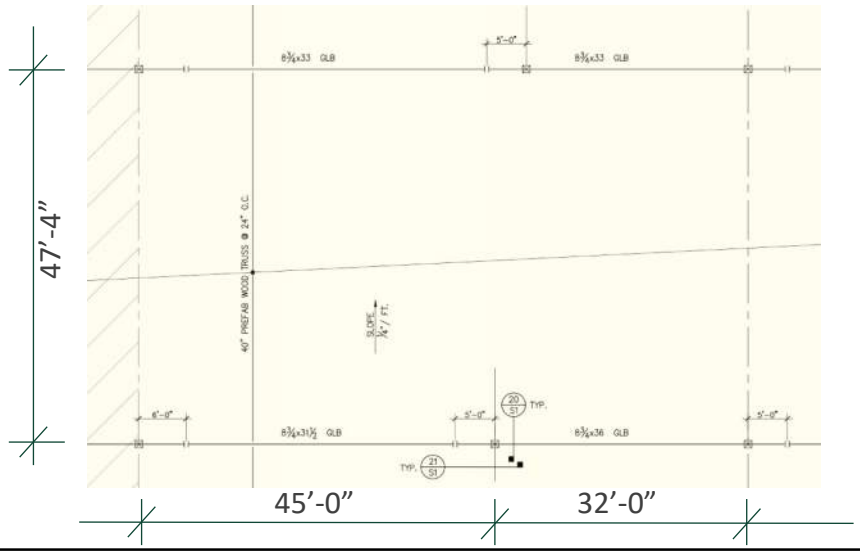
- 55,000 sf chain grocery store in northern CA
- Originally designed and built with steel and masonry
- WoodWorks commissioned structural re-design with wood framing
- Comparing original to wood re-design, WoodWorks commissioned cost estimate & LCA studies

Big Cost Savings for Retail Store

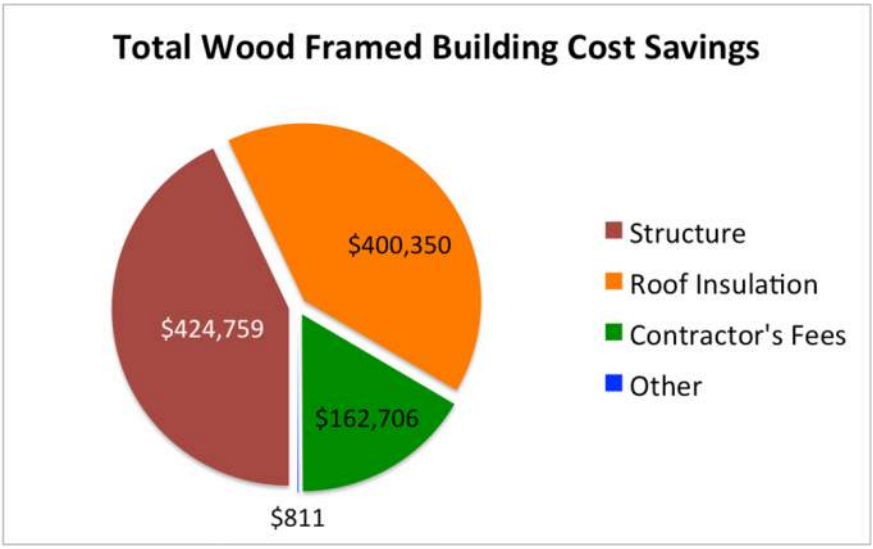
- Original Steel & Masonry Building: $4.49 M
- Wood Building: $3.5 M
- Nearly **$1 M Savings** – 22% Savings - $18/sf Savings

Retail Store: Gravity Framing System

Partial Roof Framing Plan



Cost Savings Factor: Structure



Cost Savings Factor: Roof Insulation

- Original Steel & Masonry Building: 4.5” Extruded Polystyrene (XPS) Rigid Insulation on Top of Steel Roof Deck. R-22. Cost = $783,000
- Wood Building: 5.5” Fiberglass Batts Between Roof Trusses. R-22. Cost = $383,000
- **Roof Insulation Savings of $400,000**

Source: Owens Corning

Source: Networx

Cost Savings Factor: Structure

Source: Canadian Wood Council

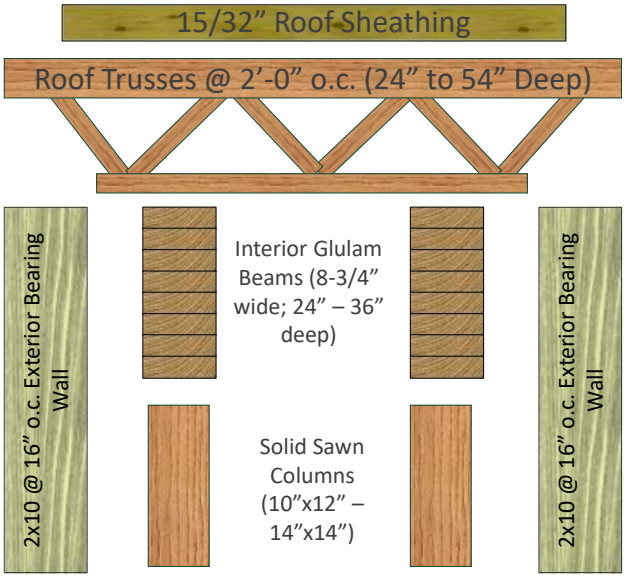
Cost Savings Factor: Structure

Total Structure Cost Savings for Wood Building = $425,000

Source: APA

Source: LP Building Products

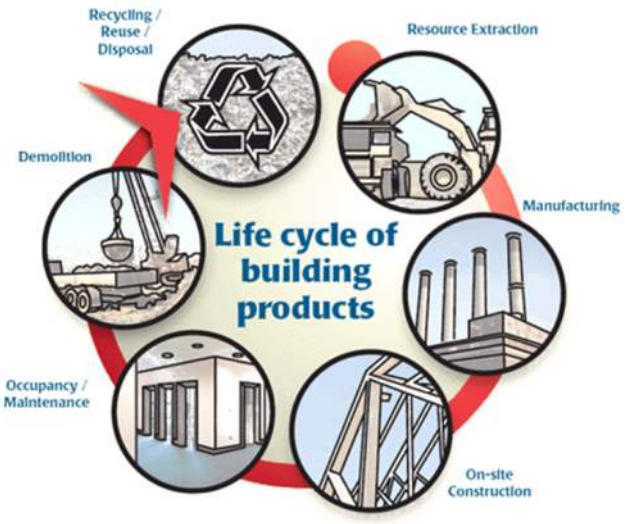
Retail Store: Gravity Framing System



Cost Savings Factor: Structure

Category	Steel Bldg Element	Wood Bldg Element	Wood Bldg Cost Savings
Roof Beams	Open web steel joist girders	Glulam Beams	$164k
Roof Decking	1-1/2" Steel Deck	15/32" Sheathing	$114k
Columns	HSS Columns	Solid Sawn Columns	$107k
Primary Roof Framing	Open web steel joists	Prefab Trusses	$66k
Wall Framing	6" metal studs & 8" masonry	2x10 @ 16" o.c.	$54k
Ceiling	N.A.	5/8" gyp & RC	$80k Extra
Total Wood Structure Cost Savings			**$425k**

Life Cycle Assessment

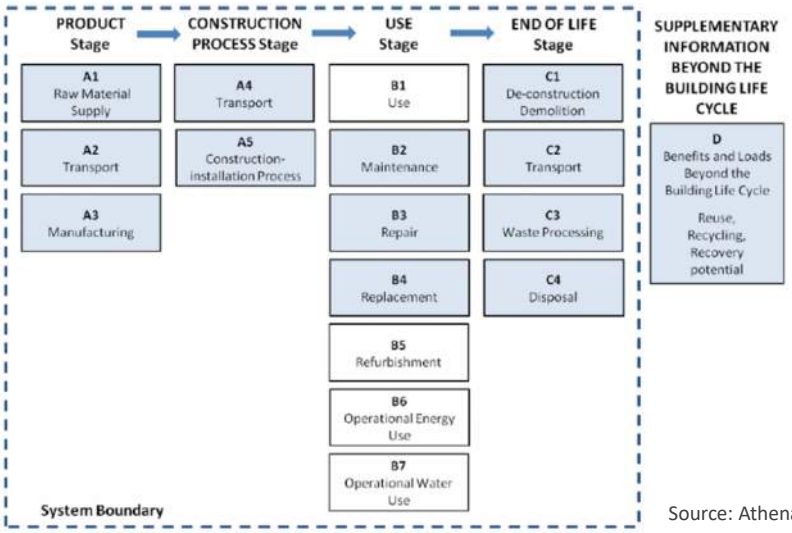


Source: Athena Sustainable Materials Institute

Life Cycle Assessment

- Measures the environmental impacts of materials, assemblies or buildings over their entire lives—from extraction or harvest of raw materials through manufacturing, transportation, installation, use, maintenance and disposal or recycling.
- Allows design professionals to compare different building designs based on their environmental impacts and make informed choices about the materials they use.

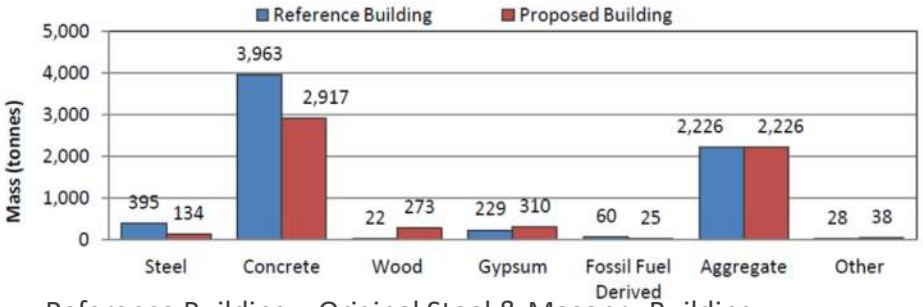
Life Cycle Assessment (LCA)



Source: Athena Sustainable Materials Institute

Retail Store: LCA Comparison

Life Cycle Product Use Mass Comparison by Building Product Type

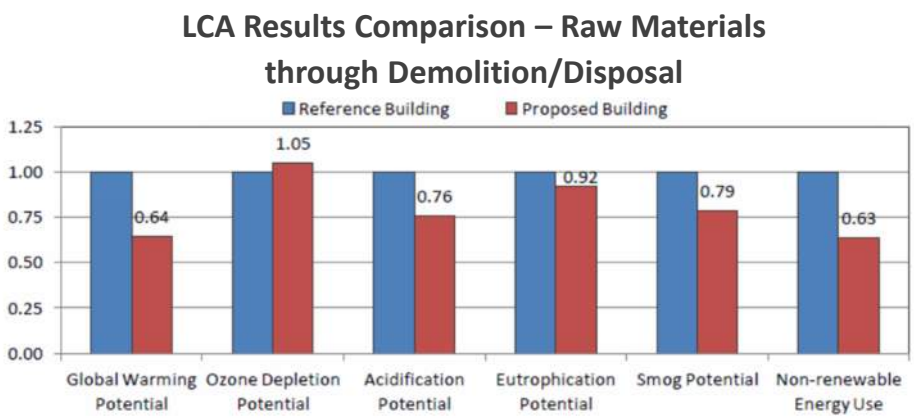


Reference Building = Original Steel & Masonry Building

Proposed Building = Wood Building

Source WoodWorks Case Study "Big Box Retail: Wood Saves Nearly $1 million" available at http://www.woodworks.org/wp-content/uploads/Big-Box-Retail-Wood-vs-Steel-Oct-2015.pdf

Retail Store: LCA Comparison



Reference Building = Original Steel & Masonry Building

Proposed Building = Wood Building

Source WoodWorks Case Study "Big Box Retail: Wood Saves Nearly $1 million" available at http://www.woodworks.org/wp-content/uploads/Big-Box-Retail-Wood-vs-Steel-Oct-2015.pdf

Additional Resources

American Wood Council Publications: www.awc.org

- National Design Specification (NDS) for Wood Construction
- Special Design Provisions for Wind and Seismic (SDPWS)
- Wood Frame Construction Manual (WFCM)
- Code Conforming Wood Design Series

Force Transfer Around Openings Paper by APA

- www.apawood.org/Data/Sites/1/documents/technicalresearch/seaoc-2015-ftao.pdf

Metal Plated Wood Trusses:

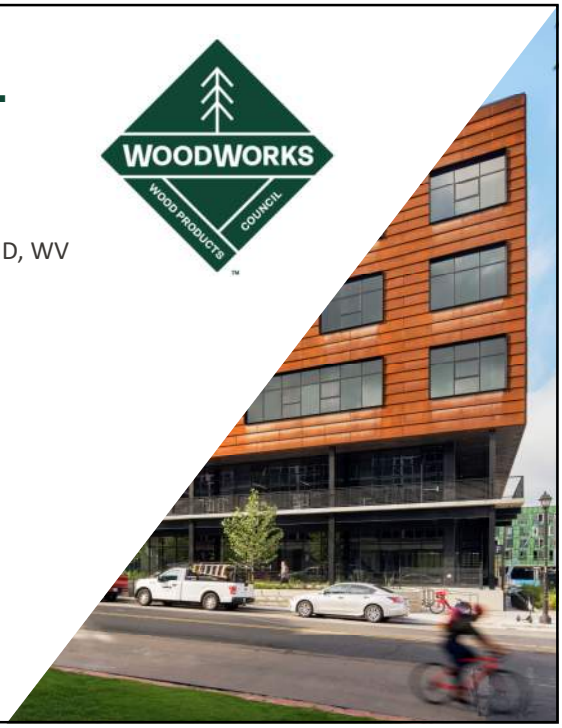
- Structural Building Components Association. www.SBCIndustry.com

Big Box Retail Design Case Study:

- www.woodworks.org/wp-content/uploads/Big-Box-Retail-Wood-vs-Steel-Oct-2015.pdf

Questions? Ask us anything.

John O'Donald II, PE
Regional Director | VA, DC, DE, MD, WV
(814) 880-5636
john.odonald@woodworks.org



901 East Sixth, Thoughtbarn-Delineate Studio, Leap!Structures, photo Casey Dunn

Copyright Materials

Funding provided in part by the Softwood Lumber Board