Shear Wall Selection for Wood Framed Buildings

Presented by: Ron Nuttall

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

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Webinar Attendee Survey

Ron Nuttall

https://www.apawood.org/shear-wall-selection-survey

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Course Description

From wall bracing to FTAO, there are many ways to secure the walls of a building. It's great to have options, but how do you evaluate which is best for a project? As architects and builders, you may be in the dark about this evaluation process being made by your structural engineer and how it impacts your architectural vision and ease of construction. And as an engineer, you may have always gone with the status quo. But what could you be overlooking? This session examines shear wall options along with the pros and cons of each to help building professionals determine and communicate what structural approach is best for your next wood framed project.

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Learning Objectives

- Identify the shear wall options allowed by the International Building Code (IBC).
- Recognize the difference between shear wall solutions per the International Building Code and wall bracing per the International Residential Code.
- Assess the practical implications of shear wall solutions from construction to architectural design.
- Describe APA's resources and APA's research into Force Transfer Around Openings.

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Agenda

- What is a shear wall?
- Shear wall options
- Comparison of shear wall options
- APA Resources

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What is a Shear Wall?

- Walls that resist lateral loads (wind and seismic)
- 'Engineered'
- May contain additional hardware (ex. strapping or lateral tie plates)
- May be only a portion of a longer wall

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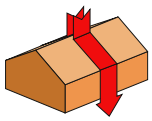
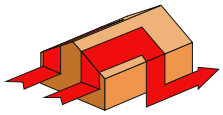
Load Path

A load path takes a load on the structure from the point of origin to the foundation.

There are 2 types of load paths:



Vertical Load Path
- fairly intuitive



Lateral Load Path
- not as intuitive

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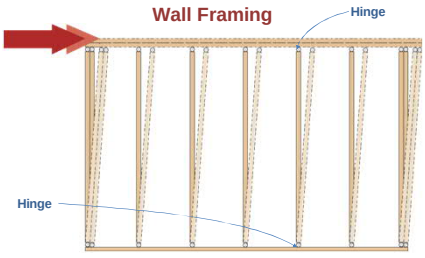
Load Path Basics



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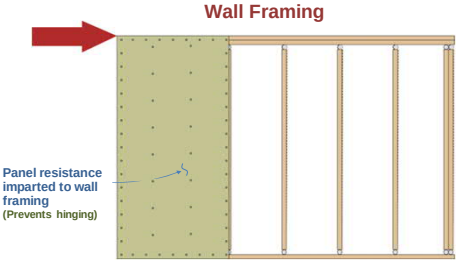
Load Path Basics

Wall Framing



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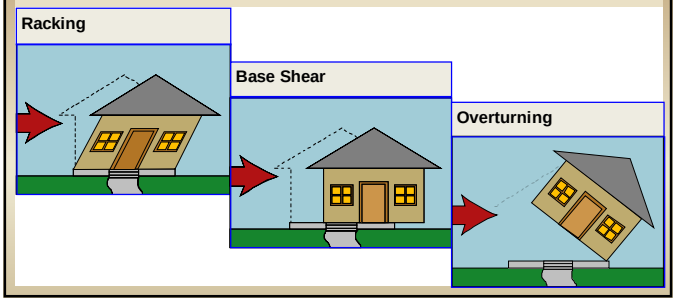
Lateral Load Failures



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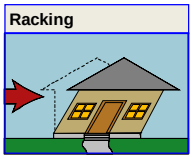
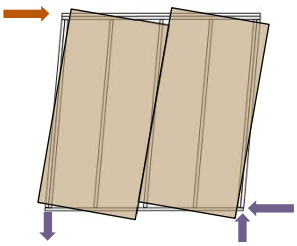
Load Path Basics

Shear Walls

- Nailing from panels to framing resists shear in wall





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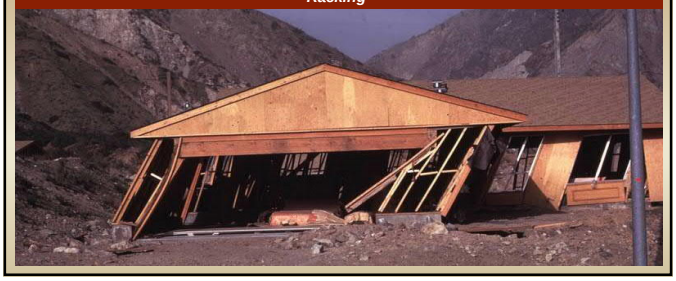
Whole House Effects of Lateral Load Path Failures

Racking



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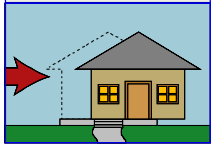
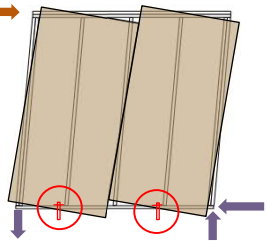
Load Path Basics

- Anchor bolts resist base shear

Base Shear



Shear Walls



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Whole House Effects of Lateral Load Path Failures

Base Shear

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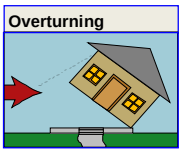
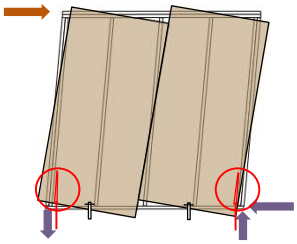
Load Path Basics

- Hold downs resist overturning

Overturning



Shear Walls



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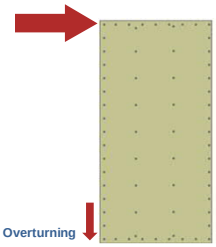
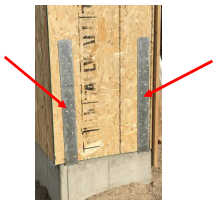
Overturning



Overturning



Hold-down straps next to a garage opening

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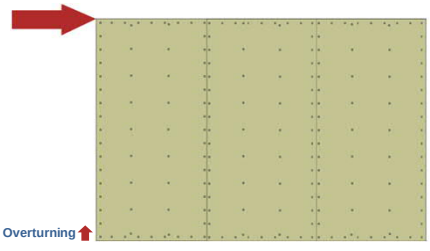
Overturning



Overturning

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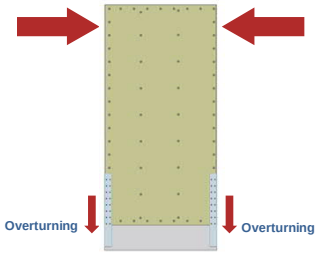
House – to – Foundation

Overturning Loads – Hold-Downs



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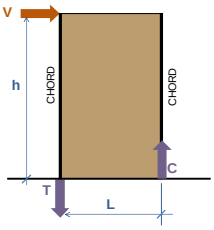
Load Path Basics

Shear Walls

- Components of a shear wall
  - Sheathing
  - Blocking
  - Chords
- Higher aspect ratio = higher deflection



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Agenda

- Shear wall options
  - What type of building are you designing?
  - What does the IBC and IRC allow?

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What type of building are you designing?

Single Family

- International Residential Code (IRC)
  - Wall bracing
- International Building Code (IBC)
  - Shear walls
- Hybrid approach (IRC & IBC)
  - Wall bracing & Shear walls

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Evolution of Home Designs

1950-1960's

1970-1990's

2000-on

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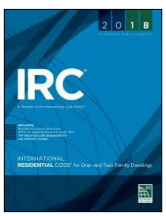
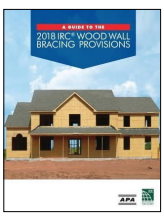
A Guide to the Wood Wall Bracing Provisions





2018 IRC Wall Bracing

46 pages on wall bracing
(includes simplified wall bracing)
281-page guide

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Wall bracing in a nutshell

Follow the recipe!

- Identify design criteria = "Lateral Load"
  - Seismic Design Category (SDC) & Wind speed
  - Check irregularity requirements (High seismic only)
  - Geometry of building: # Stories, Wall heights, Spacing between braced wall lines
- Resistance
  - Select bracing method & material:
    - Intermittent or continuous
    - WSP or GB, for example
  - Layout the bracing panels in accordance w/ IRC prescribed placement and length rules
- Confirm Resistance > Lateral Loads, if not add more bracing

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Shear Walls vs. Braced Wall Panels

Shear Walls (SWs)	Braced Wall Panels (BWPs)
BOTH resist lateral loads	
BOTH may contain holdowns, straps or lateral tie plates	
Engineered (IBC)	Prescriptive (IRC)
Range from 2" to 6" o.c. edge nails	Typically*, 6"o.c. edge nails
3.5:1 Aspect Ratio Limit	Typically*, 48" minimum width

*Where narrow BWPs are used, special detailing is used.

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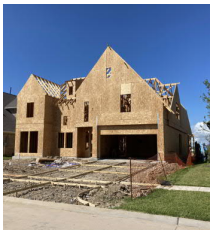
When to use a SW vs. a BWP?

- Structures that aren't covered under the IRC
  - Size/occupancy/geometry of structure
  - Wind/earthquake loads
- Limited space for BWPs (lots of windows/doors on the elevation)
  - BWP length of wall, end distance, and distance between panels requirements
  - Minimum panel width requirements
- SW may be more familiar



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Alternates?

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2021 International Building Code (IBC)

Multifamily and Nonresidential

- International Building Code (IBC)
  - ASCE 7
  - SDPWS

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Evolution of Commercial Designs

Religious

Multifamily/Commercial

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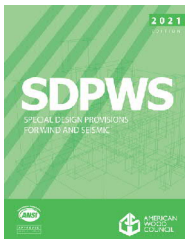
How Are Shear Walls Designed?



- Special Design Provisions for Wind and Seismic (SDPWS – spid-wiz)
  - Referenced in US building codes and used to design wood structures worldwide
- SDPWS allows 3 different methods
  - Segmented, Perforated or Force Transfer Around Openings (FTAO)
  - Each one has different restrictions and requirements regarding shear walls

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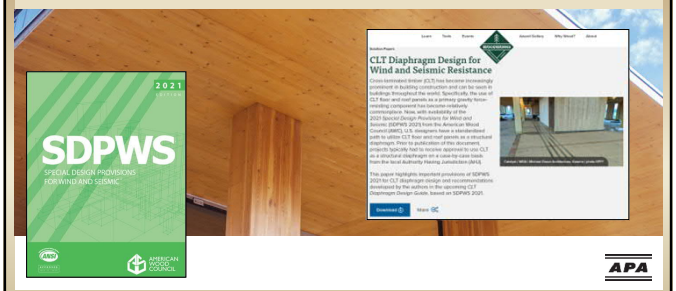
What About CLT?



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Wood Shear Wall Design

Shear Values

- Function of fastener size and spacing, panel thickness and the specific gravity of the framing materials
- Values in tables in SDPWS-21
- Alternately, capacities can be calculated by principles of mechanics

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Shear walls in a nutshell

There is no recipe!

- Analyze structure to quantify design load for each wall
  - IBC Ch 16 and ASCE 7
- Shear wall design
  - SDPWS
  - Select design option
    - Can mix design methods throughout structure, even within wall line provided designed and detailed to provide load transfer

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Shear Wall Design Challenges (SDPWS-21 4.3.2)

No openings allowed

Segmented

- Original design approach

Shear wall may include multiple openings

Perforated

- Design using empirical equations and tables

Force Transfer Around Openings (FTAO)

- Design using rational analysis

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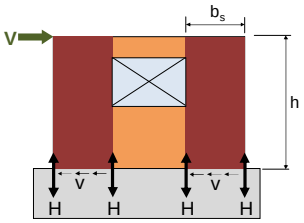
Segmented Wood Shear Walls

- Only full height, solid segments considered
- Aspect ratio calculated using full wall height
  - An 8' wall with a 4' panel has an aspect ratio of 2:1
- Hold-downs required on each segment



Aspect ratio h:b_s as shown in figure

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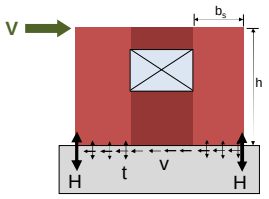
Perforated Shear Wall

- Aspect ratio calculated using full wall height
- All sheathing is considered for resistance
- Restrictions on opening sizes
- Uplift anchorage at full height segments required
- Hold-downs only at ends



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Perforated Shear Wall Approach

- Table 4.3.5.6 Shear Capacity Adjustment Factor, C_O

Percent Full-Height Sheathing (A_{hs}/A_{wall})	Percentage Wall Area Openings (A_o / A_{wall})									
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
	Shear Capacity Ratio, C_o									
10%	1.00	1.00	1.00	1.00	0.77	0.63	0.53	0.45	0.40	0.36
20%	1.00	1.00	1.00	0.91	0.71	0.59	0.50	0.43	0.38	-
30%	1.00	1.00	1.00	0.83	0.67	0.56	0.48	0.42	-	-
40%	1.00	1.00	1.00	0.77	0.63	0.53	0.45	-	-	-
50%	1.00	1.00	0.91	0.71	0.59	0.50	-	-	-	-
60%	1.00	1.00	0.83	0.67	0.56	-	-	-	-	-
70%	1.00	1.00	0.77	0.63	-	-	-	-	-	-
80%	1.00	0.91	0.71	-	-	-	-	-	-	-
90%	1.00	0.83	-	-	-	-	-	-	-	-
100%	1.00	-	-	-	-	-	-	-	-	-

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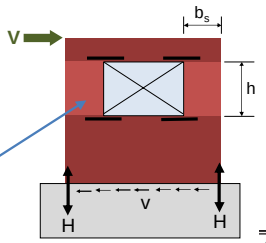
Force Transfer Around Openings (FTAO)

- All sheathing is considered for resistance
- Hold-downs only at ends
- Shear transferred around openings via strapping and blocking
- Aspect ratio calculated using pier height



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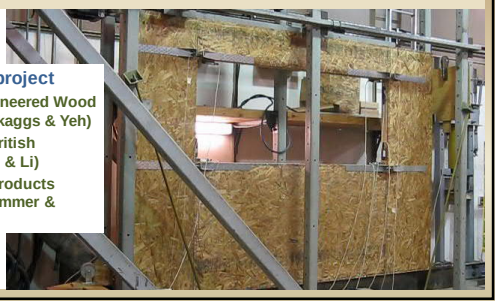
FTAO Research at APA



Joint research project

- APA - The Engineered Wood Association (Skaggs & Yeh)
- University of British Columbia (Lam & Li)
- USDA Forest Products Laboratory (Rammer & Wacker)

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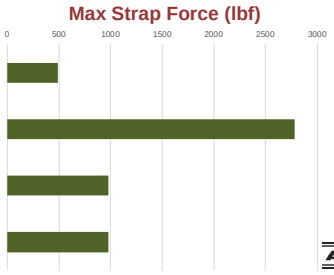
Design Example Results

- Drag Strut Analogy
  - F1 = 489 lbf
  - F2 = 285 lbf
- Cantilever Beam Analogy
  - F1 = 2,779 lbf
  - F2 = 1,368 lbf
- Diekmann Method
  - F1 = 979 lbf
  - F2 = 570 lbf
- Thompson Method
  - F1 = 570 lbf
  - F2 = 979 lbf



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Test Plan

- 12 assemblies tested, examining the three approaches to designing and detailing walls with openings
  - Segmented
  - Perforated Shear Wall
  - Force Transfer Around Openings
- All walls were 12 feet long x 8 feet tall
- Wall nailing: 10d commons (0.148″ x 3″) at 2″ o.c.
- Sheathing: 15/32 PERF CAT oriented strand board (OSB) APA Structural I

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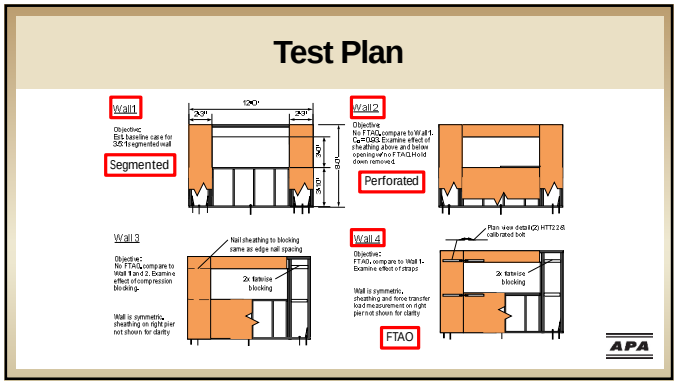
Test Plan
Wall 1
Segmented
Wall 2
Perforated
Wall 3
Wall 4
FTAO
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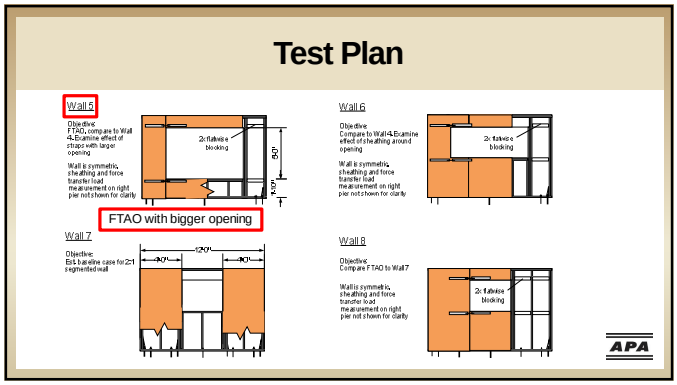
Test Plan
Wall 5
FTAO with bigger opening
Wall 6
Wall 7
Wall 8
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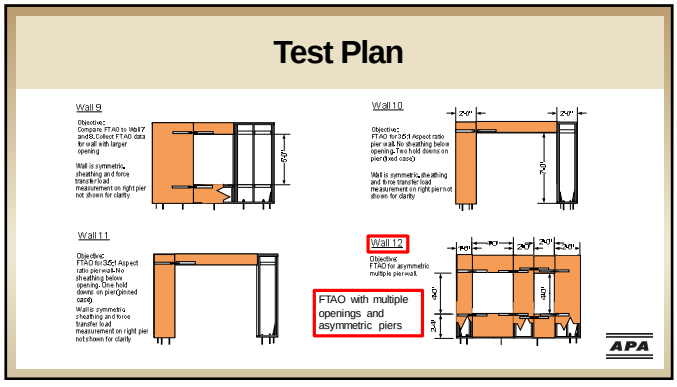
Test Plan
Wall 9
Wall 10
Wall 11
Wall 12
FTAO with multiple openings and asymmetric piers
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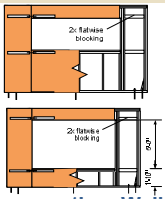
Testing Conclusions

- Wall 4
  - Narrow piers
  - Deep sill
- Wall 5
  - Increased opening from Wall 4
  - Shallow sill
  - Lower stiffness and lower strength
- Wall 4 & 5 (FTAO walls) stiffer and stronger than Walls 1 & 2 (segmented and perforated)



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Measured vs. Predicted Strap Forces

= analysis method less than lab results

= analysis method greater than lab results by > 300%

Wall ID	Measured Strap Forces (lbf) [1]		Error For Predicted Strap Forces at ASD Capacity of the Panel (%)							
			Drag Strut Technique		Cantilever Beam Technique		Diekmann Technique	SEAOC/Thompson Technique		
	Top	Bottom	Top	Bottom	Top	Bottom	Top/Bottom	Top	Bottom	
Wall 4a	687	1,485	176%	82%	652%	183%	132%	406%	119%	
Wall 4b	560	1,477	219%	83%	800%	184%	133%	499%	119%	
Wall 4c [2]	668	1,316	183%	93%	670%	207%	149%	418%	129%	
Wall 4d	1,006	1,665	122%	73%	445%	164%	118%	278%	102%	
Wall 5b	1,883	1,809	69%	68%	327%	256%	173%	204%	160%	
Wall 5c [2]	1,611	1,744	76%	70%	382%	265%	187%	238%	166%	
Wall 5d	1,633	2,307	75%	53%	377%	201%	141%	235%	125%	
Wall 6a	421	477	291%	256%	1063%	571%	410%	663%	357%	
Wall 6b	609	614	201%	199%	729%	444%	319%	455%	277%	
Wall 8a	985	1,347	118%	86%	608%	359%	138%	269%	120%	
Wall 8b [2]	1,493	1,079	78%	108%	533%	449%	124%	177%	150%	
Wall 9a	1,675	1,653	69%	70%	475%	383%	185%	217%	166%	
Wall 9b	1,671	1,594	69%	73%	476%	397%	185%	218%	172%	
Wall 10a	1,580	n.a. [3]	73%	n.a. [3]	496%	n.a. [3]	n.a. [3]	n.a. [3]	n.a. [3]	
Wall 10b	2,002	n.a. [3]	58%	n.a. [3]	391%	n.a. [3]	n.a. [3]	n.a. [3]	n.a. [3]	
Wall 11a	2,466	n.a. [3]	47%	n.a. [3]	318%	n.a. [3]	n.a. [3]	n.a. [3]	n.a. [3]	
Wall 11b	3,062	n.a. [3]	38%	n.a. [3]	256%	n.a. [3]	n.a. [3]	n.a. [3]	n.a. [3]	
Wall 12a	807	1,163	81%	94%	553%	348%	128%	172%	120%	
Wall 12b	1,083	1,002	60%	109%	442%	403%	138%	128%	139%	

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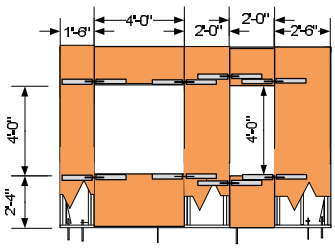
Multiple Openings and Asymmetric Piers



- APA FTAO Testing Wall 12
  - Multiple openings
  - Asymmetric pier widths
- Accurate analysis method
  - Diekmann Technique
  - Expanded to incorporate multiple openings and asymmetric piers

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Agenda

- Comparison of shear wall options
  - Structurally
  - Architecturally
  - Constructability

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Structural Design Comparison

Segmented

+ Design is straight forward

- Don't capture strength of sheathing around openings

Perforated

+ Design capacities adjusted based on number and size of openings

- Connection design required at base of each full height segment

Force Transfer

+ Walls detailed for FTAO resulted in better global response

- Increased stiffness and strength

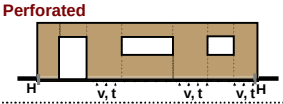
51

Structural Design Comparison

Segmented Approach

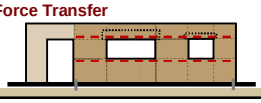
15/32 Category Rated Sheathing
8d @ 4"o.c. (3'-6" walls)
8d @ 6" o.c. (4' walls)
8 – hold-downs @ 2,000+ lb capacity

Perforated



15/32 Category Rated Sheathing
8d @ 4"o.c.
2 – hold-downs @ 2,435 lb capacity
extensive plate anchorage

Force Transfer

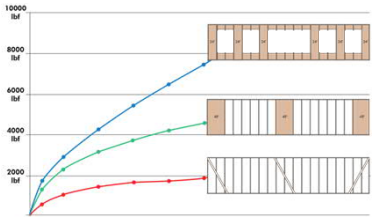


15/32 Category Rated Sheathing
8d @ 4"o.c.
2 – hold-downs @ 1,550 lb capacity
2 Straps – 865 lb

52

Bracing for Lateral Loads: Racking Strength

APA Full-Scale 3D Wall Bracing Tests, Form T2007-73



CS-WSP resists 88% more load than WSP bracing

WSP wall bracing – Base case

Diagonal bracing resists 31% of WSP load

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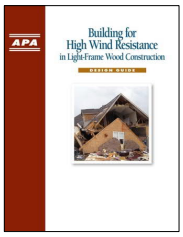
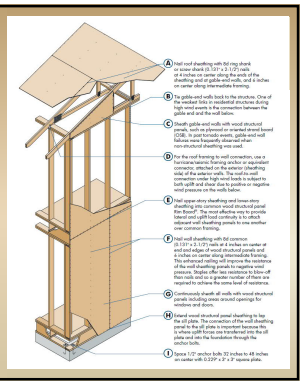
Building for High Wind Resistance





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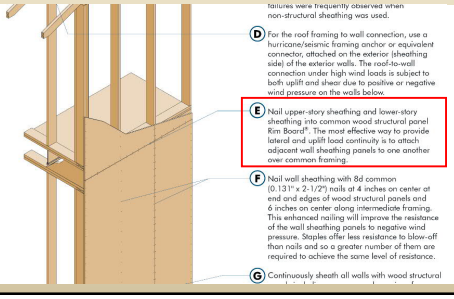
Connections between floors



failures were frequently observed when non-structural sheathing was used.

(D) For the roof framing to wall connection, use a hurricane/seismic framing anchor or equivalent connector, attached on the exterior (sheathing side) of the exterior walls. The roof-to-wall connection under high wind loads is subject to both uplift and shear due to positive or negative wind pressure on the walls below.

(E) Nail upper-story sheathing and lower-story sheathing into common wood structural panel Rim Board®. The most effective way to provide lateral and uplift load continuity is to attach adjacent wall sheathing panels to one another over common framing.

(F) Nail wall sheathing with 8d common (0.131" x 2-1/2") nails at 4 inches on center at end and edges of wood structural panels and 6 inches on center along intermediate framing. This enhanced nailing will improve the resistance of the wall sheathing panels to negative wind pressure. Staples offer less resistance to blow-off than nails and so a greater number of them are required to achieve the same level of resistance.

(G) Continuously sheath all walls with wood structural

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Architectural Impacts

- Shear wall choices affect
  - Architectural vision
    - Shear walls with narrower aspect ratios = more doors and windows

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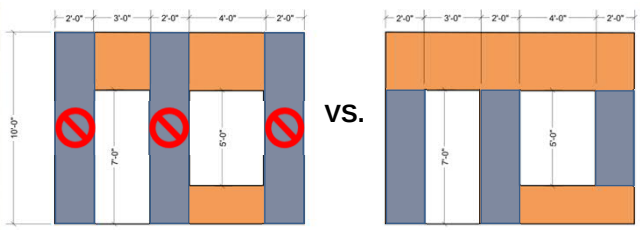
Aspect Ratio Examples



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Architectural Impacts

- Shear wall choices affect
  - Building envelope
    - Moisture intrusion
    - Air intrusion
    - Energy efficiency
    - Cladding attachment

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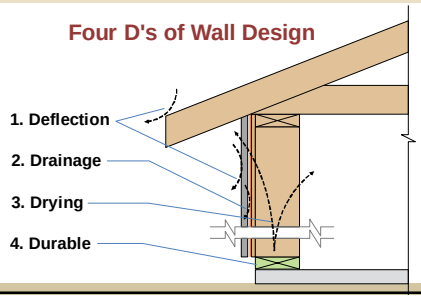
Prevent Moisture Intrusion

Four D's of Wall Design



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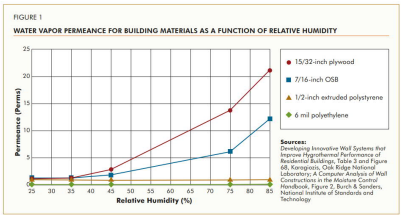
Prevent Moisture Intrusion

- Smart Vapor Retarders
  - APA Technical Note J450



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DID YOU KNOW?

10 Benefits of Wood Structural Panel Wall Sheathing

Fully Sheathed Wood Walls

61

Wood Structural Panels in Air Barrier Systems

Recognized as air barrier materials by:

- ASHRAE
- International Residential Code
- International Energy Conservation Code
- National Building Code of Canada

62

Wood Structural Panels in Air Barrier Systems

- Must be installed continuously
- Select durable materials
- Save on energy bills
- Airtightness is a key function of a building's overall energy performance

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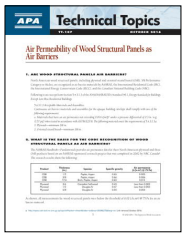
Wood Structural Panels in Air Barrier Systems

APA Technical Topic

- Form TT-107
  - Answers questions regarding the performance of wood structural panels in air barrier systems
  - Free download at www.apawood.org



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Fully Sheathed Walls for Higher R-Values

Insulation Options

- Spray-in-place cellulose, fiberglass and mineral wool
- Spray foam
- Blanket batts and rolls

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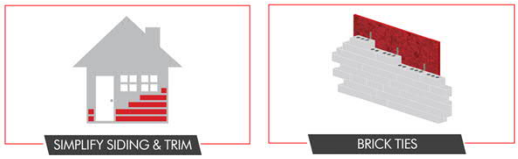
DID YOU KNOW?

10 Benefits of Wood Structural Panel Wall Sheathing

Fully Sheathed Wood Walls



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Advantages of Nail-Base Sheathing

- Eliminates the need for precise fastener spacing.
- Allows for the use of shorter fasteners.
- Helps ensure that siding remains in place during high-wind events.
- Eliminates the need for blocking when siding ends don't fall on studs.

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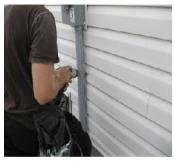
Nail-Base Sheathing for Siding and Trim Attachment



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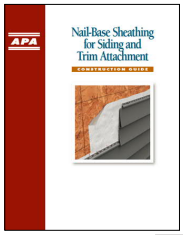
Nail-Base Sheathing for Siding and Trim Attachment

APA Construction Guide

- APA Form Q250
  - Provides guidance regarding the use of wood structural panel wall sheathing as a nail base
  - Applicable for cladding materials with weights up to 3 psf
  - Free download at www.apawood.org



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Nail-Base Sheathing for Siding and Trim Attachment

TABLE 1
Fastener Substitution Schedule for Nail-Base Sheathing[a,b,c]

Fastener Diameter	Fastener Type	Sheathing Performance Category 3/8	Sheathing Performance Category 7/16
Use same diameter for all types of fastener as the smooth-shank nail diameter recommended by siding manufacturer	Smooth-or screw-shank nails	4:1 (use 3 additional fasteners per specified fastener spacing)	3:1 (use 2 additional fasteners per specified fastener spacing)
	Ring-shank nails[d]	1:1	1:1
	Wood screws[d]	1:1	1:1

Notes:
a. The table above is based on the siding manufacturer's installation recommendations for 1.25-inch penetration into spruce-pine-fir lumber framing by smooth-shank nails.
b. The table above is based on the use of a siding product with a weight of not more than 3 psf.
c. Additional nails may be required if the siding manufacturer's installation recommendations are based on framing lumber with a specific gravity (SG) greater than 0.42.
d. Use same number of fasteners and fastener spacing recommended by the siding manufacturer for fastening to studs.

Please note: See 2021 IRC Section R703.3.4

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Tested and Code Accepted

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Nail-Base Sheathing for Siding and Trim Attachment

APA Technical Topic

- APA Form TT-109
  - Applicable for cladding materials with weights up to 11 psf
  - Free download at www.apawood.org

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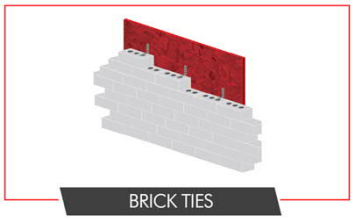
Nail-Base Sheathing for the Attachment of Brick Ties



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Nail-Base Sheathing for the Attachment of Brick Ties

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Nail-Base Sheathing for the Attachment of Brick Ties

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Nail-Base Sheathing for the Attachment of Brick Ties

IRC 2021

TABLE R703.8.4(2)
REQUIRED BRICK TIE SPACING FOR DIRECT APPLICATION TOWOOD STRUCTURAL PANEL SHEATHING[a, b, c]

FASTENER TYPE[d]	SIZE (DIA. OR SCREW #)	REQUIRED BRICK-TIE SPACING (VERTICAL-TIE SPACING/HORIZONTAL-TIE SPACING) (inches/inches)											
		110 mph V_{ult}			115 mph V_{ult}			130 mph V_{ult}			140 mph V_{ult}		
		Zone 5, Exposure B	Zone 5, Exposure C	Zone 5, Exposure D	Zone 5, Exposure B	Zone 5, Exposure C	Zone 5, Exposure D	Zone 5, Exposure B	Zone 5, Exposure C	Zone 5, Exposure D	Zone 5, Exposure B	Zone 5, Exposure C	Zone 5, Exposure D
Ring Shank Nails	0.091	16/16, 16/12, 12/16, 12/12	16/12, 12/16, 12/12	12/12	16/16, 16/12, 12/16, 12/12	16/12, 12/16, 12/12	12/12	16/12, 12/16, 12/12	12/12	—	12/12	—	—
	0.148	24/16, 16/24, 16/16, 16/12, 12/16, 12/12	16/16, 16/12, 12/16, 12/12	16/16, 16/12, 12/16, 12/12	24/16, 16/24, 16/16, 16/12, 12/16, 12/12	16/16, 16/12, 12/16, 12/12	16/16, 16/12, 12/16, 12/12	16/16, 16/12, 12/16, 12/12	16/12, 12/16, 12/12	16/12, 12/16, 12/12	16/16, 16/12, 12/16, 12/12	16/12, 12/16, 12/12	12/12

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Constructability

- WSP installation basics
- Hardware needs

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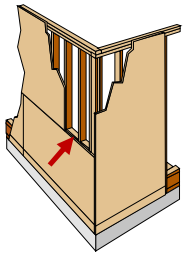
Constructability Shear Walls

- Wall sheathing
  - Plywood or OSB
  - Orientation



Resource: APA Technical Topics: Plywood or OSB? Used as Intended, the Two Products are Interchangeable, Form TT-047

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Constructability

Hold-down hardware

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Improper hold down installation

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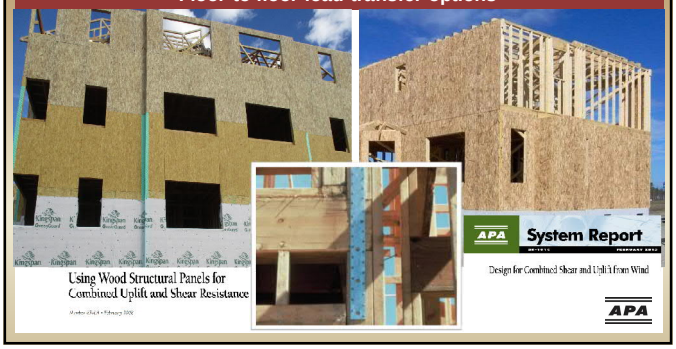
Floor to floor load transfer options



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FTAO Detailing

- Strap location
  - Outside
  - Inside
  - Discontinuous

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FTAO Detailing

- Blocking
  - Inside

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It's an FTAO World!

- Narrower Piers
- Larger Openings
- Reduced Hold-downs

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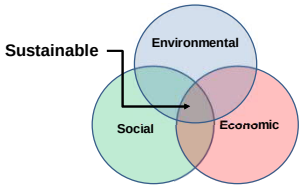
Case Study: Santa Barbara Apartments

- Value engineering save



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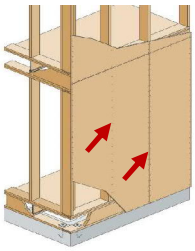
Benefits of Wall Sheathing

Wall Sheathing

- Racking/shear resistance
- Wind pressure resistance
- Nonstructural benefits
- Installation:
  - Per engineer's design
  - Min. fastening: 8d nails @ 6" o.c. perimeter and 12" o.c. in the field min.



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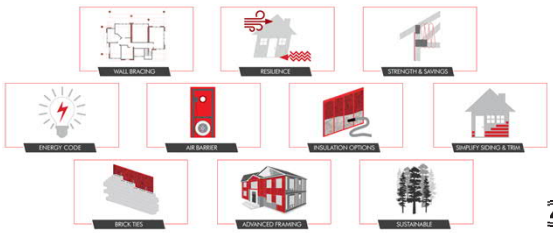
DID YOU KNOW?

10 Benefits of Wood Structural Panel Wall Sheathing

Fully Sheathed Wood Walls



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Agenda

- APA Resources
  - Wall bracing
  - Shear walls

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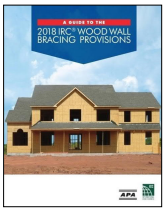
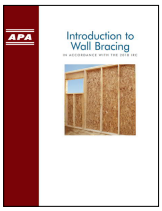
Resources

www.iccsafe.org
- Item 7102S12



www.apawood.org
- Form F430



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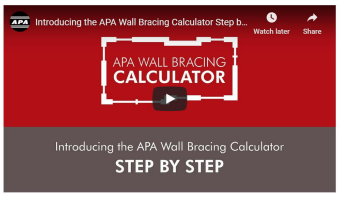
APA Wall Bracing Calculator

www.apawood.org/wall-bracing-calculator



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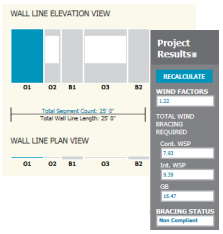
APA Wall Bracing Calculator

Benefits:

- The user locates the bracing segments, which offers user creativity while automating the code check, flagging incorrect or insufficient design.
- The output makes plan review clear and concise, and implementation into the construction plans straightforward.



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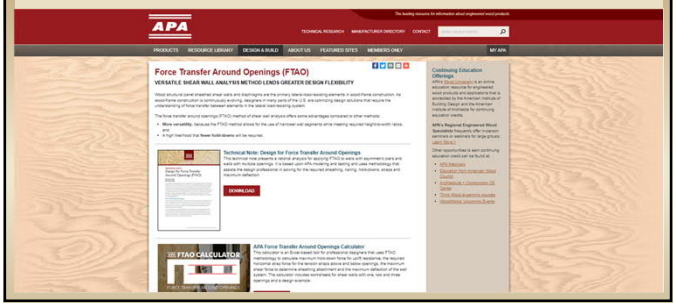
www.apawood.org/FTAO



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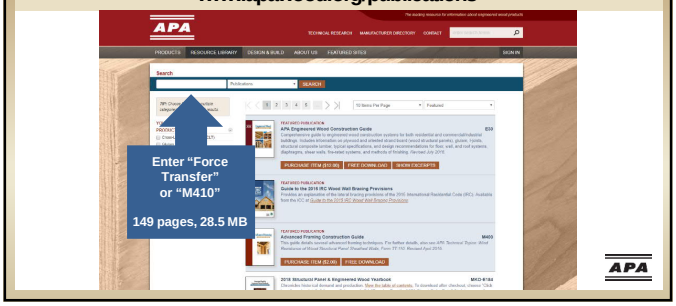
Report Available

www.apawood.org/publications



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FTAO Technical Note: Form T555

KBS3

- Technical Note: Design for Force Transfer Around Openings (FTAO)
- Presents a method for applying FTAO to walls with asymmetric piers and walls with multiple openings based on the Diekmann technique
- Based on Wall 12 testing configuration
- Includes a design example with 2 wall openings

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APA FTAO Calculator

- Excel-based tool updated January 2022
- Based on design methodology developed by Diekmann
- Calculates:
  - Max hold-down force for uplift resistance
  - Required horizontal strap force above and below openings
  - Max shear force for sheathing attachments
  - Max deflection
- Design example corresponds with FTAO Technical Note, Form T555

APA Force Transfer Around Openings Calculator

This calculator is an Excel-based tool for professional designers that uses FTAO methodology to calculate maximum hold-down force for uplift resistance, the required horizontal strap force for the tension straps above and below openings, the maximum shear force to determine sheathing attachment, and the maximum deflection of the wall system. The calculator includes worksheets for shear walls with one, two, and three openings and a design example.

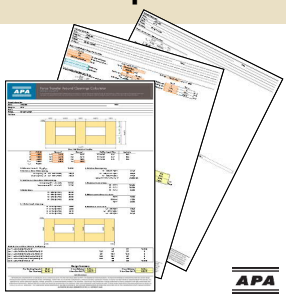
DOWNLOAD

95

FTAO Calculator: Final Output

Final Design Output

- Summary of input parameters
- FTAO shear wall analysis
- Summary of final design requirements
- Total calculated deflection
- Three-page shear wall design to include in calculation package
  - Print directly from Excel
  - Save as PDF



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Agenda

- What is a shear wall?
- Shear wall options
- Comparison of shear wall options
- APA Resources
- Conclusion

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Questions?

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APA Update Newsletter
(www.apawood.org)

November 2020

APAUPDATE
PUBLICATIONS, VIDEOS, CAD DETAILS AND MORE

Note: Due to Covid-19 control measures, we are unable to fulfill orders of printed publications at this time. These publications are available as downloadable PDFs.

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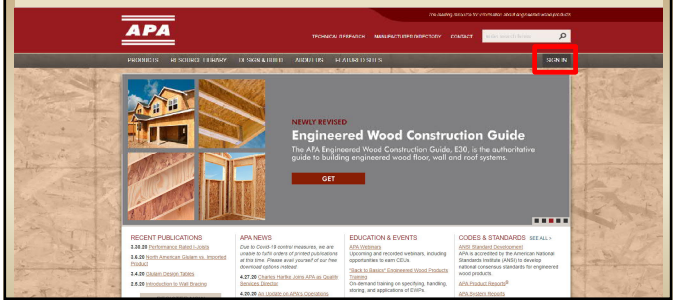
APA Update Newsletter
(www.apawood.org)



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APA Update Newsletter
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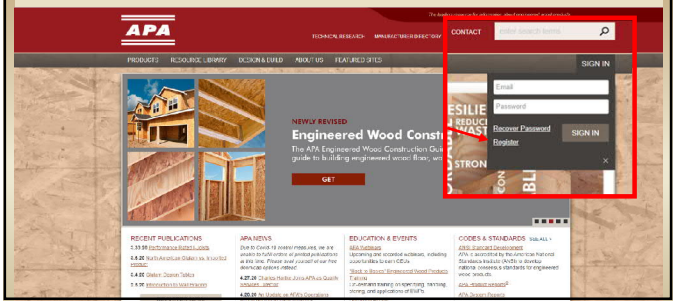

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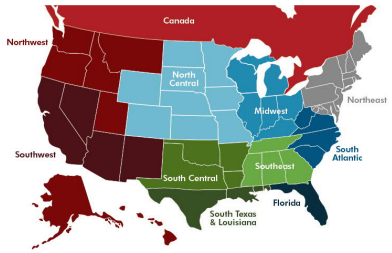
Field Services Division Territories



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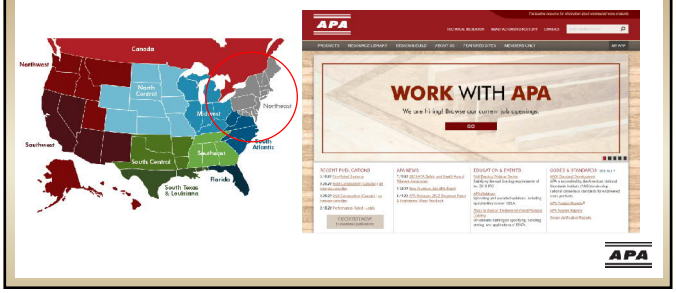
Field Services Division Territories



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