Wood Diaphragm Deflections and Flexibility

March 13, 2024

Presented by

Terry Malone, PE, SE

Scott Breneman, PhD, PE, SE

WoodWorks – Wood Products Council

1430 Q / The HR Group Architects / Buehler Engineering / photo Greg Folkins Photography

“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.

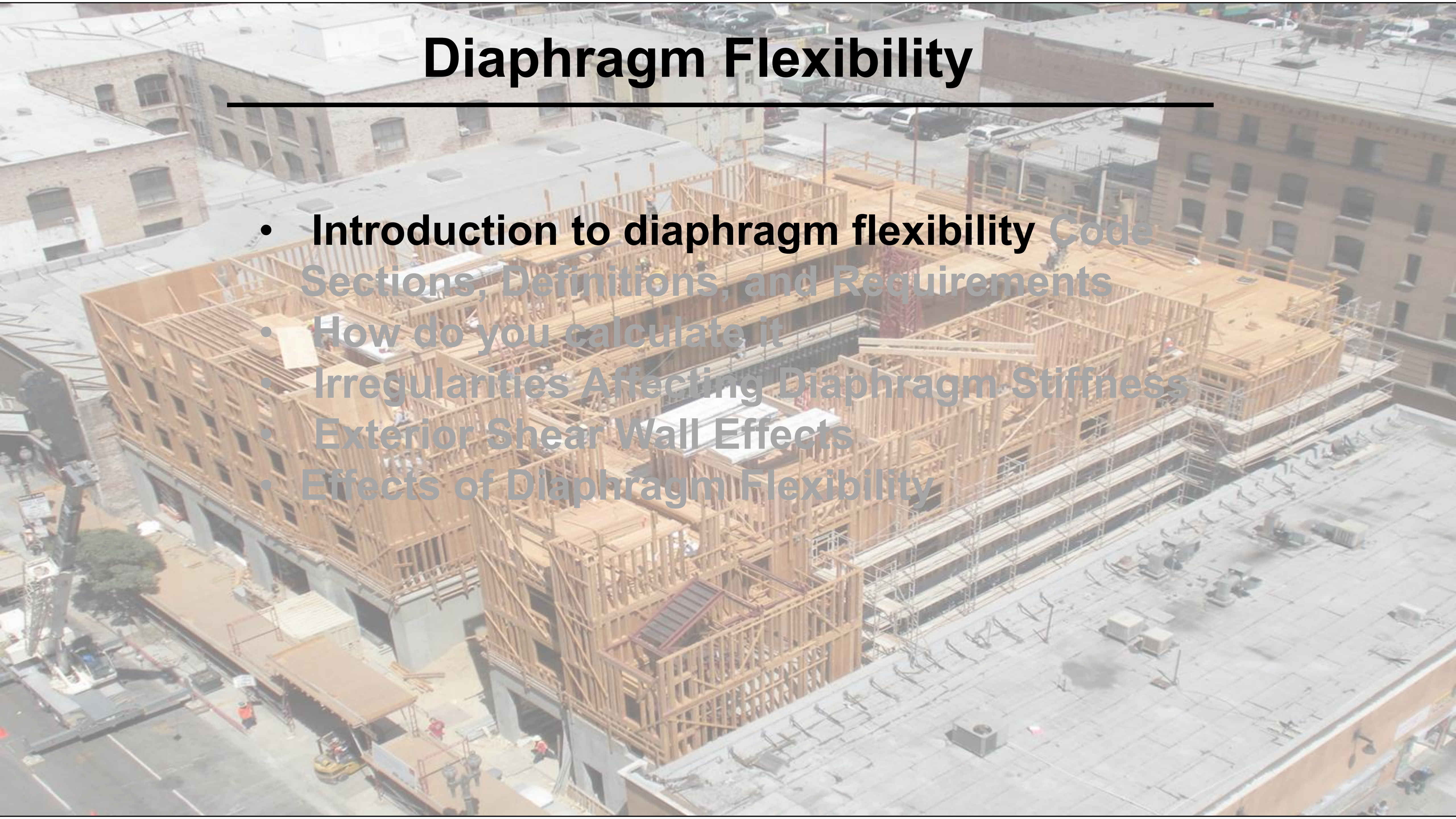
AIA Approved Continuing Education

Course Description

In the design of many wood buildings, the flexibility of horizontal force-distributing diaphragms is given little consideration. However, in certain building configurations, diaphragm deflections are a critical aspect of structural design. This webinar will review the conditions under which designers should consider the deflections of structural wood panel-sheathed diaphragms, and how these deflections help determine the classification of a diaphragm as rigid, flexible, or semi-rigid. Another important consideration is the impact of the location and detailing of vertical shear walls on the horizontal distribution of forces in the diaphragms, which will be illustrated through the results of a design study. Finally, the speakers will review methods available to stiffen diaphragms and reduce total deflections when needed.

Learning Objectives

- Explain the conditions where diaphragm deflections are a significant consideration of a wood floor or roof design.
- Explore requirements in the International Building Code (IBC) and referenced standards for determining diaphragm flexibility for use with horizontal distribution of seismic and wind loads.
- Review the impact of the location and stiffness of vertical force-resisting elements (e.g., shear walls) on the distribution of forces within a horizontal diaphragm.
- Understand methods to stiffen a diaphragm to reduce total deflections.

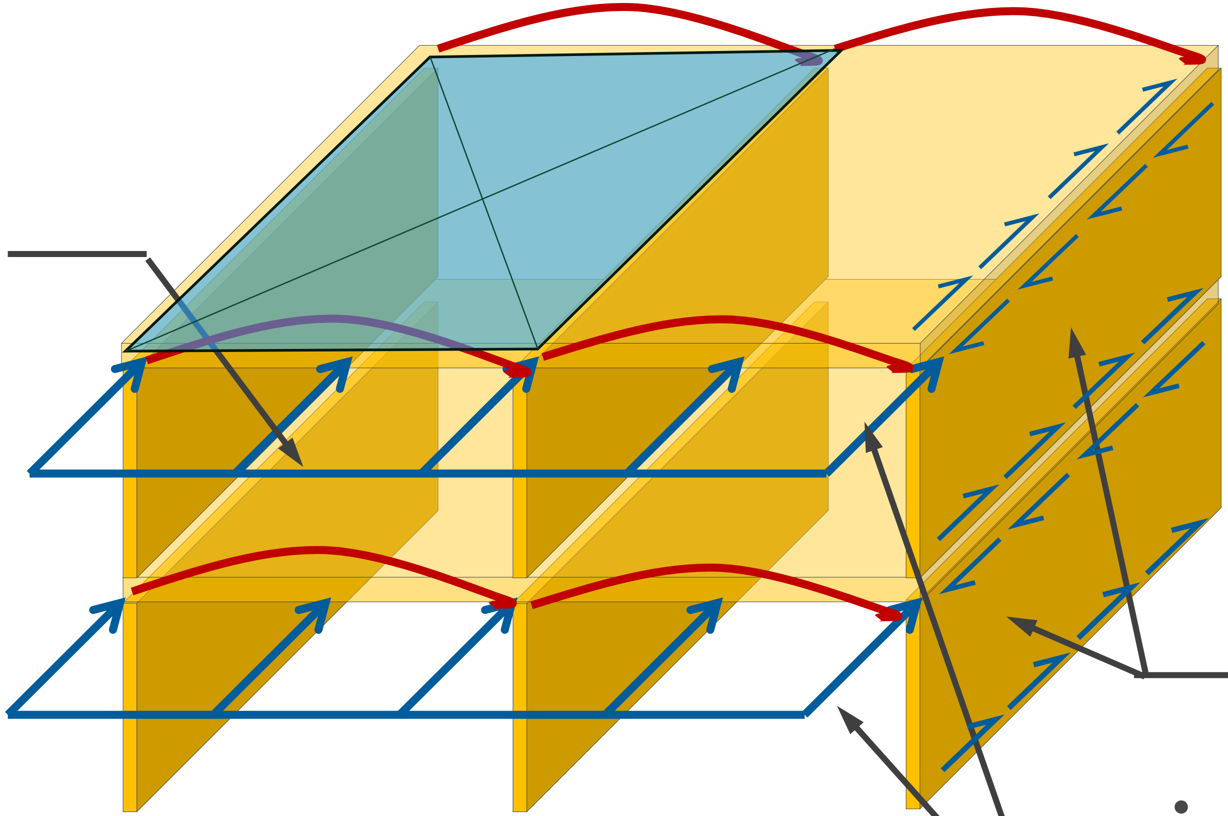


Diaphragm Flexibility

- **Introduction to diaphragm flexibility** Code Sections, Definitions, and Requirements
- How do you calculate it
- Irregularities Affecting Diaphragm Stiffness
- Exterior Shear Wall Effects
- Effects of Diaphragm Flexibility

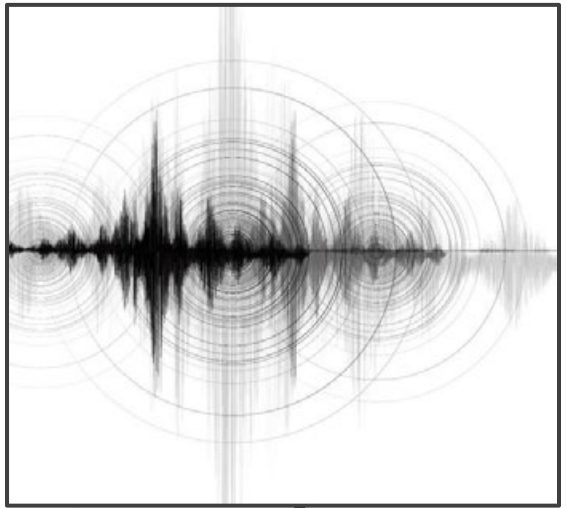
Lateral Forces on Diaphragms

Linear force (plf) on edge and/or area force (psf) on diaphragm



Wind forces

Shear wall, or other vertical elements



Seismic forces

Combine lateral wall loads and (seismic) floor load into equivalent distributed forces

- Seismic forces caused by ground movement and building mass.
- Wind forces caused by windward and leeward wind pressures.

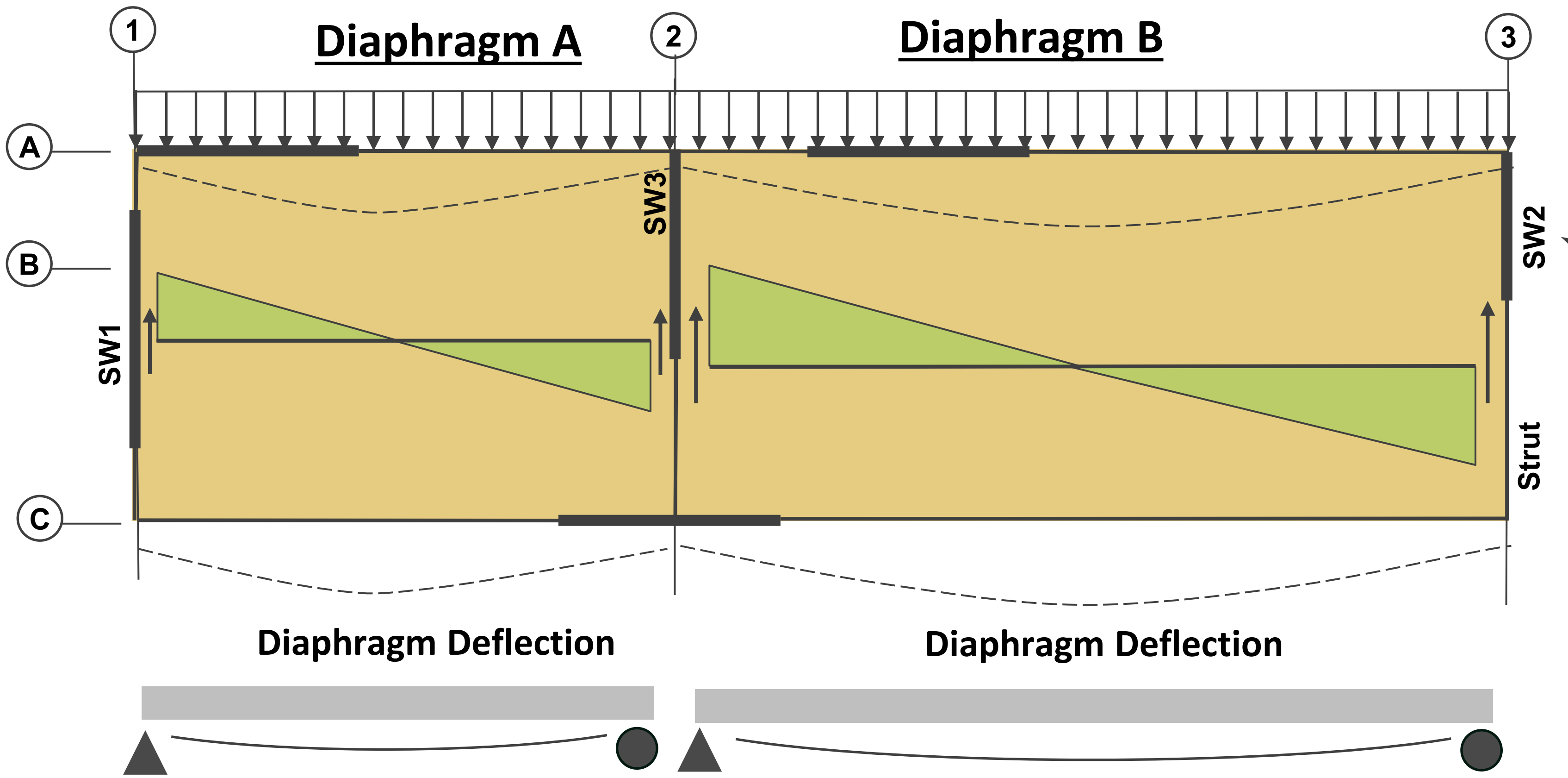
How are the diaphragm force distributed to the vertical elements?

Two most common ways:

» Idealized as a Flexible Diaphragm

» Idealized as Rigid Diaphragm

Flexible Diaphragm Assumptions

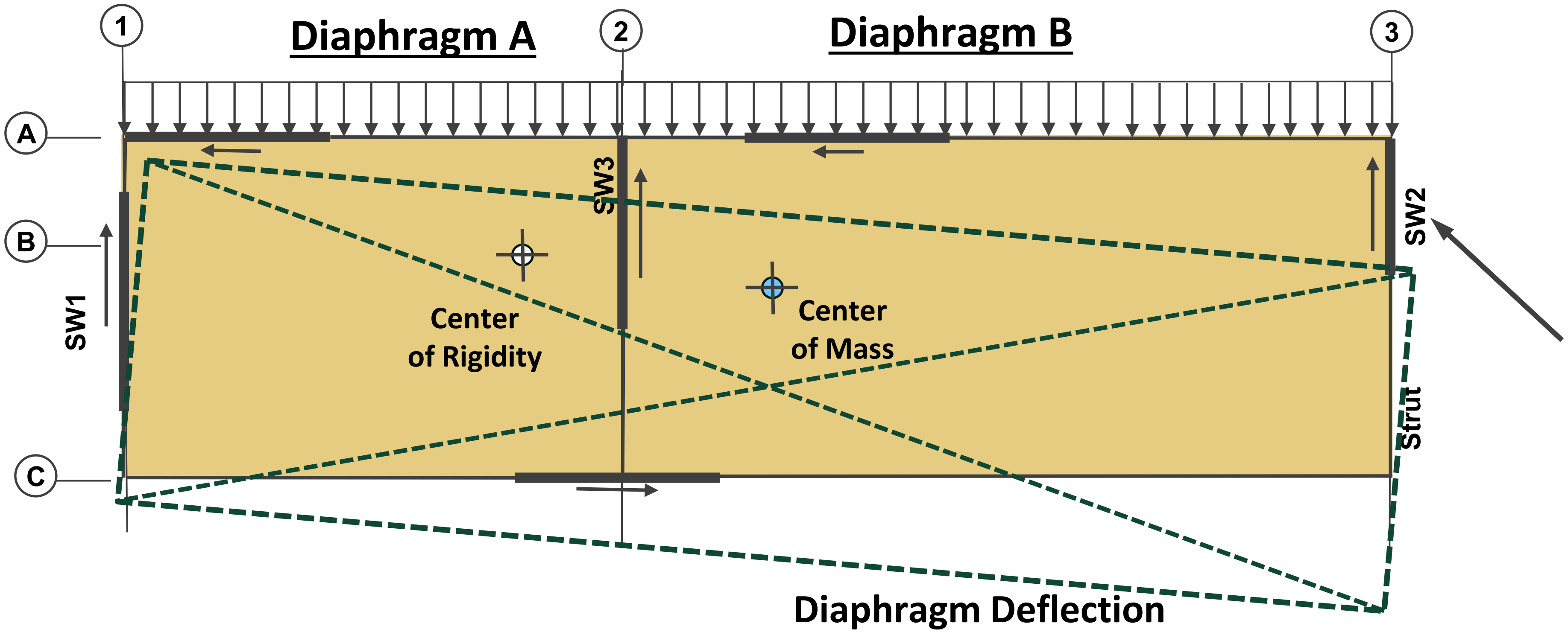


No consideration of wall stiffness to distribute loads

- Each diaphragm span is independent
- Forces distributed to wall lines using a tributary area or simply-supported, single-span “beam” models

It’s just statics… use a free body diagram of the diaphragm

Rigid Diaphragm Assumptions

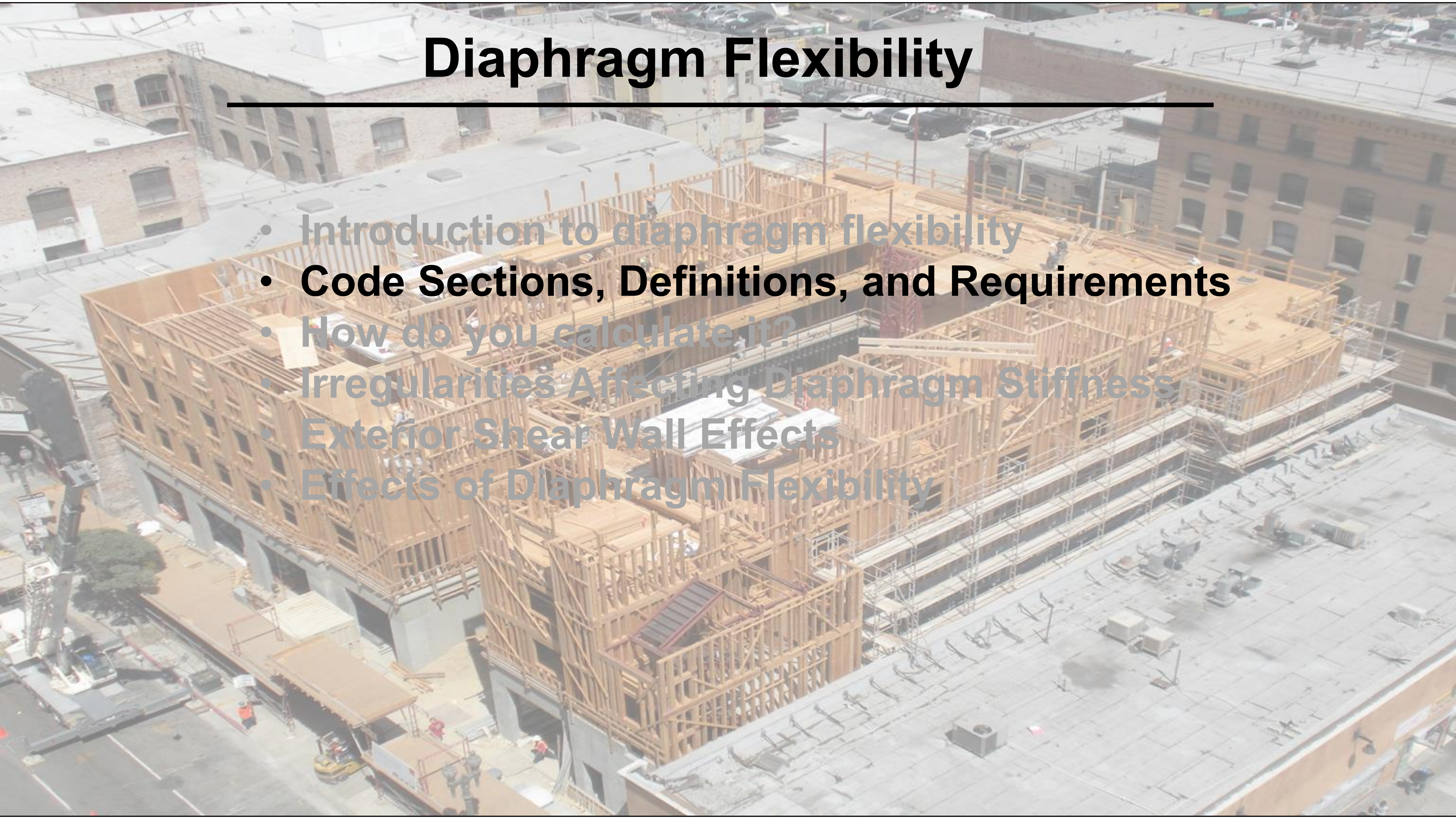


Location and stiffness of each vertical force resisting element (shear wall) impacts distribution

- Diaphragm idealized as single rigid element with 3 degrees of freedom (lateral displacements, and rotation)
- No consideration of diaphragm stiffness (or shape) to distribute loads

Find example of rigid diaphragm analysis in *Design Example of a Cantilever Wood Diaphragm*
https://www.woodworks.org/resources/design-example-of-a-cantilever-wood-diaphragm/

Diaphragm Flexibility



- Introduction to diaphragm flexibility
- **Code Sections, Definitions, and Requirements**
- How do you calculate it?
- Irregularities Affecting Diaphragm Stiffness
- Exterior Shear Wall Effects
- Effects of Diaphragm Flexibility

A matter of Stiffness

Diaphragm flexibility is based on the relative stiffnesses between the diaphragm and the vertical resisting elements

Seismic:

ASCE 7-16, 22 Section 12.3.1- Diaphragm flexibility-The structural analysis shall consider the relative stiffnesses of diaphragms and the vertical elements of the seismic force resisting system.

Wind:

ASCE 7-16 Section 27.4.5 Diaphragm flexibility-The structural analysis shall consider the relative stiffness of diaphragms and vertical elements of the MWFRS. **(Section no longer in ASCE 7-22)-** **Diaphragm flexibility only mentioned in definitions “Diaphragms” in ASCE 7-22.**

Flexible structures are susceptible to damage from wind or seismic forces

Can require engineering judgement

Diaphragm Flexibility

NEHRP Seismic Design Brief 10 and ASCE 7-16 commentary-"The diaphragms in most buildings braced by wood light-frame shear walls are semi-rigid".

- **The diaphragm stiffness relative to the stiffness of the supporting vertical seismic force-resisting system is important to define.**

ASCE 7-16, 22, 12.3.1.1 Flexible Diaphragm Condition is allowed provided:

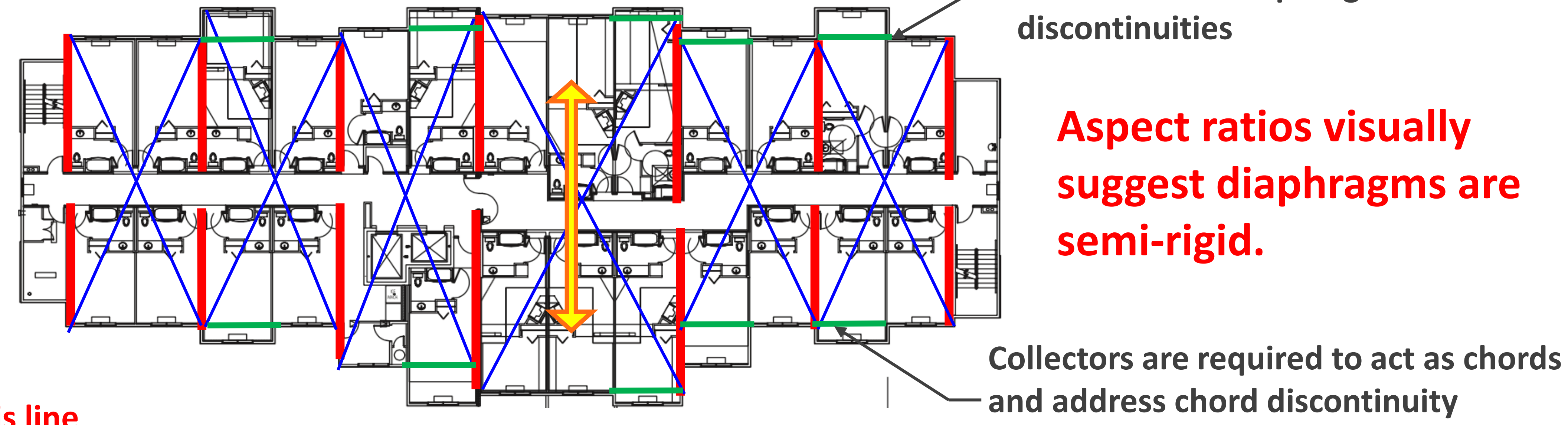
- All light framed construction
- 1 ½"or less of non-structural concrete topping
- Each line of LFRS is less than or equal to allowable story drift

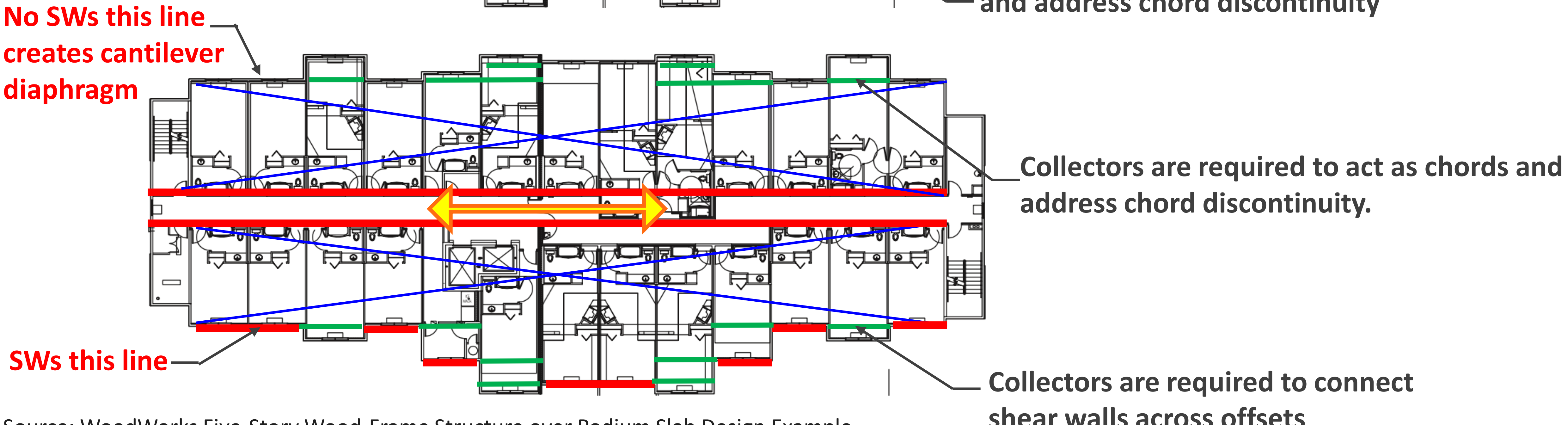
Engineering judgement should be used.

Compliance with story drift limits along each line of shear walls is intended as an indicator that the shearwalls are substantial enough to share load on a tributary area basis and do not require torsional force redistribution.

Multi-Story Wind and Seismic Design

Potential Shear Wall Layouts





Source: WoodWorks Five-Story Wood-Frame Structure over Podium Slab Design Example

Horizontal Distribution of Shear – Pros and Cons

Distribution of shear to vertical resisting elements shall be based on an analysis, where the diaphragm is modeled as:

- **Idealized as flexible-based on tributary area.**
  - Can under-estimate forces distributed to the corridor walls (long walls) and over-estimate forces distributed to the exterior walls (short walls).
  - Can inaccurately estimate diaphragm shear forces

- **Idealized as rigid-Distribution based on relative lateral stiffnesses of vertical-resisting elements of the story below.**
  - More conservatively distributes lateral forces to corridor, exterior and party walls
  - Allows easier determination of building drift
  - Can over-estimate torsional drift
  - Can also inaccurately estimate diaphragm shear forces

- **Modelled as semi-rigid.**
  - Not idealized as rigid or flexible
  - Distributed to the vertical resisting elements based on the relative stiffnesses of the diaphragm <u>and</u> the vertical resisting elements accounting for both shear and flexural deformations.
  - In lieu of a semi-rigid diaphragm analysis, it shall be permitted to use an enveloped analysis.

Note:
Offsets in diaphragms can also affect the distribution of shear in the diaphragm due to changes in the diaphragm stiffness.

ASCE7-16, 22 Section 12.3 Diaphragm Flexibility Seismic

Section 12.3.1- The structural analysis shall consider the relative stiffnesses of diaphragms and the vertical elements of the lateral force resisting system.

ASCE 7
- idealized as flexible
- idealized as rigid
- calculated as flexible

SDPWS and IBC
- idealized as flexible
- idealized as rigid
- calculated as rigid.

All have the semi-rigid modelling option.

ASCE 7-16, 22 section 12. 3.1.2 only refers to concrete slabs and concrete topped steel deck as being classified as idealized rigid diaphragm condition, not wood diaphragms.

For wood lateral systems ASCE 7 refers to AWC SDPWS. Whereas ASCE 7 does not allow a calculated rigid diaphragm condition, SDPWS does.

Start

Is diaphragm untopped steel decking or Wood Structural Panels

Yes

Is any of the following true?

1 & 2 family Dwelling	Vertical elements one of the following : 1. Steel braced frames 2. Composite steel and concrete braced frames 3. Concrete, masonry, steel SW or composite concrete and steel shear walls.	Light framed construction where all of the following are met: 1. Topping of concrete or similar material is not placed over wood structural panel diaphragms except for non-structural topping not greater than 1 ½” thick. 2. Each line of vertical elements of the seismic force-resisting system complies with the allowable story drift of Table 12.12-1.

Yes

Idealize as flexible

No

No

Is diaphragm concrete slab or concrete filled steel deck ?

Yes

Is span to depth ratio ≤ 3 and having no horizontal irregularities ?

Yes

Idealize as rigid

No

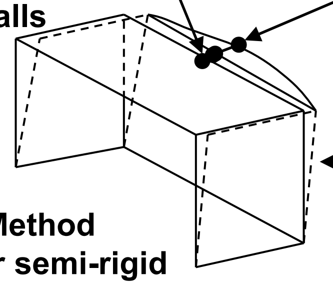
No

(Could apply to CLT or Heavy timber diaphragms)

Idealize as flexible

Yes

Average drift of walls



Maximum diaphragm deflection

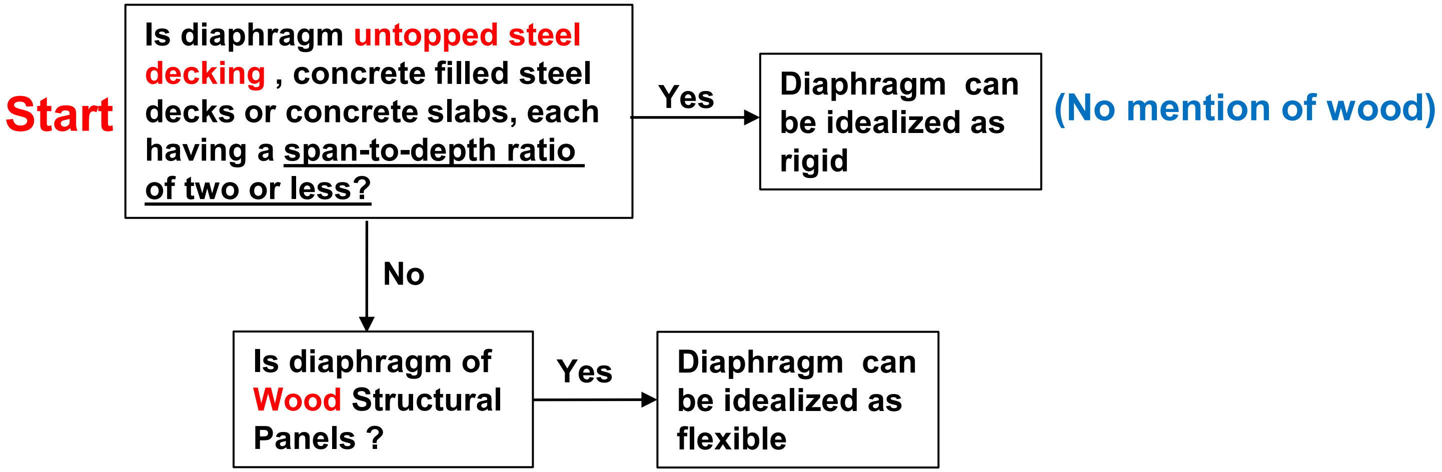
Is maximum diaphragm deflection (MDD) >2x average story drift of vertical elements, using the Equivalent Force Procedure of Section 12.8?

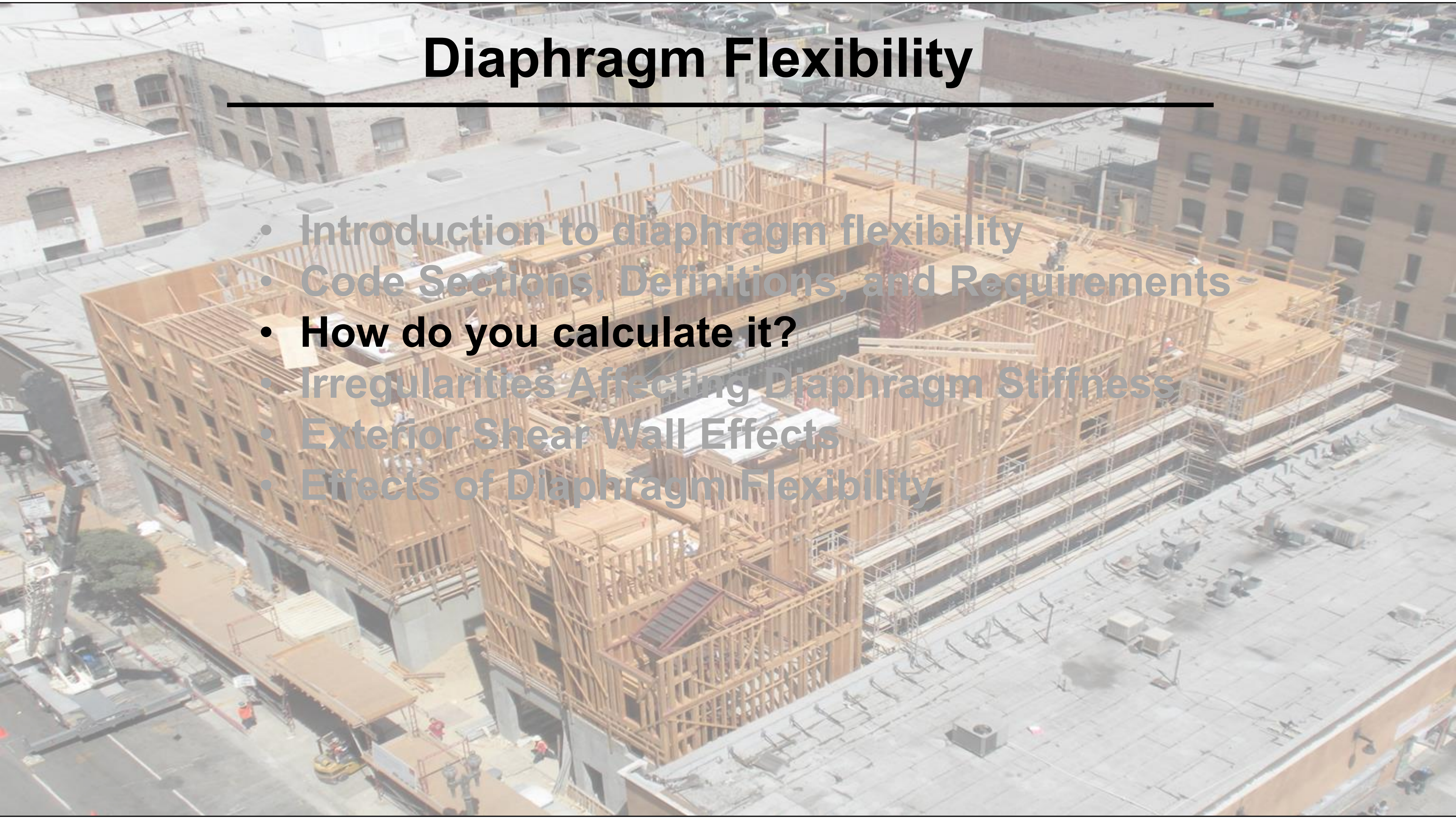
No

Structural analysis must explicitly include consideration of the stiffness of the diaphragm (i.e. semi-rigid modeling), or calculated as rigid in accordance with 2021 IBC Section 1604.4 or ASCE 7-16, 22 Section 12.3.1.2.

Envelope Method Allowed for semi-rigid modelling

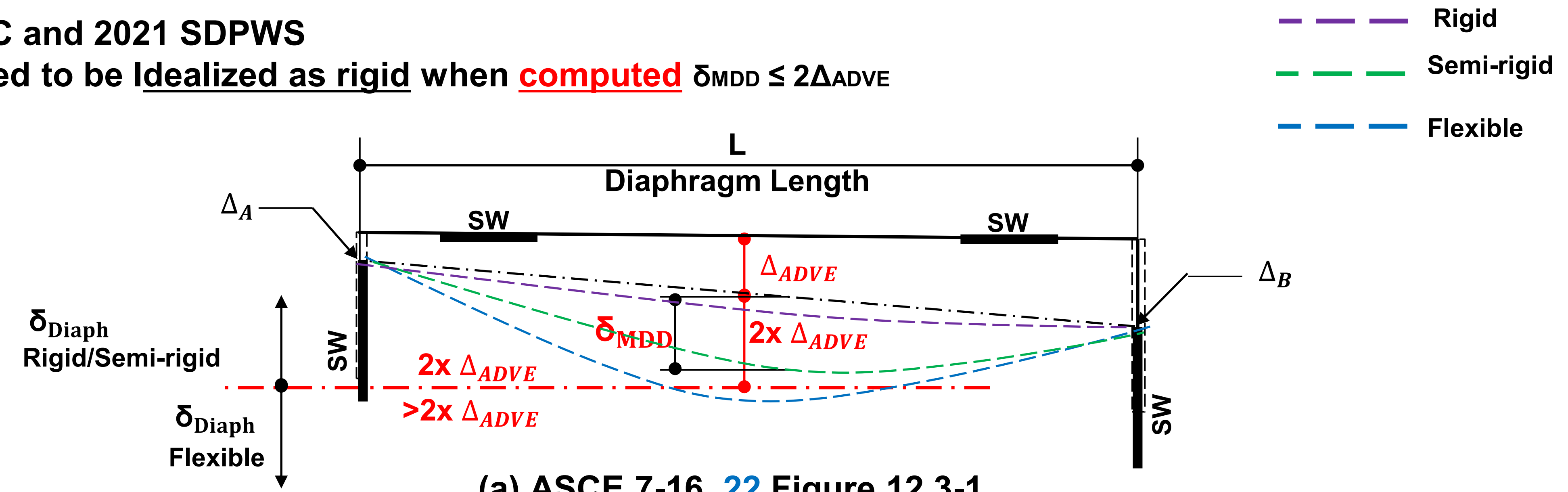
ASCE7-16, 22, Section 26.2 Diaphragm Flexibility Wind



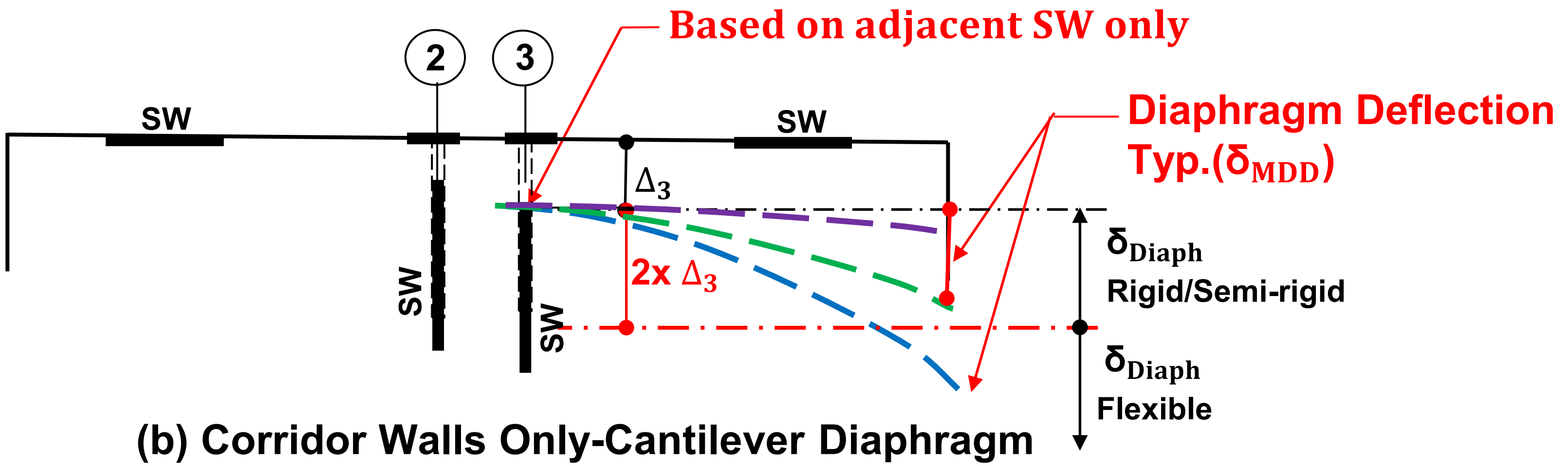

Diaphragm Flexibility
• Introduction to diaphragm flexibility
• Code Sections, Definitions, and Requirements
• How do you calculate it?
• Irregularities Affecting Diaphragm Stiffness
• Exterior Shear Wall Effects
• Effects of Diaphragm Flexibility

Diaphragm Flexibility

- **ASCE 7-16, 22 Calculated Flexible Diaphragm Condition.** **Permitted to be idealized as flexible provided:** $\delta_{MDD} > 2\Delta_{ADVE}$.
- **2021 IBC and 2021 SDPWS** **Permitted to be Idealized as rigid when computed** $\delta_{MDD} \leq 2\Delta_{ADVE}$

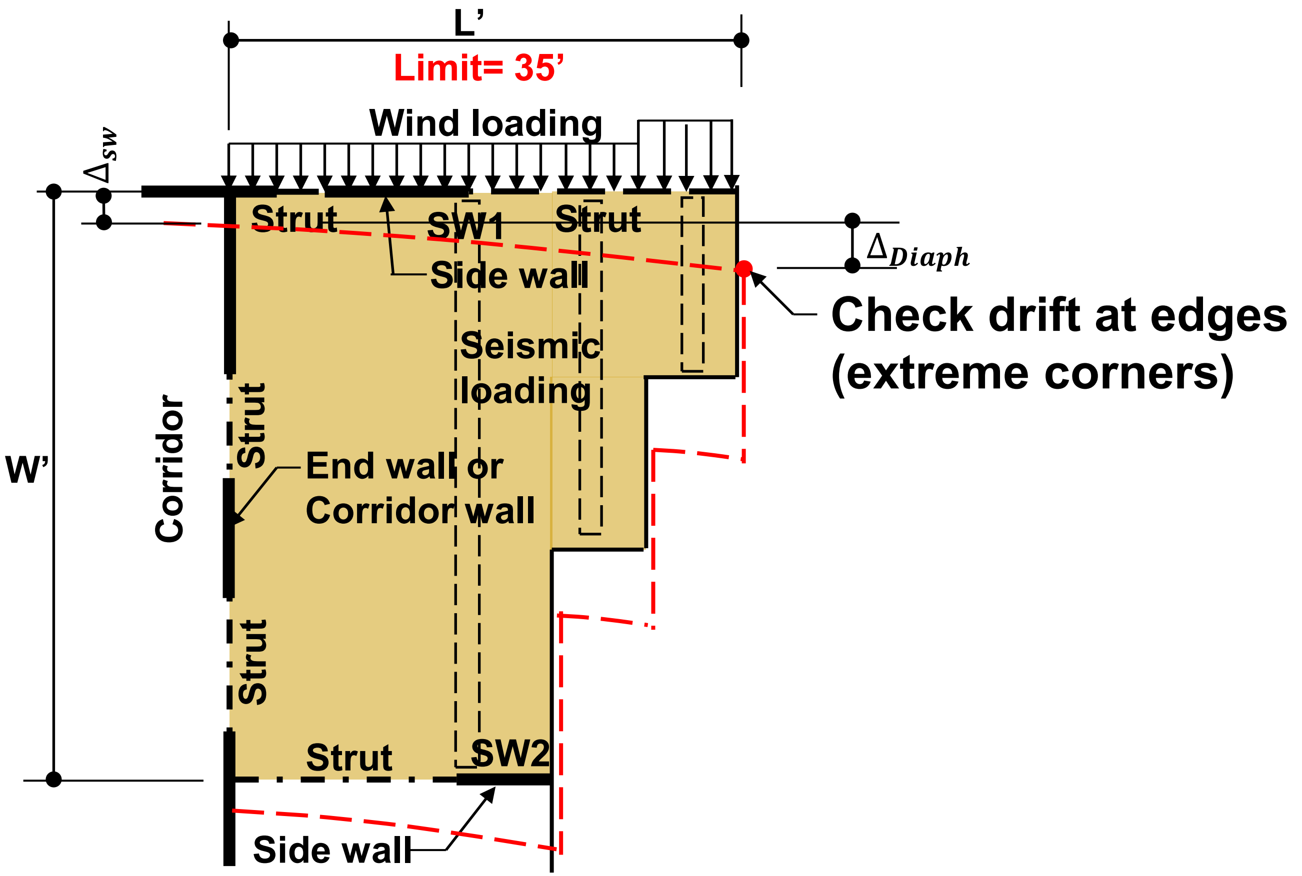


(a) ASCE 7-16, 22 Figure 12.3-1
Simple Span Diaphragm



(b) Corridor Walls Only-Cantilever Diaphragm

Example-Open Front Diaphragms

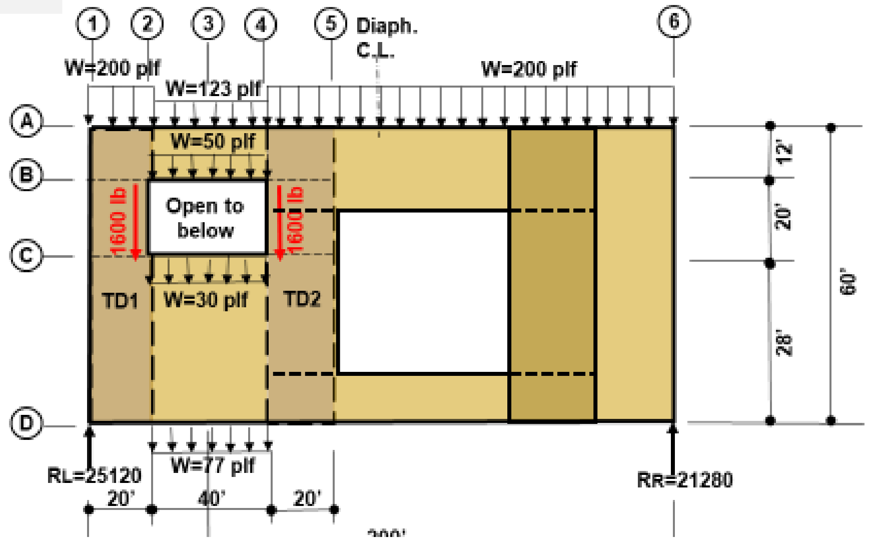


Corridor only shear walls

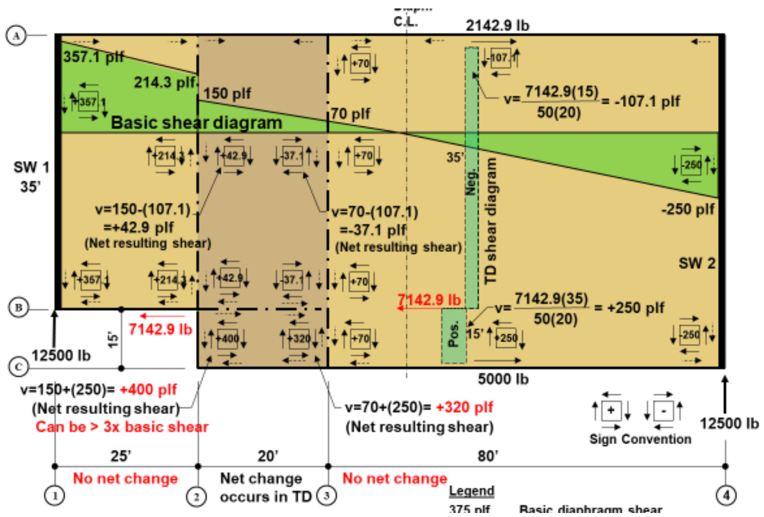
Diaphragm Flexibility

- Introduction to diaphragm flexibility
- Code Sections, Definitions, and Requirements
- How do you calculate it?
- **Irregularities Affecting Diaphragm Stiffness**
- Exterior Shear Wall Effects
- Effects of Diaphragm Flexibility

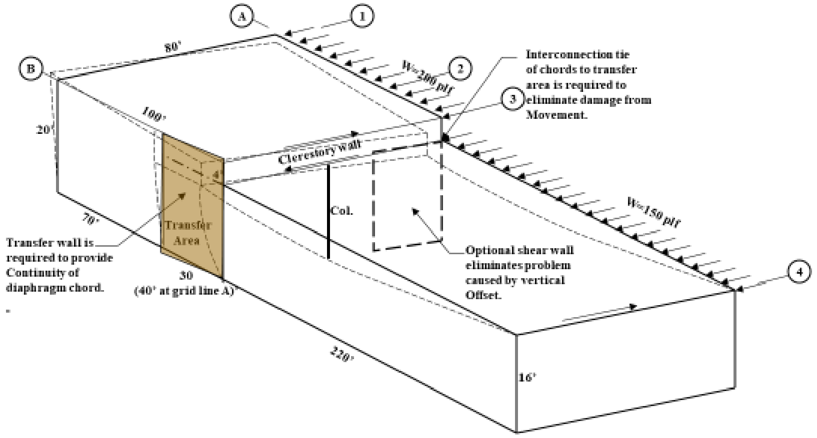
Conditions Affecting Diaphragm Stiffness



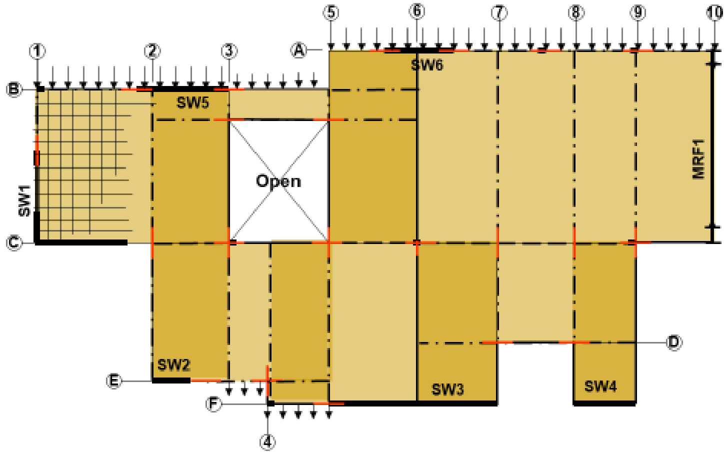
Diaphragms with Openings



Horizontally Offset Diaphragms

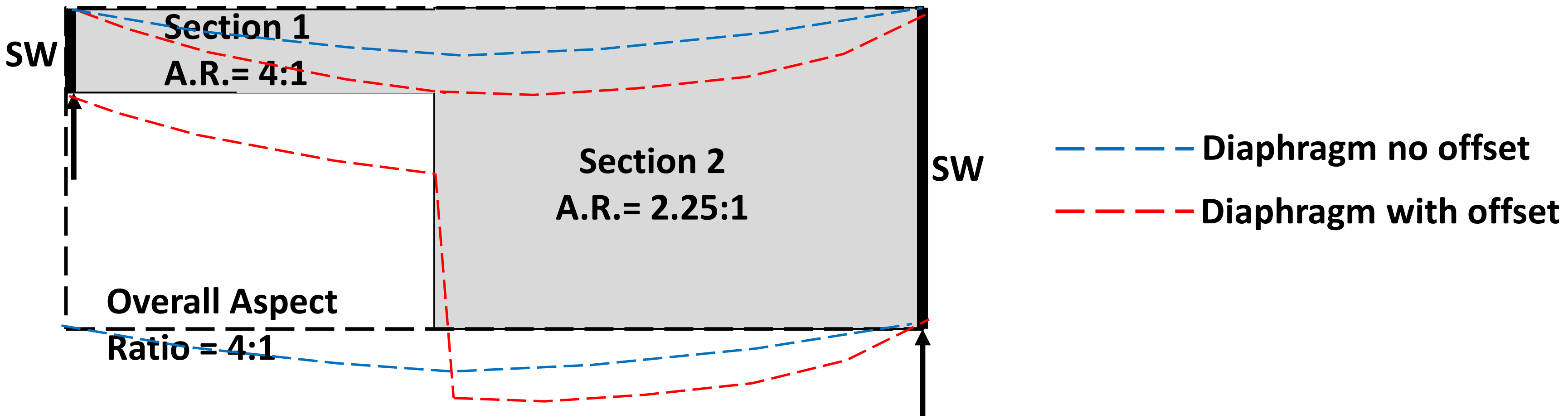


Vertically Offset Diaphragms



Irregular Shaped Diaphragms

Allowable Aspect Ratios for Rectangular and Irregular Shaped Diaphragms



Unacceptable Layout

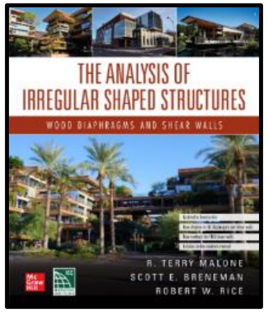
4.2.2 Maximum Diaphragm Aspect Ratios

Diaphragm Sheathing Type	Maximum L/W Ratio
Wood structural panel, unblocked	3:1
Wood structural panel, blocked	4:1
Single-layer straight lumber sheathing	2:1
Single-layer diagonal lumber sheathing	3:1
Double-layer diagonal lumber sheathing	4:1

Courtesy, American Wood Council, Leesburg, VA.

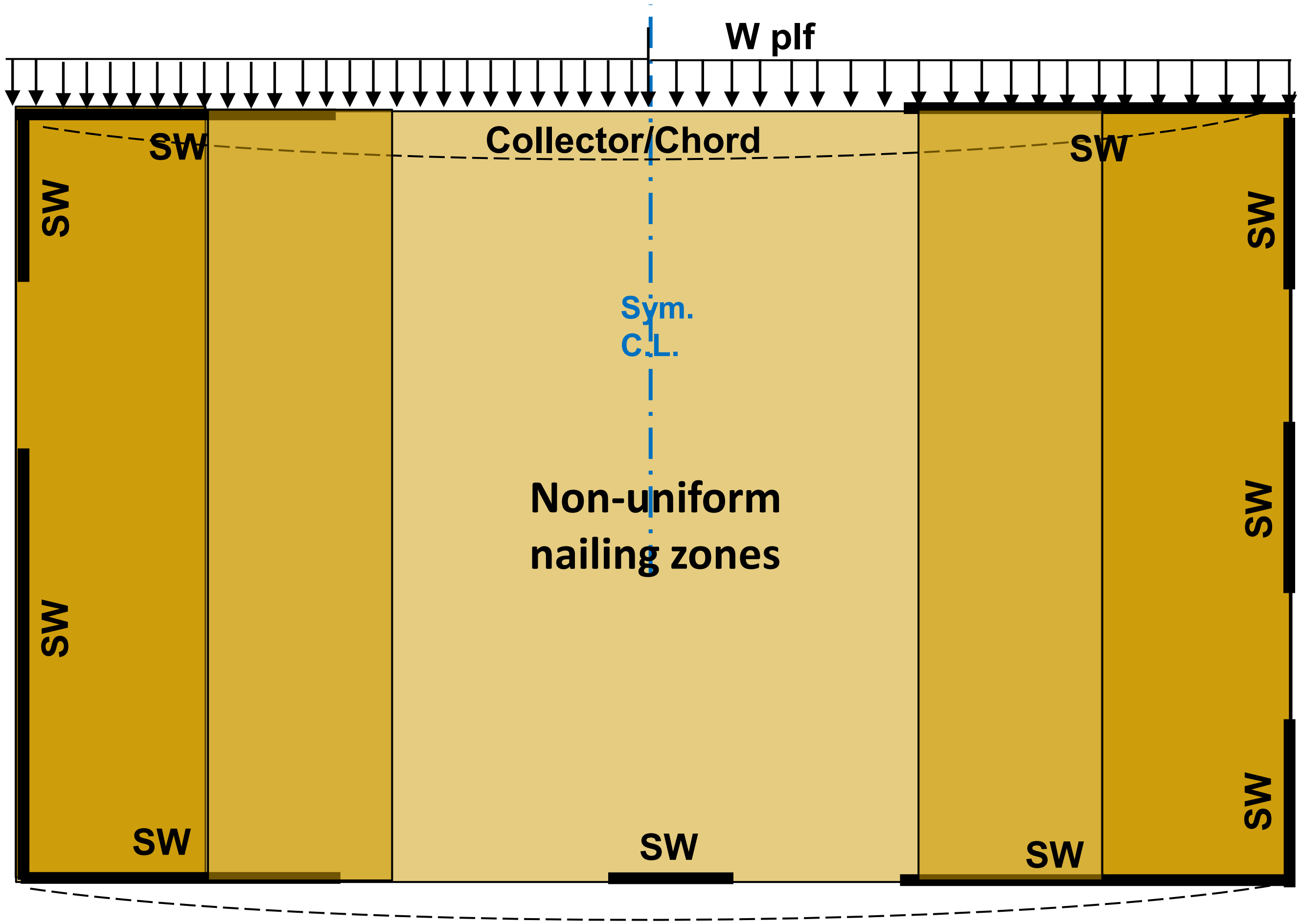
SDPWS Table 4.2.2
Maximum Diaphragm Aspect Ratios (Horizontal or sloped diaphragms)

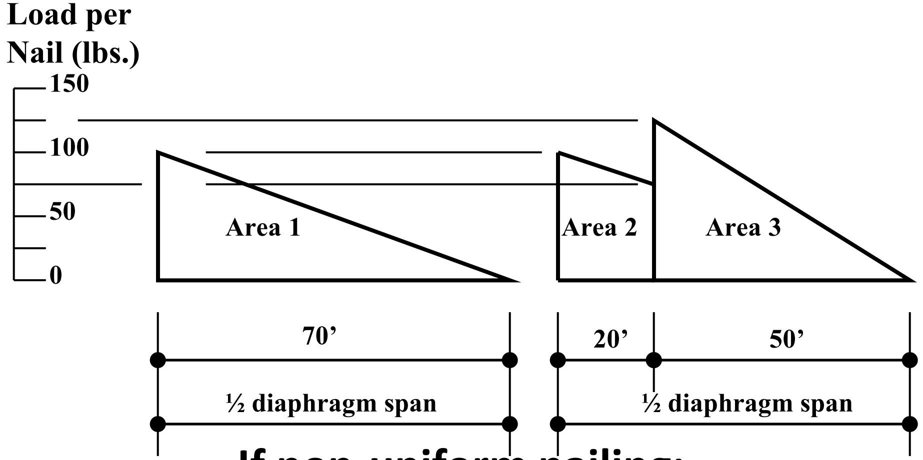
Excerpts from the
2nd Edition, 2022



Terry Malone, PE, SE
Scott Breneman, PhD, PE, SE
Robert Rice, CBO

Blocked/unblocked diaphragm combinations will decrease the diaphragm stiffness





If non-uniform nailing:

- Modified nail slip constant = 0.188(Vn')/Vn .
- SDPWS 3-term equation and tables have an apparent shear stiffness value, Ga, for blocked and unblocked (seismic), However, no guidance for mixing blocked and unblocked portions of the diaphragm.

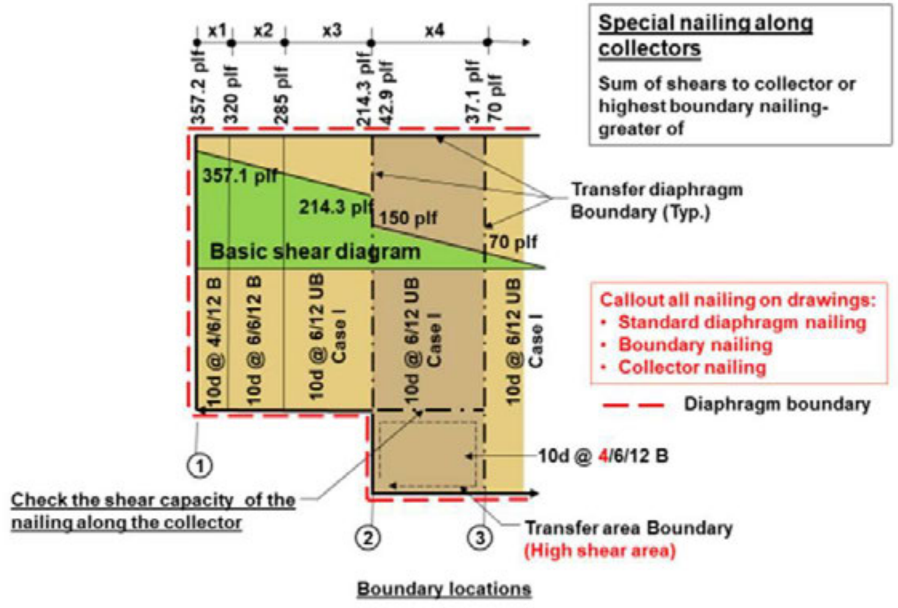
Deflection Equations-Simply Supported Rectangular Diaphragm

$$\delta_{Diaph\ Unif} = \frac{3v_{max}L'^3}{EAW'} + \frac{0.5v_{max}L'}{1000G_a} + \frac{\Sigma A_C X_C}{W'}$$ 3-term eq.

$$\delta_{\mathrm{Diaph\ Unif}} = \frac{3vL'^3}{EAW'} + \frac{0.5vL'}{Gvtv} + 0.376\,L'\,e_n + \frac{\Sigma x\Delta_C}{W'}$$ 4-term eq.

Both equations are based on:

- Uniform load full length of diaphragm.
- Uniform nailing and nail size full length of diaphragm.
- Blocking full length of diaphragm.



Diaphragm Nailing Callouts

Offsets or large openings will increase shears in the diaphragm.

Example 5, 2006 SEAOC Seismic Design Manual, Volume 2

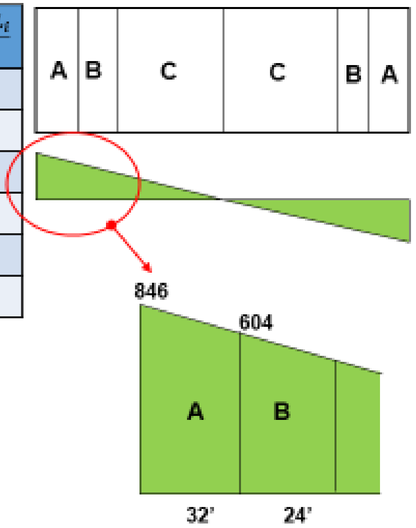
Another method based on virtual work principles is presented in SEAOC's 2006 IBC Structural/Seismic Design Manual (SEAOC, 2006). This method creates a table format computing average shears over respective diaphragm lengths.

$$\Delta_{shear}=\Sigma\frac{0.5v_{i\ ave}L_i}{1000G_{ai}}$$ Virtual work Eq.

Where:
Vi=the average diaphragm shear within each shear stiffness zone.
Li=the length of each stiffness zone measured perpendicular to the loading.
Gai=the apparent shear stiffness of each shear stiffness zone being considered.

Zone	Vi left	Vi right	Vi ave	Li	Ga	$\frac{0.5v_{i\ ave}L_i}{1000G_{ai}}$
A	846	604	725	32'	20	0.58"
B	604	423	514	24	15	0.41"
C	423	0	212	56	24	0.25"
C	0	423	212	56	24	0.25"
B	423	604	514	24	15	0.41"
A	604	846	725	32	20	0.58"
						2.48"

Web shear plus nail slip deflection



1. If 3-term equation, Ga from Table 4.2C must be used for unblocked diaphragm areas.
2. If 4-term equation, unblocked area deflection of diaphragm might have to be increased per TT-064 for Zone C. (e.g., 2.5x or 3.0x)

(Far too big)
4-15

Virtual work can be used to solve for the shear deflection in zones of different shear stiffness. Also refer to ATC-7 for examples.

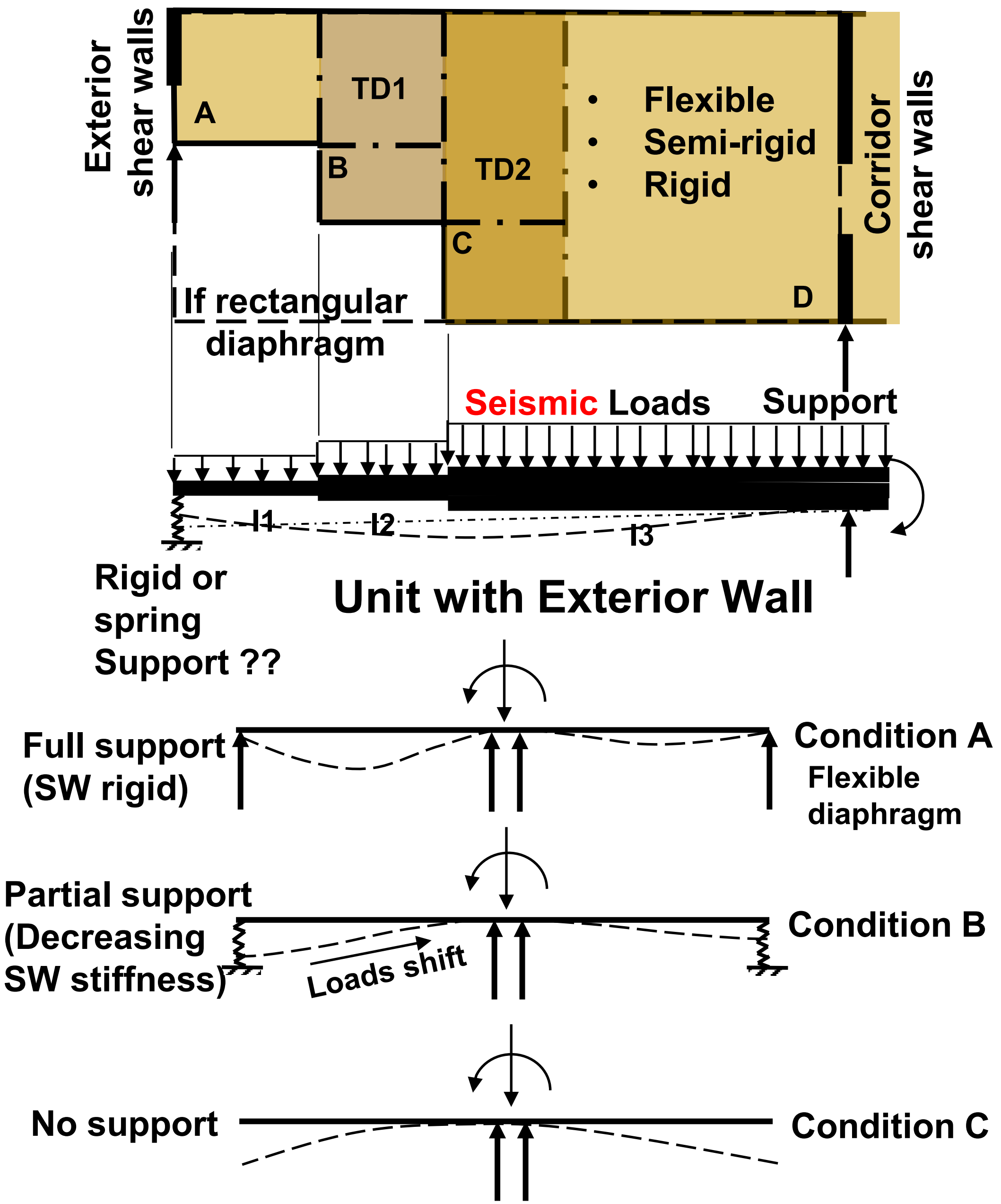
There is still insufficient guidance today. "Back in the days", the structures and diaphragms were simple rectangular in nature, and diaphragm deflection was rarely checked as long as allowable aspect ratios were met.

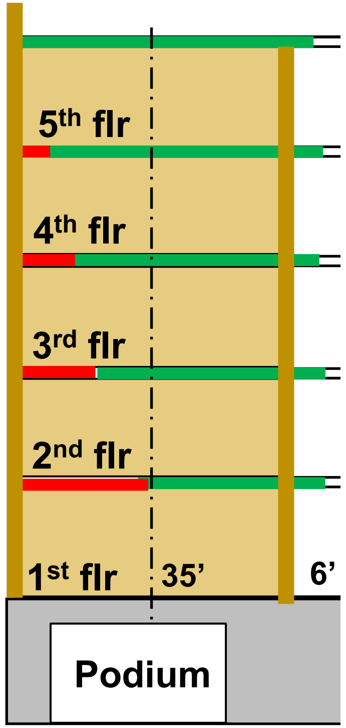
In today's structures checking diaphragm and shear wall stiffness's is becoming increasingly more important, especially with open-front diaphragms.

Diaphragm Flexibility

- Introduction to diaphragm flexibility
- Code Sections, Definitions, and Requirements
- How do you calculate it?
- Irregularities Affecting Diaphragm Stiffness
- **Exterior Shear Wall Effects**
- Effects of Diaphragm Flexibility

Force Distribution Due to Diaphragm/SW stiffness





Full cantilever, no exterior wall support

no significant exterior wall support. Conserv. to design as cantilever

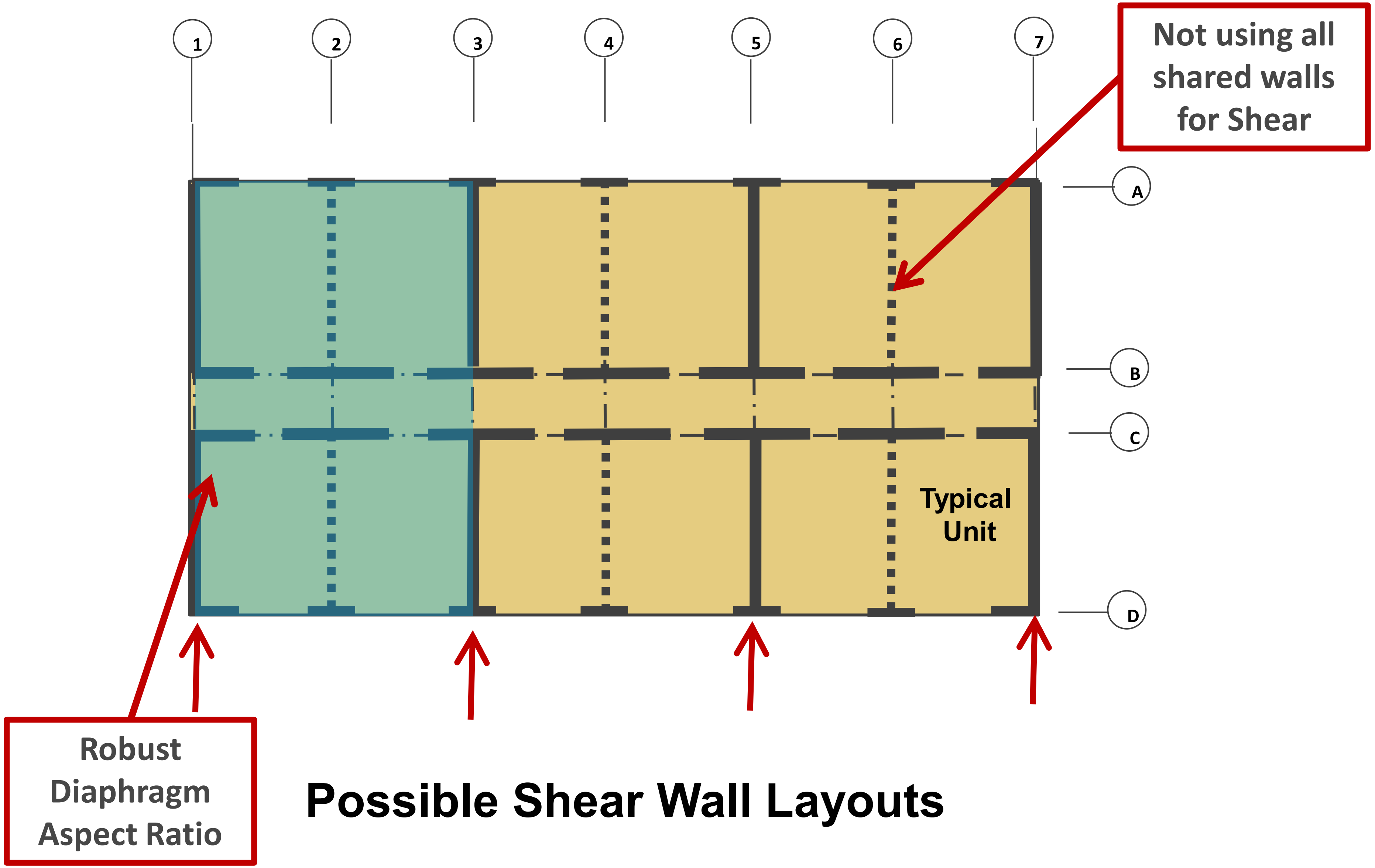
Most load goes to corridor walls. Check Diaph./SW stiffness, use RDA to design diaphragm

Can be idealized as flexible diaphragm

Diaphragm Flexibility

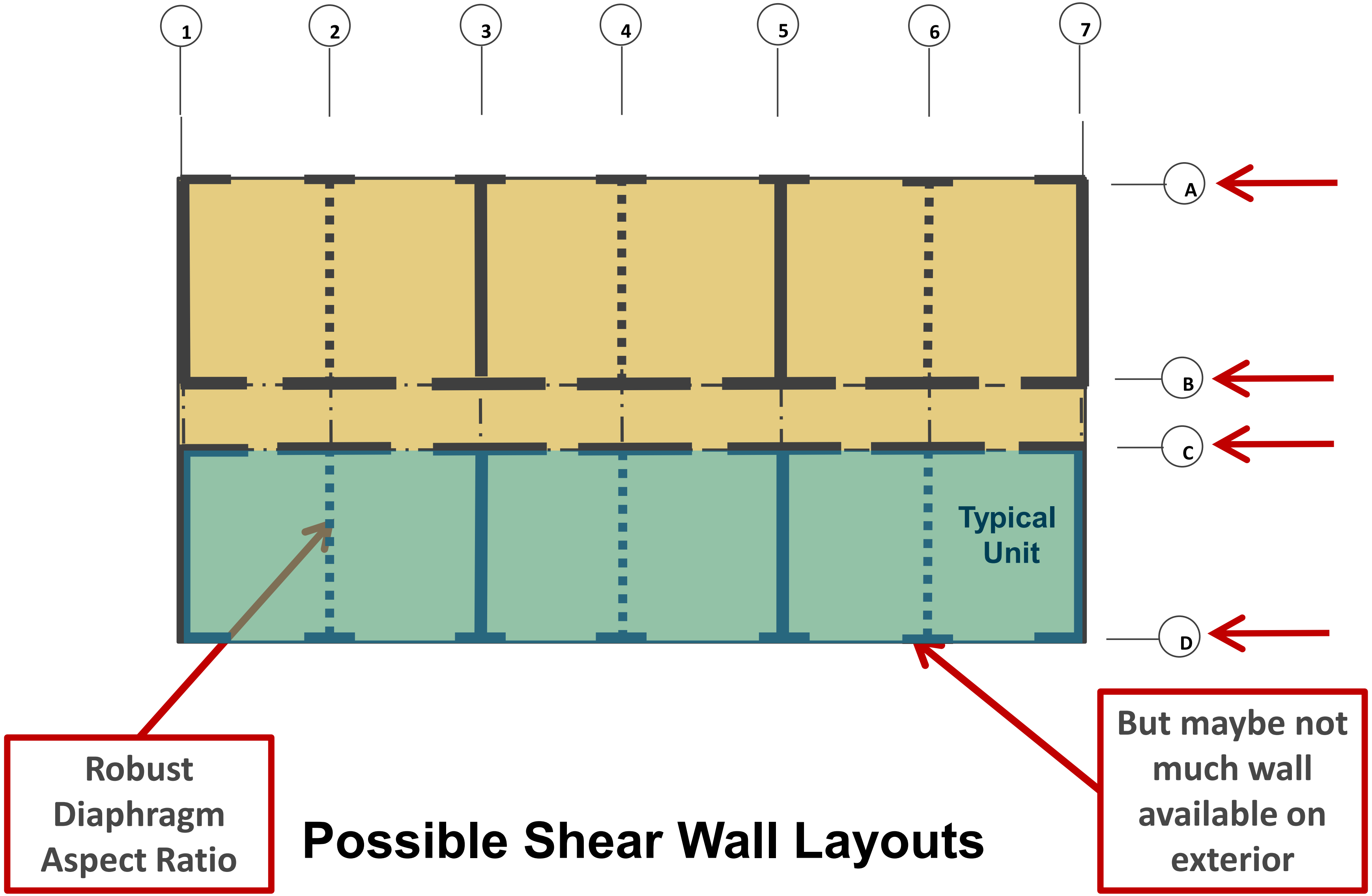
- Introduction to diaphragm flexibility
- Code Sections, Definitions, and Requirements
- How do you calculate it?
- Irregularities Affecting Diaphragm Stiffness
- Exterior Shear Wall Effects
- **Effects of Diaphragm Flexibility**

Multi-Story Lateral Design

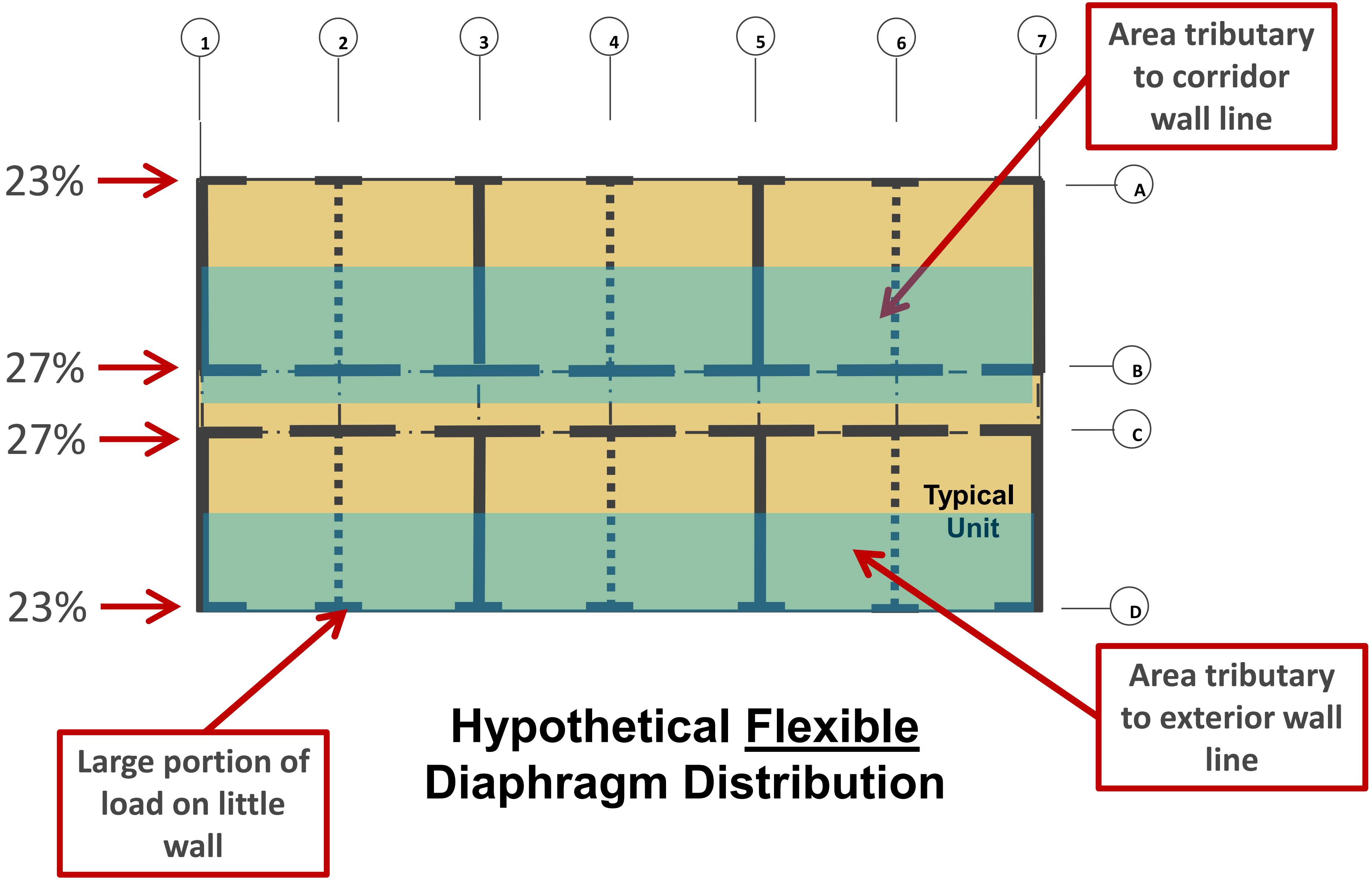


Possible Shear Wall Layouts

Multi-Story Lateral Design

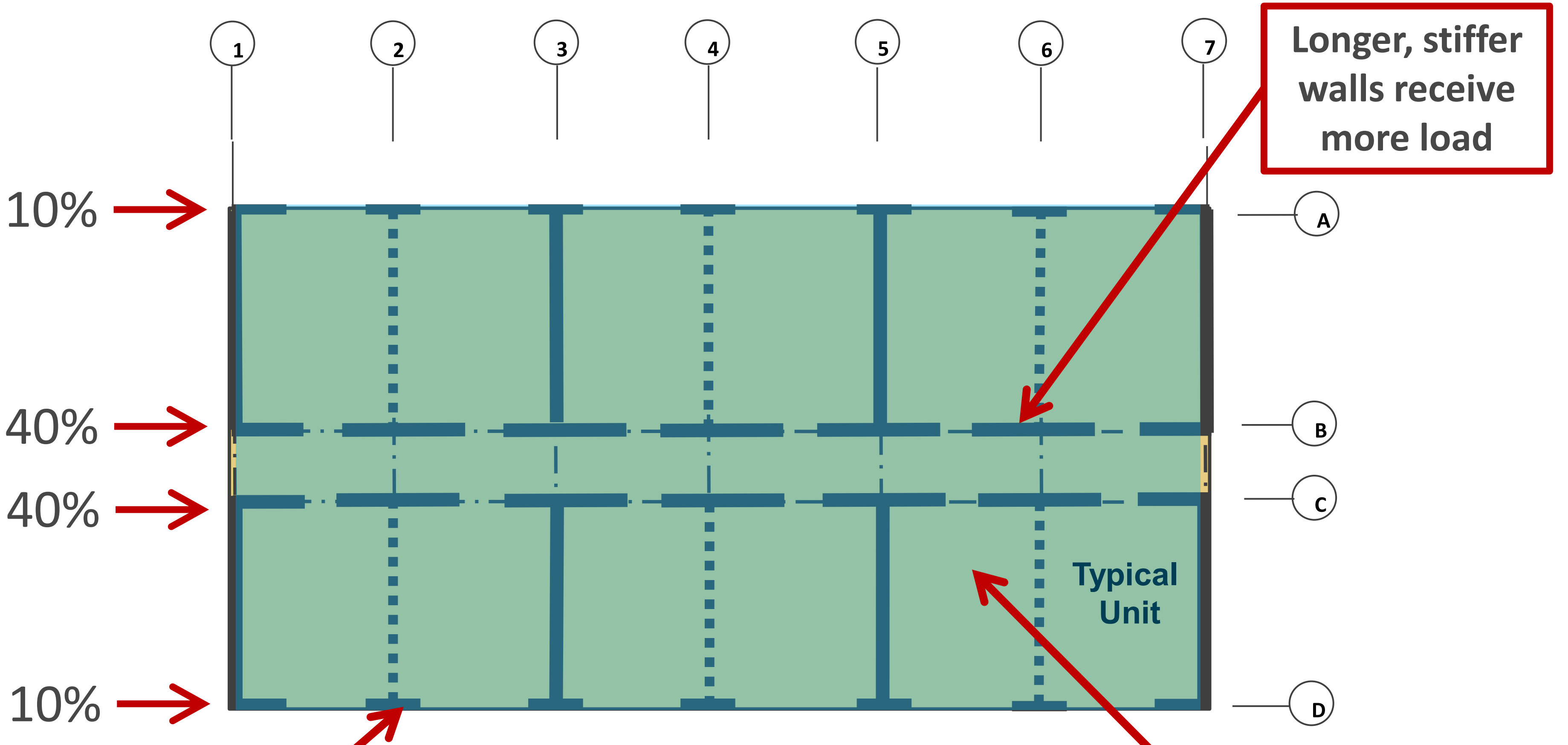


Possible Shear Wall Layouts



Hypothetical Flexible Diaphragm Distribution

Changing wall construction does NOT impact load to wall line



Narrow, flexible walls receive less load

Hypothetical Rigid Diaphragm Distribution

Diaphragm assumed to be rigid body.

Changing wall length and construction does impacts load to wall line

Two More Diaphragm Approaches

Semi-Rigid Diaphragm Analysis

» Neither idealized flexible nor idealized rigid

» Explicit modeling of diaphragm deformations with shear wall deformations to distribute lateral loads

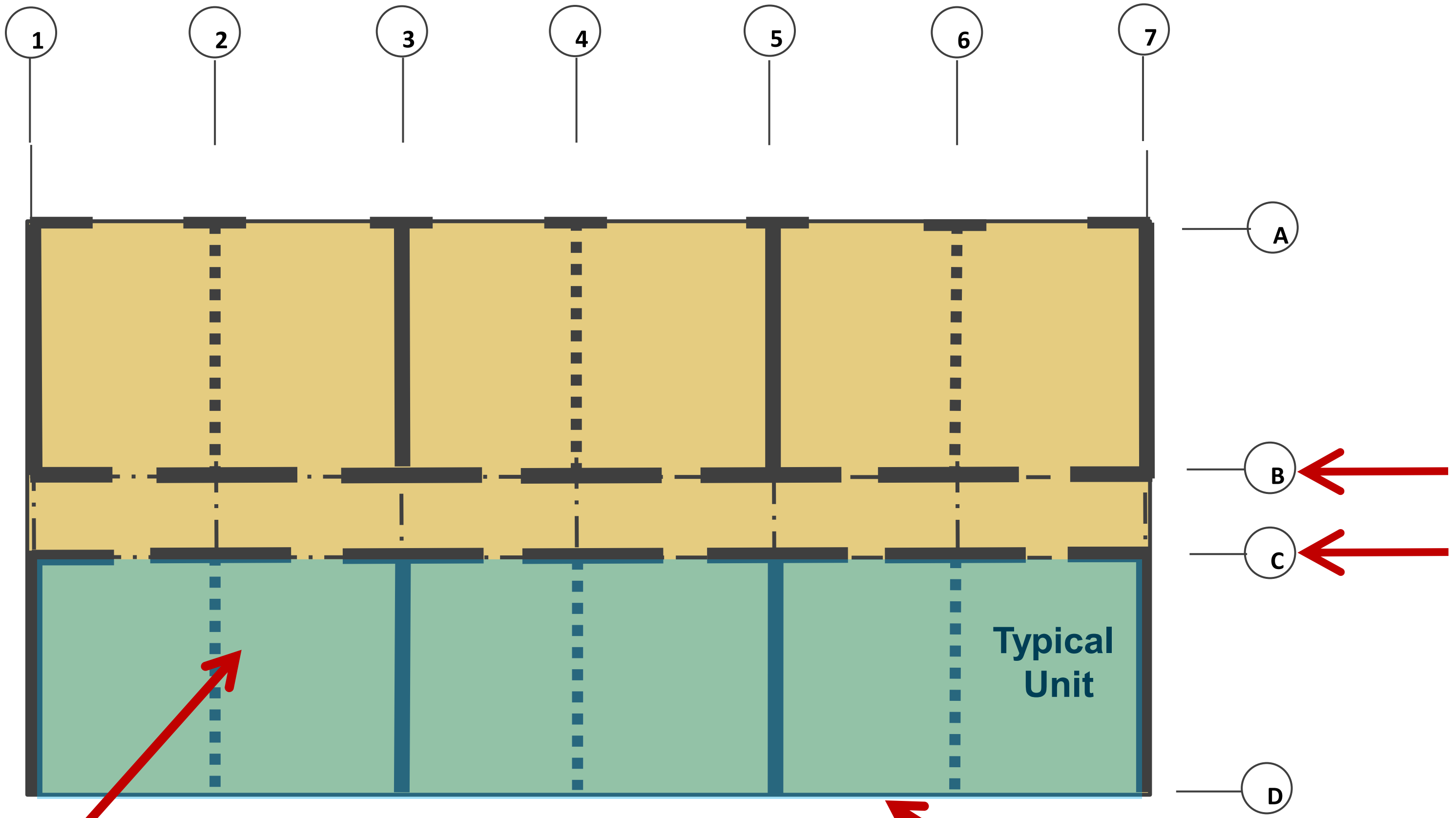
» Not quick or easy

Enveloping Method

» Idealized as BOTH flexible and rigid.

» Individual components designed for worst case from each approach

» Recognized in the SDPWS as alternative to semi-rigid

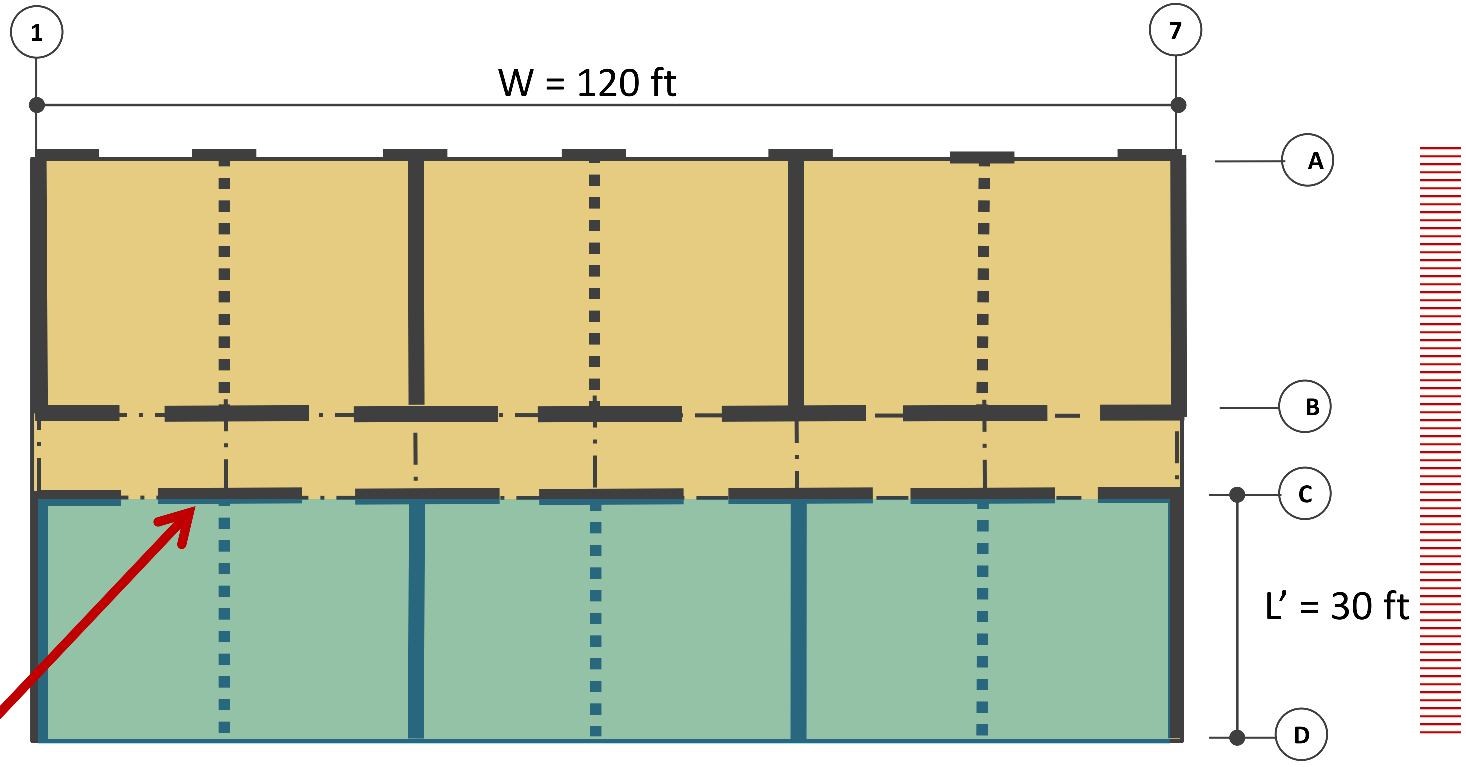


Robust Aspect Ratio but only supported on 3 sides…

Possible Shear Wall Layouts

The Cantilever Diaphragm Option

Simple example with a few numbers



w = 10 psf
ASD Seismic

ASD design diaphragm shear at support line
v = 10 psf (30 ft) = 300 plf

Use 19/32" OSB Sheathing with 10d at 6" o.c. each way in 2" Doug-Fir Larch or Southern Pine framing

Table 4.2A Nominal Unit Shear Capacities for Sheathed Wood-Frame Diaphragms

Blocked Wood Structural Panel Diaphragms[1,2,3,4,6]

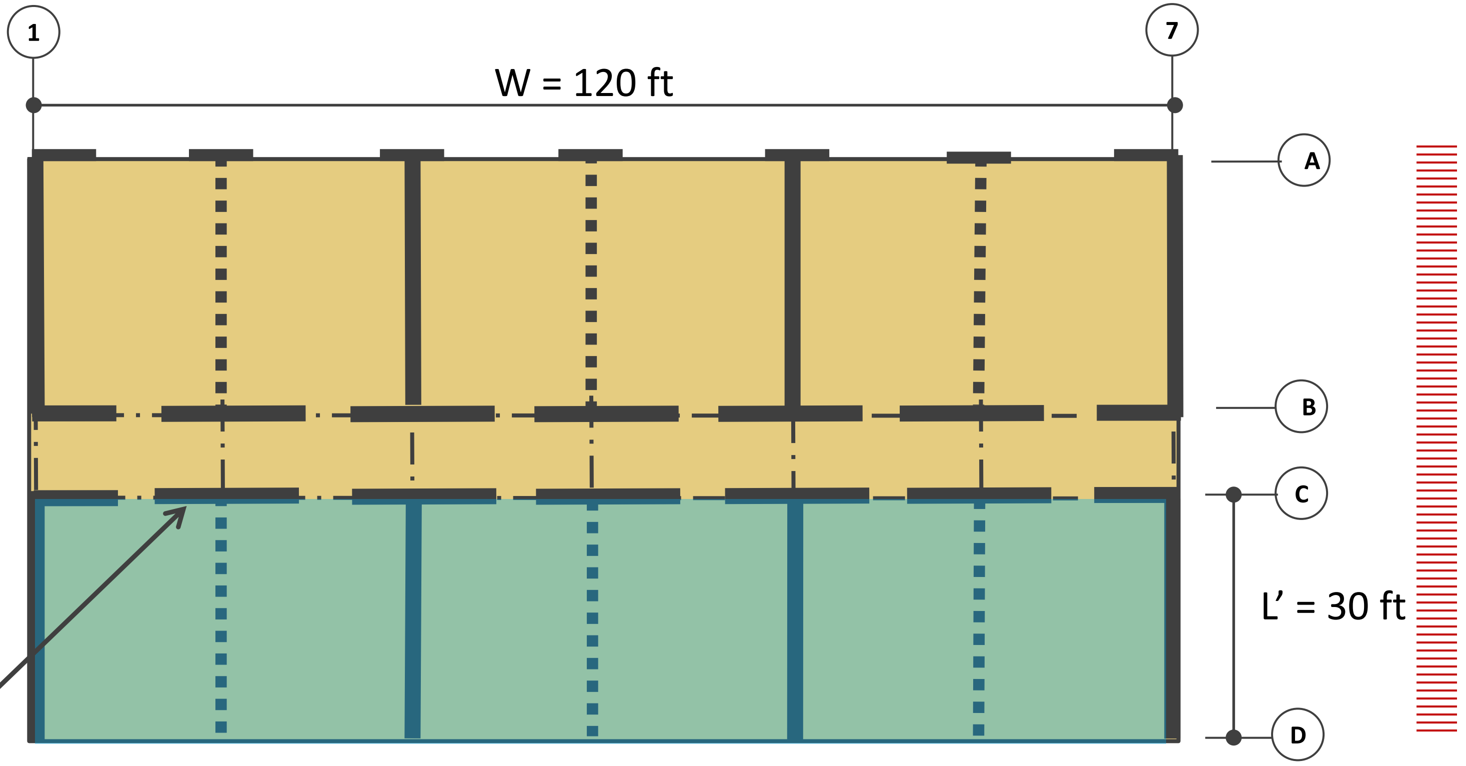
Sheathing Grade	Common Nail Size[5] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Minimum Nail Bearing Length in Framing Member or Blocking, ℓ_m (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Adjoining Panel Edges and Boundaries (in.)	Nail Spacing (in.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 & 4), and at all panel edges (Cases 5 & 6)											
					6			4			2-1/2			2		
					Nail Spacing (in.) at other panel edges (Cases 1,2,3, & 4)											
					6			6			4			3		
					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
Sheathing and Single-Floor	6d (2 x 0.113 x 0.266)	1-1/4	5/16	2	475	15	10	630	9.0	7.0	940	13	9.5	1065	21	13
				3	530	12	9.0	700	7.0	6.0	1065	10	8.0	1205	17	12
			3/8	2	520	13	9.5	700	7.0	6.0	1050	10	8.0	1175	18	12
				3	590	10	8.0	785	5.5	5.0	1175	8.5	7.0	1330	14	10
	8d (2-1/2 x 0.131 x 0.281)	1-3/8	3/8	2	670	15	11	895	9.5	7.5	1345	13	9.5	1525	21	13
				3	755	12	9.5	1010	7.5	6.0	1510	11	8.5	1710	18	12
			7/16	2	715	14	10	950	8.5	7.0	1415	12	9.5	1610	20	13
				3	800	11	9.0	1065	7.0	6.0	1595	10	8.0	1805	17	12
			15/32	2	755	13	9.5	1010	7.5	6.5	1485	11	8.5	1680	19	13
				3	840	10	8.5	1120	6.0	5.5	1680	9.0	7.5	1890	15	11
	10d (3 x 0.148 x 0.312)	1-1/2	15/32	2	810	25	15	1080	15	11	1610	21	14	1835	33	18
				3	910	21	14	1205	12	9.5	1820	17	12	2060	28	16
			19/32	2	895	21	14	1190	13	9.5	1790	18	12	2045	28	17
				3	1010	17	12	1345	10	8.0	2015	14	11	2295	24	15

Shear capacity check

v_n = 895 plf

ASD Seismic Capacity = 895 plf / 2.8 = 319 plf > 300 plf

2.8 per SDPWS 2021 4.1.4



w = 10 psf
ASD Seismic

ASD design diaphragm shear at support line
v = 10 psf (30 ft) = 300 plf

Flexible diaphragm assumption not valid per SDPWS 4.2.6
Does this diaphragm qualify at a Rigid Diaphragm? Check at LRFD level forces

$$\delta_{dia,cant} = \frac{3vL'^3}{EAW'} + \boxed{\frac{0.5vL'}{1000G_a}} + \frac{\Sigma(x'\Delta_C)}{W'} = 0.33\ in$$

Shear Wall design:
15/32” <u>OSB</u> Sheathing with 10d at 6” o.c. on DF or SP framing near 100% Capacity

$$\delta_{wall} = \frac{8vh^3}{EAb} + \boxed{\frac{vh}{1000G_a}} + \frac{h}{b}\Delta_a = 0.16\ in$$

$$0.33\ in > 2\ (0.16) = 0.32\ in$$

Does not qualify as Rigid!!
(it’s close)

How to stiffen a diaphragm: More nails?

Table 4.2A Nominal Unit Shear Capacities for Sheathed Wood-Frame Diaphragms

Blocked Wood Structural Panel Diaphragms[1,2,3,4,6]

Sheathing Grade	Common Nail Size[5] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Minimum Nail Bearing Length in Framing Member or Blocking, ℓ_m (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Adjoining Panel Edges and Boundaries (in.)	Nail Spacing (in.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 & 4), and at all panel edges (Cases 5 & 6)											
					6			4			2-1/2			2		
					Nail Spacing (in.) at other panel edges (Cases 1,2,3, & 4)											
					6			6			4			3		
					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
Sheathing and Single-Floor	6d (2 x 0.113 x 0.266)	1-1/4	5/16	2	475	15	10	630	9.0	7.0	940	13	9.5	1065	21	13
				3	530	12	9.0	700	7.0	6.0	1065	10	8.0	1205	17	12
			3/8	2	520	13	9.5	700	7.0	6.0	1050	10	8.0	1175	18	12
				3	590	10	8.0	785	5.5	5.0	1175	8.5	7.0	1330	14	10
	8d (2-1/2 x 0.131 x 0.281)	1-3/8	3/8	2	670	15	11	895	9.5	7.5	1345	13	9.5	1525	21	13
				3	755	12	9.5	1010	7.5	6.0	1510	11	8.5	1710	18	12
			7/16	2	715	14	10	950	8.5	7.0	1415	12	9.5	1610	20	13
				3	800	11	9.0	1065	7.0	6.0	1595	10	8.0	1805	17	12
			15/32	2	755	13	9.5	1010	7.5	6.5	1485	11	8.5	1680	19	13
				3	840	10	8.5	1120	6.0	5.5	1680	9.0	7.5	1890	15	11
	10d (3 x 0.148 x 0.312)	1-1/2	15/32	2	810	25	15	1080	15	11	1610	21	14	1835	33	18
				3	910	21	14	1205	12	9.5	1820	17	12	2060	28	16
			19/32	2	895	21	[illegible]	[illegible]	13	[illegible]	[illegible]	18	12	2045	28	17
				3	1010	17	12	1345	10	8.0	2015	14	11	2295	24	15

Same framing with more nails <u>often does not increase </u>stiffness G_a, so often not helpful

How to stiffen a diaphragm: Plywood vs OSB?

Table 4.2A Nominal Unit Shear Capacities for Sheathed Wood-Frame Diaphragms

Blocked Wood Structural Panel Diaphragms[1,2,3,4,6]

Sheathing Grade	Common Nail Size[5] Length (in.) x Shank diameter (in.) x Head diameter (in.)	Minimum Nail Bearing Length in Framing Member or Blocking, ℓ_m (in.)	Minimum Nominal Panel Thickness (in.)	Minimum Nominal Width of Nailed Face at Adjoining Panel Edges and Boundaries (in.)	Nail Spacing (in.) at diaphragm boundaries (all cases), at continuous panel edges parallel to load (Cases 3 & 4), and at all panel edges (Cases 5 & 6)											
					6			4			2-1/2			2		
					Nail Spacing (in.) at other panel edges (Cases 1,2,3, & 4)											
					6			6			4			3		
					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
Sheathing and Single-Floor	6d (2 x 0.113 x 0.266)	1-1/4	5/16	2	475	15	10	630	9.0	7.0	940	13	9.5	1065	21	13
				3	530	12	9.0	700	7.0	6.0	1065	10	8.0	1205	17	12
			3/8	2	520	13	9.5	700	7.0	6.0	1050	10	8.0	1175	18	12
				3	590	10	8.0	785	5.5	5.0	1175	8.5	7.0	1330	14	10
	8d (2-1/2 x 0.131 x 0.281)	1-3/8	3/8	2	670	15	11	895	9.5	7.5	1345	13	9.5	1525	21	13
				3	755	12	9.5	1010	7.5	6.0	1510	11	8.5	1710	18	12
			7/16	2	715	14	10	950	8.5	7.0	1415	12	9.5	1610	20	13
				3	800	11	9.0	1065	7.0	6.0	1595	10	8.0	1805	17	12
			15/32	2	755	13	9.5	1010	7.5	6.5	1485	11	8.5	1680	19	13
				3	840	10	8.5	1120	6.0	5.5	1680	9.0	7.5	1890	15	11
	10d (3 x 0.148 x 0.312)	1-1/2	15/32	2	810	25	15	1080	15	11	1610	21	14	1835	33	18
				3	910	21	14	1205	12	9.5	1820	17	12	2060	28	16
			19/32	2	895	21	14	1190	13	9.5	1790	18	12	2045	28	17
				3	1010	17	12	1345	10	8.0	2015	14	11	2295	24	15

Same framing with same nailing, plywood has lower stiffness than OSB, so higher deflection

How to Soften a Shear Wall: Plywood vs OSB?

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 - Sheathing [4,5]	5/16	1-1/4	6d common nail (2 x 0.113 x 0.266) [8]	505	13	9.5	755	18	12	980	24	14	1260	37	18
	3/8			560	11	8.5	840	15	11	1090	20	13	1430	32	17
	3/8 [2]	1-3/8	8d common nail (2-1/2 x 0.131 x 0.281) [8]	615	17	12	895	25	15	1150	31	17	1485	45	20
	7/16 [2]			670	15	11	980	22	14	1260	28	17	1640	42	21
	15/32			730	13	10	1065	19	13	1370	25	15	1790	39	20
	15/32	1-1/2	10d common nail (3 x 0.148 x 0.312) [8,10]	870	22	14	1290	30	17	1680	37	19	2155	52	23
	19/32			950	19	13	1430	26	16	1860	33	18	2435	48	22

Same framing with same nailing, plywood has lower stiffness than OSB, so higher deflection

Wall
G_a = 22 OSB
G_a = 14 PLY

$$\delta_{dia,cant} = \frac{3vL'^3}{EAW'} + \frac{0.5vL'}{1000G_a} + \frac{\Sigma(x'\Delta_C)}{W'} = 0.33\ in$$

$$\delta_{wall} = \frac{8vh^3}{EAb} + \frac{vh}{1000G_a} + \frac{h}{b}\Delta_a = 0.25\ in$$

$$0.33\ in < 2\ (0.25) = 0.50\ in$$

Diaphragm Does Qualify as Rigid!!

Mixed shearwalls

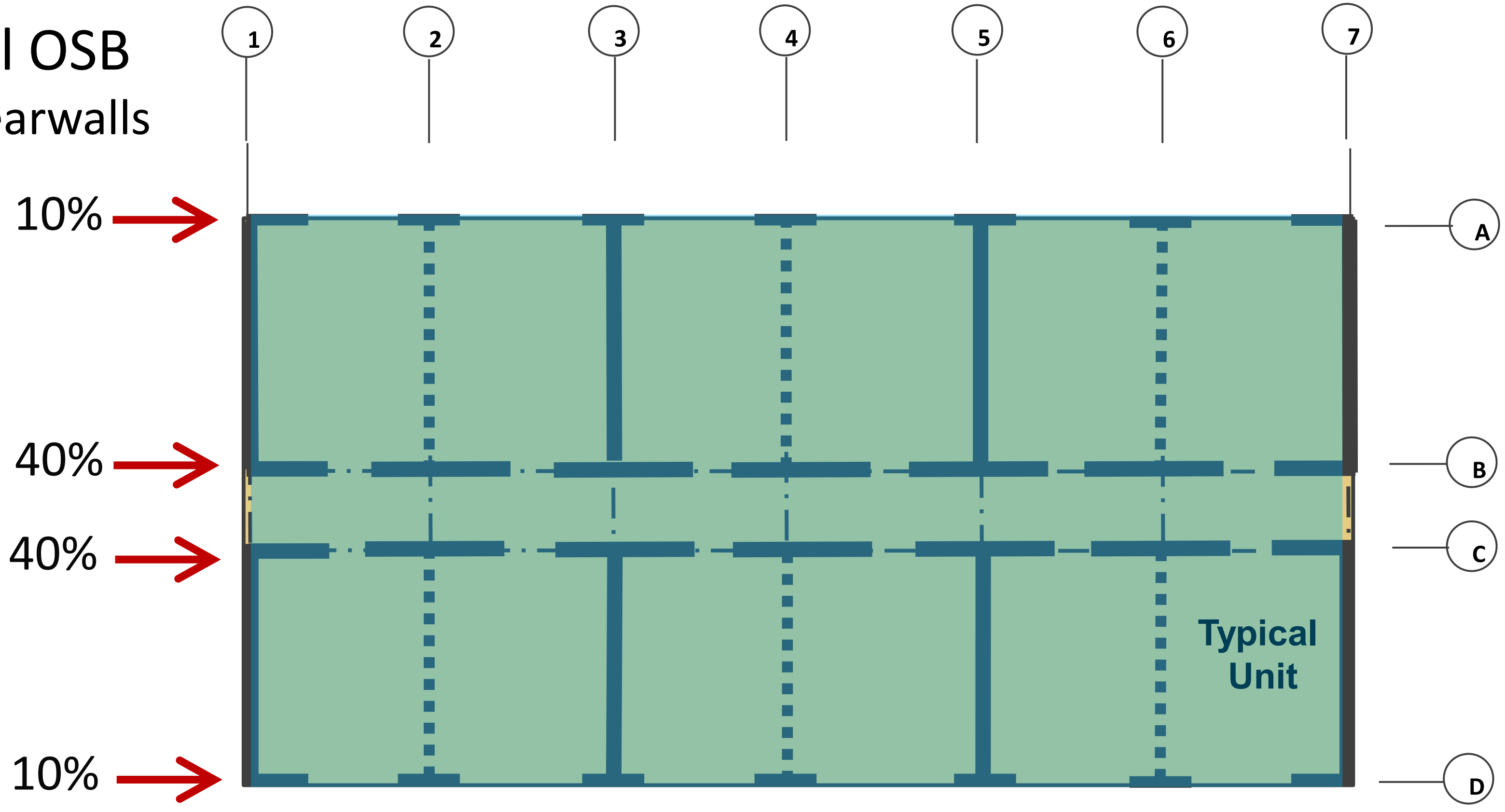
PLY 7%

OSB 43% 43%

PLY 7%

FRT Plywood on exterior of Type III building?

All OSB shearwalls



Hypothetical Rigid Diaphragm Distribution

Changing type of sheathing can impact force distribution in RDA

How to stiffen a diaphragm: Different Calculations?

SDPWS Eq. 4.2-2 (3-term equation)

$$\delta_{dia,cant} = \frac{3vL'^3}{EAW'} + \frac{0.5vL'}{1000G_a} + \frac{\Sigma(x'\Delta_C)}{W'} = 0.33\ in$$

4-term equation for uniformly loaded cantilever diaphragm:

$$\delta_{dia,cant,4} = \frac{3vL'^3}{EAW'} + \boxed{\frac{vL'}{2G_v t_v} + 0.375L'e_n} + \frac{\Sigma(x'\Delta_C)}{W'} = 0.27\ in$$

$$\delta_{dia} < 2\,\delta_{wall}\,?$$

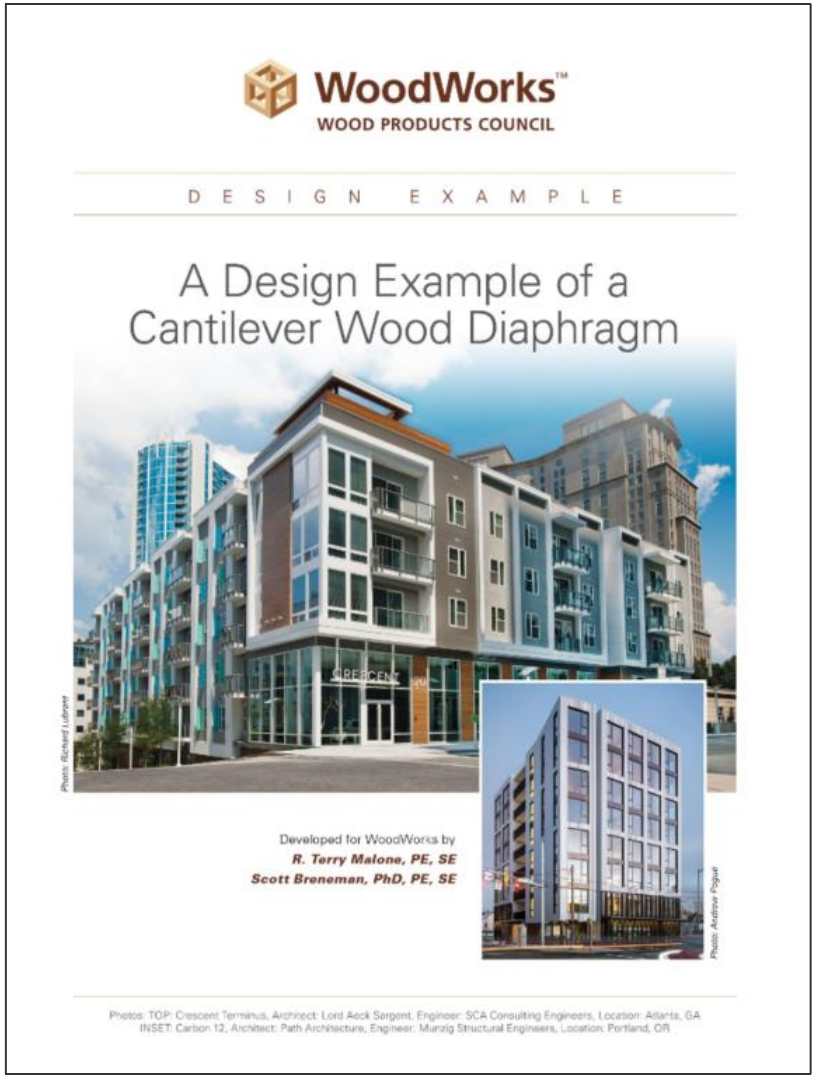
$$0.27\ in < 2\ (0.16\ in) = 0.32\ in$$

Diaphragm Qualifies as Rigid?

3-term deflection equations are conservative (low) stiffness values based on nail slip at LRFD capacity.

Calculated deflections at lower demands result in 4-term equation value less 3-term equation value.

Design Example of a Cantilever Wood Diaphragm



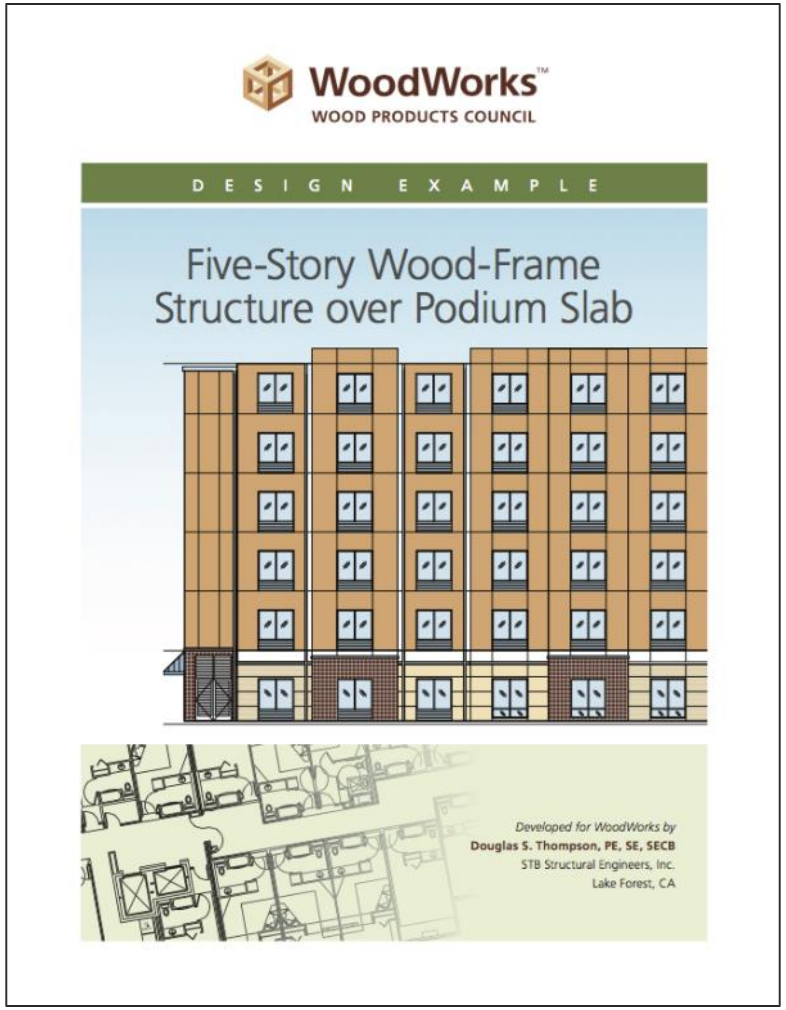
Covers diaphragm classification as rigid by calculation, rigid diaphragm analysis calculations, 3-term vs 4-term deflection calculations of diaphragms and shear walls, torsional irregularities, story drift checks, etc.

https://www.woodworks.org/resources/design-example-of-a-cantilever-wood-diaphragm/

Design Example: Five-Story Wood-Frame Over Podium

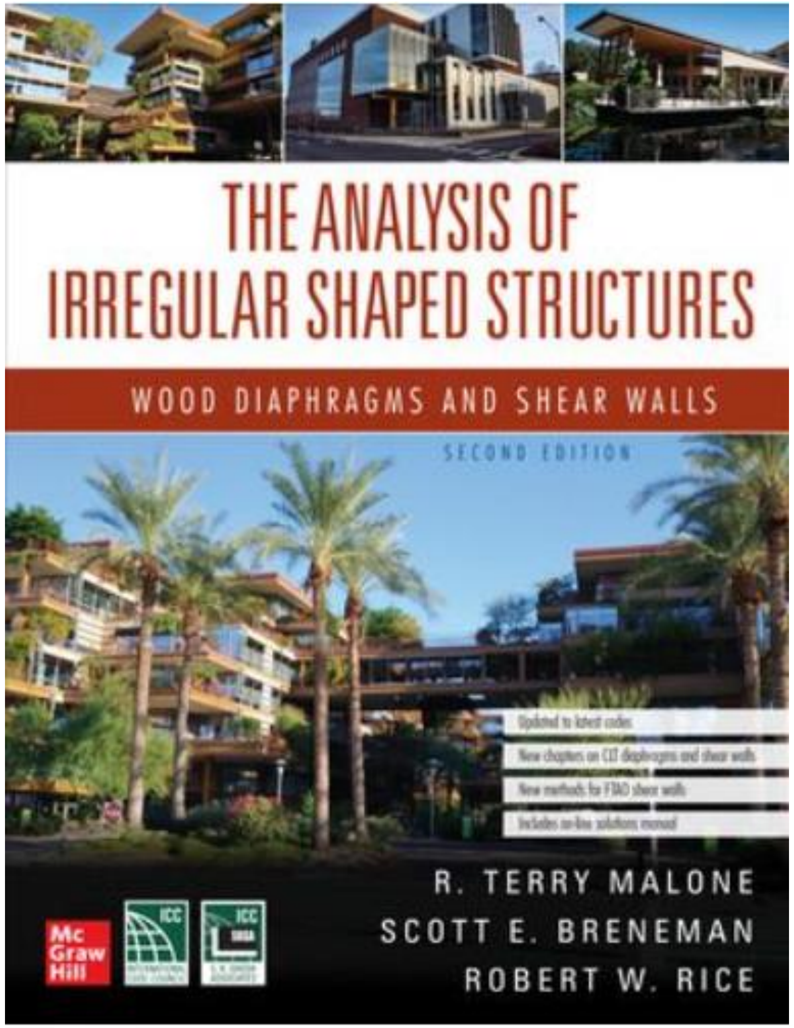
Covers lateral design approaches, seismic emphasis, 2-stage analysis,

Shrinkage considerations, Type III detailing, gravity detailing, etc.



https://www.woodworks.org/resources/five-story-wood-frame-structure-over-podium-slab/

Detailed book on wood diaphragm and shear walls



500+ pages of discussion and worked examples, many of complicated real world irregularly-shaped wood buildings.

Regional Directors: **One-on-One Project Support**

Solutions Team

Scott Breneman, PhD, PE, SE

Ashley Cagle, PE, SE

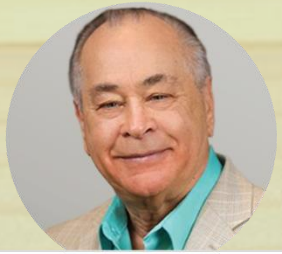
Karen Gesa, PE

Erin Kinder, PE, SE, LEED AP

Melissa Kroskey, AIA, SE

Taylor Landry, PE, MLSE

Bruce Lindsey

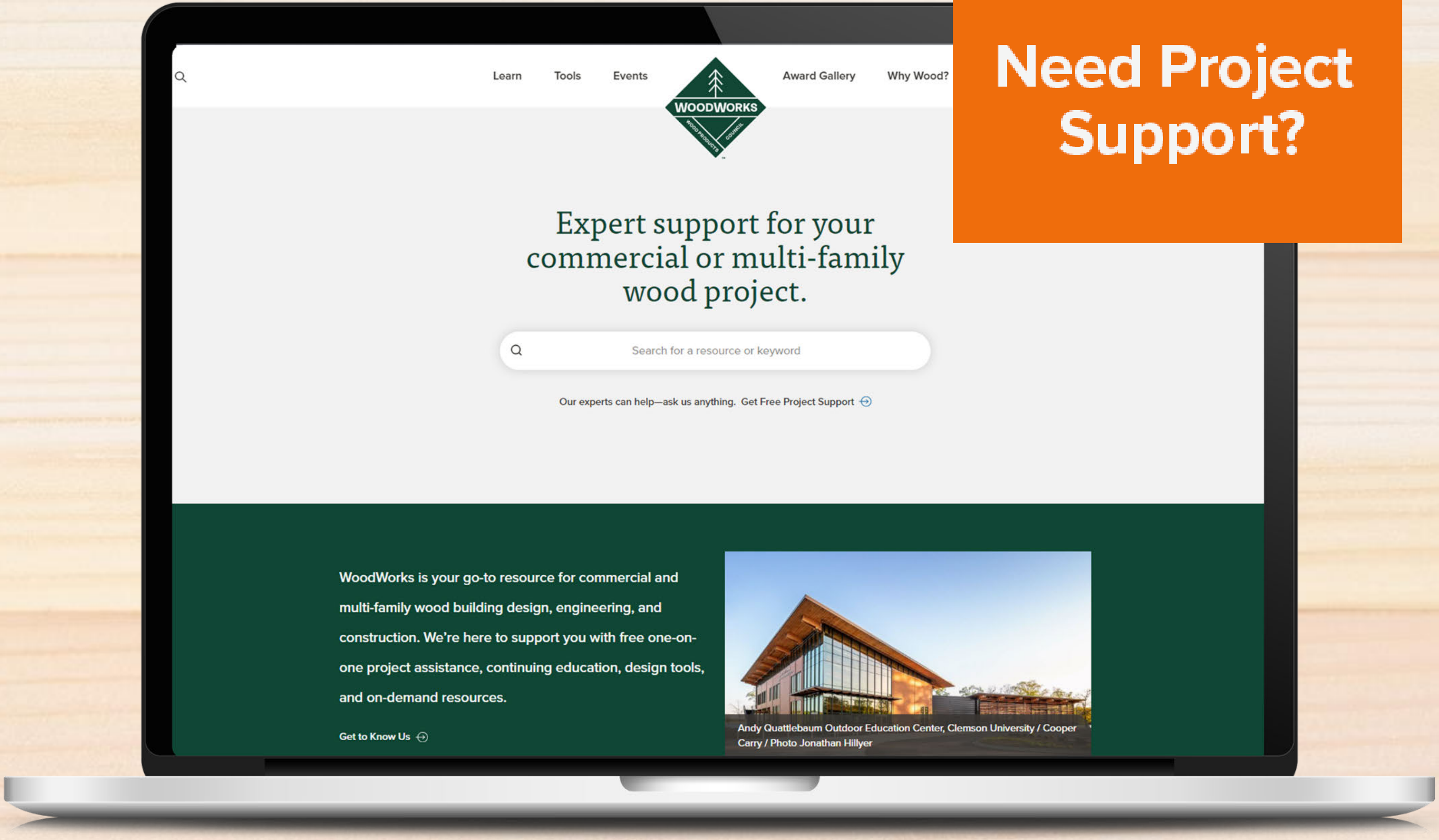


Terry Malone, PE, SE

Ricky McLain, PE, SE

woodworks.org

Need Project Support?



QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

Terry Malone, PE, SE
WoodWorks – Wood Products Council
Senior Technical Director, Project Resources and Solutions Division
terrym@woodworks.org | woodworks.org

Scott Breneman, PhD, PE, SE
WoodWorks – Wood Products Council
Senior Technical Director, Project Resources and Solutions Division
scott.breneman@woodworks.org | woodworks.org

Copyright Materials

Funding provided in part by the Softwood Lumber Board