Design for Force Transfer Around Openings

Presented By: Noah Humberston
Engineered Wood Specialist
APA – The Engineered Wood Association

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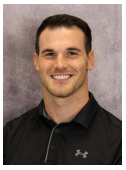
Webinar Attendee Survey



Noah Humberston
Engineered Wood Specialist
Northeast Region

https://www.apawood.org/ftao-survey

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Learning Objectives

1. Overview of the tool's development and a brief history of APA's FTAO research
2. The main benefits of the design tool, including key features and design capabilities
3. Demonstration of the tool's operation and design inputs
4. Highlight the design outputs and end product that the tool provides

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The Main Ideas

- Review code requirements for shear walls and FTAO methods
- Understand APA's FTAO research
- Demonstrate calculator's inputs and operation
- Highlight outputs

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Shear Wall Design Challenges




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Design for Force Transfer Around Openings

Shear Wall Design Challenges (SDPWS-21 4.3.2)


Segmented


Perforated


Force Transfer

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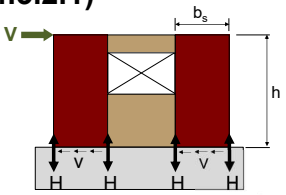
Design for Force Transfer Around Openings

Individual Full–Height Wall Segments (SDPWS-21 Section 4.3.2.1)

- Only full height segments considered
- Aspect ratio calculated using full wall height
- Hold-downs required on each segment



Aspect ratio h:b_s as shown in figure

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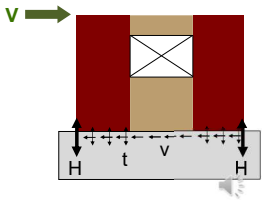
Perforated Shear Wall (SDPWS-21 Section 4.3.2.3)

- Openings accounted for by empirical adjustment factor
- Aspect ratio calculated using full wall height
- Uplift anchorage at full height segments required
- Hold-downs only at ends



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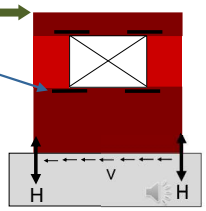
Force Transfer Around Openings (SDPWS-21 Section 4.3.2.2)

- Hold-downs only at ends
- Shear transferred around openings via strapping and framing
- Aspect ratio calculated using pier height



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Design for Force Transfer Around Openings

Aspect Ratio (SDPWS-21 Section 4.3.3)

- Definition of h and bs is the same as previous code
- All shear walls with **2:1 < aspect ratios ≤ 3.5:1** shall apply aspect ratio adjustment factor
- Aspect Ratio Factor (WSP) = **1.25-0.125h/bs**
- The adjustment factor listed prior to the 2015 SDPWS may still be used (SDPWS-21 section 4.3.5.5.1 Exception #1)

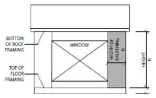

Fig 4D h:b_s ratio Segmented

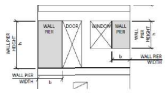

Fig. 4E h:b_s ratio FTAO

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FTAO Research at APA

Field Survey

- 18+ sites (LA, Orange and San Diego Counties)
- Multi-Family
  - 40-90% of all shear applications utilized FTAO
- Single-Family
  - 80% minimum 1 application on front or back elevation

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Design for Force Transfer Around Openings

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)
- Study was initiated to:
  - Examine the variations of walls with code-allowable h/bs ratios
  - Evaluate the effects of size of openings, size of full-height piers and different construction techniques
  - Examine the internal forces generated during full-scale testing and compare to FTAO analysis methods
  - Create analytical modeling to mimic testing data

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Design for Force Transfer Around Openings

FTAO Research at APA

Study results were used to:

- Support design methodologies in estimating the forces around the openings
- Develop rational design methodologies for adoption in the building codes and supporting standards
- Create new tools/methodology for designers to facilitate use of FTAO

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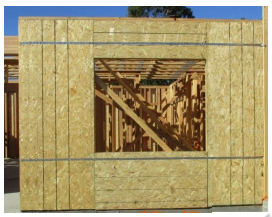
Design for Force Transfer Around Openings

Different Techniques for FTAO

- Drag Strut Analogy
- Cantilever Beam Analogy
- Diekmann Method
- Thompson Method



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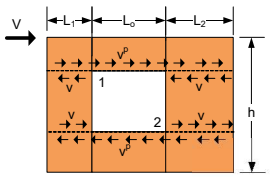
Design for Force Transfer Around Openings

Different Techniques for FTAO:

Drag Strut Analogy

- Segments above and below openings are drag struts
- Corner forces are a function of opening and pier widths



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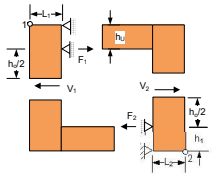
Design for Force Transfer Around Openings

Different Techniques for FTAO:

Cantilever Beam Analogy

- Wall is broken into segments
- Forces are treated as moment couples
- Corner forces are a function of height above and below opening and pier widths



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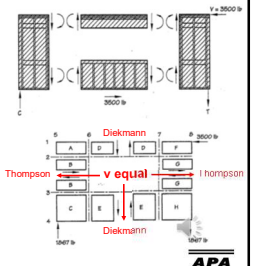
Design for Force Transfer Around Openings

Different Techniques for FTAO:

Diekmann (and Thompson)

- Assumes wall behaves as monolith
- Internal forces resolved via principles of mechanics
- Corner forces are a function of pier length and height of sheathing above and below opening
- Diekmann method assumes unit shear is equal above and below opening
- Thompson method assumes unit shear is equal across piers



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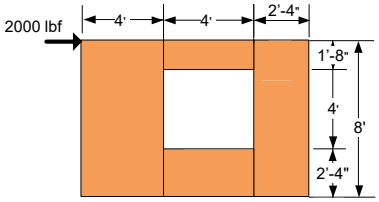
Design for Force Transfer Around Openings

Design Examples



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Design for Force Transfer Around Openings

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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Design for Force Transfer Around Openings

Laboratory Testing

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Test Plan

- 12 wall configurations tested (with and without FTAO applied)
- All walls were 12 feet long and 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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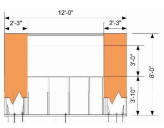
Test Plan

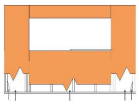
Wall1

Segmented

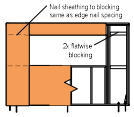


Wall 2

Perforated

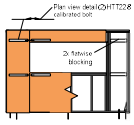


Wall 3



Wall 4

FTAO



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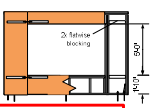
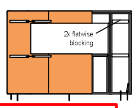
Test Plan

Wall 5



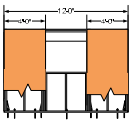
FTAO with bigger opening

Wall 6

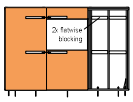


FTAO with C-shaped panel

Wall 7



Wall 8



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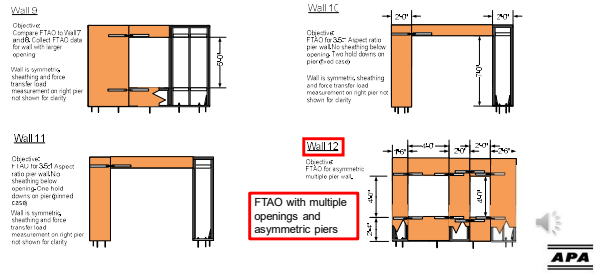
Test Plan



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Test Plan

Information obtained

- Hold-down force plots
- Anchor bolt force plots
- Plots of the applied load versus the displacement of the walls
- Plots of the applied load versus strap forces
- Cyclic hysteretic plots and various cyclic parameters of the individual walls

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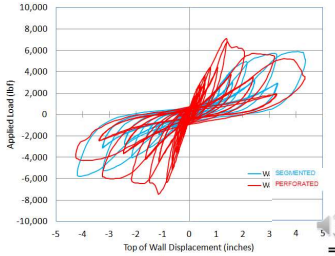
Testing Observations

- Local response of segmented and perforated walls
- Increased stiffness of perforated (red) vs. segmented (blue)



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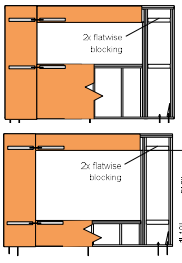
Testing Observations

- **Wall 4**
  - Narrow piers
  - Tall sill
- **Wall 5**
  - Increased opening from Wall 4
  - Low sill



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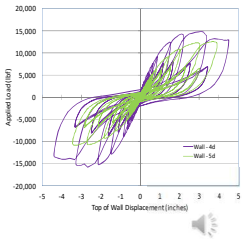
Testing Observations

Global response:

- Correlation between opening size vs. corner forces
- Larger openings resulted in both lower stiffness and lower strength
- Wall 4 & 5d demonstrated increased stiffness as well as strength over non-FTAO walls 1 & 2 (segmented and perforated)



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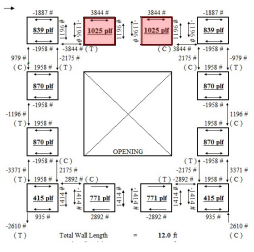
Testing Observations



Failure modes expected (Wall 5 – FTAO wall with bigger opening)

- Relatively brittle nature of walls with openings
- Concentration of forces from analysis (Thompson Method)

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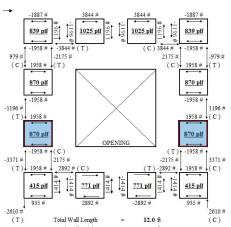
Testing Observations



Failure modes

- Variable stiffness between area adjacent and area below opening

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Testing Observations

= analysis method less than lab results

= analysis method greater than lab results by > 300%

Wall ID	Measured Strap Forces (lbf) [1]		Error [2] For Predicted Strap Forces at ASD Capacity (%)						
			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	178%	82%	652%	183%	132%	406%	115%
Wall 4b	560	1,477	219%	83%	800%	184%	133%	499%	115%
Wall 4c [3]	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	65%	68%	327%	256%	173%	204%	160%
Wall 5c [3]	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%	735%	444%	318%	458%	277%
Wall 8a	985	1,347	118%	86%	808%	359%	138%	269%	120%
Wall 8b [4]	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. [6]	73%	n.a. [6]	496%	n.a. [6]	n.a. [6]	n.a. [6]	n.a. [6]
Wall 10b	2,002	n.a. [6]	58%	n.a. [6]	391%	n.a. [6]	n.a. [6]	n.a. [6]	n.a. [6]
Wall 11a	2,466	n.a. [6]	47%	n.a. [6]	318%	n.a. [6]	n.a. [6]	n.a. [6]	n.a. [6]
Wall 11b	3,062	n.a. [6]	38%	n.a. [6]	256%	n.a. [6]	n.a. [6]	n.a. [6]	n.a. [6]
Wall 12a	807	1,163	81%	94%	542%	343%	128%	n.a. [6]	n.a. [6]
Wall 12b	1,083	1,002	60%	109%	442%	403%	138%	n.a. [6]	n.a. [6]

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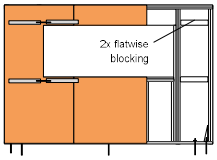
C-Shaped Panels

APA FTAO Test Wall 6

- Framing status quo some places
- Reduce/eliminate strapping



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Testing Conclusions

- 12 assemblies tested, examining the three approaches to designing and detailing walls with openings
  - Segmented
  - Perforated Shear Wall
  - Force Transfer Around Openings
- Walls detailed for FTAO resulted in better global response
  - Increased stiffness and strength

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Testing Conclusions

- Comparison of analytical methods with tested values for walls detailed as FTAO
  - The drag strut technique was consistently un-conservative
  - The cantilever beam technique was consistently ultra-conservative
  - Thompson provided similar results as Diekmann
  - Thompson & Diekmann techniques provided reasonable agreement with measured corner forces
- Use results to provide better guidance to engineers for FTAO
  - Summary of findings for validation of techniques
  - New tools for FTAO shear wall design

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Strapping Above and Below Openings

- SDPWS Section 4.3.2.2 specifies collectors between the diaphragms and the shear wall shall be full length
  - Top & bottom plates, drag struts, beams, etc.
  - Transfer forces from diaphragm into shear wall
- Strapping is not a collector
  - Can be discontinuous
  - Resists internal tension forces, not shear
  - Long enough to develop tension force
- Install strapping on interior or exterior

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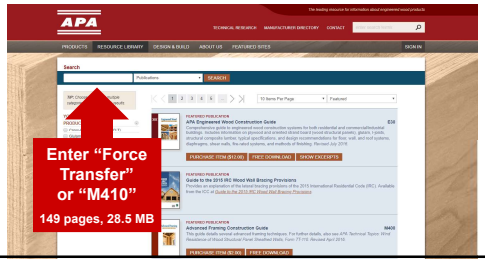
Report Available

www.apawood.org/publications



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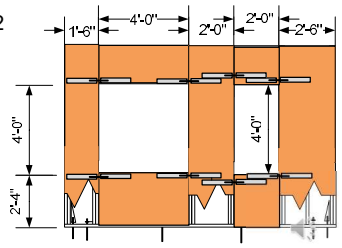
Multiple Openings and Asymmetric Piers

- 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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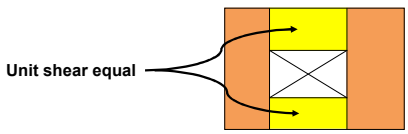
Diekmann Technique: Conceptual Keys

The method assumes the following:

- The unit shear above and below the openings is equivalent.



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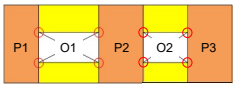
Diekmann Technique: Conceptual Keys

The method assumes the following:

- The corner forces are based on the shear above and below the openings and only the piers adjacent to that unique opening.



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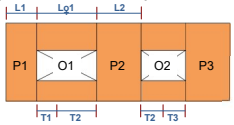
Design for Force Transfer Around Openings

Diekmann Technique: Conceptual Keys

The method assumes the following:

- Each pier assigned a tributary length (T) of each adjacent opening.
- Provides basis for calculating shear to each pier.

$$T1 = \frac{L1}{(L1+L2)} * Lo1$$



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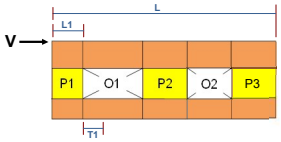
Design for Force Transfer Around Openings

Diekmann Technique: Conceptual Keys

The method assumes the following:

- The **unit shear (v)** of each pier is calculated using the unit shear of the wall and the tributary length of the pier.

$$v1 = \frac{(L1+T1)}{L1} * \frac{V}{L}$$



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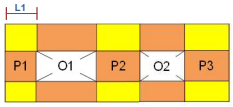
Design for Force Transfer Around Openings

Diekmann Technique: Conceptual Keys

The method assumes the following:

- The **unit shear of the corner zones (vc)** is equal to subtracting the corner force from the shear force in the pier, and then dividing by the length of the pier.

$$vc1 = \frac{(v1 * L1) - F1}{L1}$$



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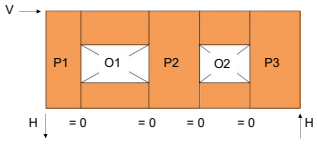
Design for Force Transfer Around Openings

Diekmann Technique: Conceptual Keys

The method assumes the following:

- Sum the shears vertically along each line to check the design.
- First and last line equal hold-down force.
- Remaining lines sum to zero.



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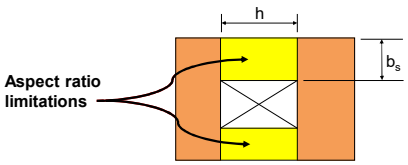
Design for Force Transfer Around Openings

Diekmann Technique: Limitation

Use engineering judgement for aspect ratios greater than 6.5:1 above or below the opening.



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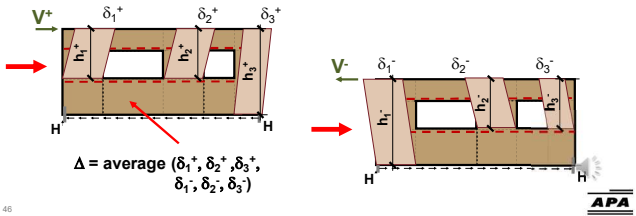
Deflection Calculations - Concept

Sheathing below the openings aids in resisting deflection



Δ = average (δ_1^+, δ_2^+ ,δ_3^+, δ_1^-, δ_2^-, δ_3^-)

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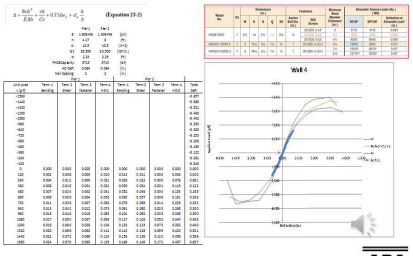
FTAO Technical Note: Form T555

- Wall drift estimation when using FTAO
- Historical 4-term deflection equation



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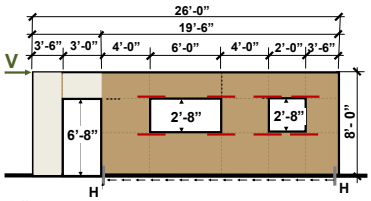
FTAO Approach



V = 3,750 lbs

Height/width Ratio = 2'-8" : 3'-6" = 0.76:1

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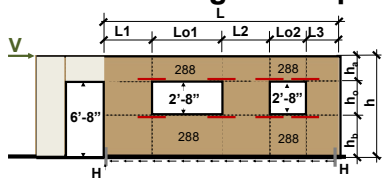
Design for Force Transfer Around Openings

FTAO Design Example



1. Calculate the hold-down forces:
   H=Vh/L = 3750# x 8'/19.5' = 1538#
2. Solve for the unit shear above and below the openings:
   va = vb = H/(ha+hb) = 1538#/(1.33'+4') = 288 plf

The unit shear above and below the openings is equivalent.

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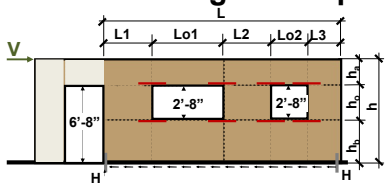
Design for Force Transfer Around Openings

FTAO Design Example



3. Find the total boundary force above and below the openings
   First opening: O1 = va x (Lo1) = 288 plf x 6' = 1731#
   Second opening: O2 = va x (Lo2) = 288 plf x 2' = 577#

The corner forces are based on the shear above and below the openings and only the piers adjacent to that unique opening.

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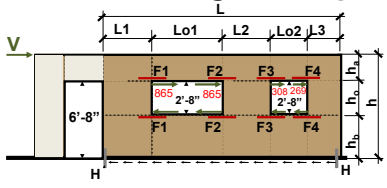
Design for Force Transfer Around Openings

FTAO Design Example



4. Calculate the corner forces:
   F1 = O1(L1)/(L1+L2) = 865#
   F2 = O1(L2)/(L1+L2) = 865#
   F3 = O2(L2)/(L2+L3) = 308#
   F4 = O2(L3)/(L2+L3) = 269#

Strap forces

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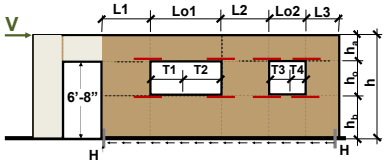
Design for Force Transfer Around Openings

FTAO Design Example



5. Tributary length of openings (ft) (Basis for calculating shear to each pier)
   Ratio of the length of the pier x length of the opening it is adjacent to, then / (length of the pier + length of the pier on the other side of the opening).
   T1 = L1(Lo1)/(L1+L2) = 3' **T2 = L2(Lo1)/(L1+L2) = 3'**
   T3 = L2(Lo2)/(L2+L3) = 1.1' **T4 = L3(Lo2)/(L2+L3) = 0.9'**

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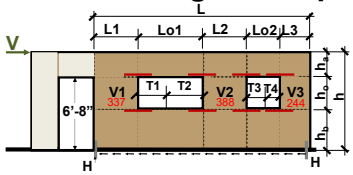
Design for Force Transfer Around Openings

FTAO Design Example



6. Unit shear beside the opening
   V1 = (V/L)(L1+T1)/L1 = 337 plf **V2 = (V/L)(T2+L2+T3)/L2 = 388 plf**
   V3 = (V/L)(T4+L3)/L3 = 244 plf **Check V1*L1 +V2*L2+V3*L3=V? YES**

The shear of each pier = the total shear / the L of the wall x (length of the pier + its tributary length)/ by the length of the pier

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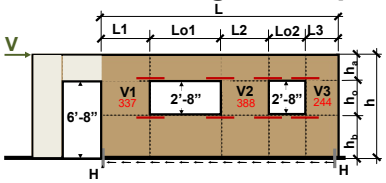
Design for Force Transfer Around Openings

FTAO Design Example



7. Resistance to corner forces
   R1=V1L1 = 1346#
   R2 = V2L2 = 1551#
   R3 = V3L3 = 853#

8. Difference of the corner force and resistance
   R1-F1 = 481#
   R2-F2-F3 = 378#
   R3-F4 = 583#

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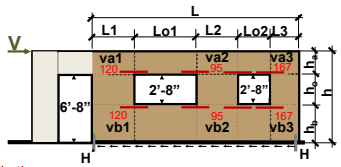
Design for Force Transfer Around Openings

FTAO Design Example



9. Unit shear in the corner zones
   - va1 = (R1-F1)/L1 = 120 plf
   - va2 = (R2-F2-F3)/L2 = 95 plf
   - va3 = (R3-F4)/L3 = 167 plf

The unit shear of the corner zones = panel resistance (R) – the corner forces R = the shear of the pier x the pier length.

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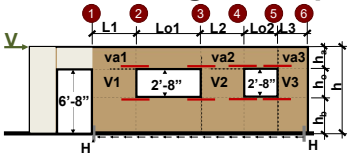
Design for Force Transfer Around Openings

FTAO Design Example



10. Check your solution – YES to all
    - Line 1: va1(ha+hb)+v1(ho)=H?
    - Line 2: va(ha+hb)-va1(ha+hb)-V1(ho)=0?
    - Line 3: va2(ha+hb)+V2(ho)-va(ha+hb)=0?
    - Line 4 = Line 3
    - Line 5: va(ha+hb)-va3(ha+hb)-V3(ho)=0?
    - Line 6: va3(ha+hb)+V3(ho)=H?

Once all segment shears are calculated, check the design by summing the shears vertically along each line. The 1st and last = hold-down force, and the rest should = zero.

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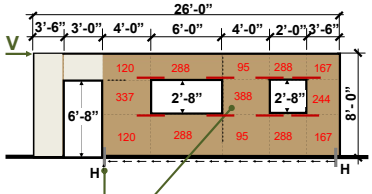
Design for Force Transfer Around Openings

FTAO Design Example



V = 3,750 lbs

Height/width Ratio = 2'-8" : 3'-6"

15/32 Category Rated Sheathing 8d @ 4"o.c.

2 – hold downs @ 1550 lb capacity

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FTAO Design Example

Table 4.3A Nominal Unit Shear Capacities for Wood-Frame Shear Walls[1,3,6,7]

Wood-based Panels[4]

Sheathing Material	Minimum Nominal Panel Thickness (in.)	Minimum Fastener Penetration in Framing Member or Blocking (in.)	Fastener Type & Size	A SEISMIC								
				Panel Edge Fastener Spacing (in.)								
				6			4			3		
				v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)		v_s (plf)	G_a (kips/in.)	
			Nail (common or galvanized box)		OSB	PLY		OSB	PLY		OSB	PLY
Wood Structural Panels – Structural I[5]	5/16	1-1/4	6d	400	13	10	600	18	13	780	23	16
	3/8[2]	1-3/8	8d	460	19	14	720	24	17	920	30	20
	7/16[2]			510	16	13	790	21	16	1010	27	19
	15/32			560	14	11	860	18	14	1100	24	17
	15/32	1-1/2	10d	680	22	16	1020	29	20	1330	36	22
Wood Structural Panels – Sheathing[5,6]	5/16	1-1/4	6d	360	13	9.5	540	18	12	700	24	14
	3/8			400	11	8.5	600	15	11	780	20	13
	3/8[2]	1-3/8	8d	440	17	12	640	25	15	820	31	17
	7/16[2]			480	15	11	700	22	14	900	28	17
	15/32			520	13	10	760		13	980	25	15
	15/32	1-1/2	10d	620	22	14	920	30	17	1200	37	19
	19/32			680	19	13	1020	26	16	1330	33	18

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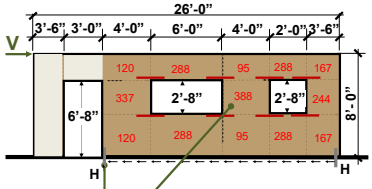
FTAO Design Example



V = 3,750 lbs

Height/width Ratio = 2'-8" : 3'-6"

15/32 Category Rated Sheathing 8d @ 4"o.c.

760/2 = 380 ~ 388

2 – hold downs @ 1550 lb capacity

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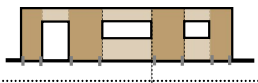
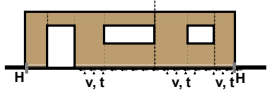
Comparison of SDPWS Shear Walls Types

Segmented Approach



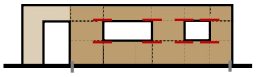
15/32 Category Rated sheathing
- 8d @ 4"o.c. (3'-6" walls)
- 8d @ 6" o.c. (4' walls)
- 8 – hold downs @ 2000+ lb capacity

Perforated



15/32 Category Rated Sheathing
- 8d @ 3"o.c.
- 2 – hold downs @ 3280 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

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Design for FTAO

www.apawood.org/ftao

Technical Note: Design for Force Transfer Around Openings
This technical note presents a rational analysis for applying FTAO to walls with asymmetric piers and walls with multiple openings. It is based upon APA modeling and testing and uses methodology that assists the design professional in solving for the required sheathing, nailing, hold-downs, straps and maximum deflection.

DOWNLOAD

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.

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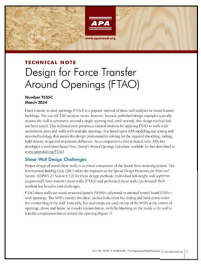
Design for Force Transfer Around Openings

FTAO Technical Note: Form T555

- Technical Note: Design for Force Transfer Around Openings (FTAO)
- Presents a rational analysis for applying FTAO to walls with asymmetric piers and walls with multiple openings
- Based on Wall 12 testing configuration
- Includes a design example with two wall opening
- 2024 revision includes a strap development length example



TECHNICAL NOTE
Design for Force Transfer Around Openings (FTAO)
Number T555C
March 2024

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Design for Force Transfer Around Openings

APA FTAO Calculator

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

- Excel-based tool
- Based on Diekmann method
- Calculates:
  - Max hold-down force for uplift resistance
  - Required horizontal corner force above and below openings
  - Max shear force for sheathing attachments
  - Max deflection

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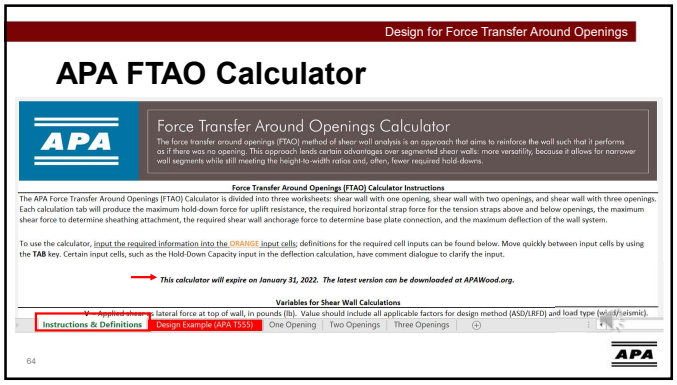
Design for Force Transfer Around Openings
APA FTAO Calculator
Force Transfer Around Openings Calculator
The force transfer around openings (FTAO) method of shear wall analysis is an approach that aims to reinforce the wall such that it performs as if there was no opening. This approach lends certain advantages over segmented shear walls; more versatility, because it allows for narrower wall segments while still meeting the height-to-width ratios and, often, fewer required hold-downs.
Force Transfer Around Openings (FTAO) Calculator Instructions
The APA Force Transfer Around Openings (FTAO) Calculator is divided into three worksheets: shear wall with one opening, shear wall with two openings, and shear wall with three openings. Each calculation tab will produce the 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, the required shear wall anchorage force to determine base plate connection, and the maximum deflection of the wall system.
To use the calculator, input the required information into the ORANGE input cells; definitions for the required cell inputs can be found below. Move quickly between input cells by using the TAB key. Certain input cells, such as the Hold-Down Capacity input in the deflection calculation, have comment dialogue to clarify the input.
This calculator will expire on January 31, 2022. The latest version can be downloaded at APAWood.org.
Variables for Shear Wall Calculations
V = Applied shearing lateral force at top of wall, in pounds (lb). Value should include all applicable factors for design method (ASD/LRFD) and load type (wind/seismic).
Instructions & Definitions
Design Example (APA T555)
One Opening
Two Openings
Three Openings
64
APA

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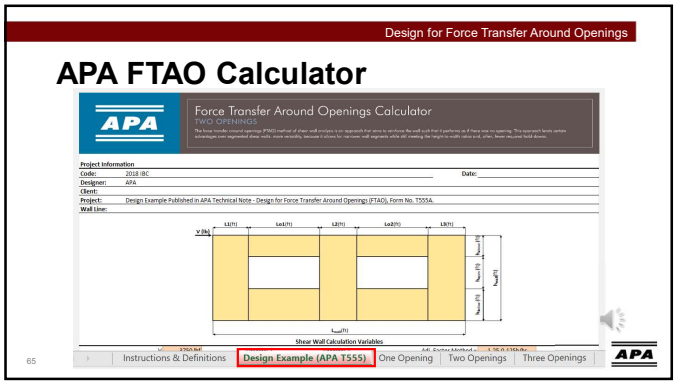
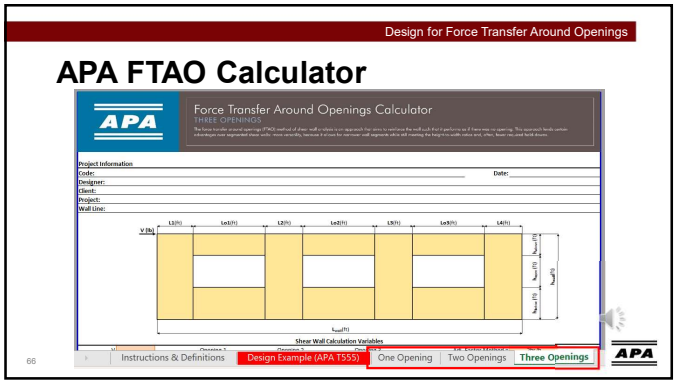

Design for Force Transfer Around Openings
APA FTAO Calculator
Force Transfer Around Openings Calculator
TWO OPENINGS
Project Information
Code: 2018 IBC
Date:
Designer: APA
Client:
Project: Design Example Published in APA Technical Note - Design for Force Transfer Around Openings (FTAO), Form No. T555A.
Wall Line:
Shear Wall Calculation Variables
Instructions & Definitions
Design Example (APA T555)
One Opening
Two Openings
Three Openings
65
APA

65


Design for Force Transfer Around Openings
APA FTAO Calculator
Force Transfer Around Openings Calculator
THREE OPENINGS
Project Information
Code:
Date:
Designer:
Client:
Project:
Wall Line:
Shear Wall Calculation Variables
Instructions & Definitions
Design Example (APA T555)
One Opening
Two Openings
Three Openings
66
APA

66

APA FTAO Calculator: Inputs

- **V** – Applied shear force at the top of the wall (lb)
- **$L_{(i)}$** – Length of each wall pier segment
- **$L_{o(i)}$** – Length of each clear opening
- **h_{o1}** – Max. clear opening height of any opening in the wall system
- **h_{a1}, h_{b1}** – Height of continuous sheathing above and below the opening
  - Correlates with the opening height
- **h_{wall}** – Total calculated height of the shear wall from bottom of sill plate to top of top plate (ft)
- **L_{wall}** – Total calculated length of shear wall (ft)

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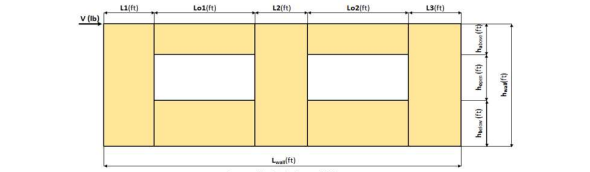
APA FTAO Calculator: Inputs



Shear Wall Calculation Variables

		Opening 1		Opening 2		Adj. Factor Method =	1.25-0.125h/bs
V	3750 lbf					Wall Pier Aspect Ratio	Adj. Factor
L1	4.00 ft	ha1	1.33 ft	ha2	1.33 ft	P1=ho1/L1=	0.67 N/A
L2	4.00 ft	ho1	2.67 ft	ho2	2.67 ft	P2=ho2/L2=	0.67 N/A
L3	3.50 ft	hb1	4.00 ft	hb2	4.00 ft	P3=ho3/L3=	0.76 N/A
hwall	8.00 ft	Lo1	6.00 ft	Lo2	2.00 ft		
Lwall	19.50 ft						

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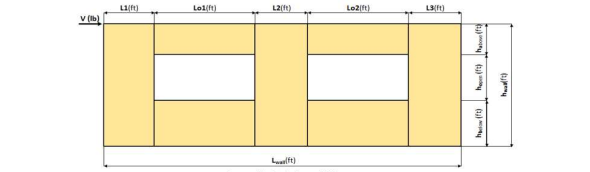
APA FTAO Calculator: Inputs



Shear Wall Calculation Variables

		Opening 1		Opening 2		Adj. Factor Method =	1.25-0.125h/bs
V	3750 lbf					Wall Pier Aspect Ratio	Adj. Factor
L1	4.00 ft	ha1	1.33 ft	ha2	1.33 ft	P1=ho1/L1=	0.67 N/A
L2	4.00 ft	ho1	2.67 ft	ho2	2.67 ft	P2=ho2/L2=	0.67 N/A
L3	3.50 ft	hb1	4.00 ft	hb2	4.00 ft	P3=ho3/L3=	0.76 N/A
hwall	8.00 ft	Lo1	6.00 ft	Lo2	2.00 ft		
Lwall	19.50 ft						

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Design for Force Transfer Around Openings

APA FTAO Calculator: Shear Wall Analysis

1. Hold-down forces: H = Vh_{max}/L_{wall} → 1538 lbf

2. Unit shear above + below opening

First opening: va1 = vb1 = H/(ha1+hb1) =	289 plf
Second opening: va2 = vb2 = H/(ha2+hb2) =	289 plf

3. Total boundary force above + below openings

First opening: O1 = va1 x (Lo1) =	1732 lbf
Second opening: O2 = va2 x (Lo2) =	577 lbf

4. Corner forces

Corner (Strap) Forces →

F1 = O1(L1)/(L1+L2) =	866 lbf
F2 = O1(L2)/(L1+L2) =	866 lbf
F3 = O2(L2)/(L2+L3) =	308 lbf
F4 = O2(L3)/(L2+L3) =	269 lbf

5. Tributary length of openings

T1 = (L1*Lo1)/(L1+L2) =	3.00 ft
T2 = (L2*Lo1)/(L1+L2) =	3.00 ft
T3 = (L2*Lo2)/(L2+L3) =	1.07 ft
T4 = (L3*Lo2)/(L2+L3) =	0.93 ft

6. Unit shear beside opening

V1 = (V/L)(L1+T1)/L1 =	337 plf
V2 = (V/L)(T2+L2+T3)/L2 =	388 plf
V3 = (V/L)(T4+L3)/L3 =	244 plf
Check V1*L1+V2*L2+V3*L3=V?	3750 lbf **OK**

7. Resistance to corner forces

R1 = V1*L1 =	1346 lbf
R2 = V2*L2 =	1551 lbf
R3 = V3*L3 =	853 lbf

8. Difference corner force + resistance

R1-F1 =	480 lbf
R2-F2-F3 =	377 lbf
R3-F4 =	583 lbf

9. Unit shear in corner zones

vc1 = (R1-F1)/L1 =	120 plf
vc2 = (R2-F2-F3)/L2 =	94 plf
vc3 = (R3-F4)/L3 =	167 plf

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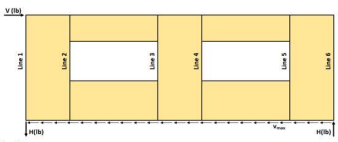
Design for Force Transfer Around Openings

APA FTAO Calculator: Shear Wall Analysis



Check Summary of Shear Values for Two Openings

Line 1: vc1(ha1+hb1)+V1(ho1)=H?		640	899	1538 lbf
Line 2: va1(ha1+hb1)-vc1(ha1+Hb1)-V1(ho1)=0?	1538	640	899	0
Line 3: vc2(ha1+hb1)+V2(ho1)-va1(ha1+hb1)=0?	503	1035	1538	0
Line 4: va2(ha2+hb2)-V2(ho2)-vc2(ha2+hb2)=0?	1538	1035	503	0
Line 5: va2(ha2+hb2)-vc3(ha2+hb2)-V3(ho2)=0?	1538	888	650	0
Line 6: vc3(ha2+hb2)+ V3(ho2) = H?		888	650	1538 lbf

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Design for Force Transfer Around Openings

APA FTAO Calculator: Design Output

Design output:

- Required sheathing capacity (includes adjustment factor)
- Required strap force above and below openings
- Required hold-down force
- Maximum deflection

Design Summary

Req. Sheathing Capacity	388 plf	4-Term Deflection	0.329 in.	3-Term Deflection	0.352 in.
Req. Strap Force	866 lbf	4-Term Story Drift %	0.014 %	3-Term Story Drift %	0.015 %
Req. HD Force	1538 lbf	See Page 2		See Page 3	
Req. Shear Wall Anchorage Force	192 plf				

*The Design Summary assumes that the shear wall is designed as blocked.

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APA FTAO Calculator: Deflection Inputs

Shear Wall Deflection Calculation Variables

Induced Shear Load $V_{induced}$: 5357 (lbf)

Sheathing:		Wood End Post Values:			Nail Type:	8d common	(penny weight)
OSB	Sheathing Material	Species:	Douglas Fir-Larch No. 2				
15/32	Performance Category	E:	1.60E+06	(psi)		Pier 1	Pier 3
APA Rated Sheathing	Grade		Qty	Stud Size	Nail Spacing:	4	4 (in.)
		Dimensions:	2	2x6	HD Capacity:	2145	2145 (lbf)
	Gt Override	A:	16.5	($in.^2$)	HD Deflection:	0.128	0.128 (in.)
	Ga Override	A Override:		($in.^2$)			

The calculator does not check the sheathing selection for the required capacity calculated above.

APA FTAO Calculator: Error Messages

- This error message appears when 7/16 CAT plywood is selected because this product is not commonly produced.
- Affects both 3-term and 4-term equations.

Sheathing Composition is not valid. Please review Sheathing inputs.

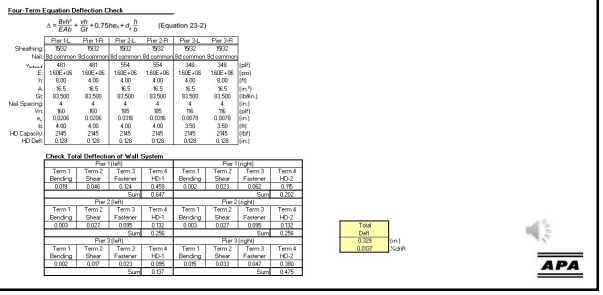
APA FTAO Calculator: Error Messages

- This error message appears when:
  - 3/8 or 7/16 CAT Rated Sheathing and Structural I OSB is selected with 10d nails
  - 19/32 CAT Rated Sheathing OSB with 8d nails
  - 19/32 CAT Structural I OSB or plywood is selected
  - 3/8 CAT Rated Sheathing and Structural I plywood with 10d nails
  - 19/32 CAT Rated Sheathing plywood with 8d nails
- SDPWS does not provide Ga in Table 4.3A for these combinations or sheathing types
- Also appears when 7/16 CAT plywood selected – not commonly produced
- Affects only 3-term equation

Sheathing and Nail Type are not a valid combination. Please review Nail Type input.

Design for Force Transfer Around Openings

APA FTAO Calculator: Deflection Output



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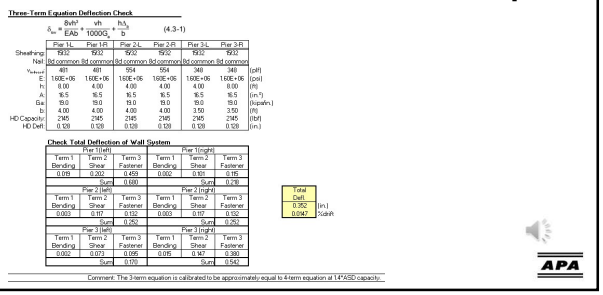
Design for Force Transfer Around Openings

APA FTAO Calculator: Deflection Output



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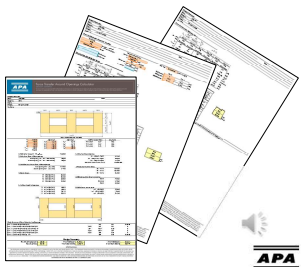
Design for Force Transfer Around Openings

APA 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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Design for Force Transfer Around Openings

APA Calculator Expiration Date

When the expiration date is past:

- Calculator will continue to function properly
- Header will change to indicate it has expired

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Design for Force Transfer Around Openings

What's New – Technical Note?

Technical note T555 changes:

- Methodology presented is based on a maximum width-to-height ratio of 6.5:1 for the sheathing above and below openings
- Methodology presented is based on a minimum 12-inch height of sheathing above and below openings
- Strap development length example added

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Design for Force Transfer Around Openings

Strap Development Length Example

Assume ASTM 653 Gr. 33, 20ga. x 1.5 in. strap with (2) 8d common nails (0.131" x 2 1/2") spaced at 3 in.

- Strap length per manufacturer (9-inch end length required for full listed load capacity of 1,030 plf)

$$\frac{F_1}{\text{(Allowable Tension Load)}} \times \text{(End Length)}$$

$$= \frac{865\ lbf}{1{,}030\ lbf} \times 9\ in. = 7.6\ in. \rightarrow Use\ 8\ in.$$

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Strap Development Length Example

Assume ASTM 653 Gr. 33, 20ga. x 1.5 in. strap with (2) 8d common nails (0.131" x 2 1/2") spaced at 3 in.

- Fasteners required (panel to blocking):

$$\frac{865\ lbf}{(2\times74\ lbf\times1.6)}\times 3\ in. = 10.96in. \rightarrow Use\ 11\ \text{in.}$$

- Total Strap Length: $8\ in. + 11\ in. =$ 19 in.
- Use 20ga. x 1.5 in. x 19 in. ASTM 653 Gr. 33 strap with (2) 8d common nails (0.131" x 2 1/2") at 3" oc.

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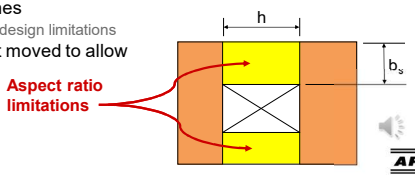
What's New – APA FTAO Calculator?

Calculator changes:

- Pop-up warning when the width-to-height ratio the sheathed area above or below an opening exceeds 6.5:1 or if the height is less than 12 inches
  - Alert user regarding design limitations
- End post size input moved to allow multiple sizes



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Conclusion

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Questions?

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APA Update Newsletter
(www.apawood.org)

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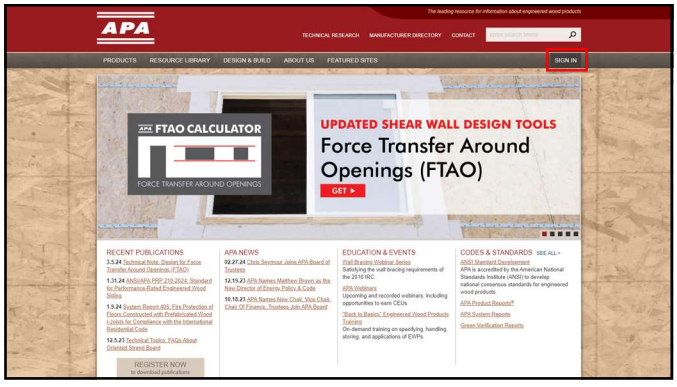

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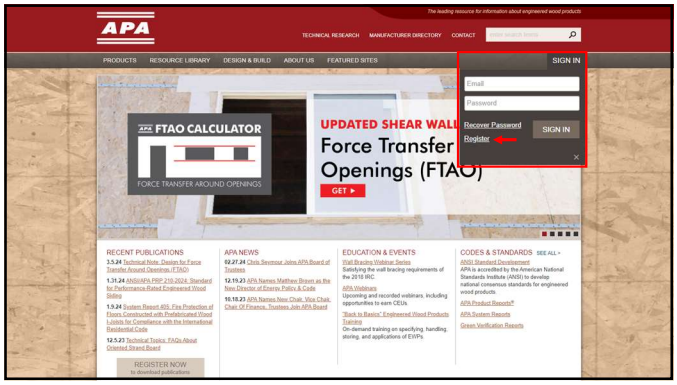
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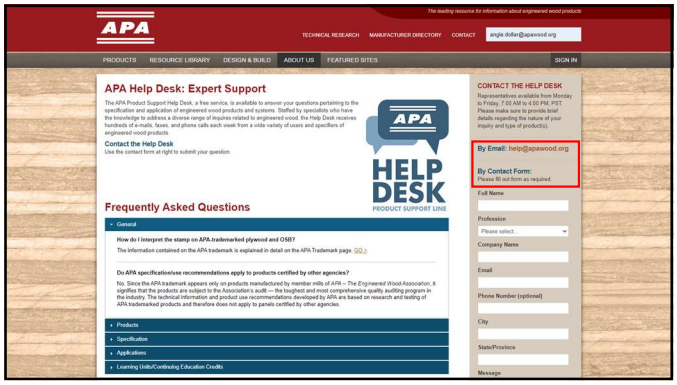
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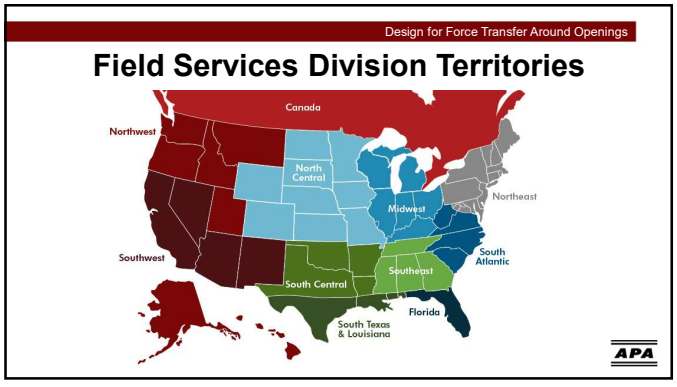
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Thank You!

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