WoodWorks

A Master Class on Wood Lateral-Resisting Systems

Harrington Recovery Center
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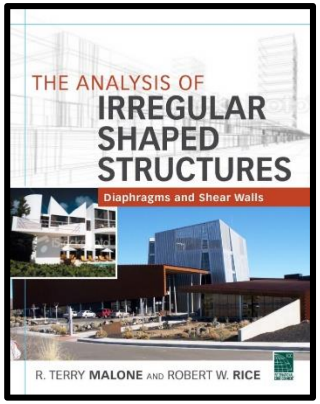

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

Creative structures are becoming increasingly common. Their aesthetically pleasing shapes create new demands and challenges on finding engineering solutions.

This presentation will provide the necessary analytical tools to solve complex lateral load paths across areas of discontinuities in irregular shaped diaphragms. A complete lateral plan review will be conducted on a two-story hotel to see how these design tools can be applied.

Learning Objectives

- **Answer some of the more commonly asked questions regarding complex diaphragm design.**
- **Review the analysis methods available to transfer shear forces across areas of discontinuities.**
- **Examine the important role of collectors for distributing forces through the diaphragm.**
- **Provide a comprehensive lateral Plan Review of a complex diaphragm.**

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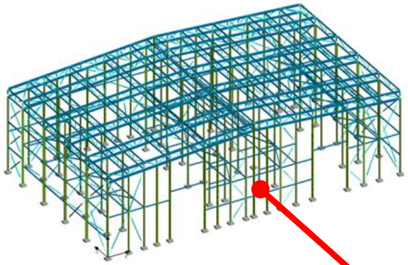
Presentation Objectives

(Based on repeated e-mails, phone calls, RD plan reviews)

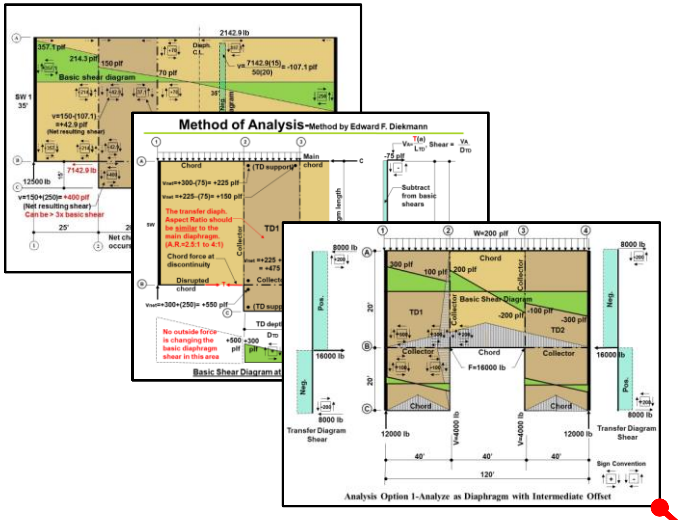
The basics

- Questions
- Computer modeling
- Design approach

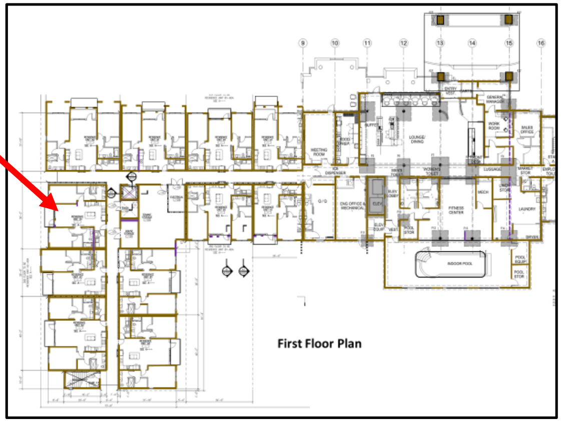
There is more than one way to analyze complex diaphragms.



The analytical methods

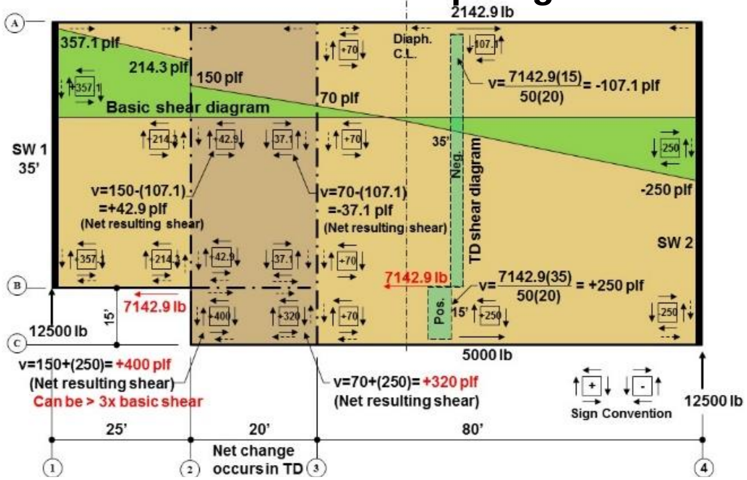


The Plan Review

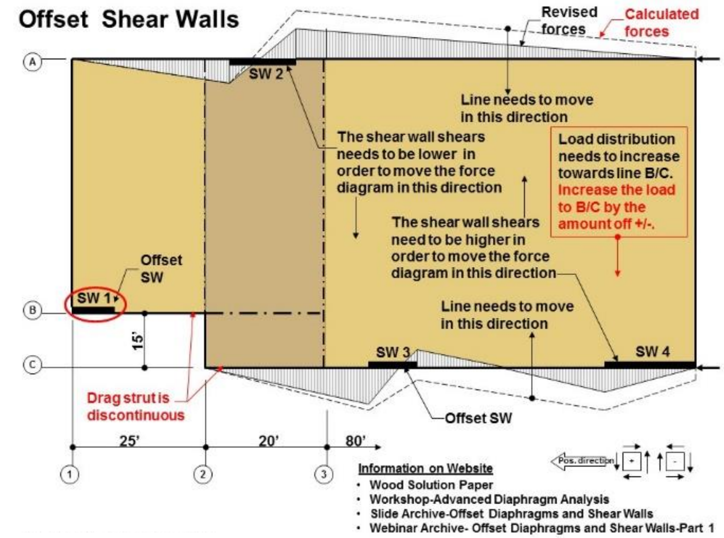


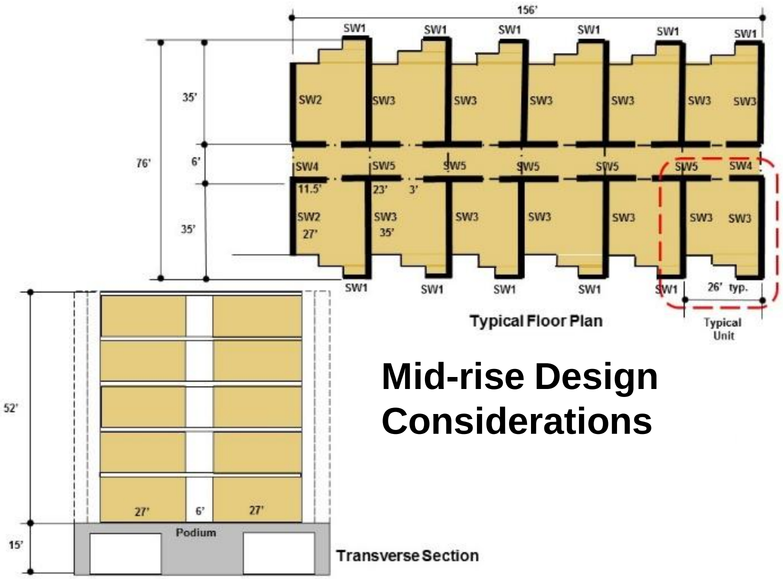
Method of Analysis and Webinar References

Offset Diaphragms

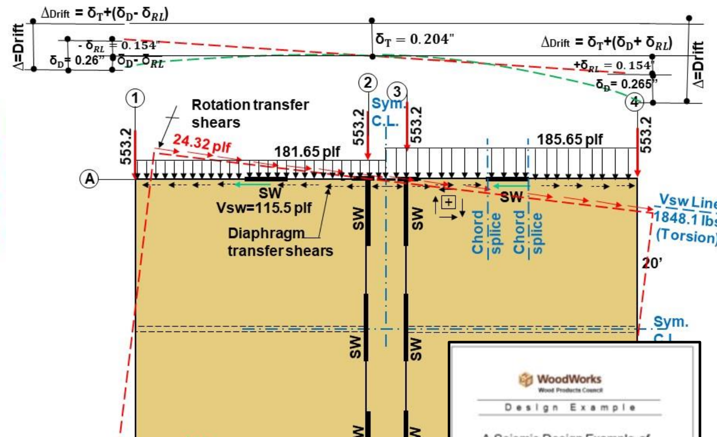


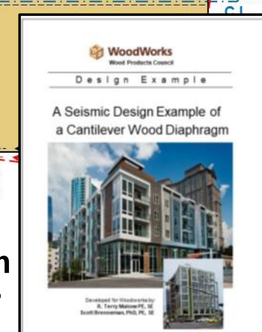
Offset Shear Walls





Mid-rise Design Considerations





Cantilever Diaphragm Workshop and Paper

The Analysis of Irregular Shaped Diaphragms

Information on Website:

Presentation Slide Archives, Workshops, White papers, research reports, Design examples

Commonly Asked Questions

- **How do you analyze a complex diaphragm layout?**
- **How do I model the diaphragm using FEA software? Pros-cons, accuracy?**
- **When is a detailed analysis required? Can I just do a quick check?**
- **What constitutes a continuous lateral load path?**
- **How do I handle diaphragm and shear wall offsets?**
- **Do I need to develop force diagrams or not?**

History has shown:

- **Textbooks and code examples commonly show simple rectangular structures for examples. All SW's line up, no offsets-Doesn't fit modern structures.**
- **There are very few references regarding the design of complicated diaphragm shapes.**
- **Plan review experience has shown that complex diaphragms irregularities are often just ignored or overlooked.**

It is not as complicated as It seems.

Computer Modeling

Preliminary considerations:

- **Diaphragms and shear walls**

  2D Spreadsheet or 3D model?

- **Assume semi-rigid, rigid or flexible diaphragms?**
  - **NEHRP Seismic Design Technical Brief No.10, Section 6.3:**
  - **Rigid walls with flexible diaphragms**
  - **Rigid diaphragms with flexible walls**

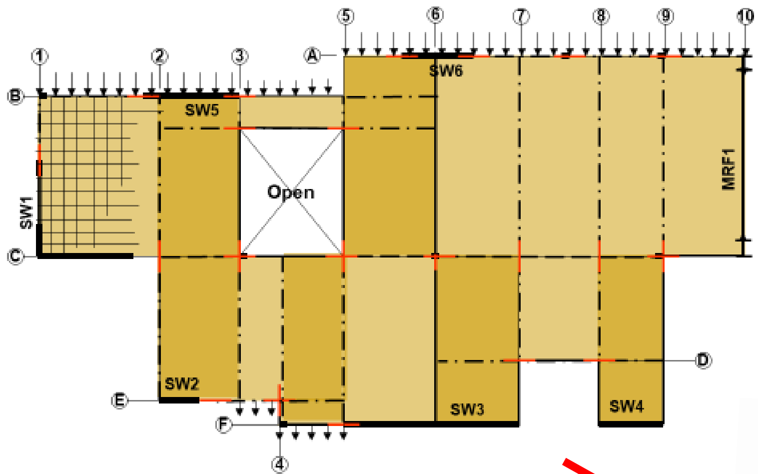
- **Recommend using Nominal SW Stiffness values**

FEA Diaphragm Modeling

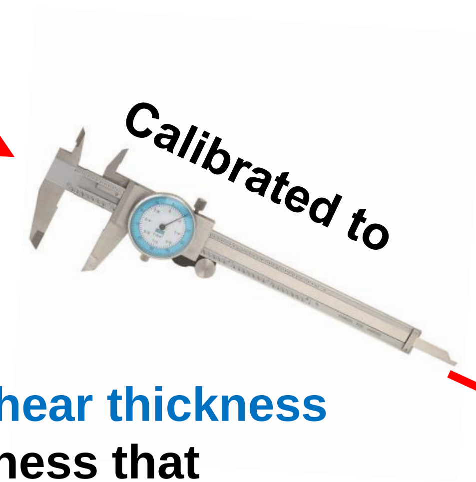
- **The model :**
  - **Some FEA software use pseudo analysis for flexible and semi-rigid analyses.**
  - **Most software does not accurately analyze diaphragm stiffness, chord offset forces, panel shear deformation, nail slip, or chord slip. (must be calibrated)**
  - **Diaphragms are typically modelled by using shell, membrane or plate elements exhibiting membrane characteristics.**
  - **Model diaphragms in 3D software, but backcheck areas of discontinuity in the diaphragms by hand or by using spreadsheets.**

Computer or No Computer?

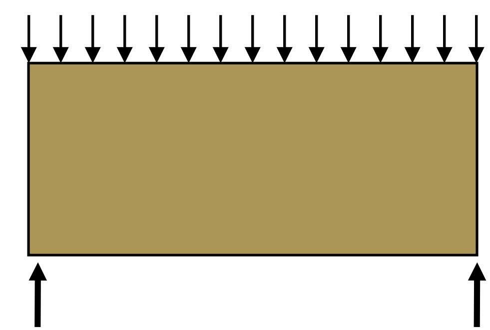
2D Spreadsheet or 3D model?



Accuracy of calibrating complex diaphragms to simple span diaphragms?



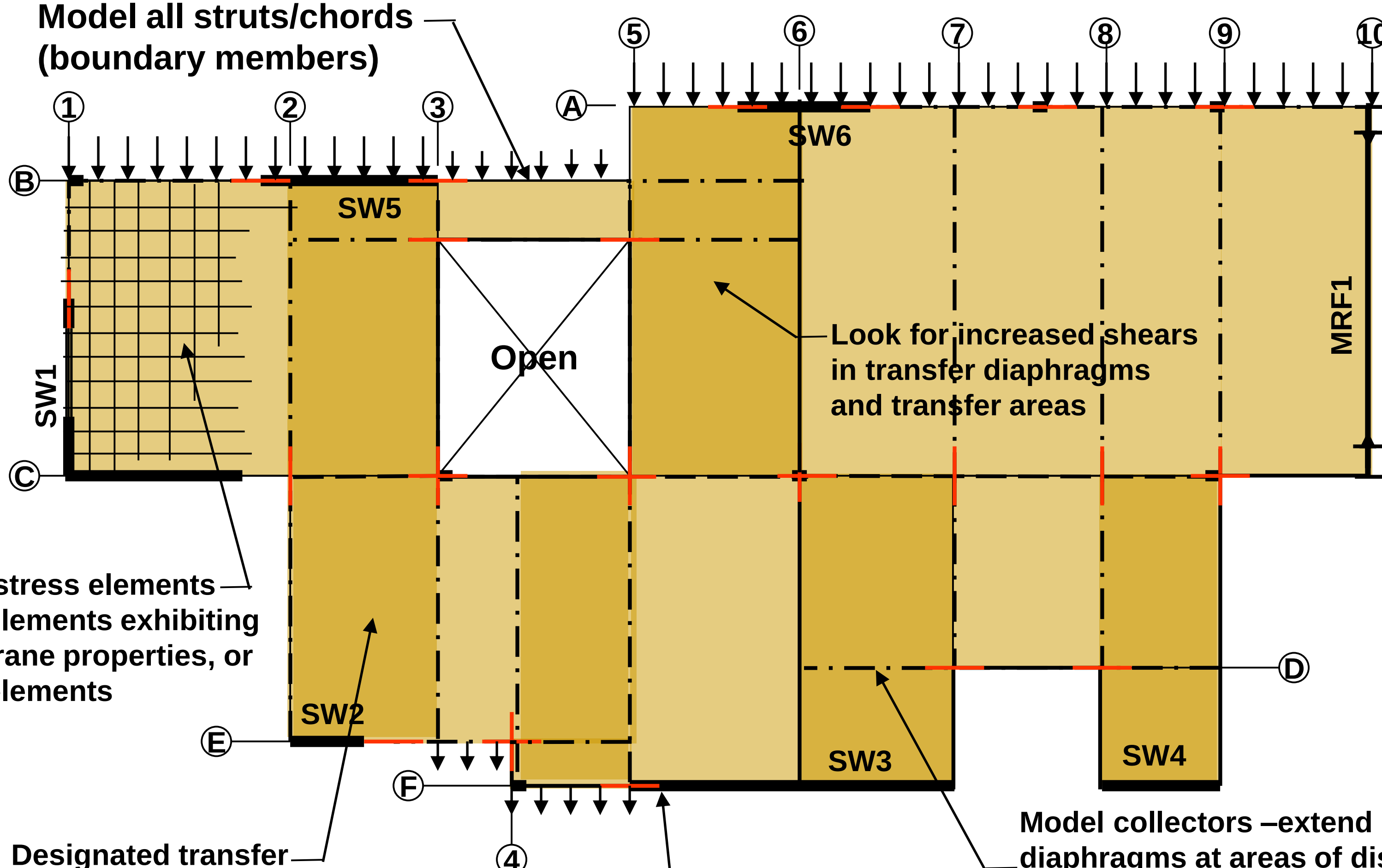
Adjust E, G, nu, or effective shear thickness to create a plate in-plane stiffness that matches the simple span diaphragm deflection equation in SDPWS (Eqn. 4.2-1)



FEA Diaphragm Modeling

Diaphragms-Model as a minimum:

Model all struts/chords (boundary members)



- Plane stress elements
- Plate elements exhibiting membrane properties, or
- Shell elements

Designated transfer diaphragm areas

Model collectors –extend into transfer diaphragms at areas of discontinuities to get collector forces

Opinion- Model as semi-rigid or rigid in FEA 3D model to capture structure response, but backcheck diaphragm using EXCEL spreadsheets or hand calculations. (strut/collector forces and force transfer at areas of discontinuity).

Wood shear walls???? Options:

1. linear spring elements at equivalent SW stiffness
2. Equivalent rectangular vertical members, Calibrated to capture flexural stiffness and nominal shear stiffness
3. Plate elements (Calibrated)?
4. By hand or spreadsheet.

Decisions, Decisions!

Choices for Complex diaphragm Analysis-2D layout

- Design as complex diaphragms as a whole:
  - Pros-Can use traditional rim joist or wall double top plate at the exterior wall line as diaphragm chords (discontinuous).
  - Cons-More difficult to design due to offsets.
- Create simple diaphragm sections within main diaphragm:
  - Pros-Easier to analyze as rectangular diaphragms.
  - Cons-Will have to create new interior chords (e.g. Floor joist, beam, etc.).
  - Cons-Have to address the effects of the appendages.

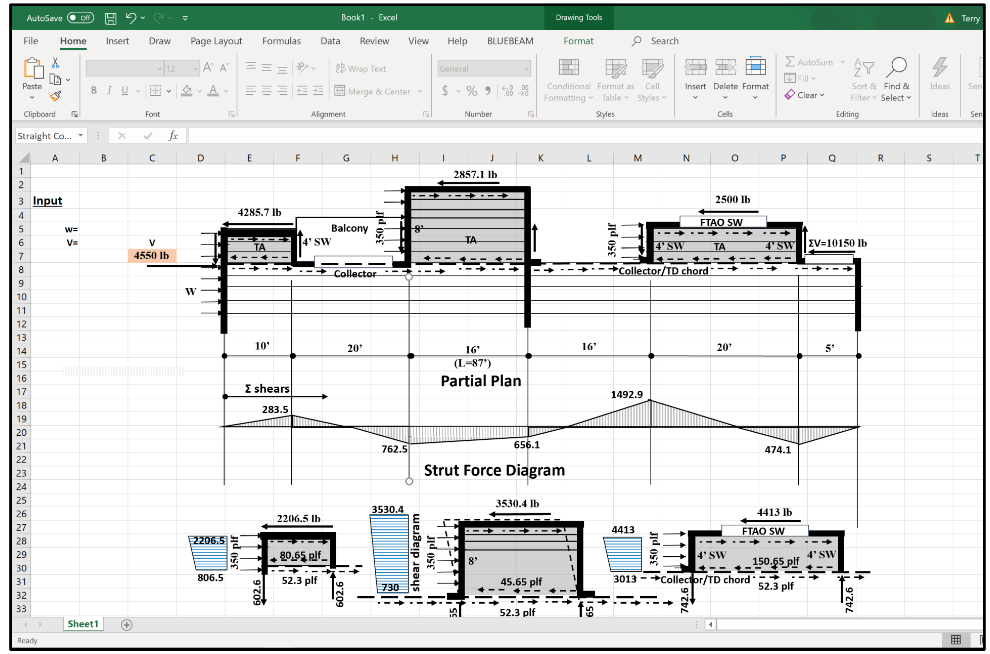
Recommendations

1. Avoid offset chords by placement of shear walls, where possible.
2. Line up shear walls where possible.
3. Avoid offset shear walls, where possible.
4. Avoid discontinuous shear walls, where possible. Line up vertically (stack)
5. Avoid long collectors, which would create large connection forces.
6. Try to minimize number and length of collectors.
7. Minimize number of flat strap and blocking collectors and their lengths.

Spreadsheets

Can be useful, but………..

- **Won’t always fit the layout.**
- **Can take additional time to adjust input data to fit the case**



Getting from

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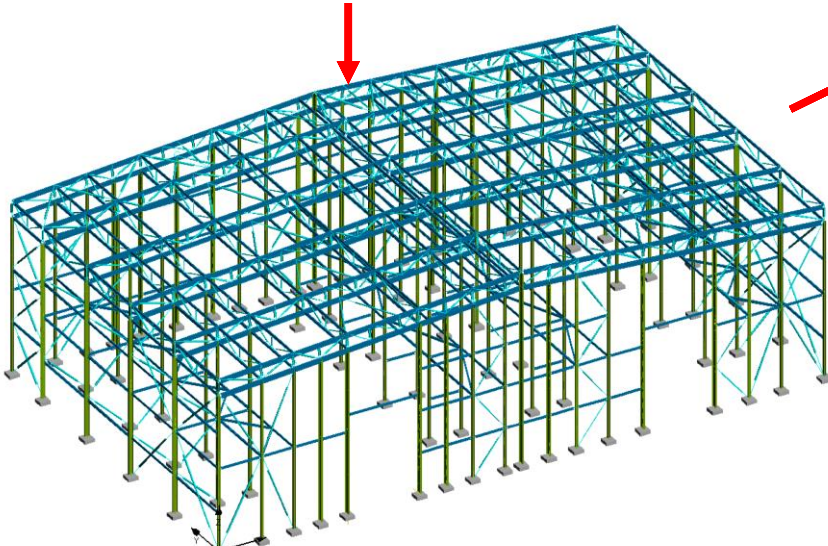

To

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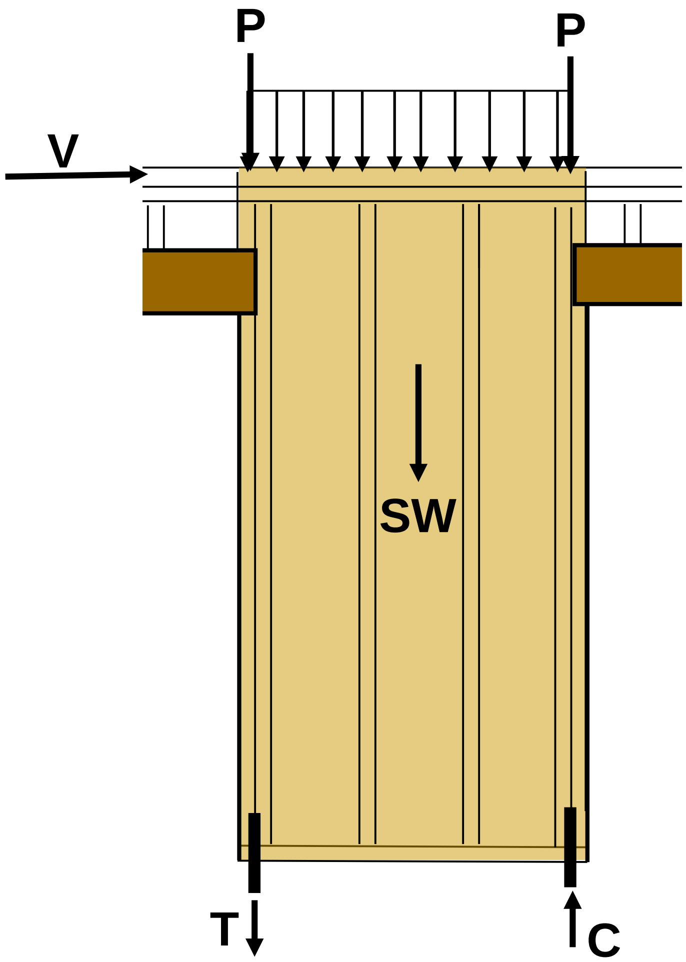
Shear Walls-Nominal Stiffness:



Determination of Nominal Wall Stiffness

Combining Rigid Diaphragm Analysis & shear wall deflection calculations is problematic due to non-linearities, which can effect the distribution of loads to the shear walls and will effect the shear wall deflections. This can lead to a different set of stiffness values that may not be consistent.

Whenever changing:

- **Load combinations**
- **Vertical or lateral loads,**
- **Direction of loading**
- **Redundancy, or**
- **Accidental torsion**

Requires an Iterative search for the point of convergence, which is not practical for multi-story structures.

Sources of non-linearities:

- **Hold-down slip at uplift (e.g. shrinkage gap)**
- **Hold-down system tension and elongation**
- **Compression crushing. Non-linear in NDS**
- **Shrinkage**
- **4-term deflection equation**

Since deflection is "non-linear"…. the stiffness can vary with the loading, even when using 3-term deflection equation.

Objective:

Use a single rational vertical and lateral load combination to calculate deflections and Nominal shear wall stiffness.

Gravity Loads: **1.0D but vertical seismic loading not included. ($EV=0.2S_{DS}D$)**

Results in single vertical loading condition to use when calculating shear wall deflections and nominal shear wall stiffnesses.

Proposing:

1. **Stiffness calculated using 3-term eq. and LC 1.0D+Qe, Vertical seismic loading not included. ($E_V=0.2S_{DS}D$) with ρ=1.0 and Ax=1.0.**

2. **Use stiffness calculated at 100% Maximum Seismic Design Capacity of the Wall for all Load Combinations and Drift Checks from RDA using 3 term equation.**

3. **Use nominal stiffness for all other analysis checks, calculating wall deflection,**

$$\delta_{SW} = \frac{F}{K},\ K = \frac{F}{\delta_{SW}}$$

4. **Maximum wall capacity =Max. allow. Shear (nailing) or HD capacity whichever is less.**

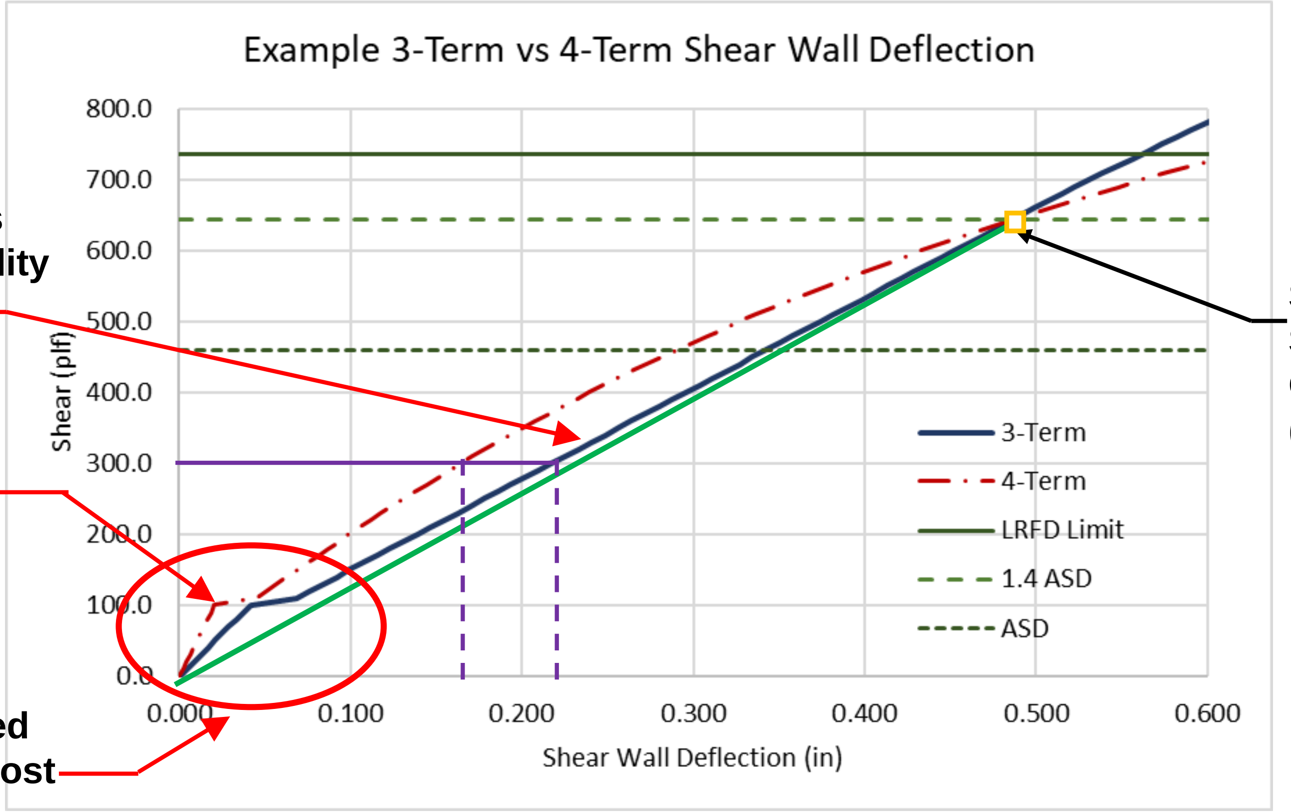
Tips-Shear Wall Deflection & Stiffness Considerations

- **3-term equation is a linear simplification of the 4-term equation, calibrated to match the applied load at 1.4 ASD.**
- **This simplification removes the non-linear behavior of e_n.**
- **Similar approach can be used to remove non-linear effects of Δ_a by calculating the wall stiffness at strength level capacity of the wall, not the applied load.**

Lower stiffness from HD flexibility after uplift

Net uplift

Lightly Loaded Walls have most non-linearity



Secant Stiffness @ Capacity (1.4 ASD)

Method allows having only one set of nominal stiffness values.

Nominal Shear Wall Stiffness's (STR) ρ=1.0, Ax=1.0

Load Combination: 1.0D + Q_E

Grid Line	Ga	V on wall	v	T	C	Δ_a	$F_{c\perp}$	Crush.	Shrink	δ_B	δ_S	δ_{Rot}	δ_{SW}
Calculate Stiffness of Walls on A & B using LRFD Capacity													
A	37	7308.0	913.5	6391	13770	0.154	556.36	0.056	0.019	0.022	0.247	0.313	0.581
B	37	7308.0	913.5	6391	13770	0.154	556.36	0.056	0.019	0.022	0.247	0.313	0.581
Calculate Stiffness of Walls on 2 & 3 using LRFD Coading													
2	30	7022.0	702.2	6391	8341	0.154	505.50	0.045	0.019	0.020	0.234	0.230	0.484
3	30	7022.0	702.2	6391	8341	0.154	505.50	0.045	0.019	0.020	0.234	0.230	0.484

Wall Capacity based on hold down

	K (k/in)
A	25.14
B	25.14
Aver.=	25.14
2	43.54
3	43.54
Aver.=	43.54

Max. capacity check (STR):

Shear controlled:

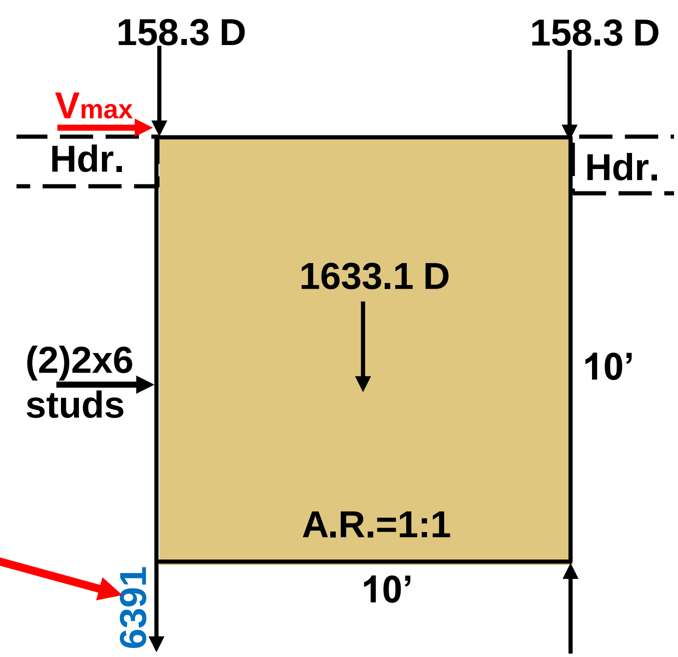
$Shear_{A,B}$= 0.8(1200)(8)=7680 lbs.
$Shear_{2,3}$= 0.8(920)(10)=7360 lbs.

Hold down controlled:

$H.D._{A,B,2,3}$=6391 lbs.(STR), Δa=0.154"

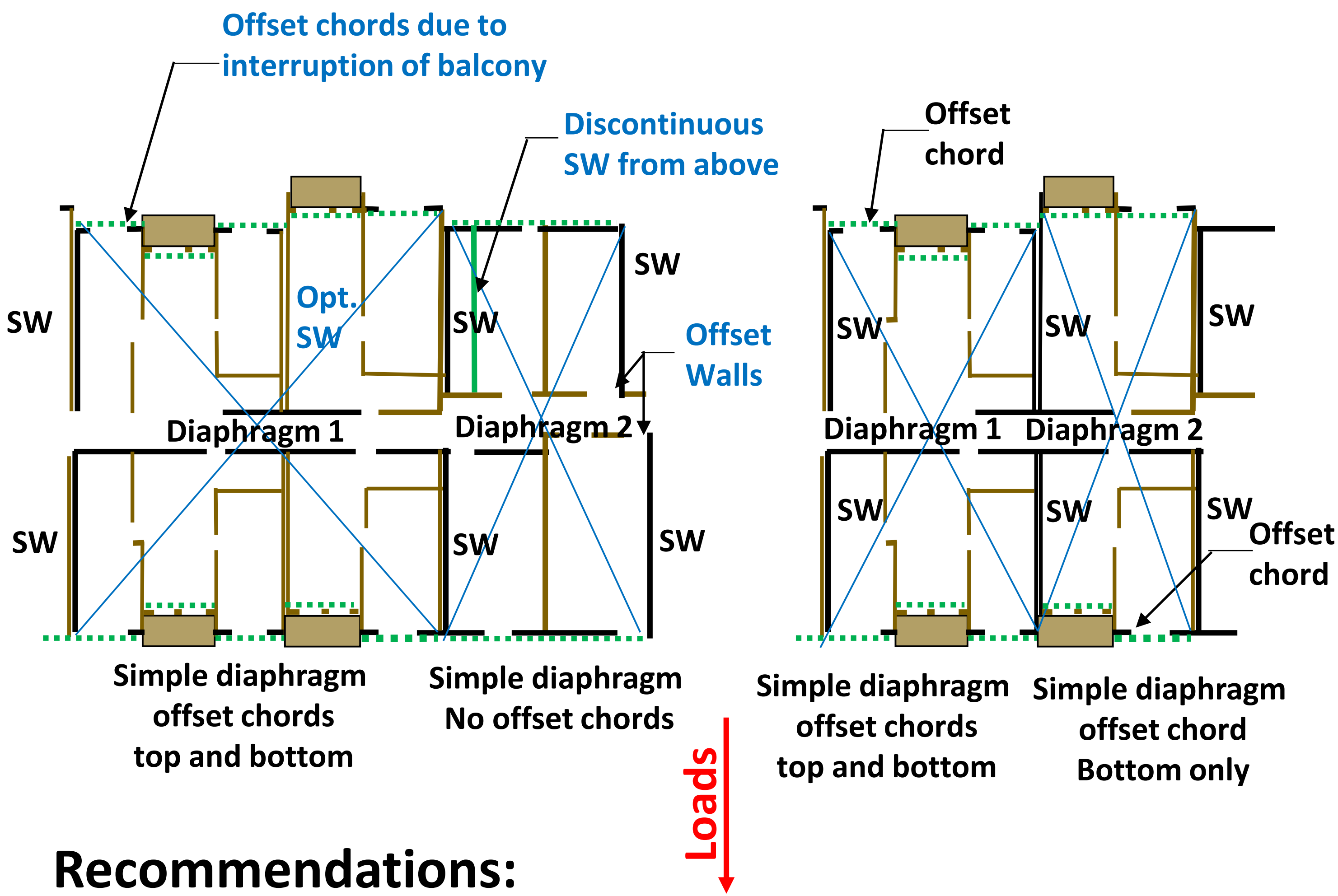
$V_{max.\ A,B}$= 7308 lbs. controls
$V_{max.\ 2,3}$= 7022 lbs. controls

Set tension force=H.D. cap. and solve for allowable V at top of wall.



Shear wall Grid 2 and 3
Trib. = 2'

Layout-Where Do I Start?

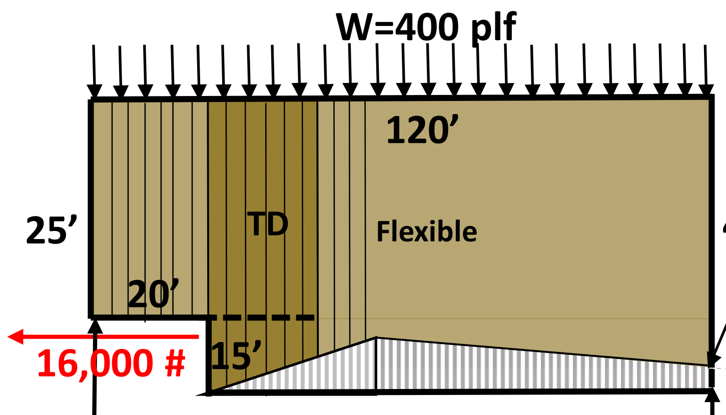


Recommendations:

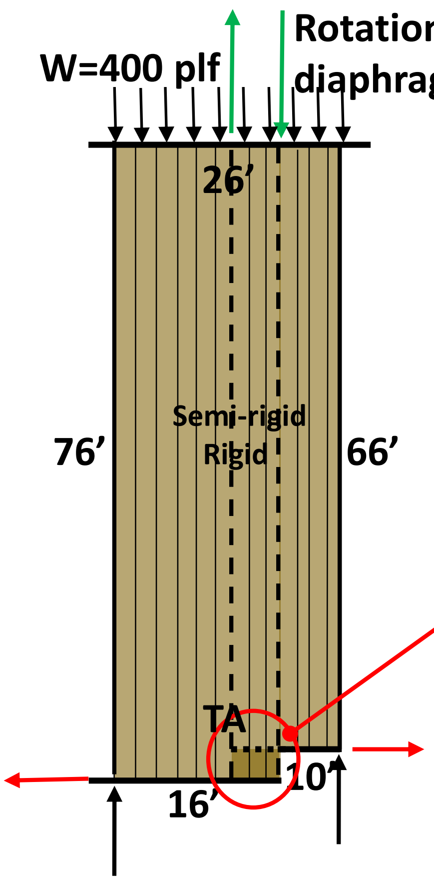
1. Avoid offset chords by placement of shear walls, where possible.
2. Avoid offset shear walls where possible.
3. Avoid discontinuous shear walls.
4. Transpose floor/floor SW's to see how they Stack.

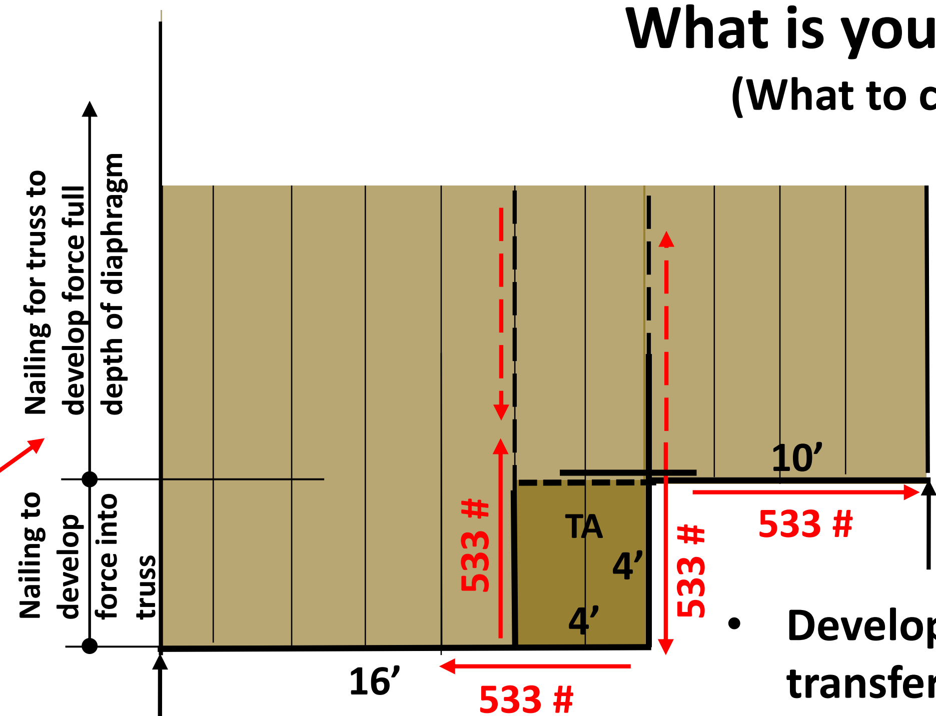
Let's Talk About Numbers

Engineering judgement required



- Small force, calculation not required?



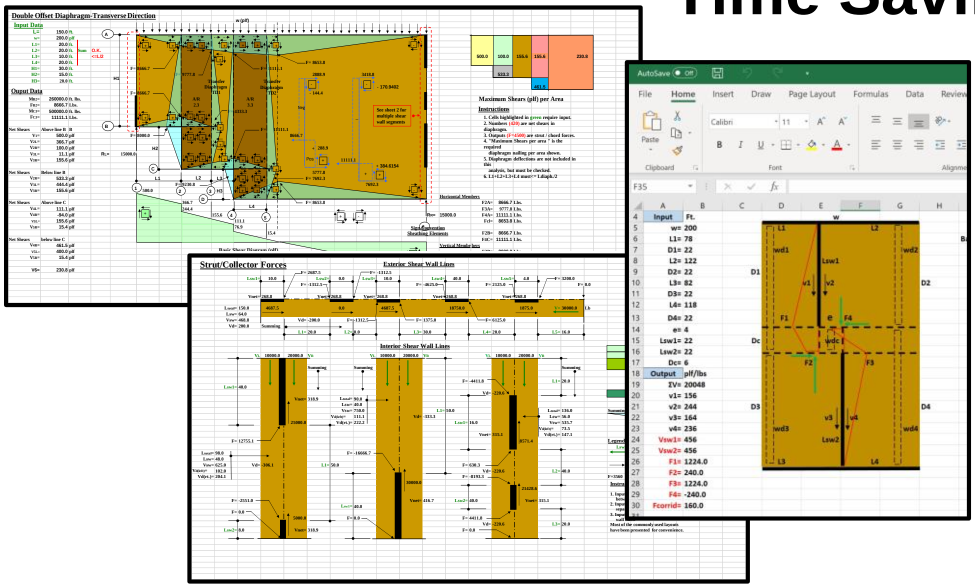


What is your comfort level?

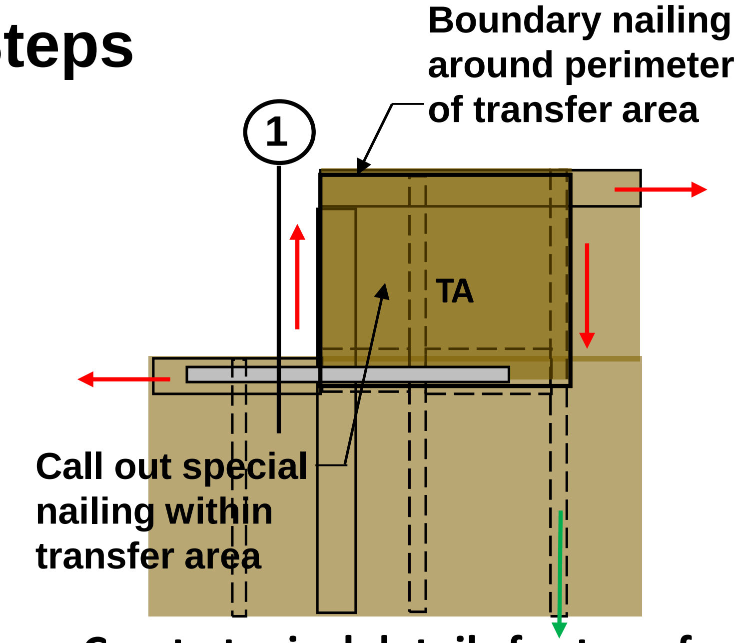
(What to check, what not)

- Magnitude of force is dependent on span and depth of the diaphragm.
- Develop detail to assure transfer of forces.

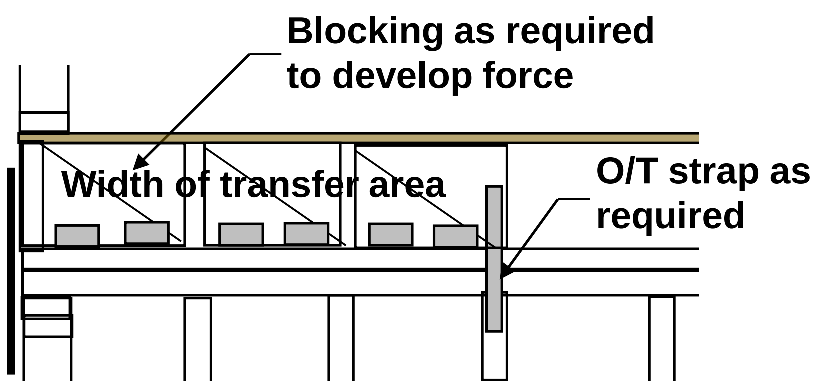
Time Saving Steps



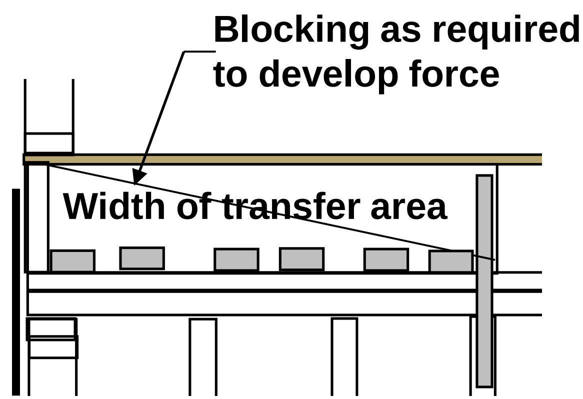
Create EXCEl spreadsheets for analysis of problem areas.



Create typical details for transfer areas when forces are too small to consider or calc.



1 Floor framing perpendicular to wall



1 Floor framing parallel to wall

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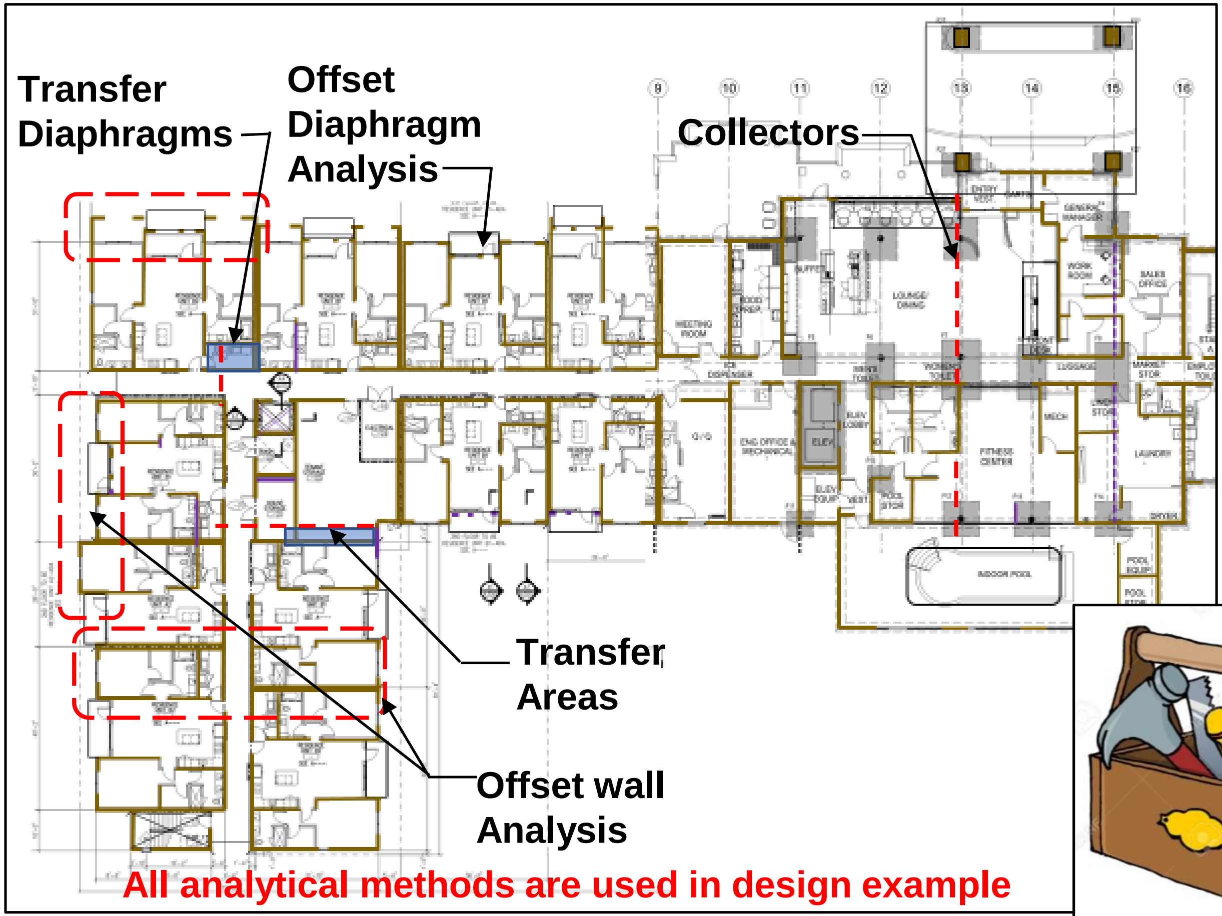
Q & A

Analysis tools you can use to solve problem areas



A minimum number of analytical tools can help you develop continuous lateral load paths

- Collectors
- Transfer Areas and Transfer Diaphragms
- Offset Shear Walls
- Offset Diaphragms

Collectors


Possible struts:
• Truss or rim joist over wall
• Double top plate
• Beam/header

Diaphragm Boundary Elements

<u>Fundamental Principles:</u>
A shear wall is a location where diaphragm forces are resisted (supported), and therefore defines a diaphragm boundary location.

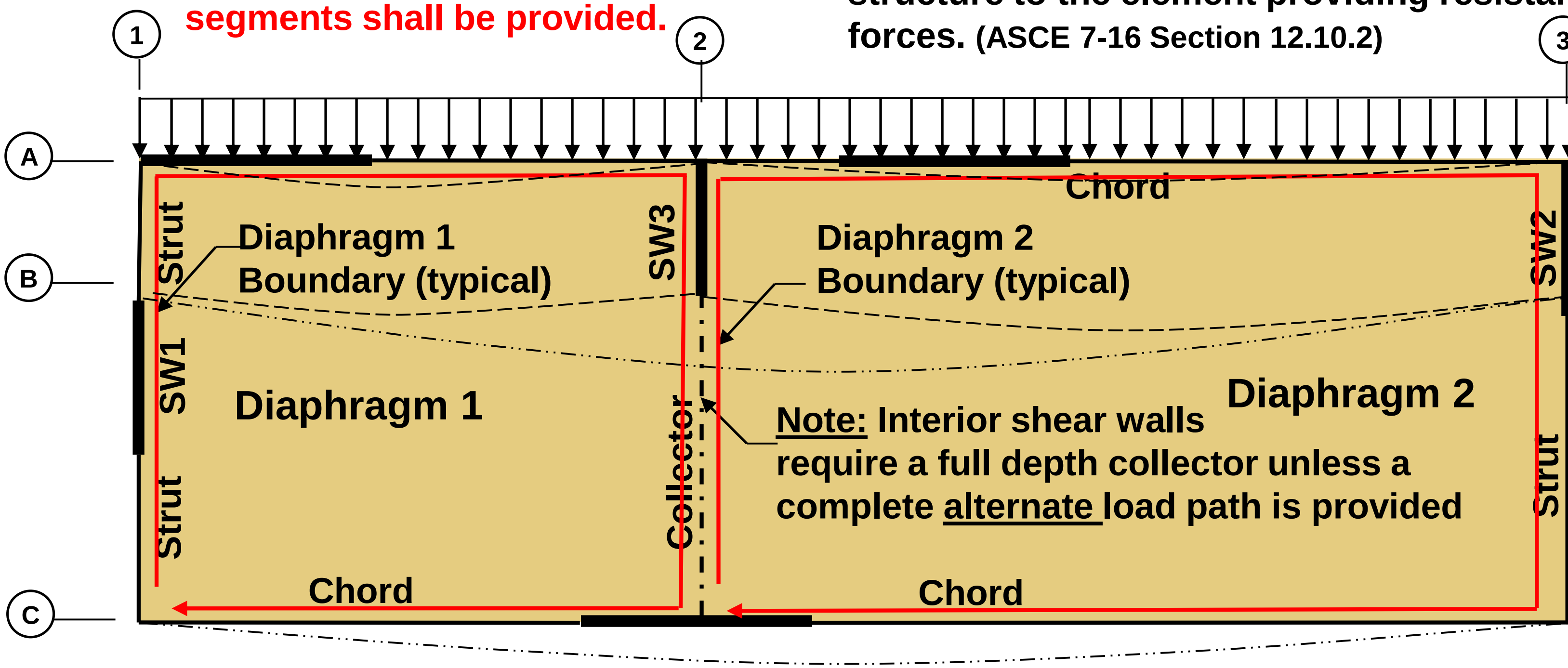
<u>Note:</u> All edges of a diaphragm shall be supported by a boundary element. **(ASCE 7-16 Section 11.2)**

SDPWS 4.3.5.1

3. **Collectors for shear transfer to individual full-height wall segments shall be provided.**

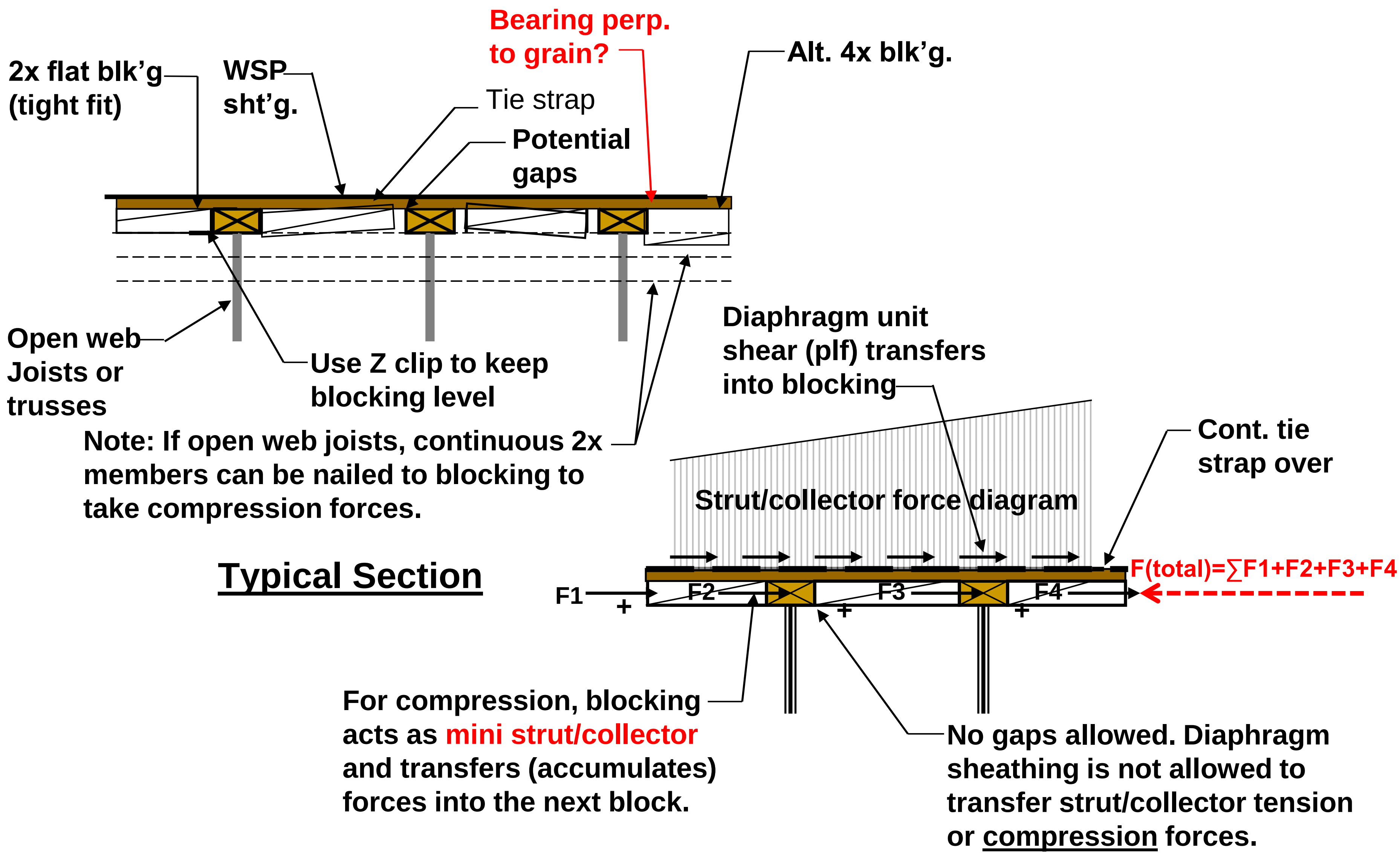
- **<u>Diaphragm Boundary Elements:</u>**
  - **Chords, drag struts, collectors, Shear walls, frames**
  - **Boundary member locations:**
    - **Diaphragm and shear wall perimeters**
    - **Interior openings**
    - **Areas of discontinuity**
    - **Re-entrant corners.**
- **Diaphragm and shear wall sheathing shall not be used to act as or splice boundary elements.** **(SDPWS 4.1.4)**
- **Collector elements shall be provided that are capable of transferring forces originating in other portions of the structure to the element providing resistance to those forces.** **(ASCE 7-16 Section 12.10.2)**

Required for Seismic and <u>wind</u>



Collector Options-Flat strap and blocking

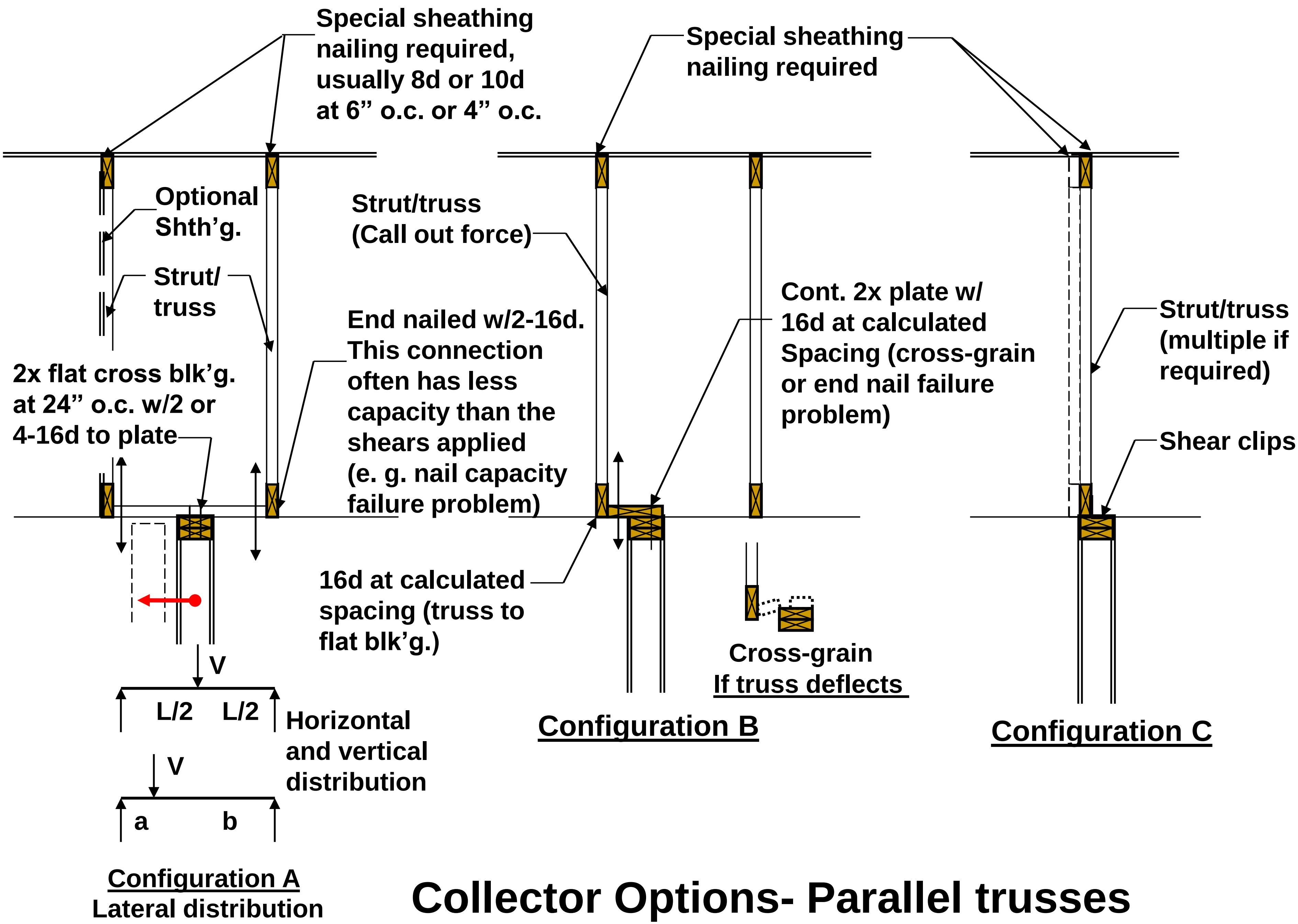
Must be capable of resisting tension and compression forces



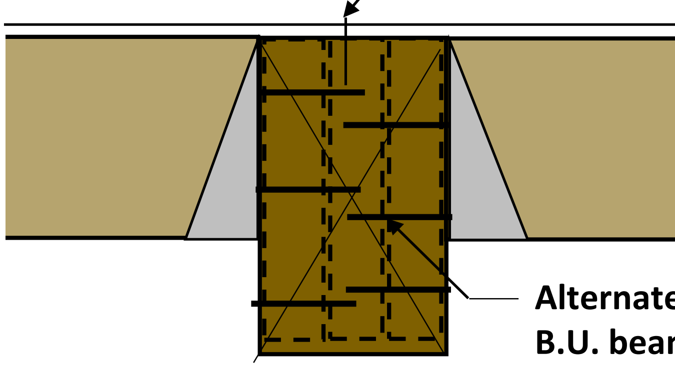
Typical Section

Collector force distribution

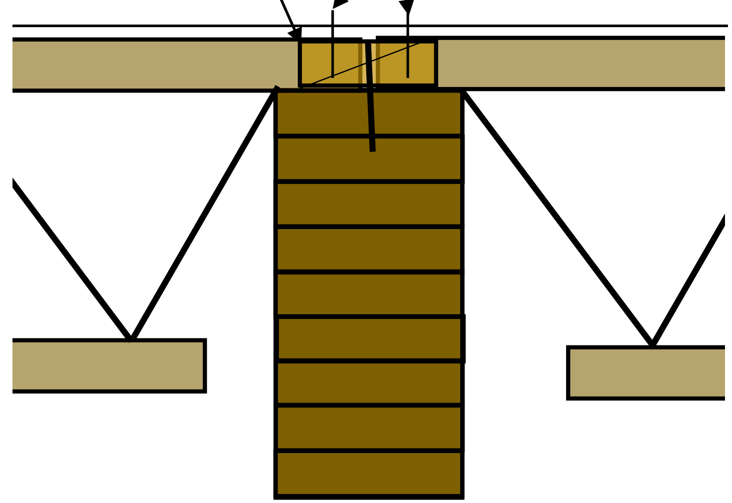
Collector Options- Parallel trusses



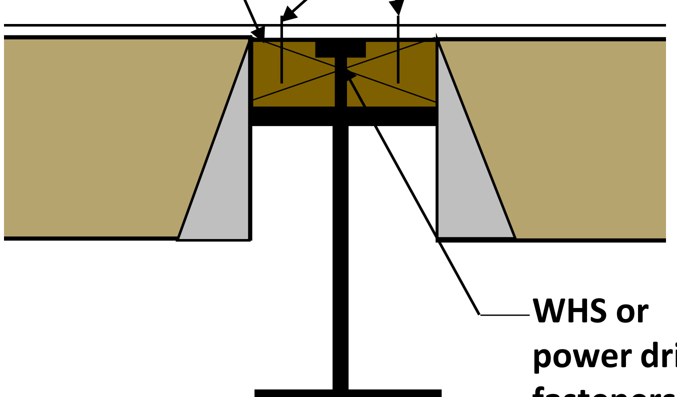
Collector Options



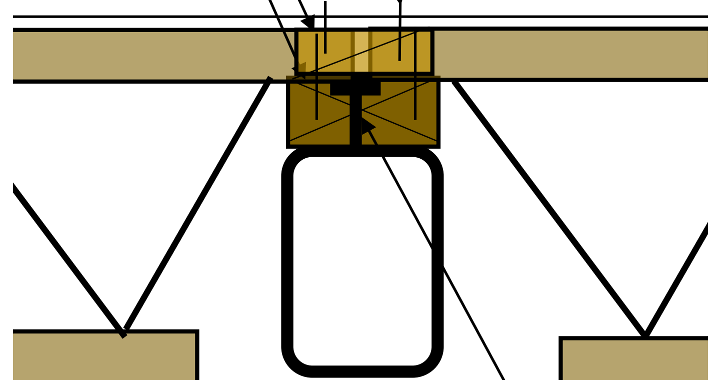
Solid Sawn Collector



Glue-lam Collector

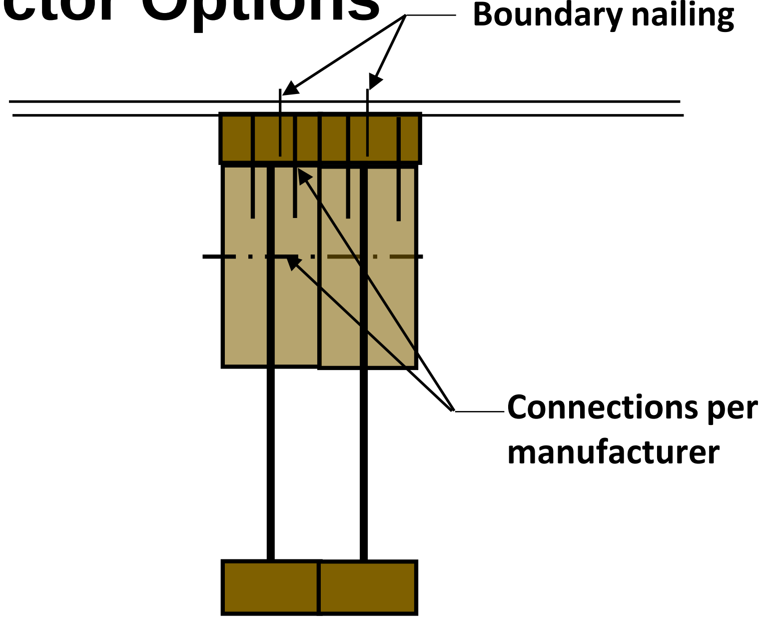


Steel Beam Collector

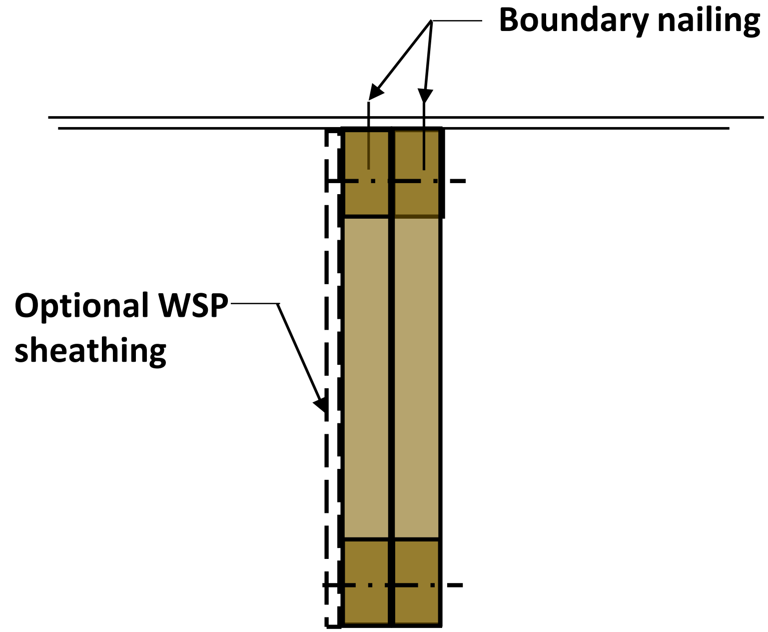


Steel Tube Collector

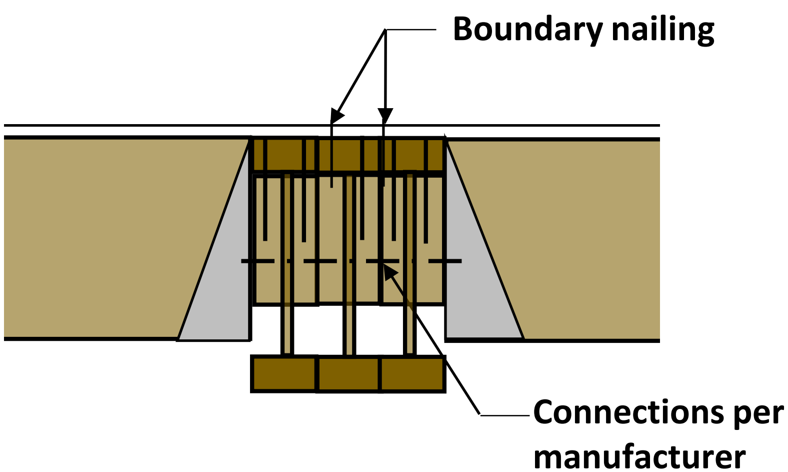
Collector Options



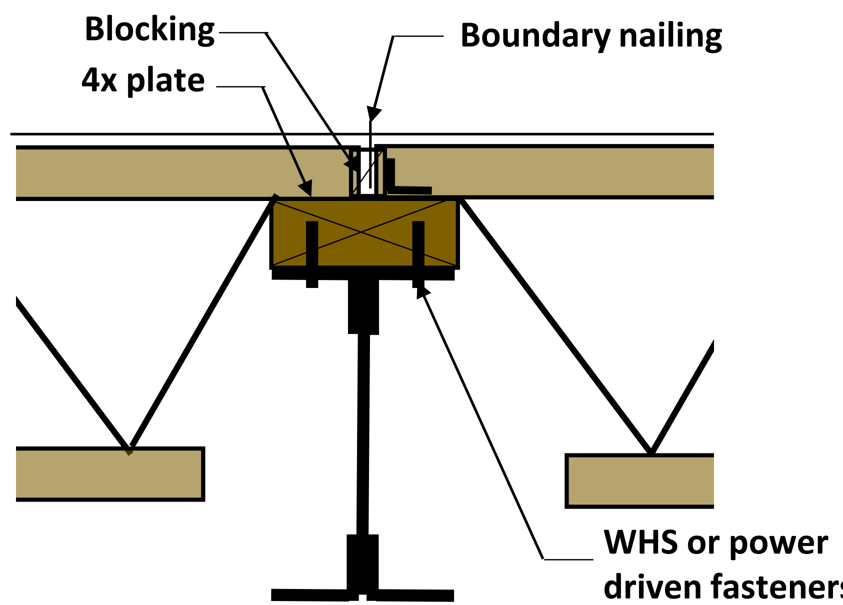
Wood flanges-open web Collector



Gang-nail Plated Truss Collector

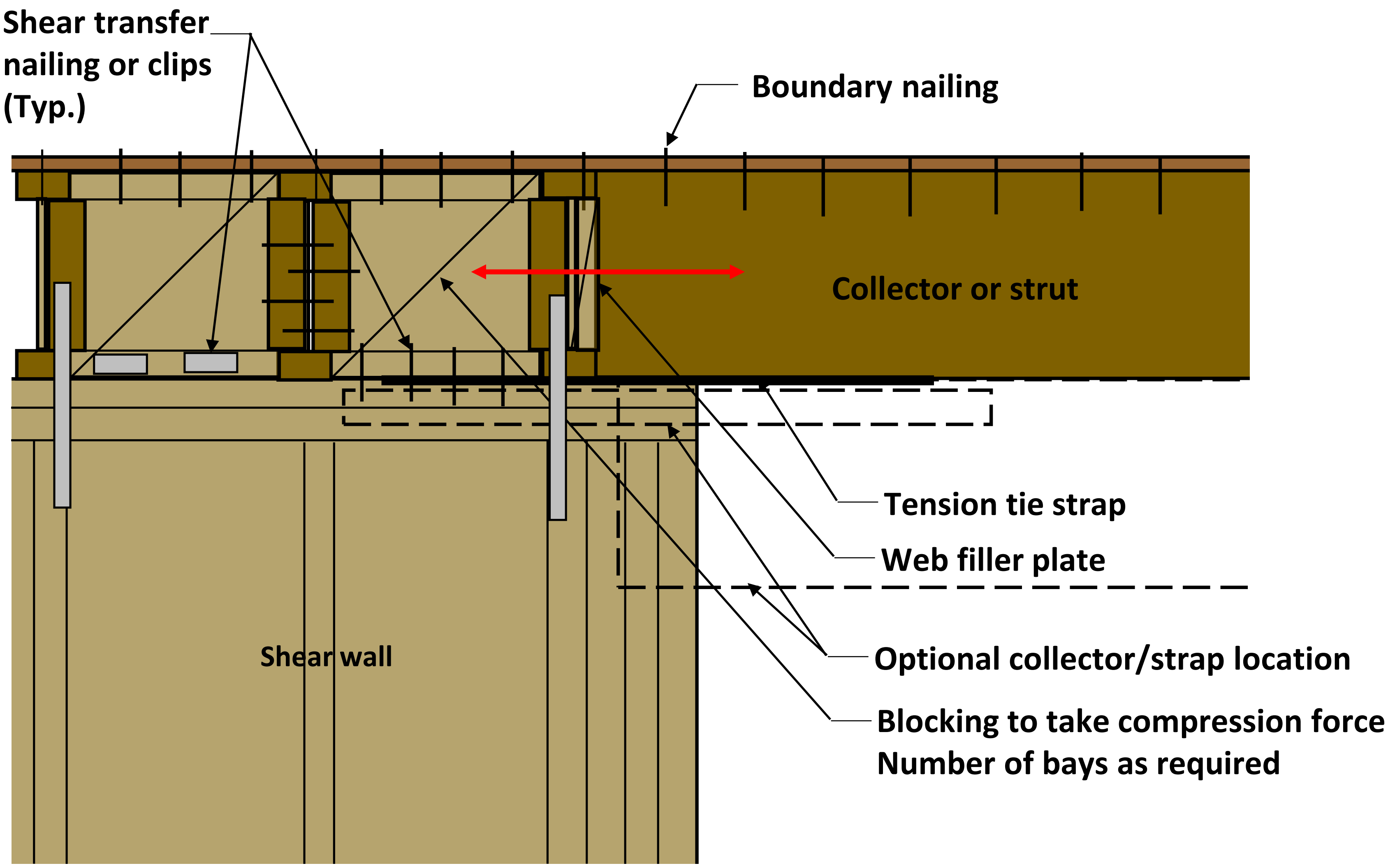


I-joist Collector



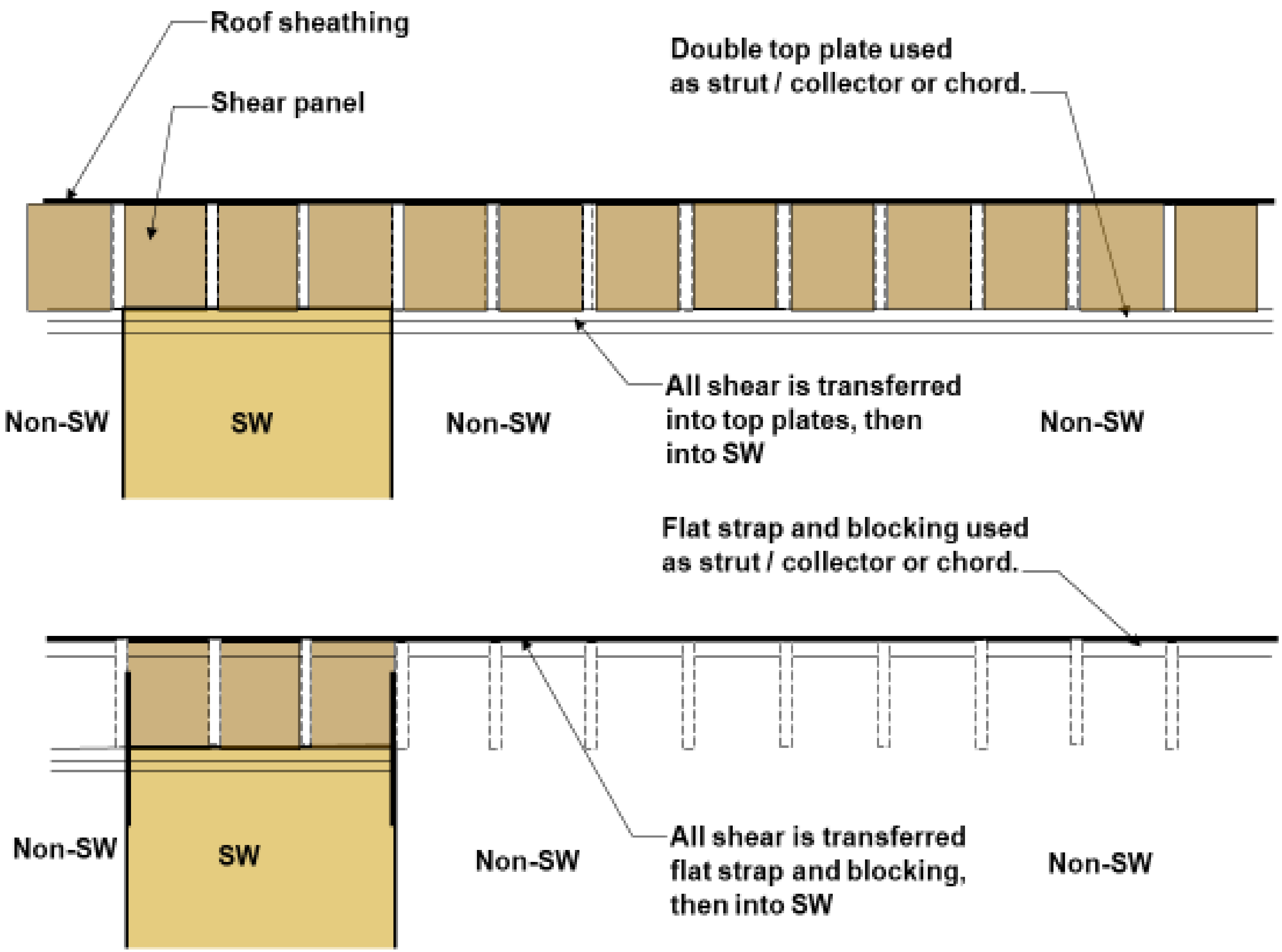
Open web Steel Truss Collector

Collector to Shear Wall Load paths



Solid Sawn Collector Over Shear Wall

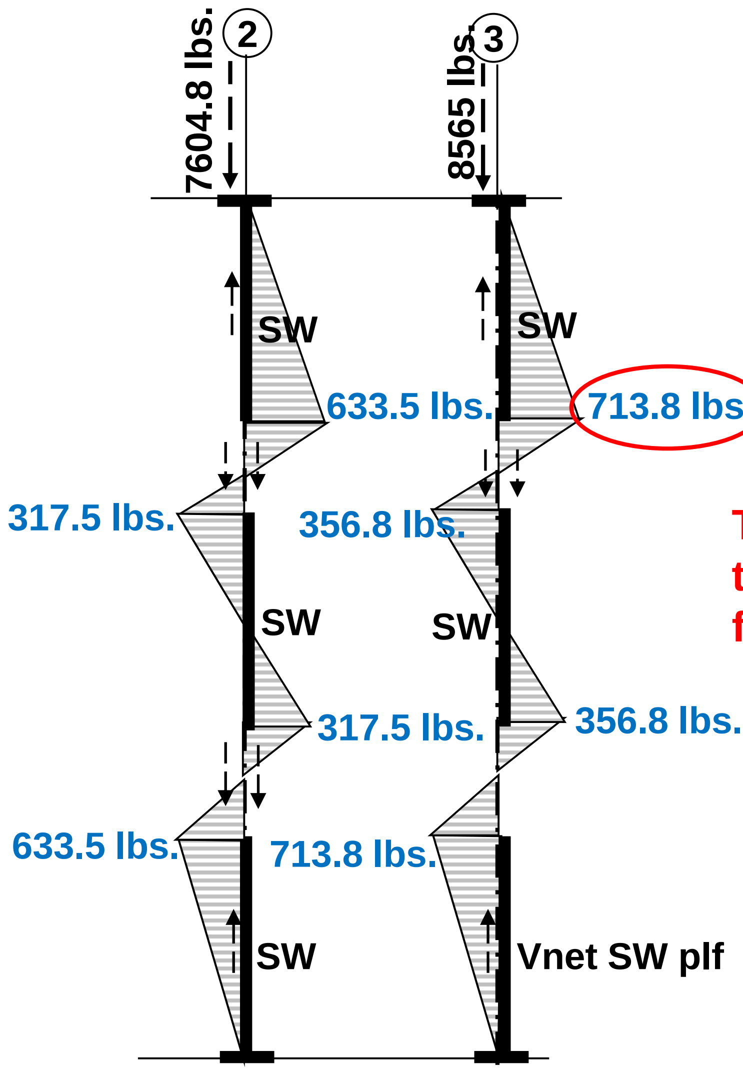
Collector to Shear Wall Load paths



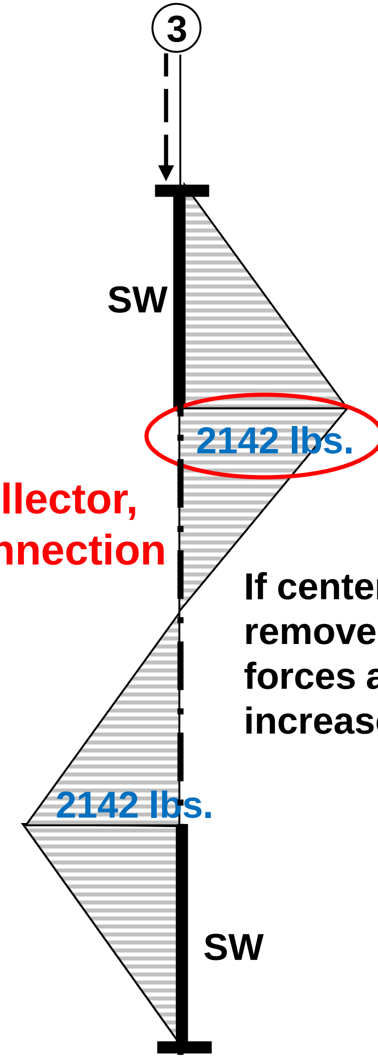
Examples of Drag Struts, Collectors and chords at Exterior Boundaries

Collectors at Corridors

Use one wall or both wall lines?

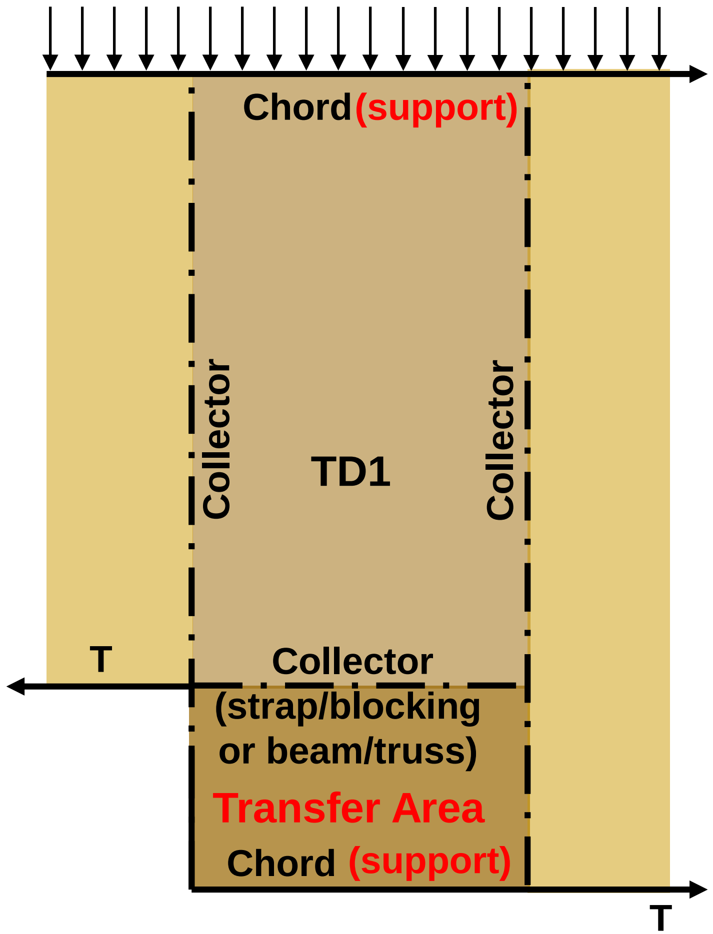


The longer the collector, the higher the connection force

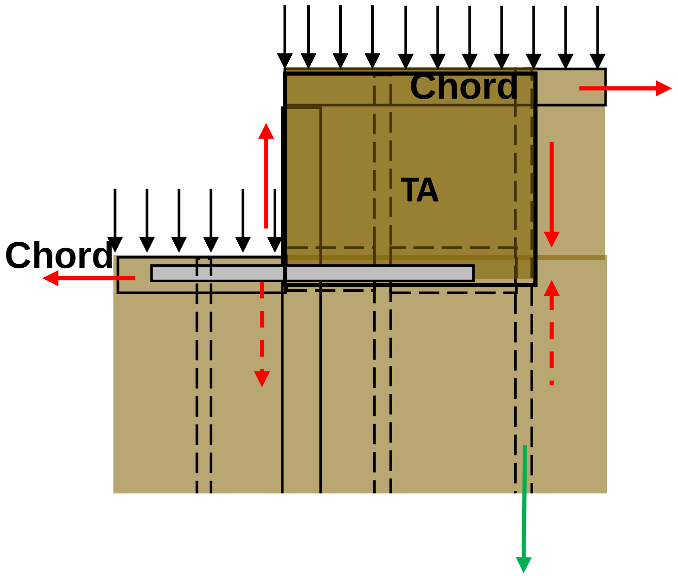


If center SW removed, strut forces are increased

Introduction to Transfer Diaphragms and Transfer Areas



Transfer Diaphragms



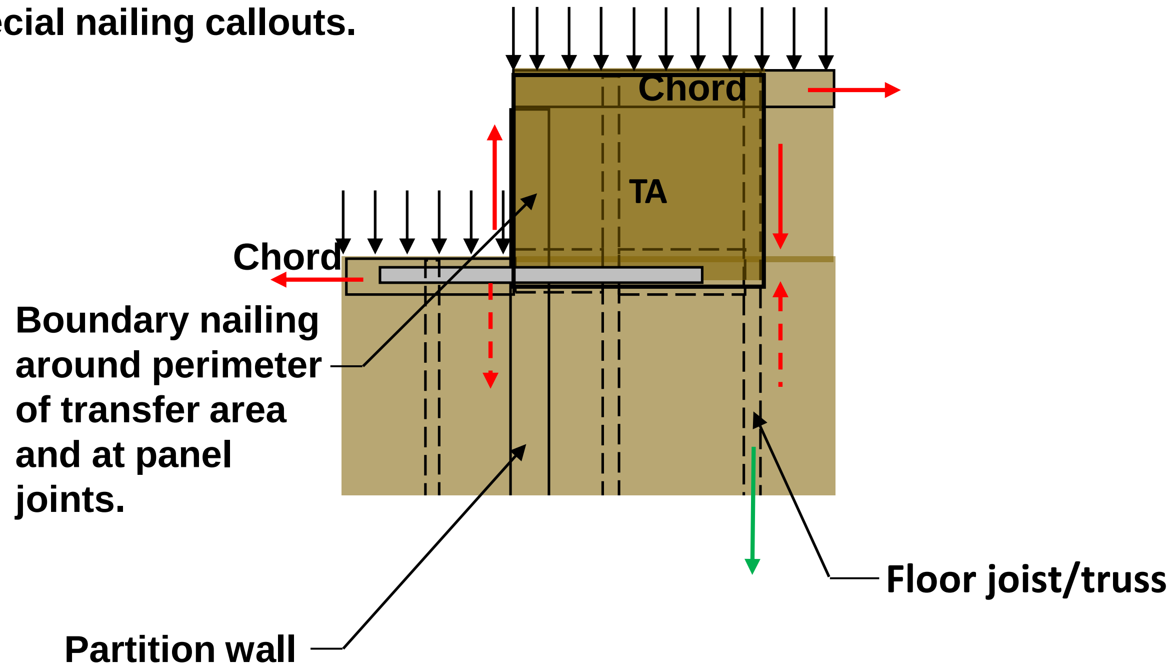
Transfer Areas

Transfer Areas

12.10.1-At diaphragm discontinuities such as openings and re-entrant corners, the design shall assure that the dissipation or transfer of edge (chord) forces combined with other forces in the diaphragm is within shear and tension capacity of the diaphragm.

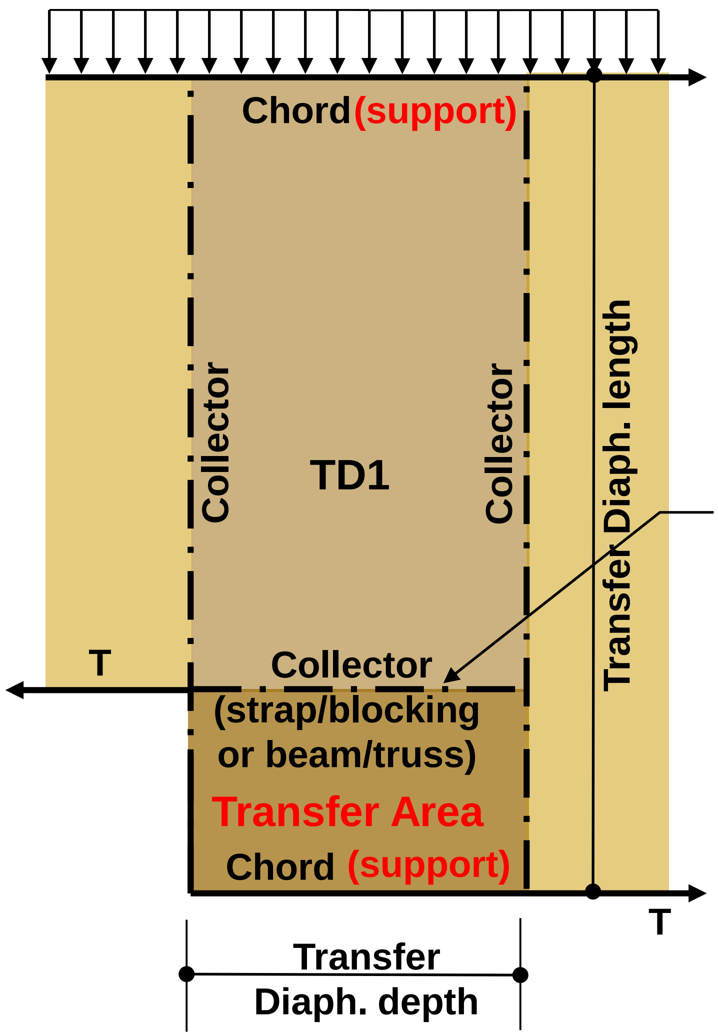
Most of the time, all of the necessary framing is already there as part of the framing plan. Additional framing is generally not required, only special nailing callouts.

Note: Resisting couple forces can be dumped into non-SW's provided they do not exceed sheathing capacity of the wall or require hold downs.



Transfer Areas

Transfer Diaphragms



Transfer Diaphragm

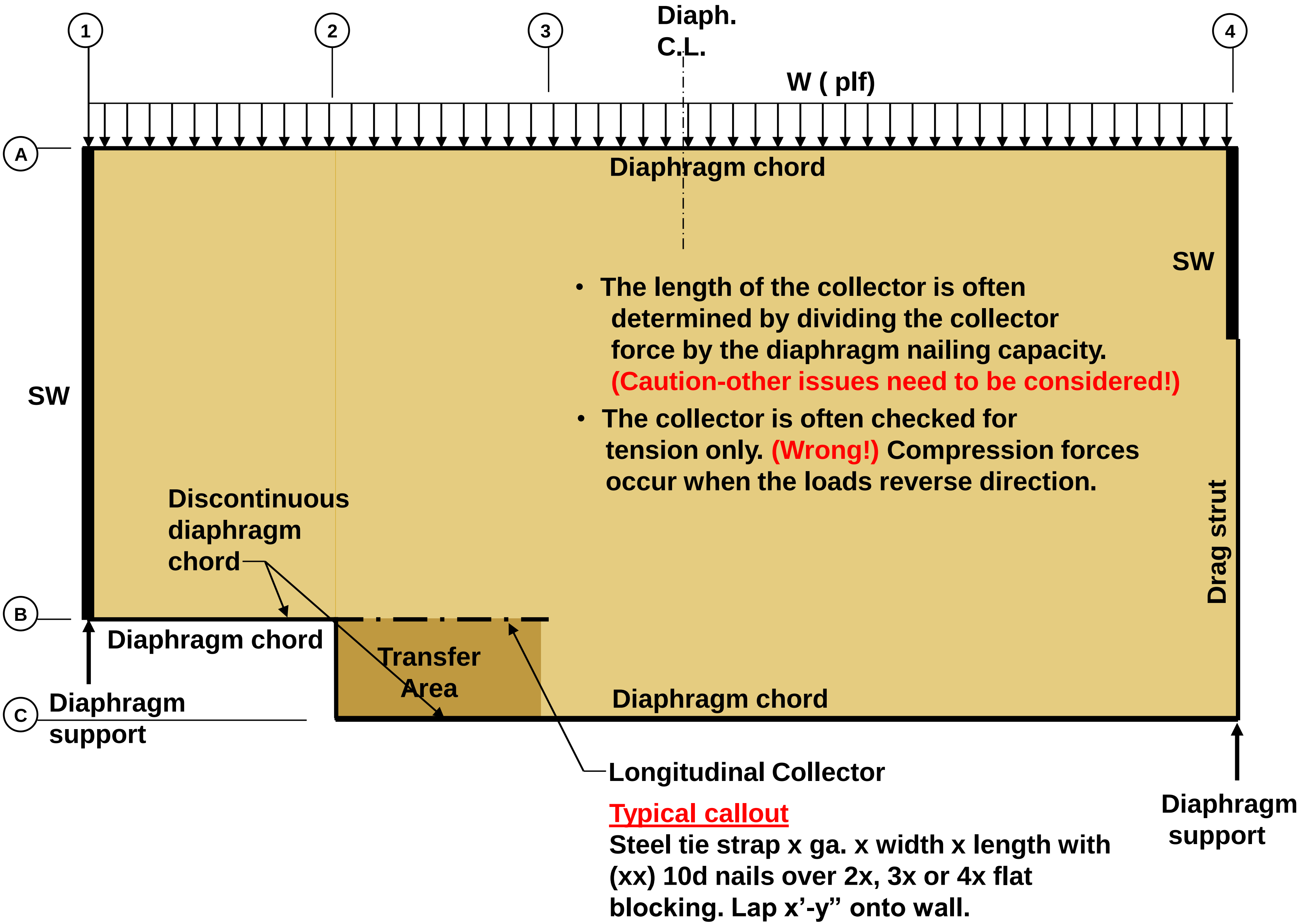
- Sub-diaphragm-don't confuse w/ sub-diaphragms supporting conc./masonry walls
- Transfers local forces out to primary chords/struts of the main diaphragm. (Based on method, ASCE 7 Section 1.4 and SDPWS 4.1.1)
- Maximum TD Aspect Ratio=2.5:1 min., 4:1 max. (Must be similar in stiffness to main diaph.)

Framing members, blocking, and connections shall extend into the diaphragm a sufficient distance to develop the force transferred into the diaphragm.
(SDPWS 4.2.1)

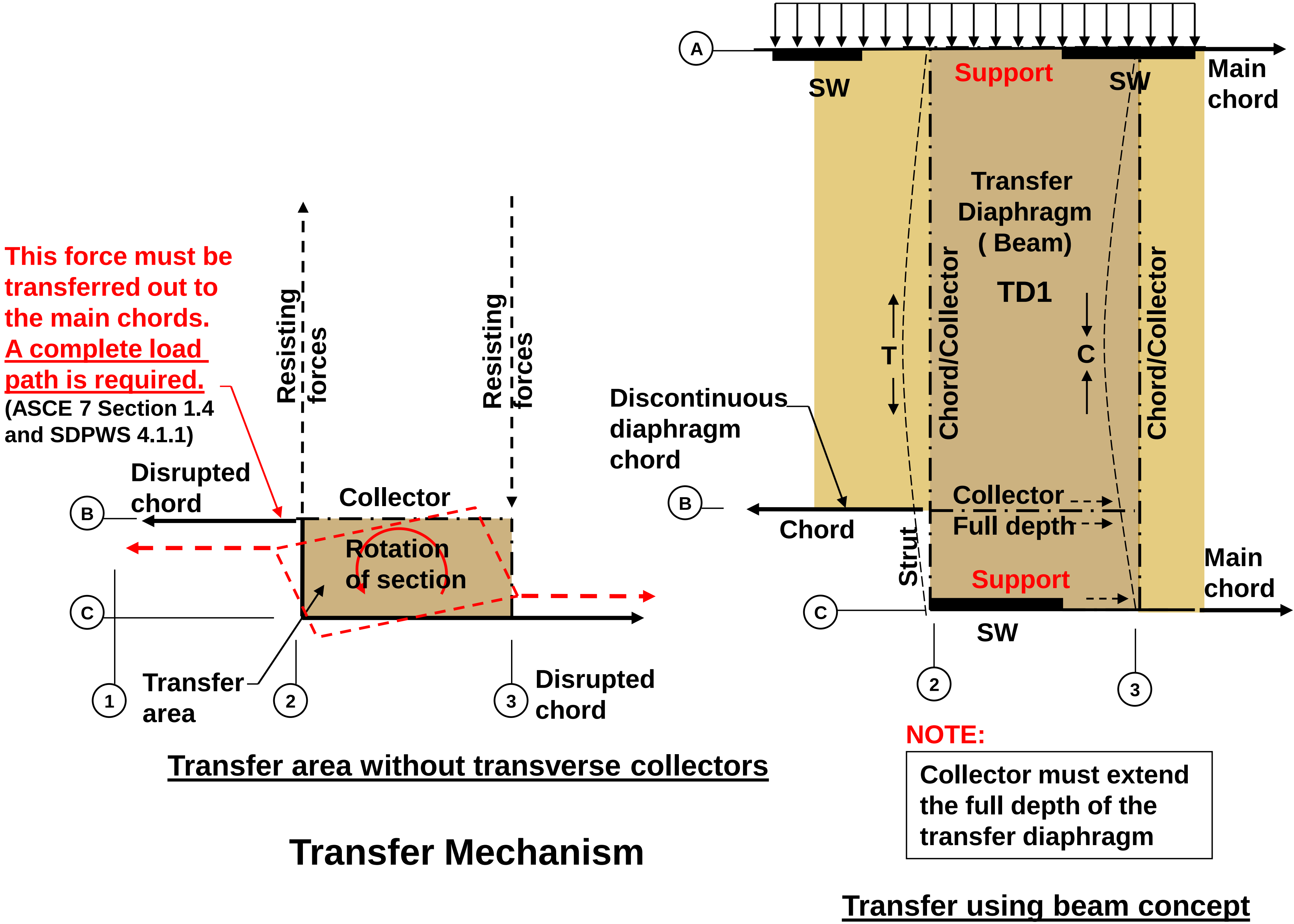
What does this mean?

Collector Length?-My rule of thumb:

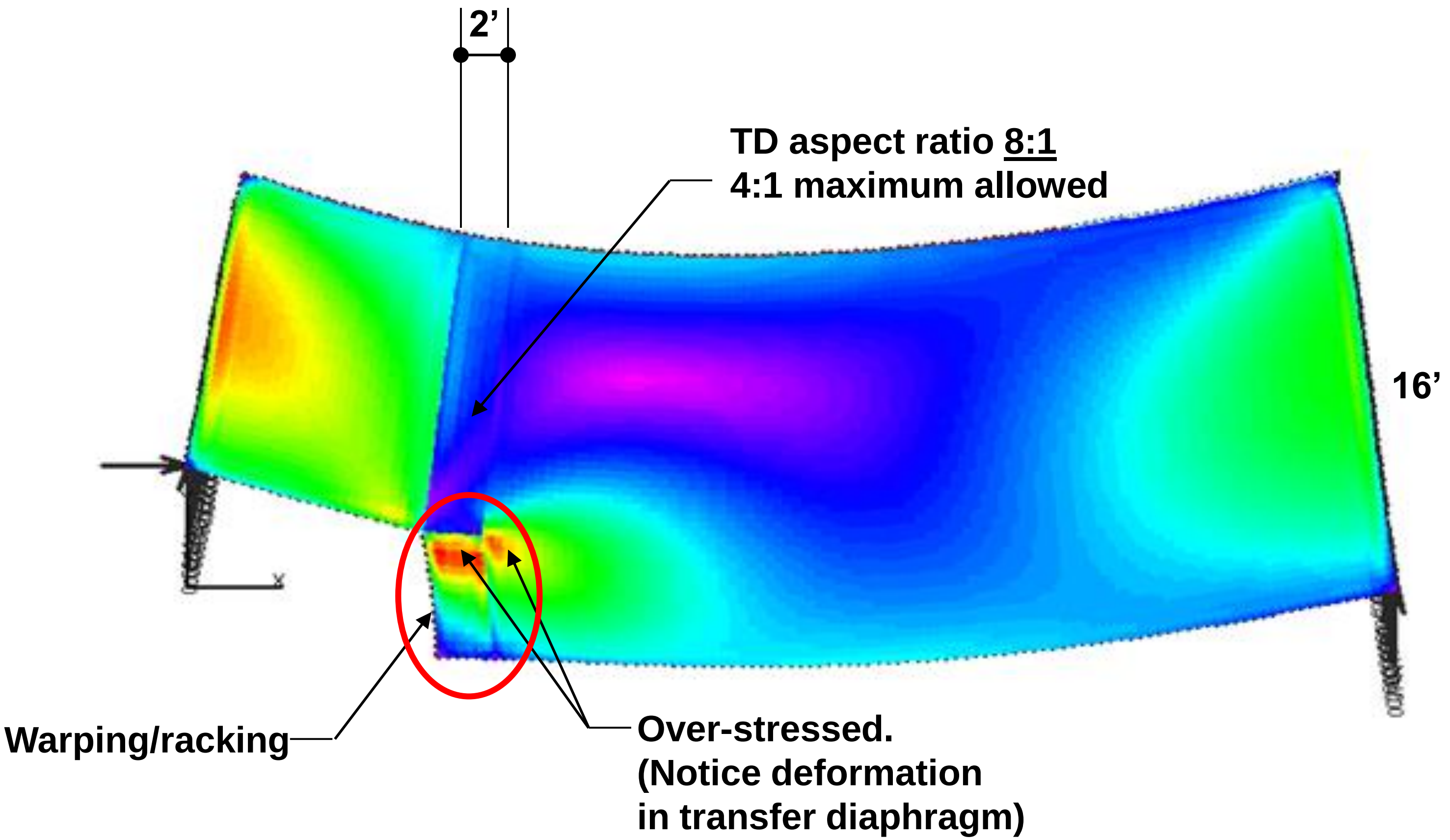
- Check length by dividing discontinuous force by the nailing capacity (other issues need to be considered)
- Length=full depth of transfer the diaphragm, set by A/R
- If L<=30' o.k. to use strap/blocking, If > 30' use beam/truss
- Increase TD depth if shears are too high in transfer area



Transfer Diaphragm Members and Elements

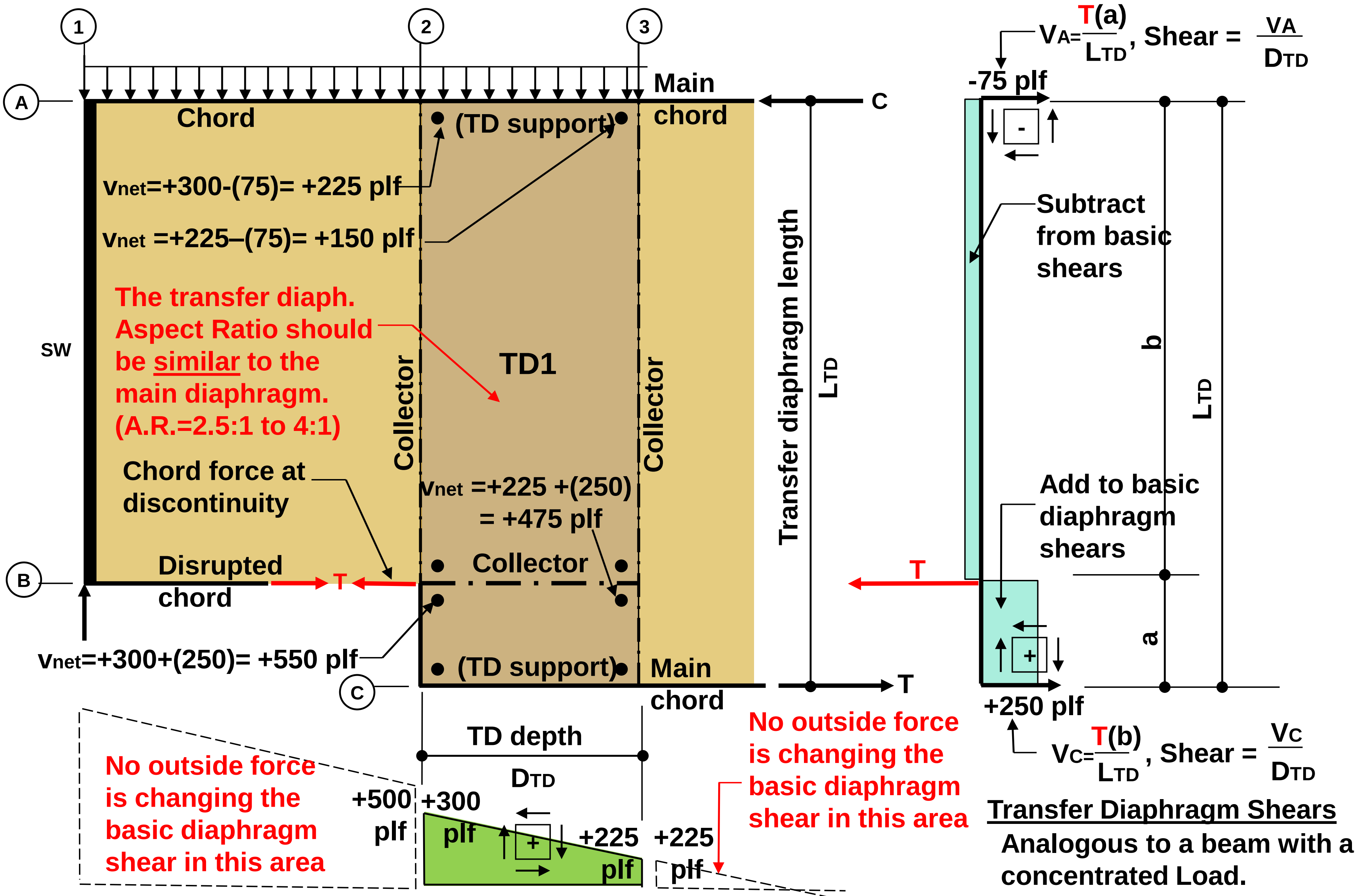


Transfer Mechanism

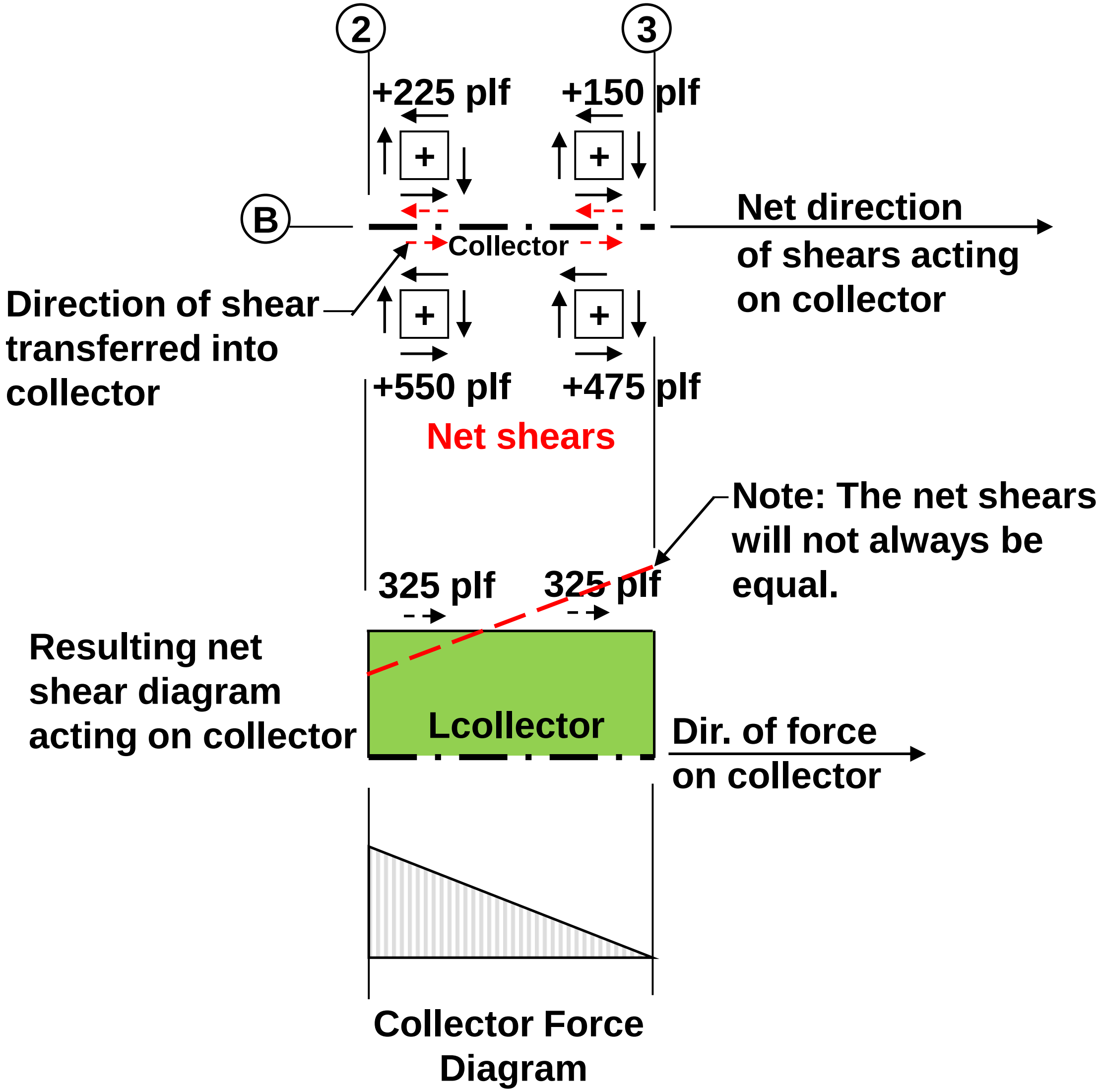


TD Aspect Ratio Too High

Method of Analysis-Method by Edward F. Diekmann



Basic Shear Diagram at transfer diaphragm



- Place the net diaphragm shear on each side of the collector
- Place the transfer shears on each side of the collector
- Sum shears on collector (based upon direction of shears transferred onto collector).

  Shear left=+550-225= +325 plf

  Shear right=+475-150=+325 plf
- Collector force=area of shear diagram

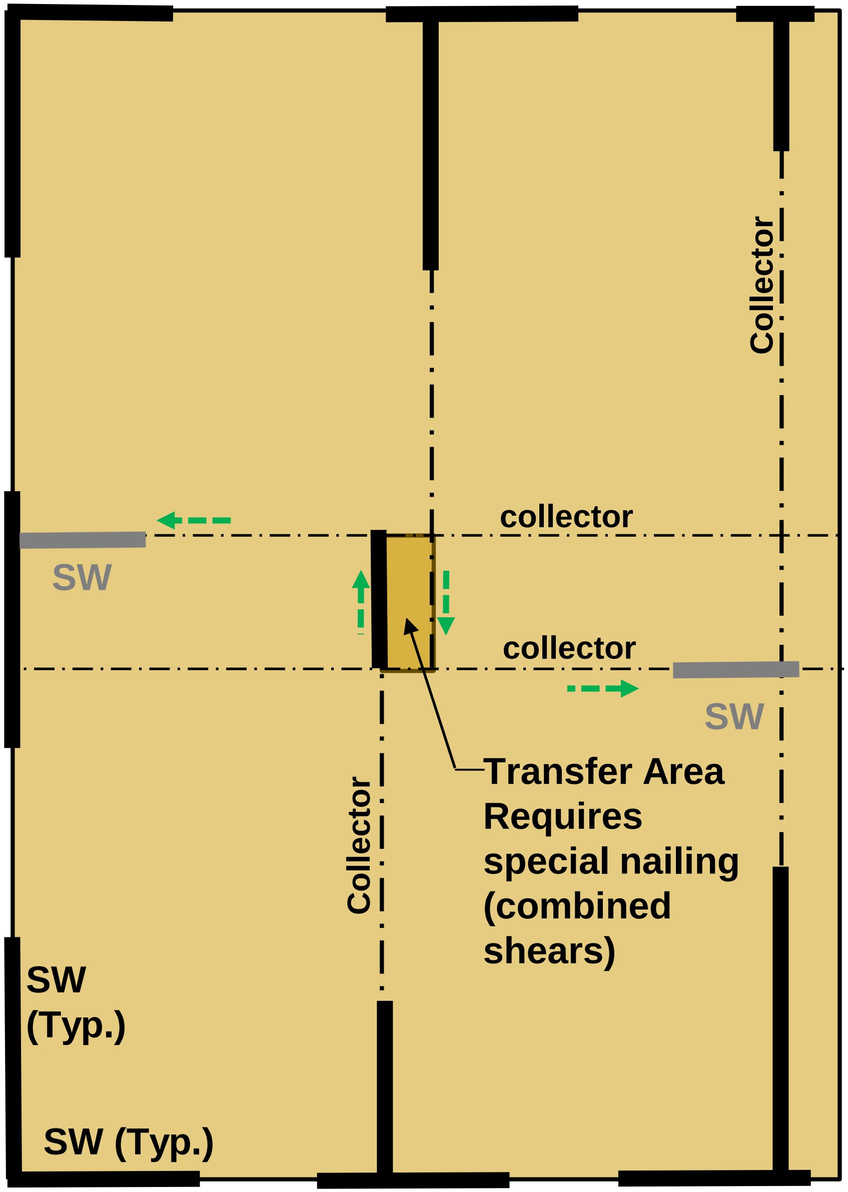
$$F_{collector} = \frac{(325+325)(L_{collector})}{2}$$

Complete Example

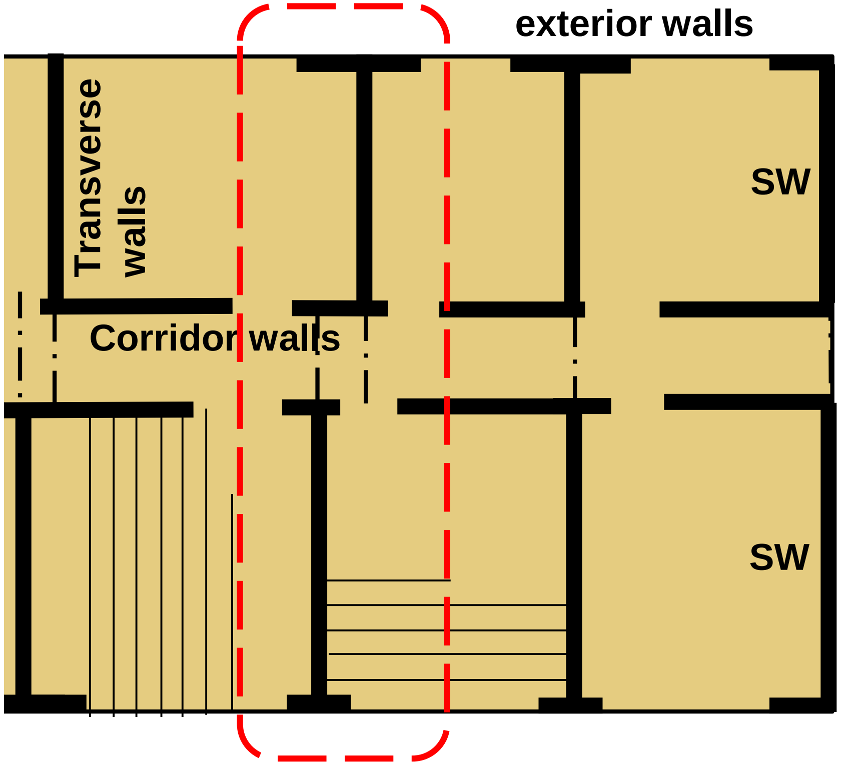
The Analysis of Irregular Shaped Diaphragms

Shear Distribution Into The Collector

Transfer Areas at Offset Walls



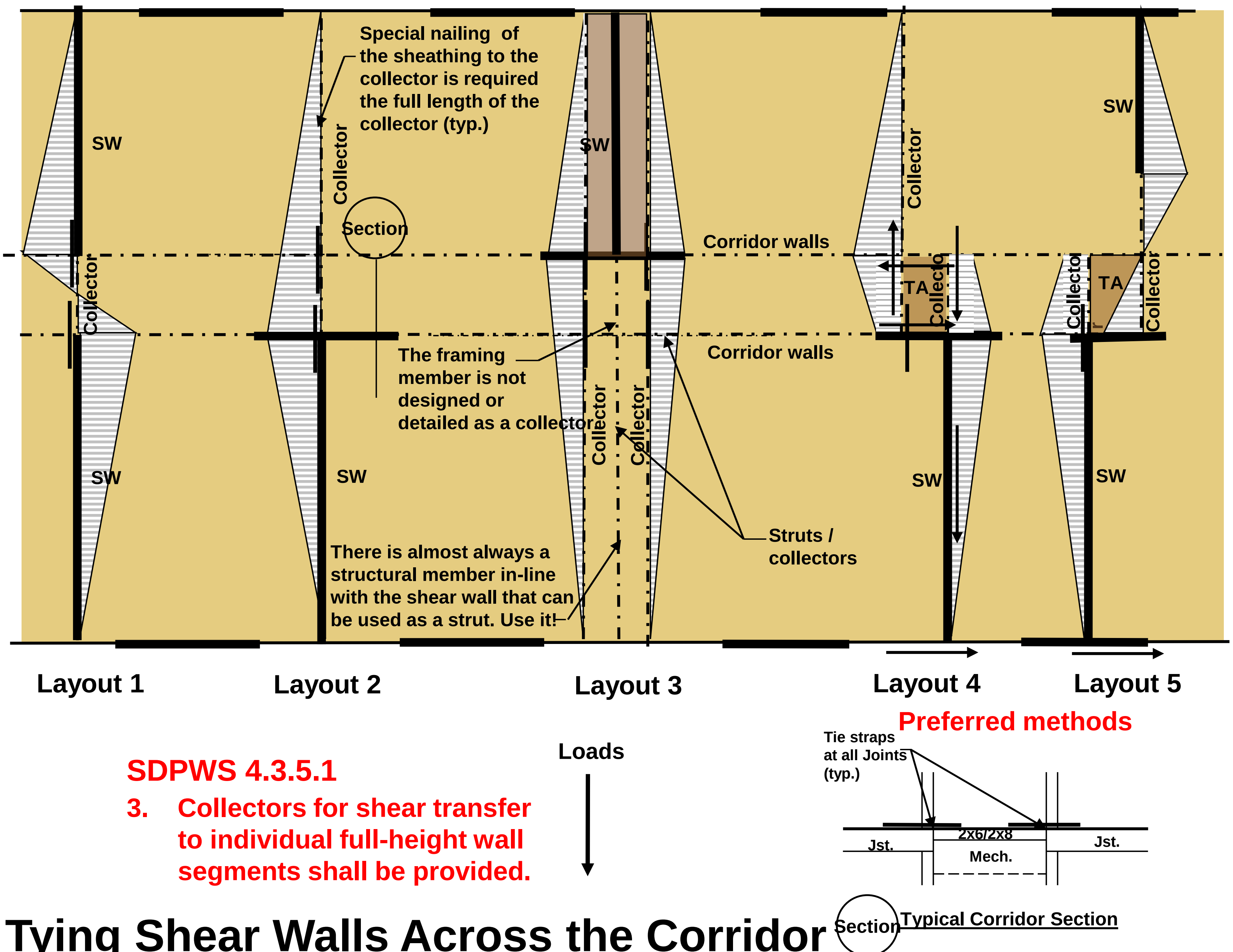
Tying Shear Walls Across a Large Diaphragm



SDPWS 4.3.5.1

3. **Collectors for shear transfer to individual full-height wall segments shall be provided.**

Must follow engineering mechanics and all force diagrams must close to zero or be resolved by other methods.

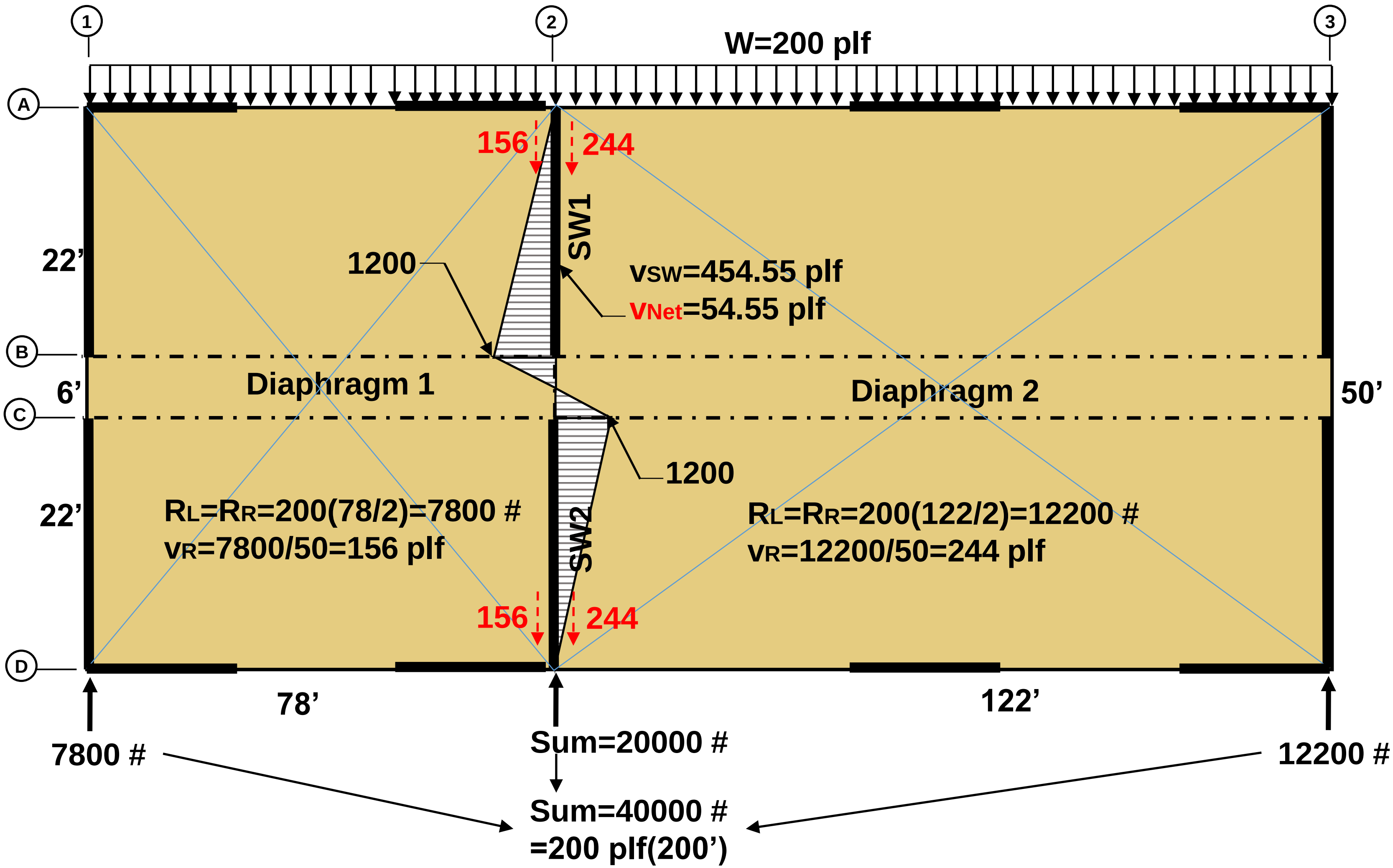


SDPWS 4.3.5.1

3. Collectors for shear transfer to individual full-height wall segments shall be provided.

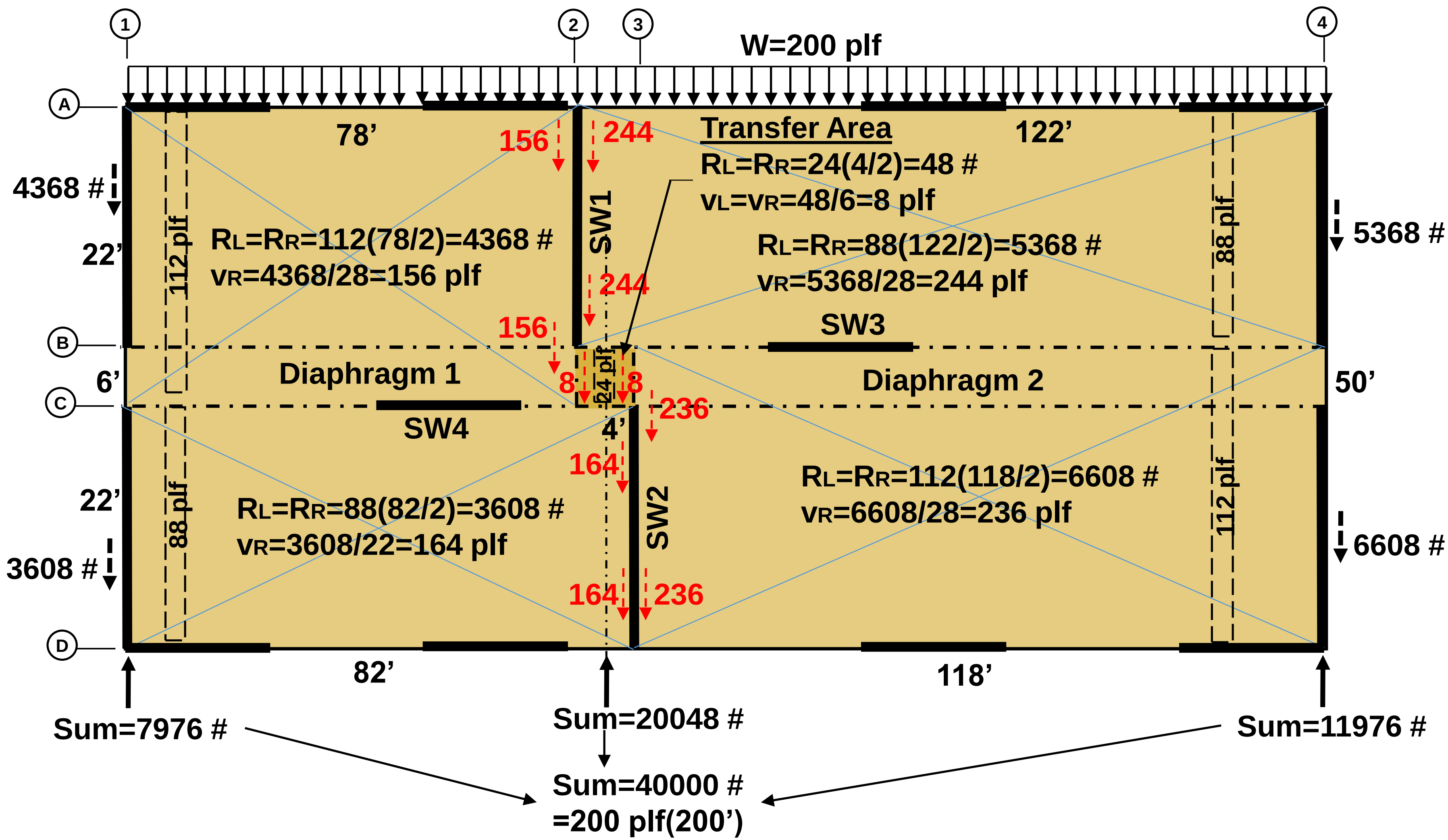
Tying Shear Walls Across the Corridor

<u>Layout 1</u>-Full length walls aligned

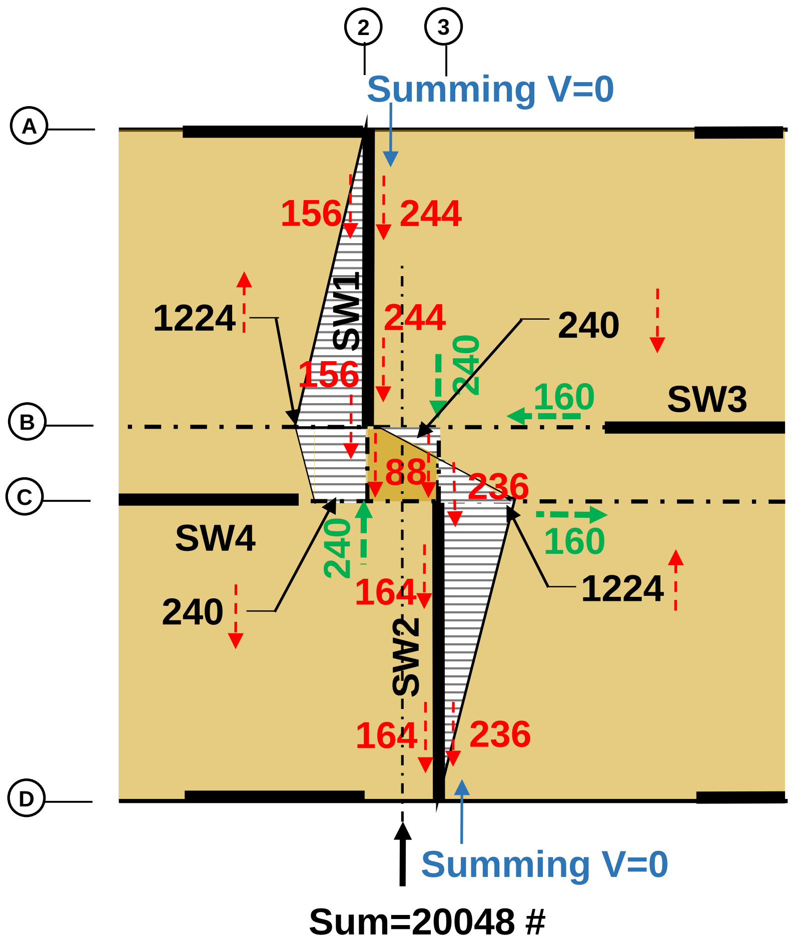


Example 4-Offset Shear Walls Across the Corridor-Layout 6

Layout 6, Case1-Full length offset walls



Case 1-Smaller resulting forces at corridor



All forces in lb., all shears in plf

Total load to grid lines 2 & 3

R_{23}=4368+3608+48+5368+6608+48=20048 # O.K.

L_{SW}=22+22=44’
V_{SW}=20048 #
v_{SW}=20048/44=455.64 plf

v_{net} SW1=455.64-156-244=55.64 plf
v_{net} SW2=455.64-164-236=55.64 plf Checks, they should be equal

SW1
F_{2AB}=55.64(22)=1224 #
F_{2BC}=(156+8)6=984 #
F_{2C}=1224-984=240 #

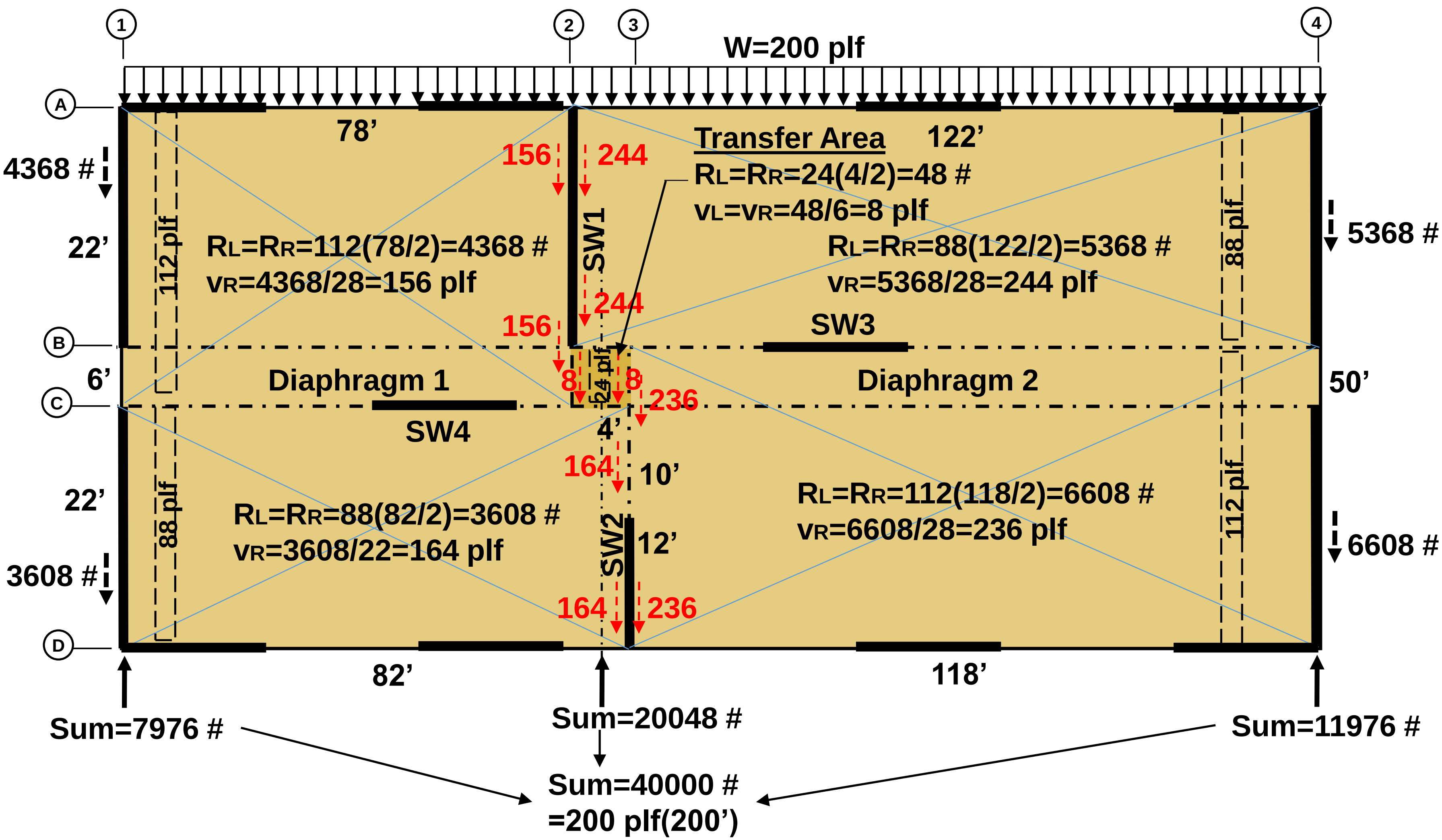
O.K.

SW2
F_{3CD}=55.64(22)=1224 #
F_{3CB}=(236+8)6=1464 #
F_{3B}=1224-1464= -240 #

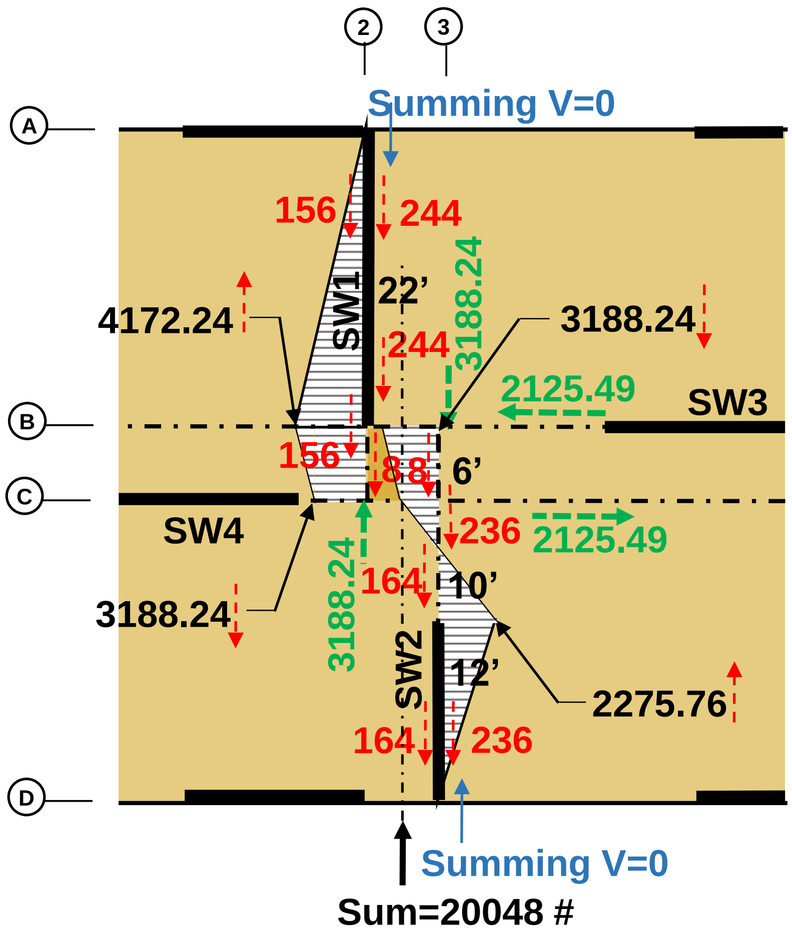
F_{B23}=F_{C23}=240(4)/6=160 #

Shear at transfer area=240/6+8=48 plf

Layout 6, Case2-Full length plus partial length offset shear walls



Case 2-Larger resulting forces at corridor



All forces in lb., all shears in plf

Total load to grid lines 2 & 3

R_{23}=4368+3608+48+5368+6608+48=20048 # **O.K.**

L_{SW}=22+12=34'
V_{SW}=20048 #
v_{SW}=20048/34=589.65 plf

v_{net} SW1=589.65-156-244=189.65 plf
v_{net} SW2=589.65-164-236=189.65 plf **Checks, they should be equal**

SW1

F_{2AB}=189.65(22)=4172.24 #
F_{2BC}=(156+8)6=984 #
F_{2C}=4172.24-984=3188.24 #

O.K.

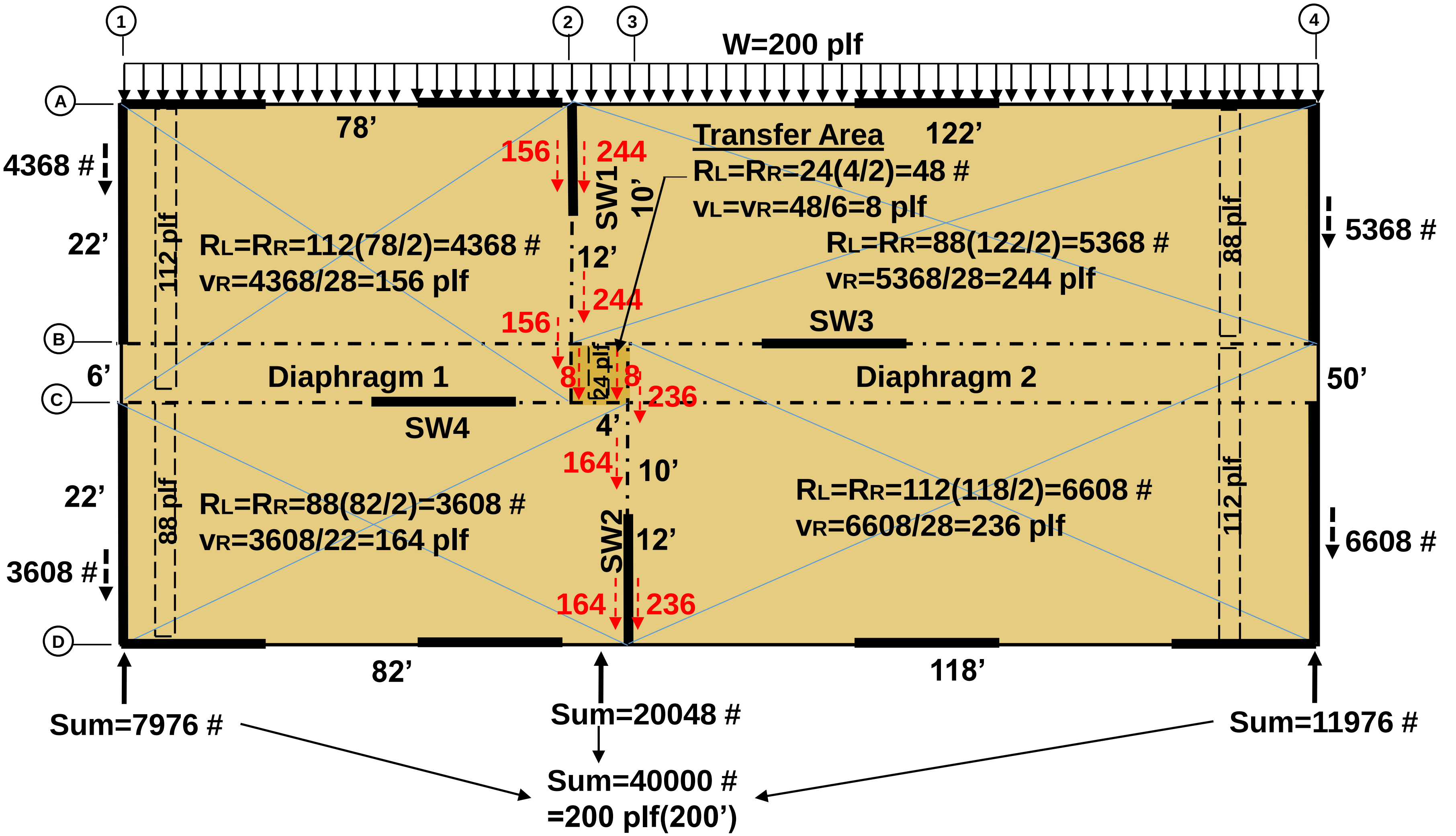
SW2

F_{SW2} =189.65(12)=2275.76 #
F_{SW2} to $_{3B}$=(236+8)6+(236+164)10=5464 #
F_{3B}=2275.76-5464= -3188.24 #

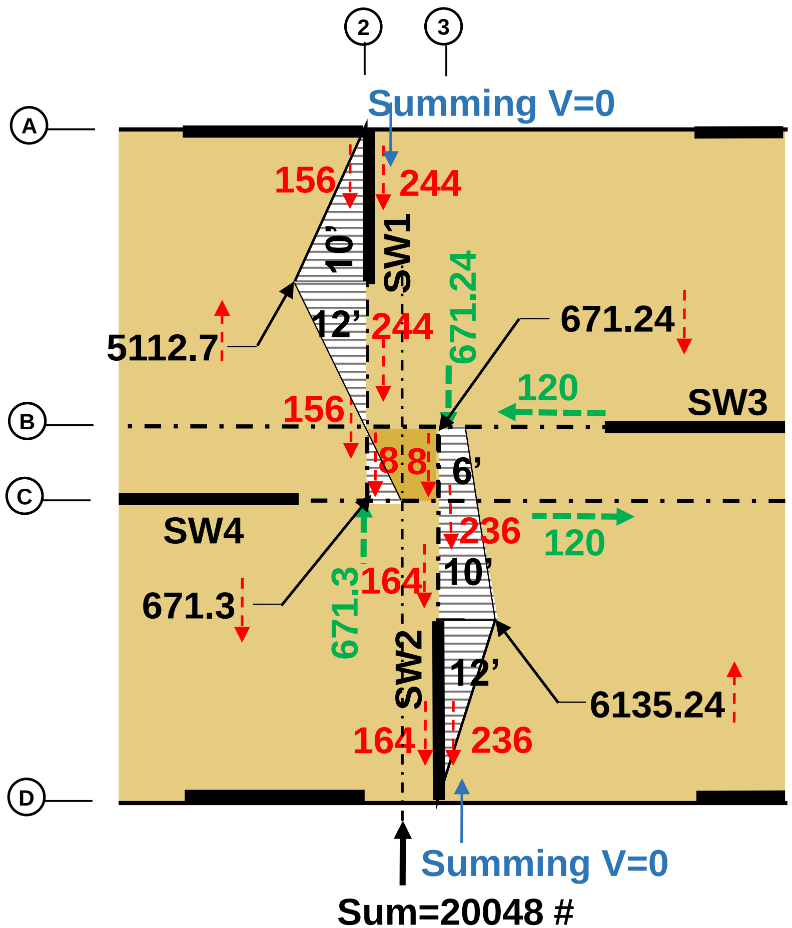
F_{B23}=F_{C23}=3188.24(4)/6=2125.49 #

Shear at transfer area=3188.24/6+8=539.37 plf

Layout 6, Case3 - Partial length offset shear walls



Case 3-Smaller resulting forces at corridor



All forces in lb., all shears in plf

Total load to grid lines 2 & 3

R23=4368+3608+48+5368+6608+48=20048 # O.K.

LSW=12+10=22'
VSW=20048 #
vSW=20048/22=911.27 plf

vnet SW1=911.27-156-244=511.27 plf
vnet SW2=911.27-164-236=511.27 plf Checks, they should be equal

SW1
FSW1=511.27(10)=5112.7 #
FSW1 to 2B=(156+244)12=4800 #
F2BC=(156+8)6=984 #
F2C=5112.7-4800-984=-671.3 #

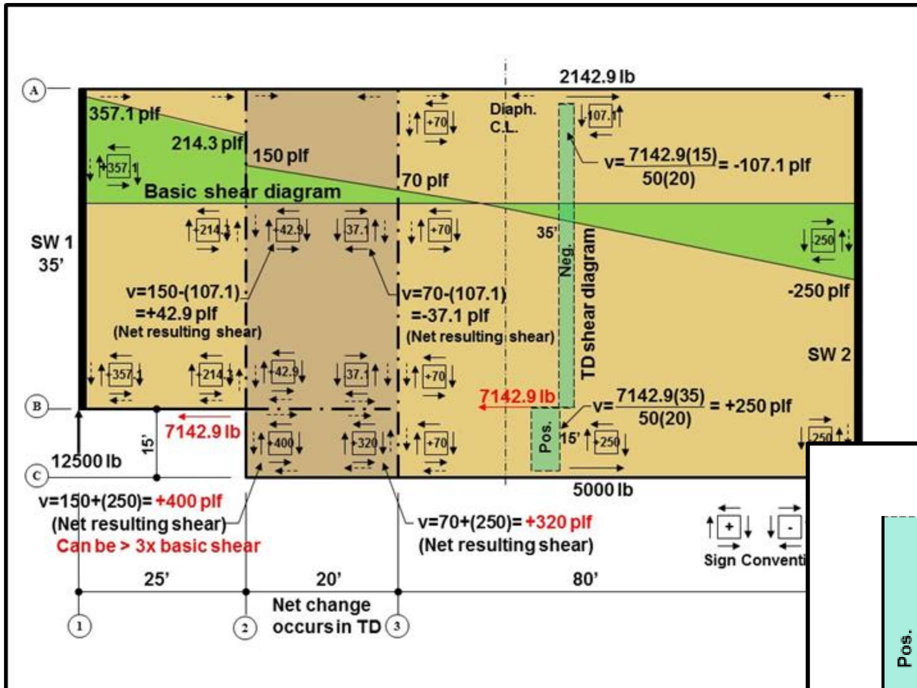
O.K.

SW2
FSW2=511.27(12)=6135.24 #
FSW2 to 3B=(236+8)6+(236+164)10=5464 #
F3B=6135.24-5464= 671.24 #

FB23=FC23=671.3(4)/6=120 #

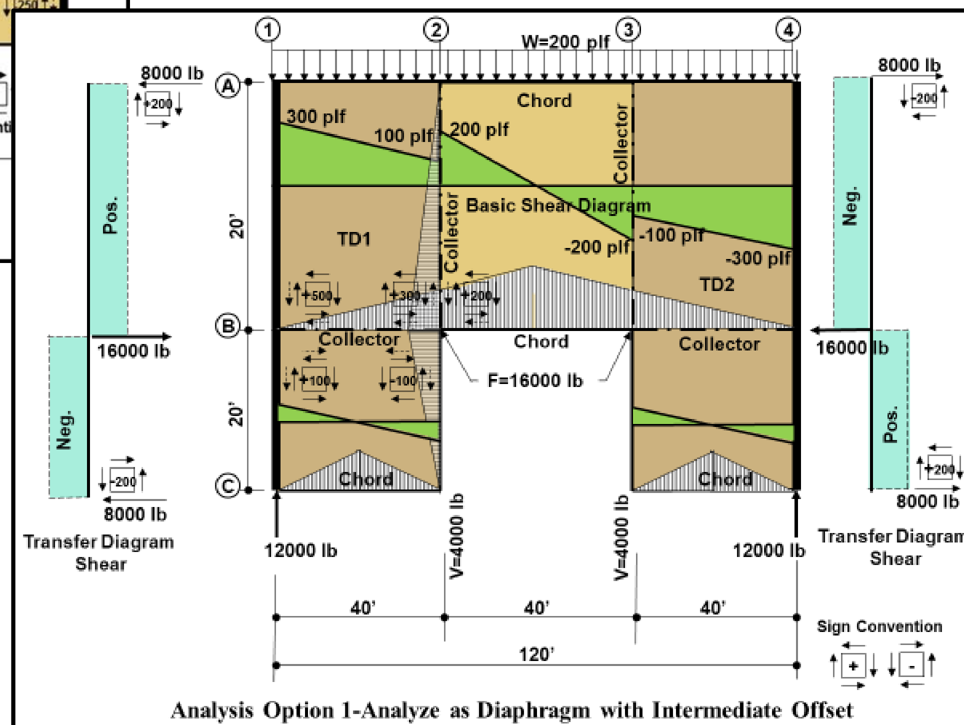
Shear at transfer area=671.3/6+8=119.9 plf

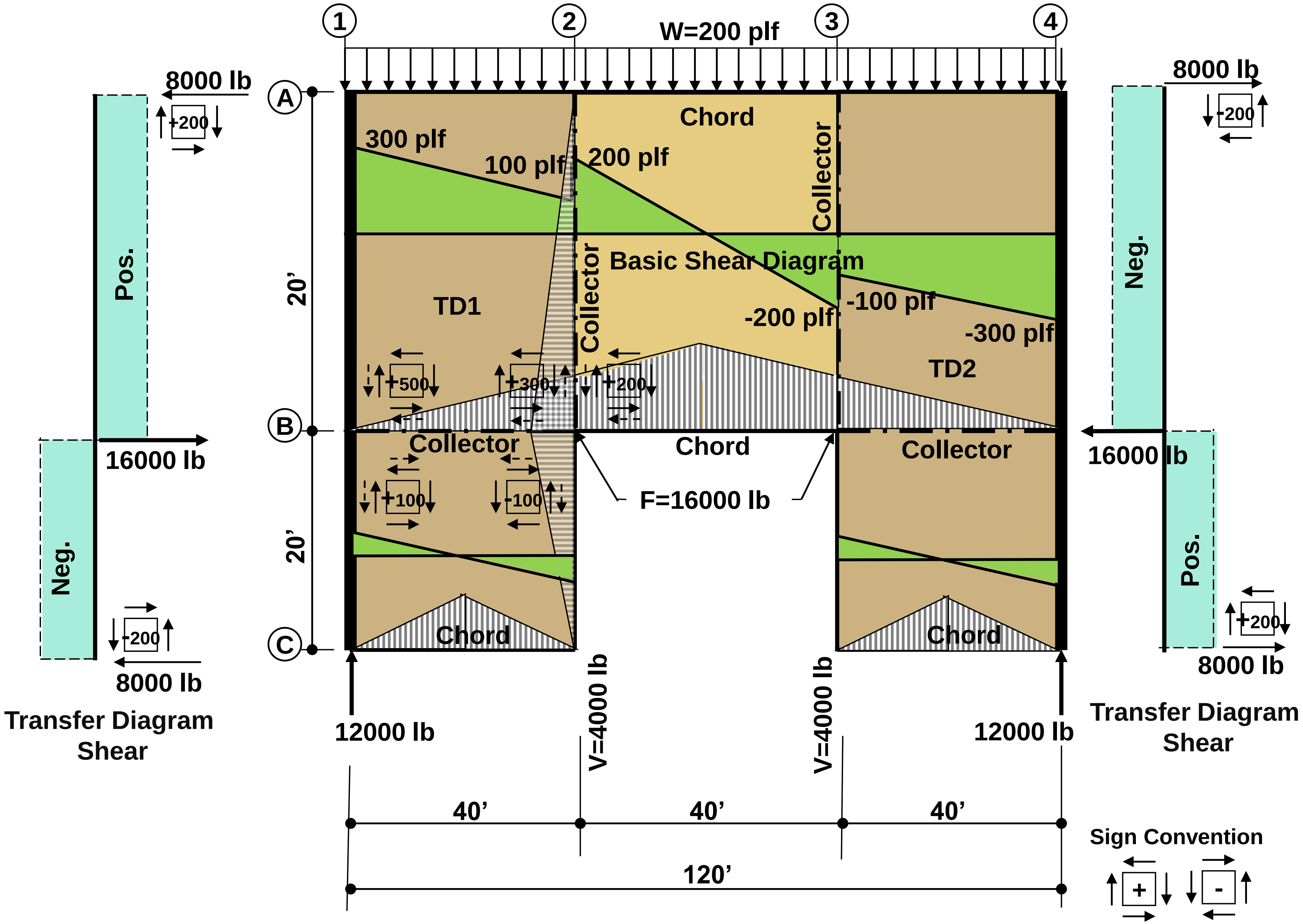
Diaphragm Offsets



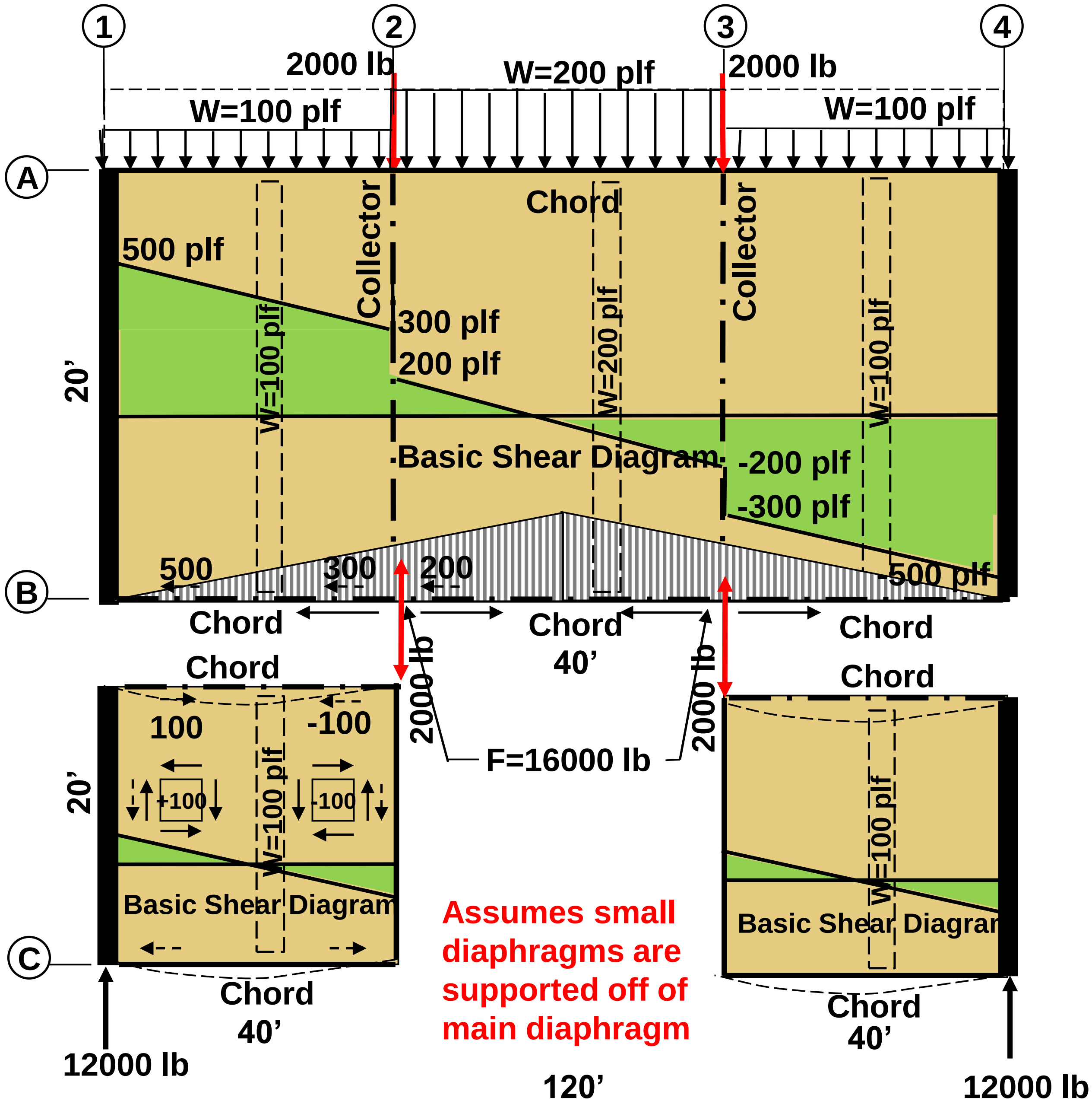
Method and example can be found in the solutions paper.

There are two methods of solving this type of offset. (As follows)





Analysis Option 1-Analyze as Diaphragm with Intermediate Offset



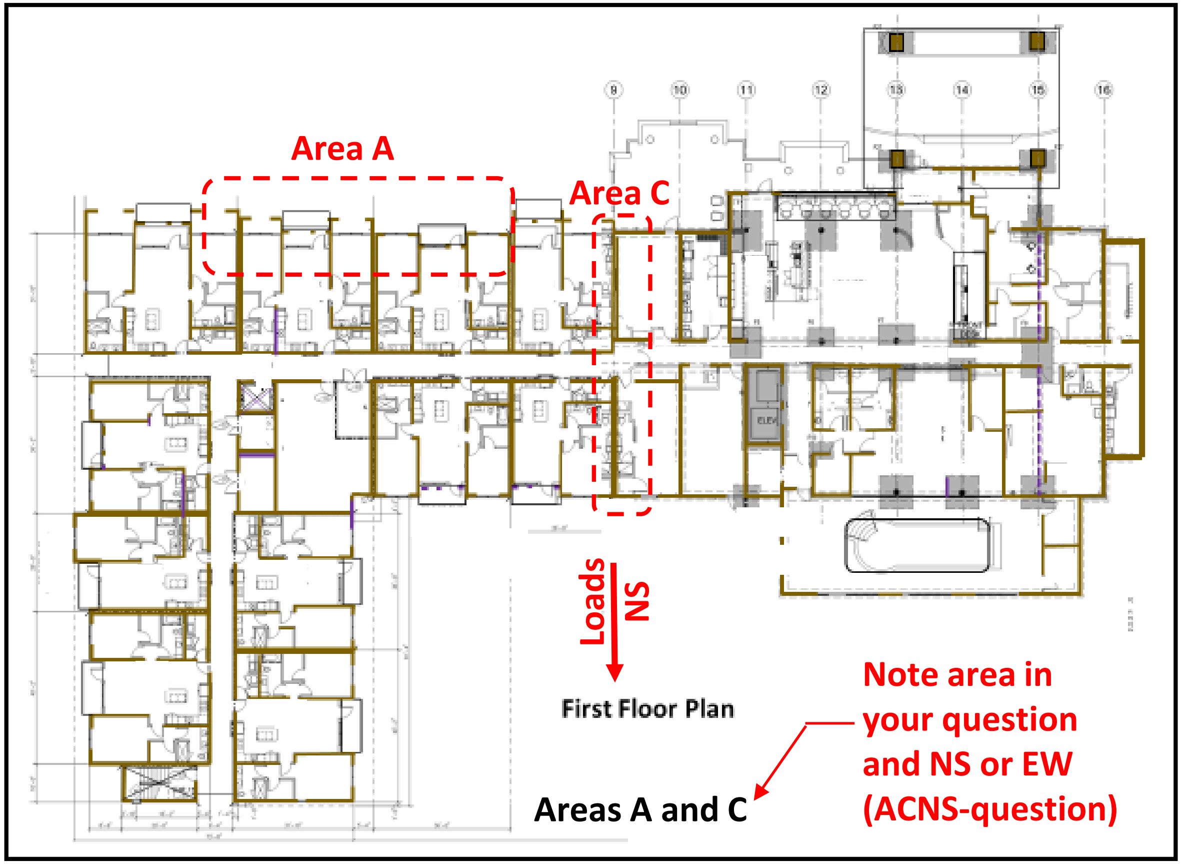
Analysis Option 2-Analyzing as separate diaphragms

WoodWorks

Q & A

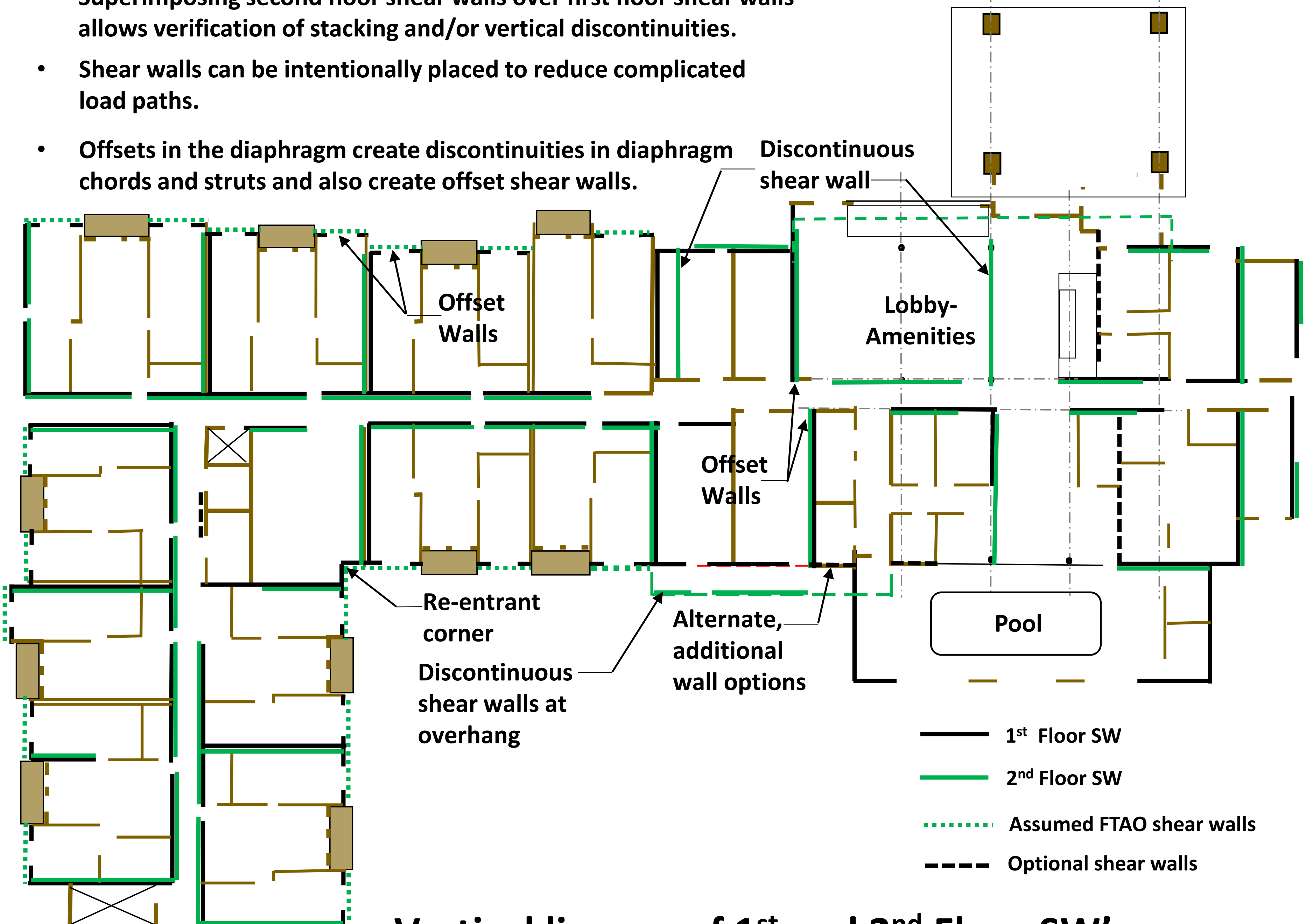
A Design Example

A 2-Story Hotel Case Study



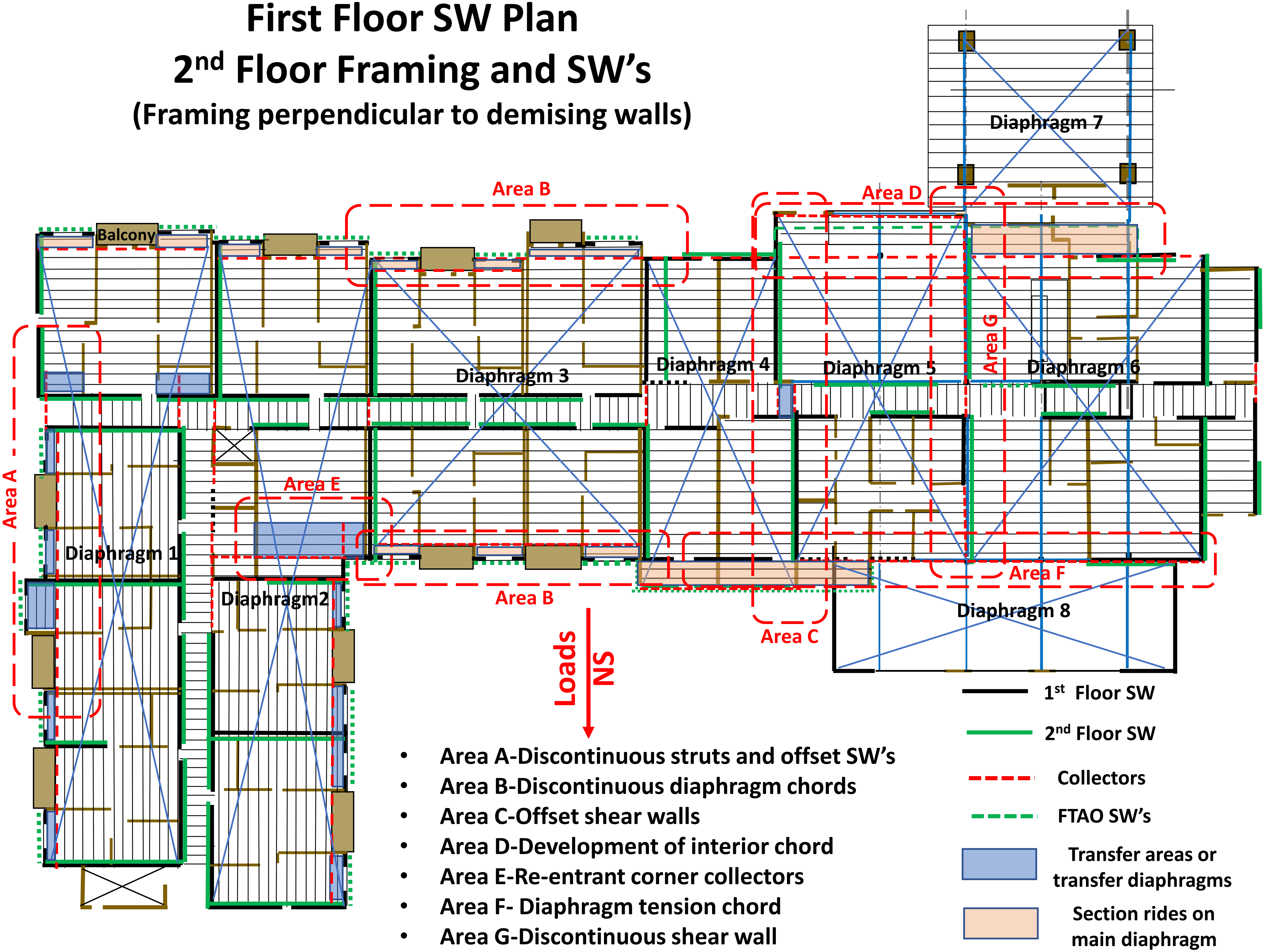
Lateral Load Paths, Discontinuities and Solutions

- Superimposing second floor shear walls over first floor shear walls allows verification of stacking and/or vertical discontinuities.
- Shear walls can be intentionally placed to reduce complicated load paths.
- Offsets in the diaphragm create discontinuities in diaphragm chords and struts and also create offset shear walls.

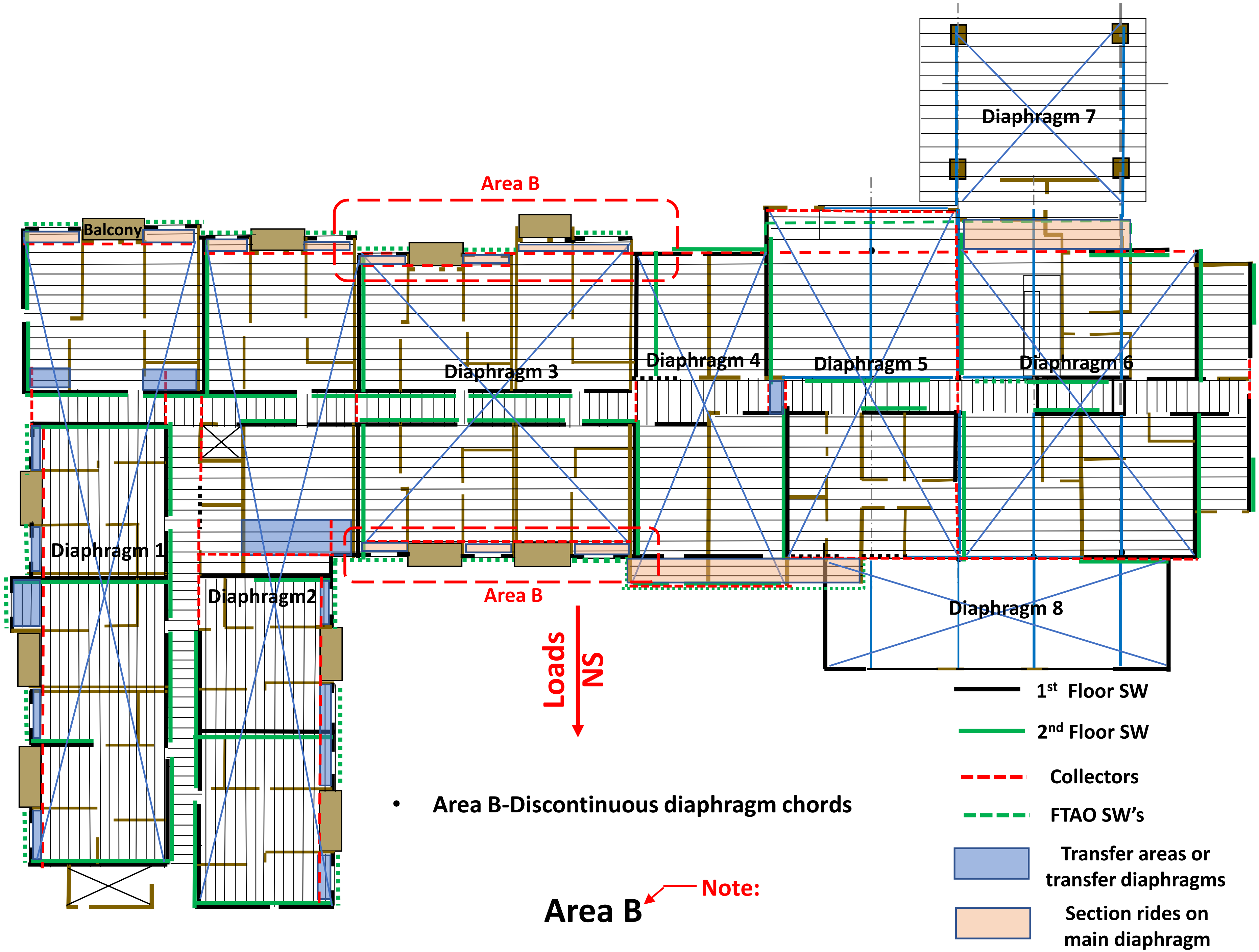


Vertical line-up of 1st and 2nd Floor SW's

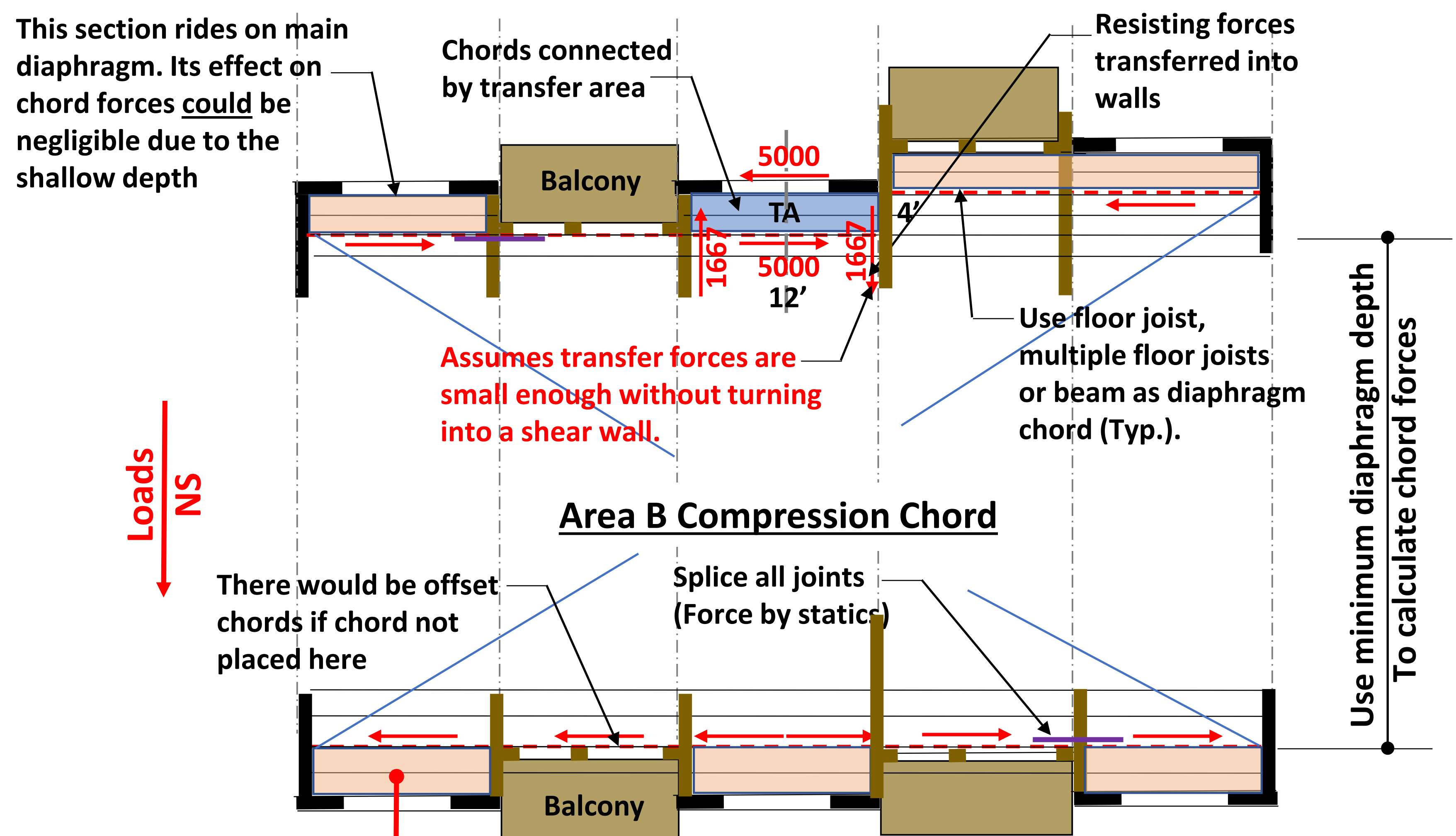
First Floor SW Plan
2nd Floor Framing and SW's
(Framing perpendicular to demising walls)

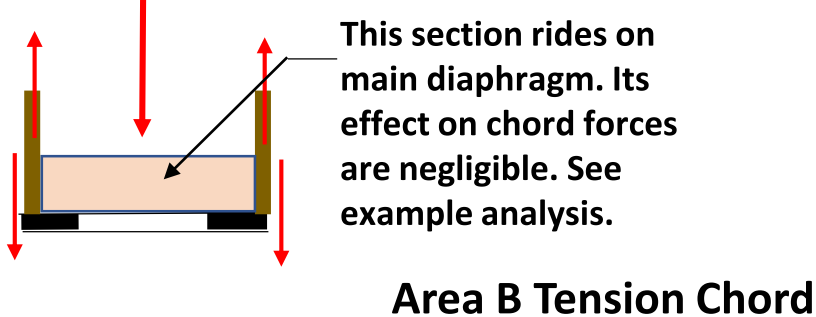


- Area A-Discontinuous struts and offset SW's
- Area B-Discontinuous diaphragm chords
- Area C-Offset shear walls
- Area D-Development of interior chord
- Area E-Re-entrant corner collectors
- Area F- Diaphragm tension chord
- Area G-Discontinuous shear wall



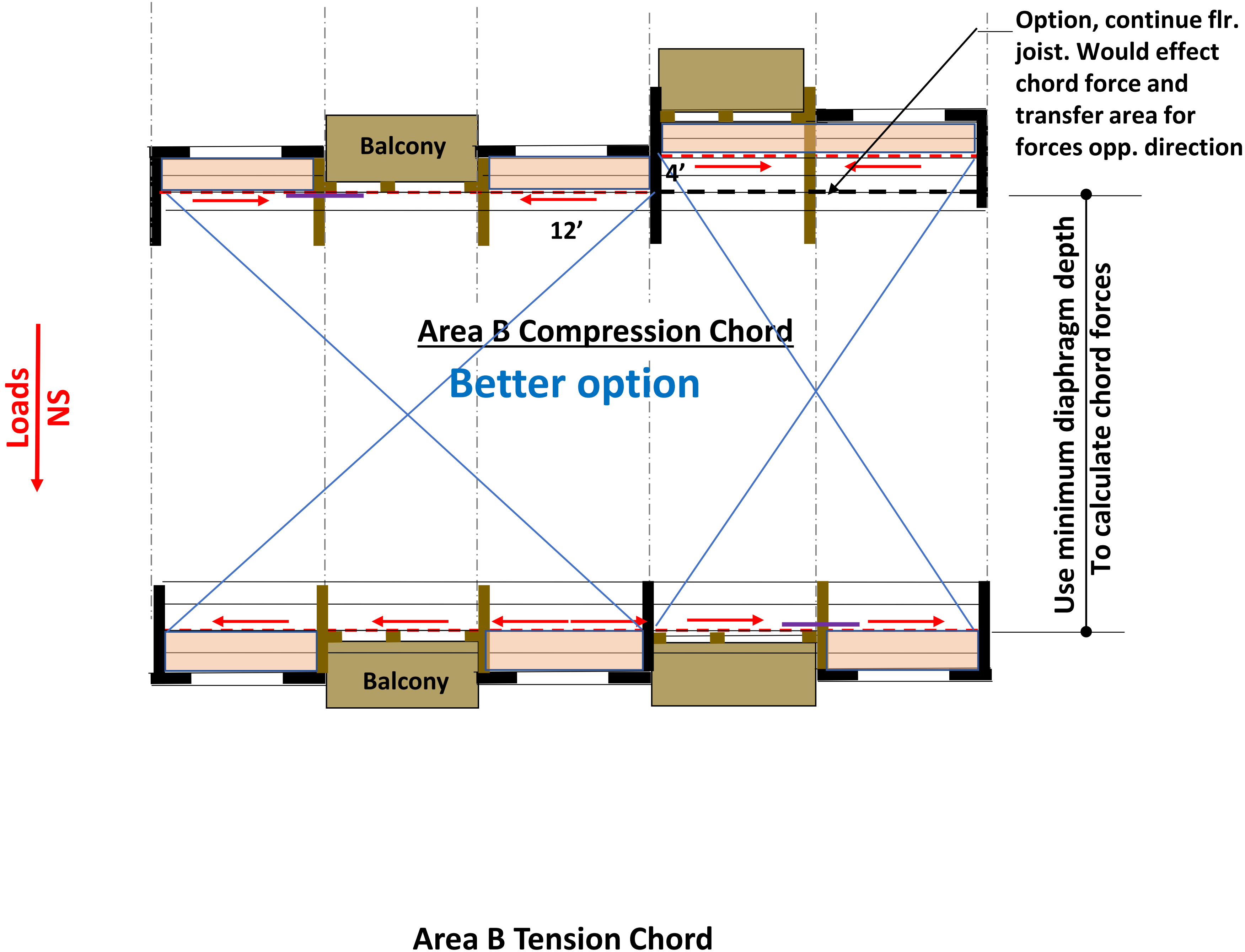
Area B
Balcony
Diaphragm 1
Diaphragm2
Diaphragm 3
Diaphragm 4
Diaphragm 5
Diaphragm 6
Diaphragm 7
Diaphragm 8
Area B
Loads
NS
1st Floor SW
2nd Floor SW
Collectors
FTAO SW's
Transfer areas or transfer diaphragms
Section rides on main diaphragm
• Area B-Discontinuous diaphragm chords
Area B
Note:

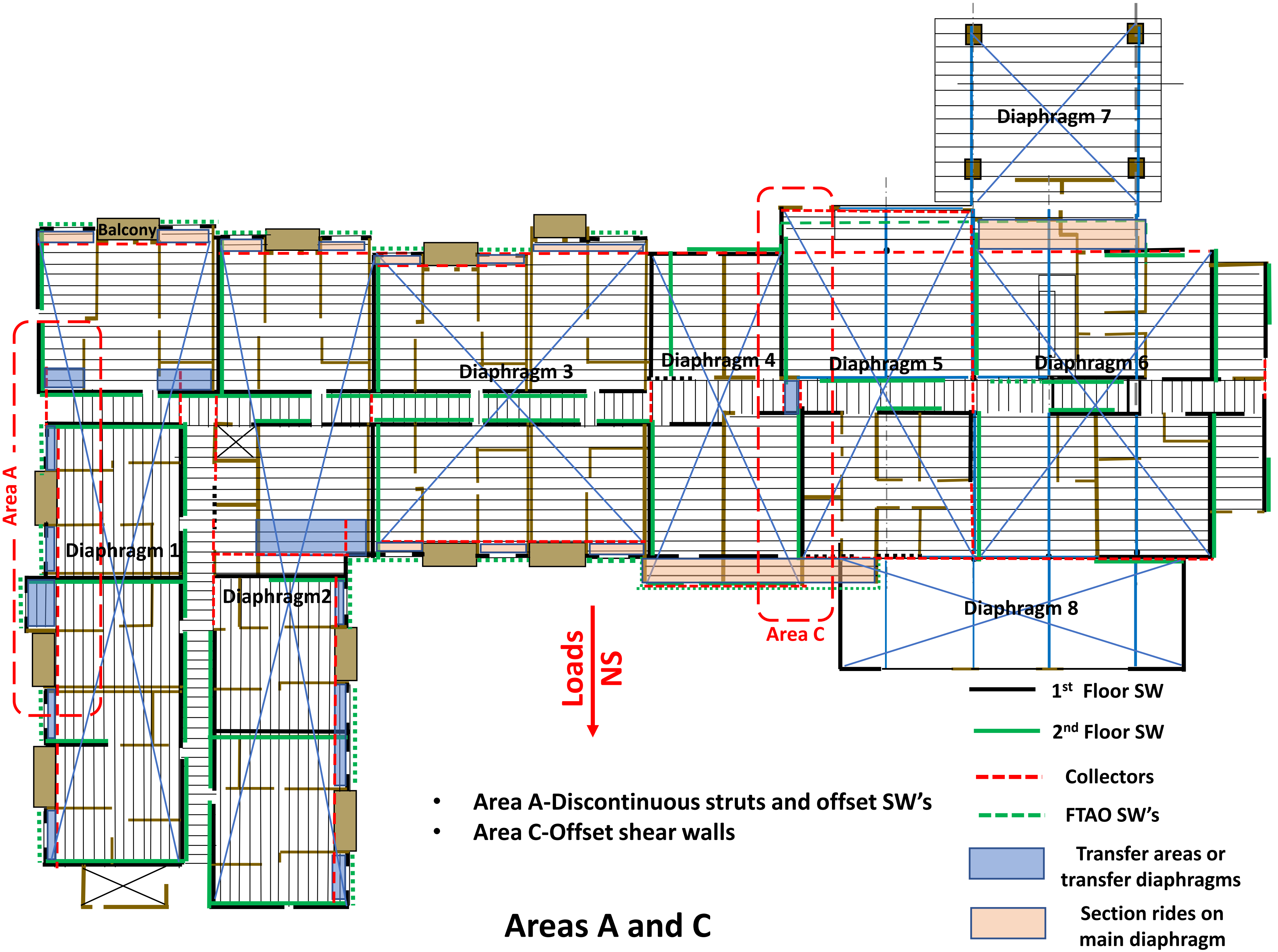




Options:

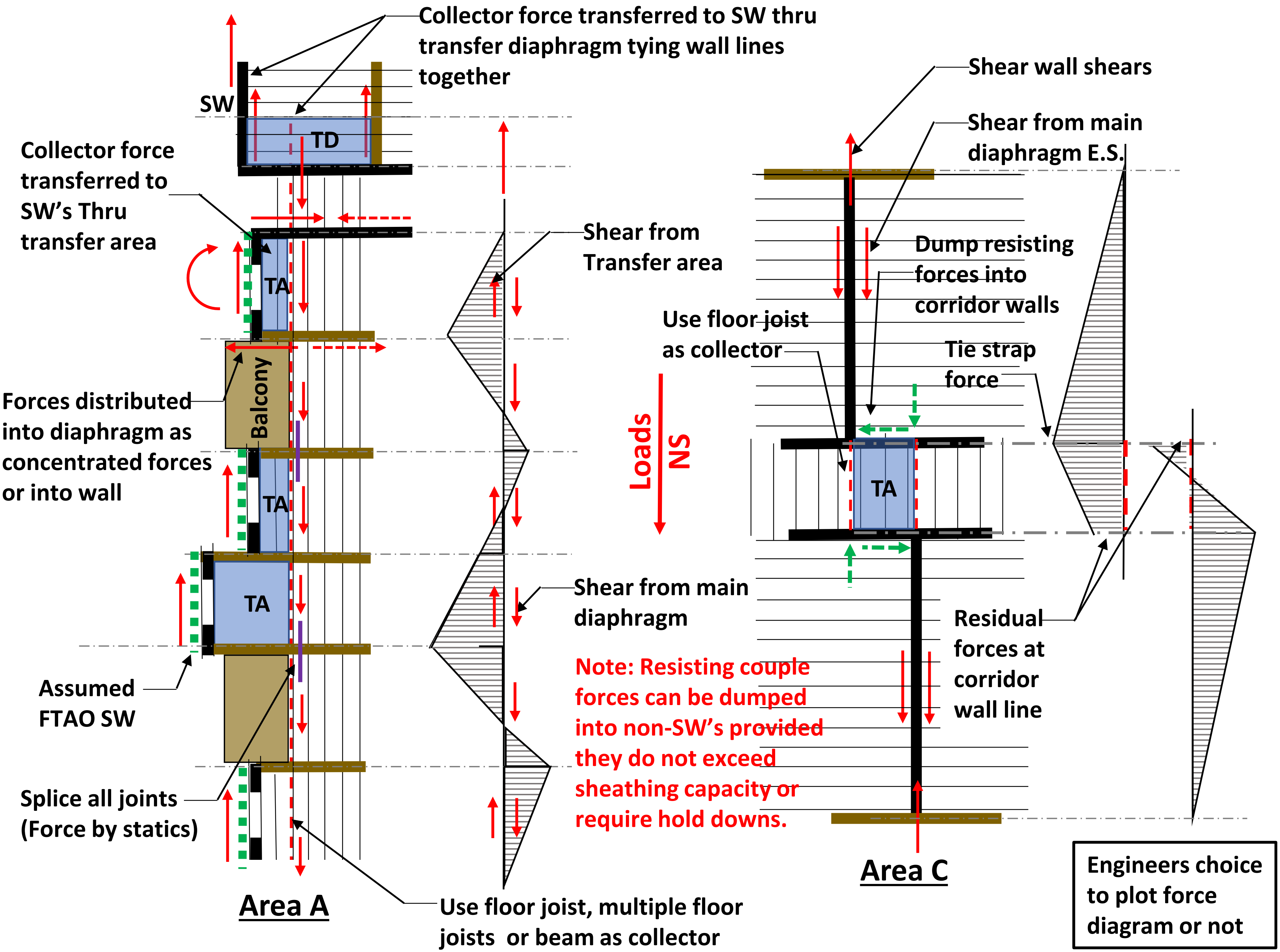
- Deal with offsets directly
- Make a continuous interior chord and adjust for attaching sections


Option, continue flr. joist. Would effect chord force and transfer area for forces opp. direction
Balcony
4’
12’
Area B Compression Chord
Better option
Loads
NS
Use minimum diaphragm depth
To calculate chord forces
Balcony
Area B Tension Chord



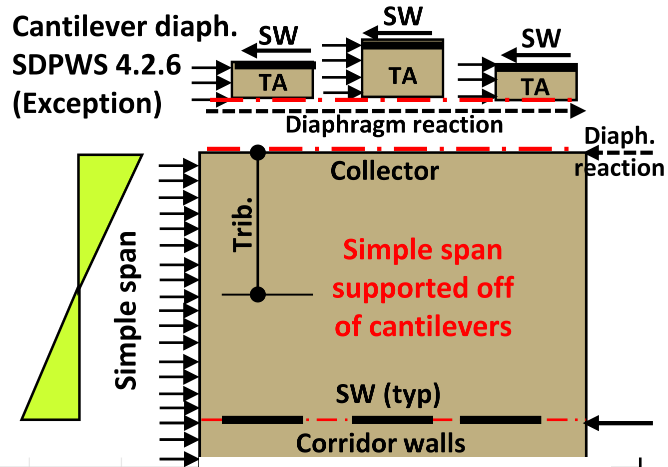
Balcony
Diaphragm 1
Diaphragm2
Diaphragm 3
Diaphragm 4
Diaphragm 5
Diaphragm 6
Diaphragm 7
Diaphragm 8
Area A
Area C
Loads
NS
• Area A-Discontinuous struts and offset SW's
• Area C-Offset shear walls
1st Floor SW
2nd Floor SW
Collectors
FTAO SW's
Transfer areas or transfer diaphragms
Section rides on main diaphragm

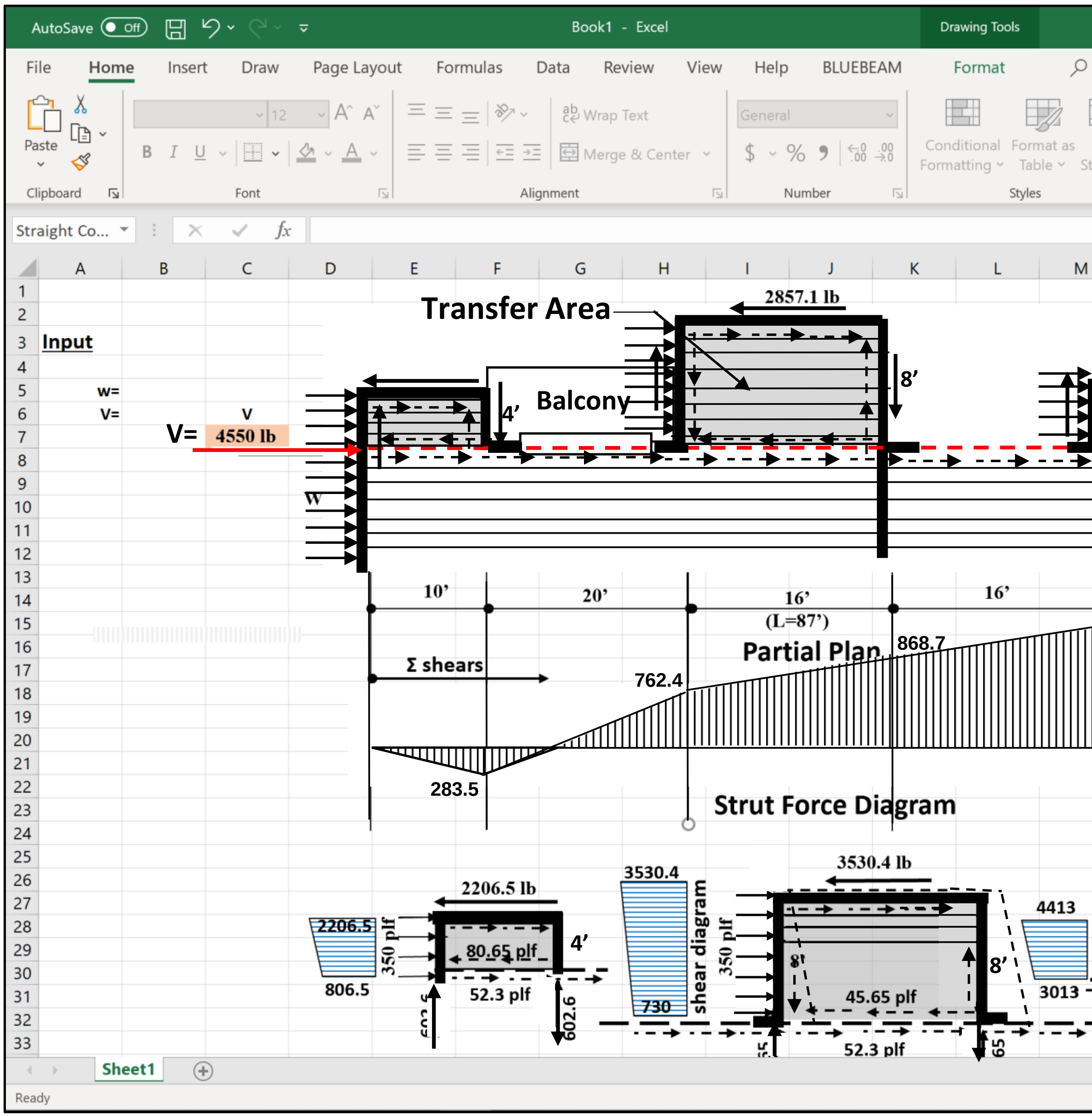
Areas A and C

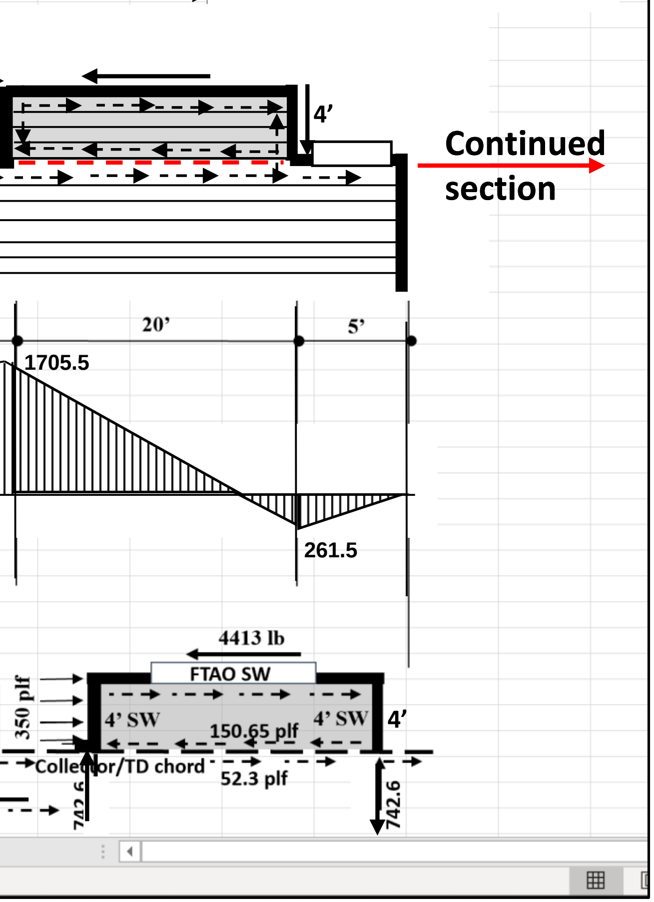


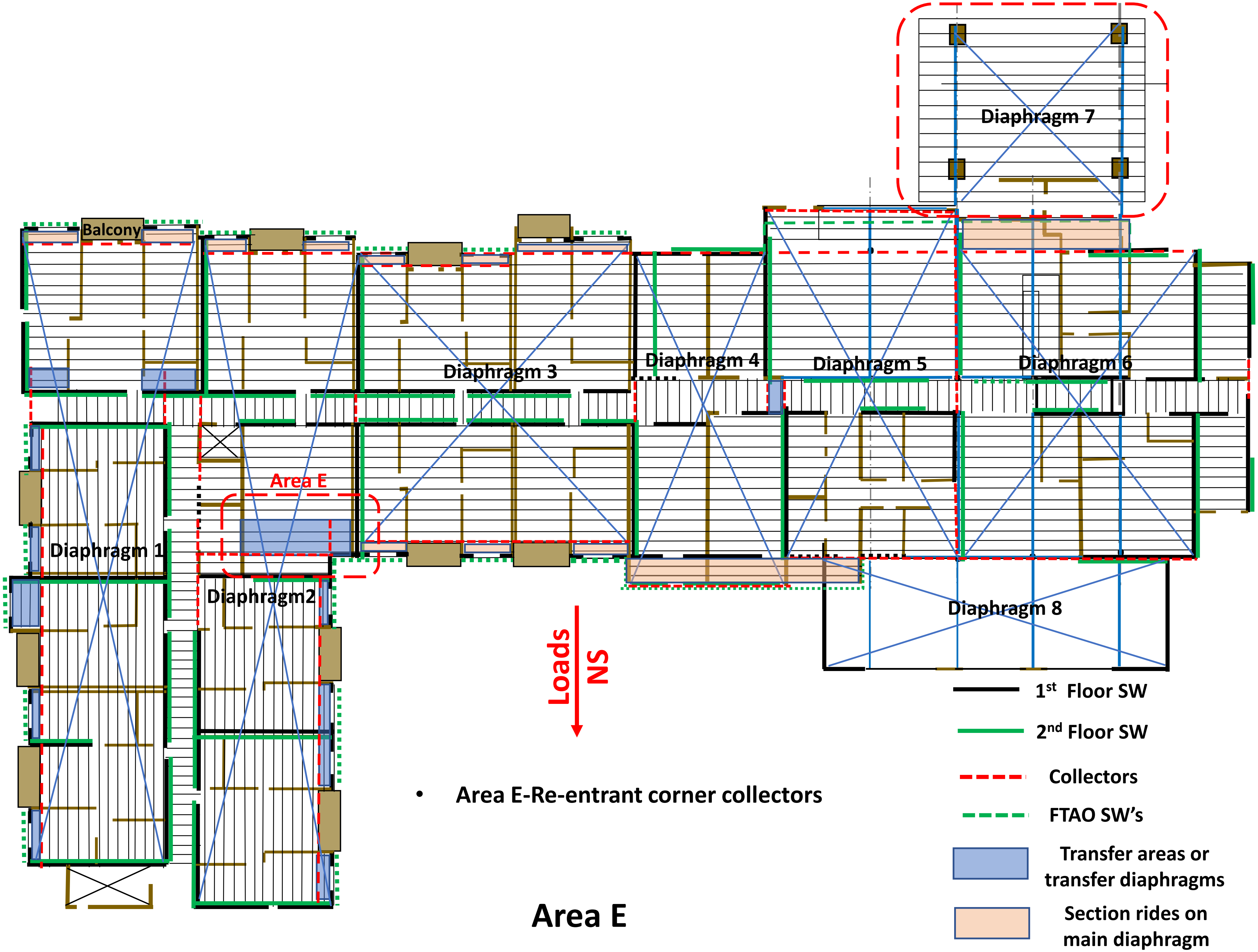
Collector force transferred to SW thru transfer diaphragm tying wall lines together
SW
TD
Collector force transferred to SW's Thru transfer area
TA
Shear from Transfer area
Balcony
Forces distributed into diaphragm as concentrated forces or into wall
TA
TA
Shear from main diaphragm
Assumed FTAO SW
Splice all joints (Force by statics)
Use floor joist, multiple floor joists or beam as collector
Area A
Loads
NS
Note: Resisting couple forces can be dumped into non-SW's provided they do not exceed sheathing capacity or require hold downs.
Shear wall shears
Shear from main diaphragm E.S.
Dump resisting forces into corridor walls
Use floor joist as collector
Tie strap force
TA
Residual forces at corridor wall line
Area C
Engineers choice to plot force diagram or not

Example Spreadsheet Solution



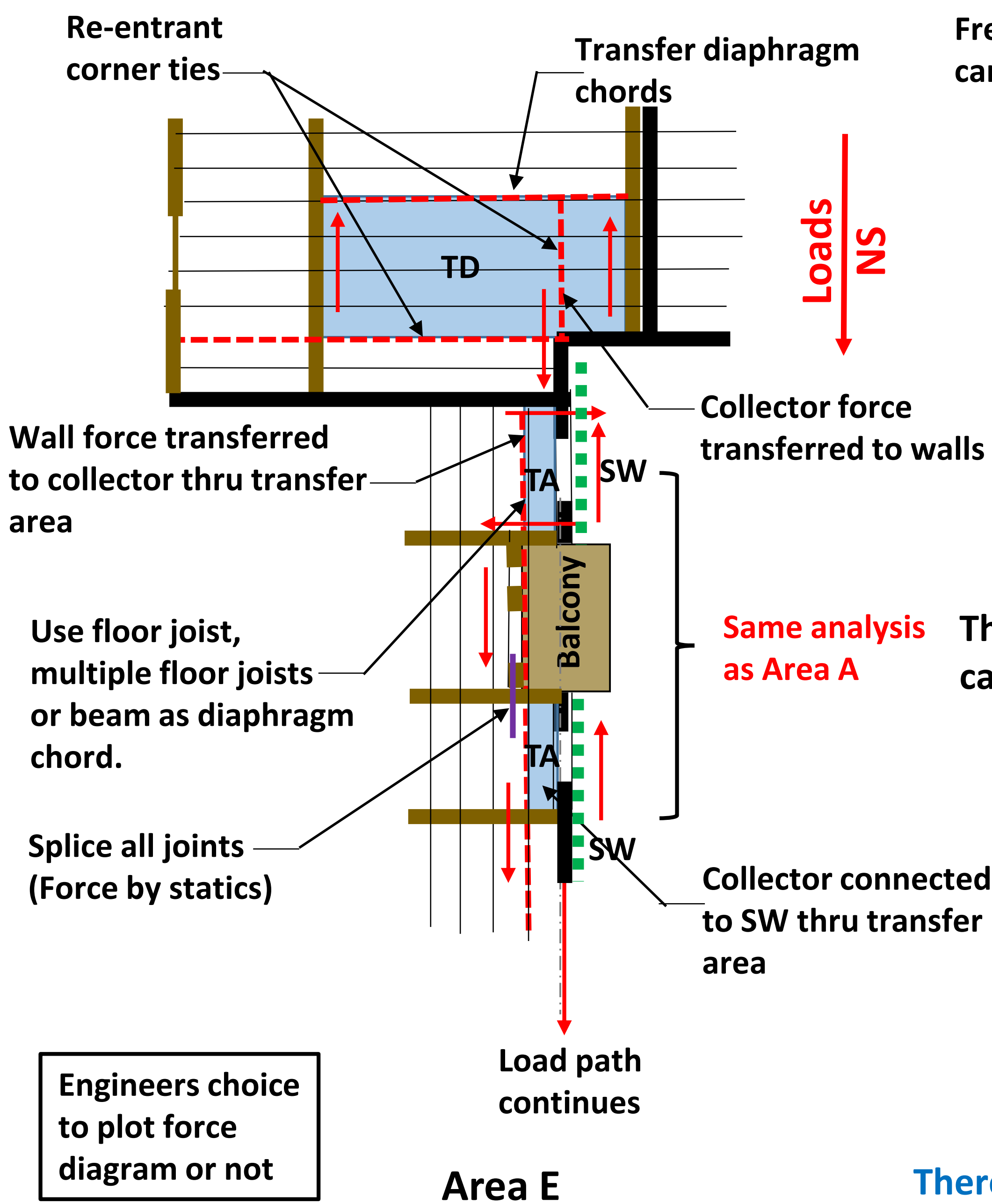


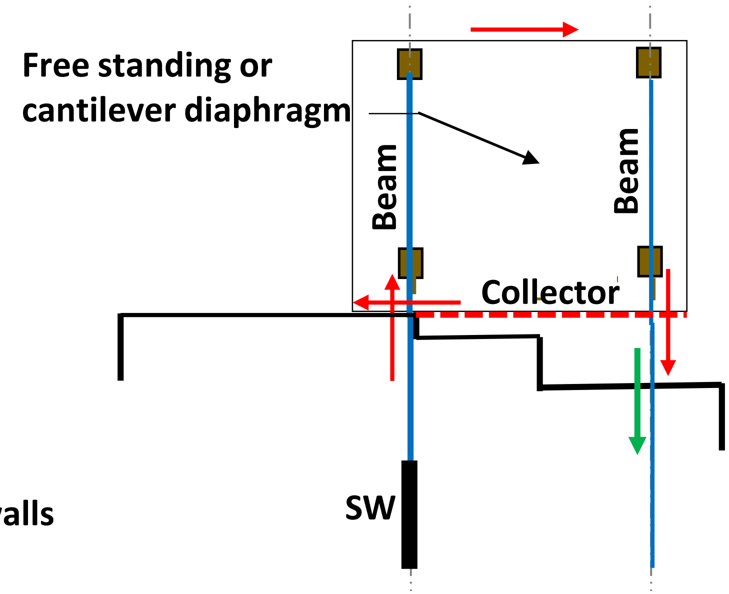




- Area E-Re-entrant corner collectors

Area E



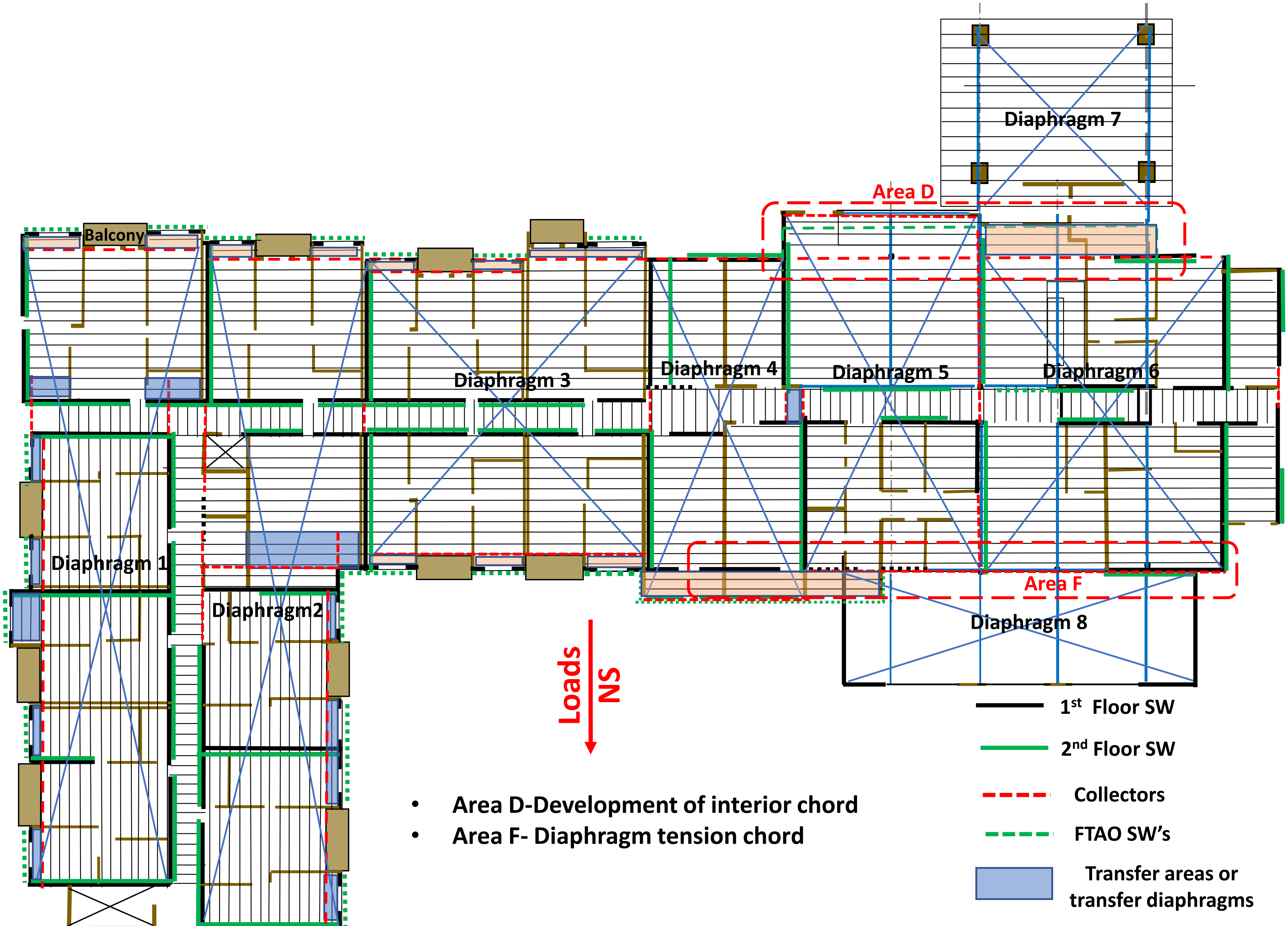


A quick note on the Porte Cochere

The Porte Cochere can be designed as a cantilever diaphragm provided:

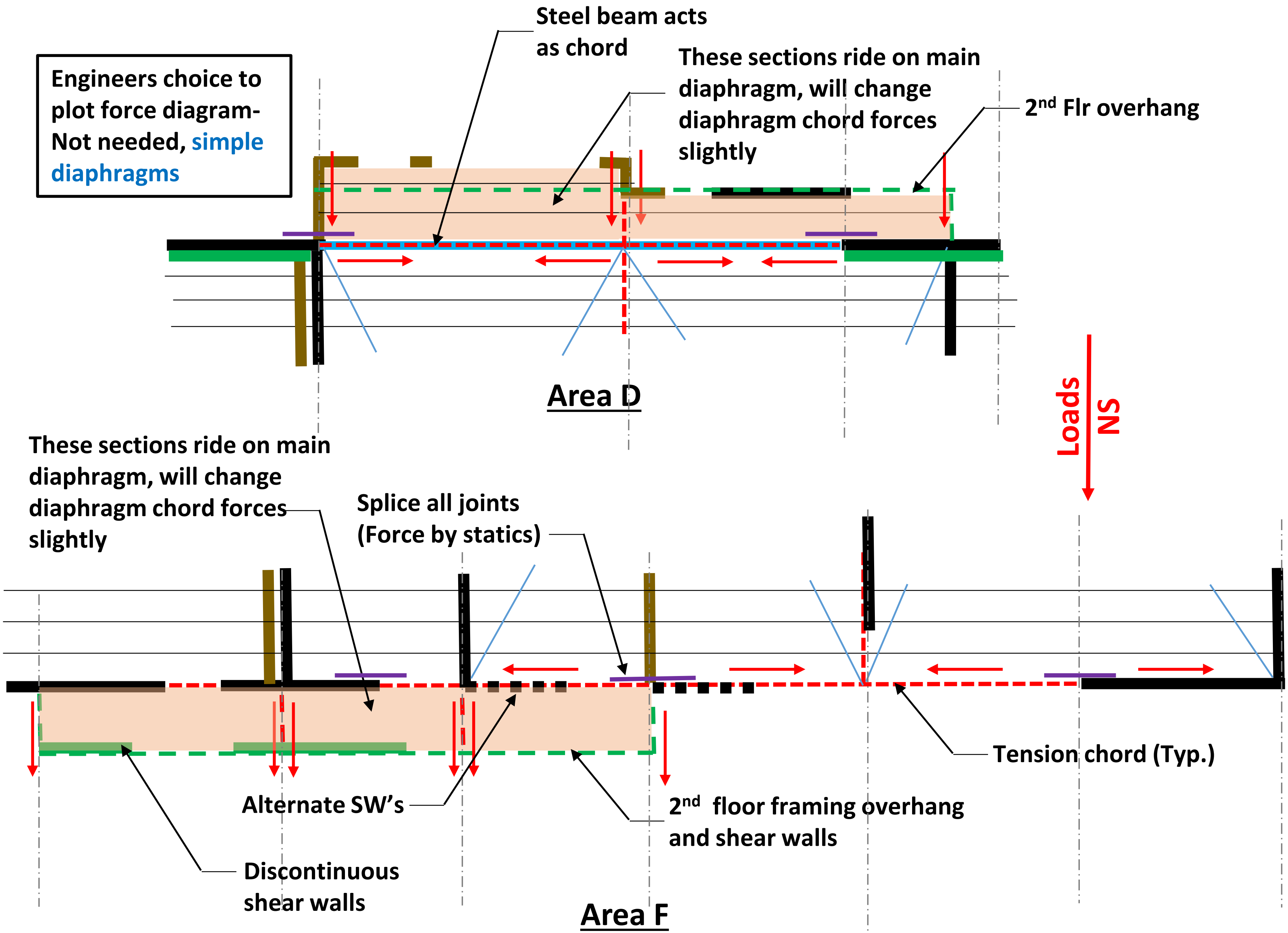
1. A collector can be tied hard to the main building, taking the lateral force.
2. The rotational forces can be transferred into the main diaphragm as a concentrated force thru beams acting as collectors or distributing them into a shear wall.
3. The cantilever length cannot exceed 35'.

There is often a seismic gap between the two structures and the height of the Porte Cache will not normally match the second floor elevation.

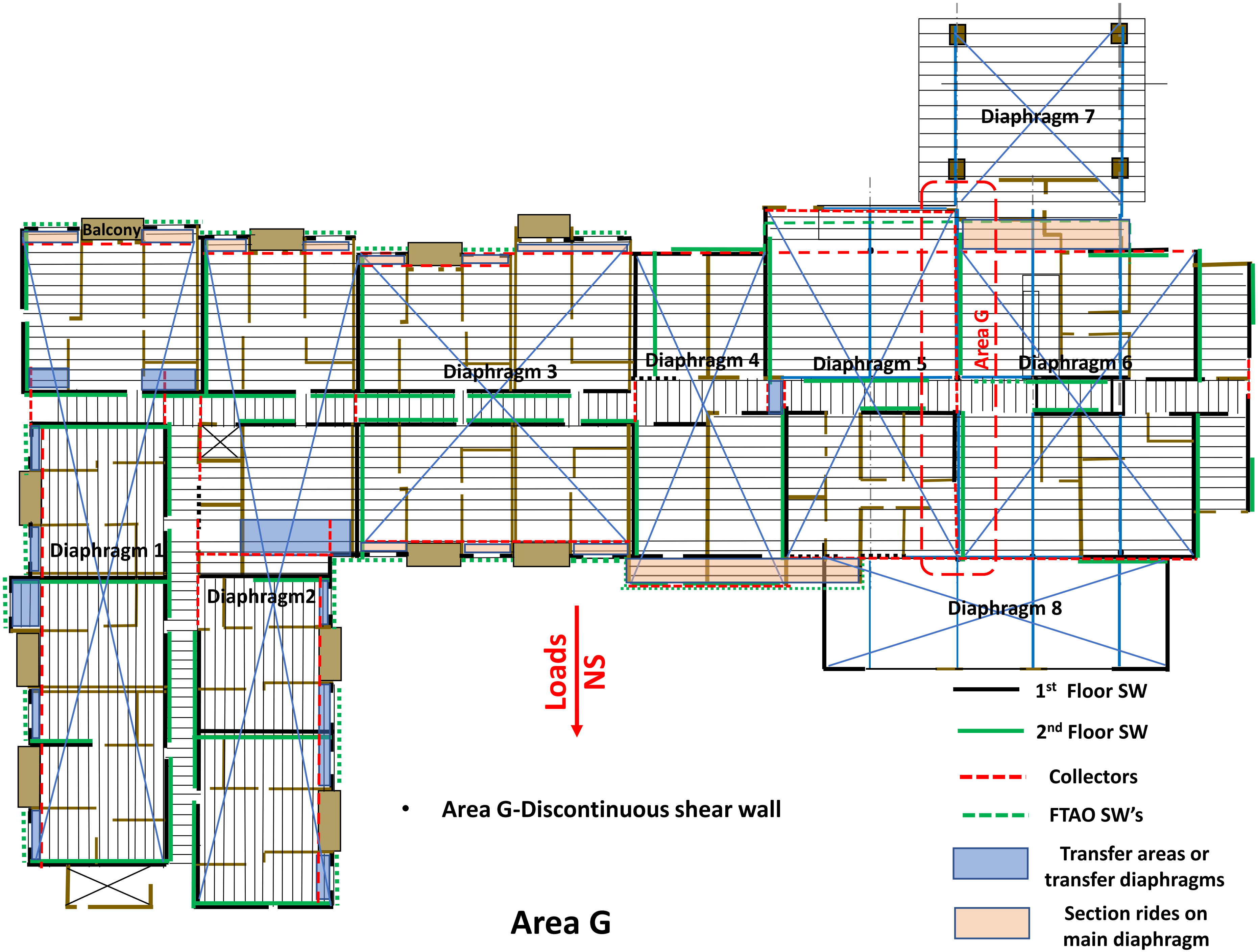


- Area D-Development of interior chord
- Area F- Diaphragm tension chord

Areas D and F

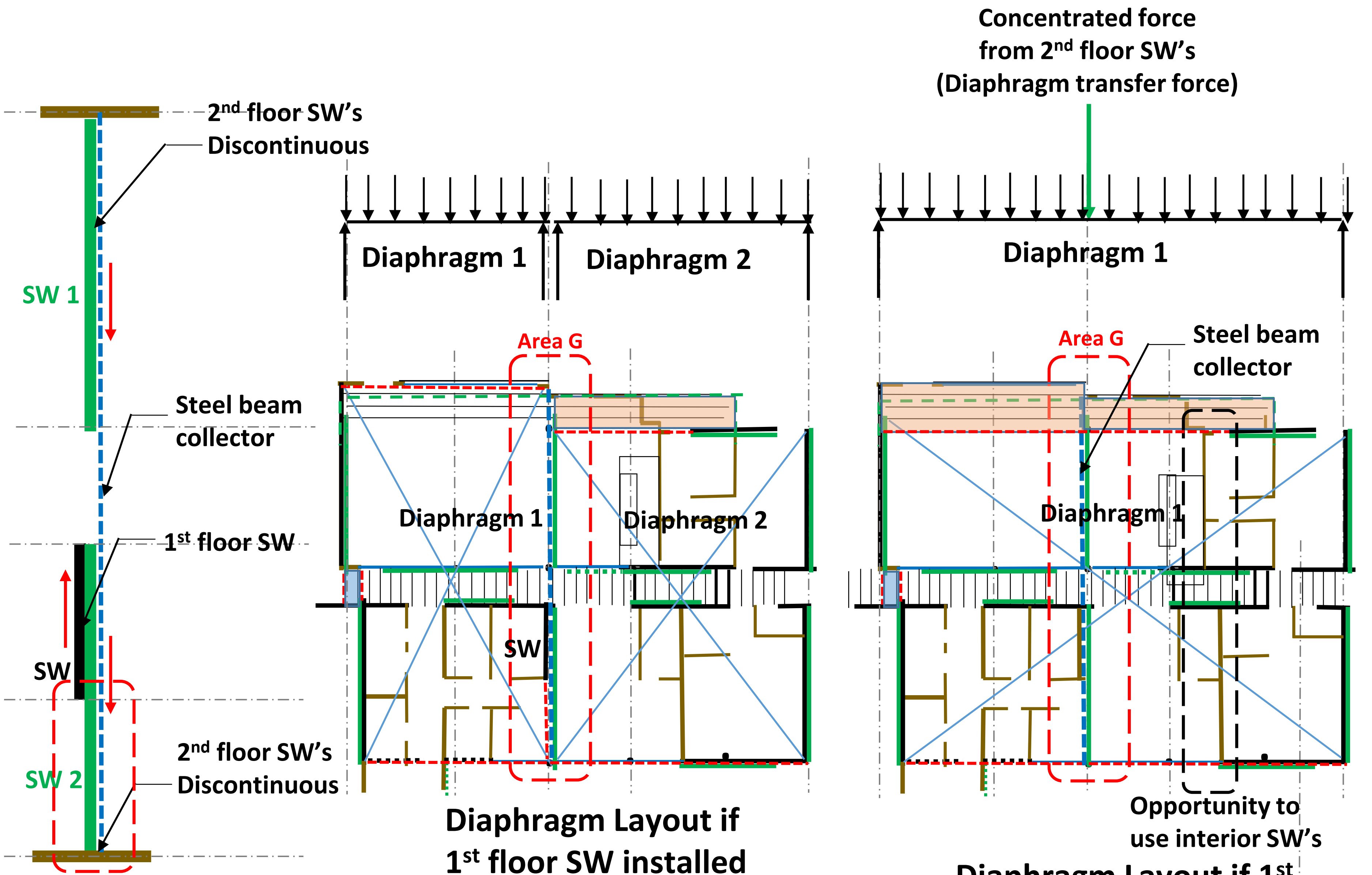


Engineers choice to plot force diagram- Not needed, simple diaphragms
Steel beam acts as chord
These sections ride on main diaphragm, will change diaphragm chord forces slightly
2nd Flr overhang
Area D
Loads NS
These sections ride on main diaphragm, will change diaphragm chord forces slightly
Splice all joints (Force by statics)
Tension chord (Typ.)
Alternate SW's
2nd floor framing overhang and shear walls
Discontinuous shear walls
Area F



- Area G-Discontinuous shear wall

Area G

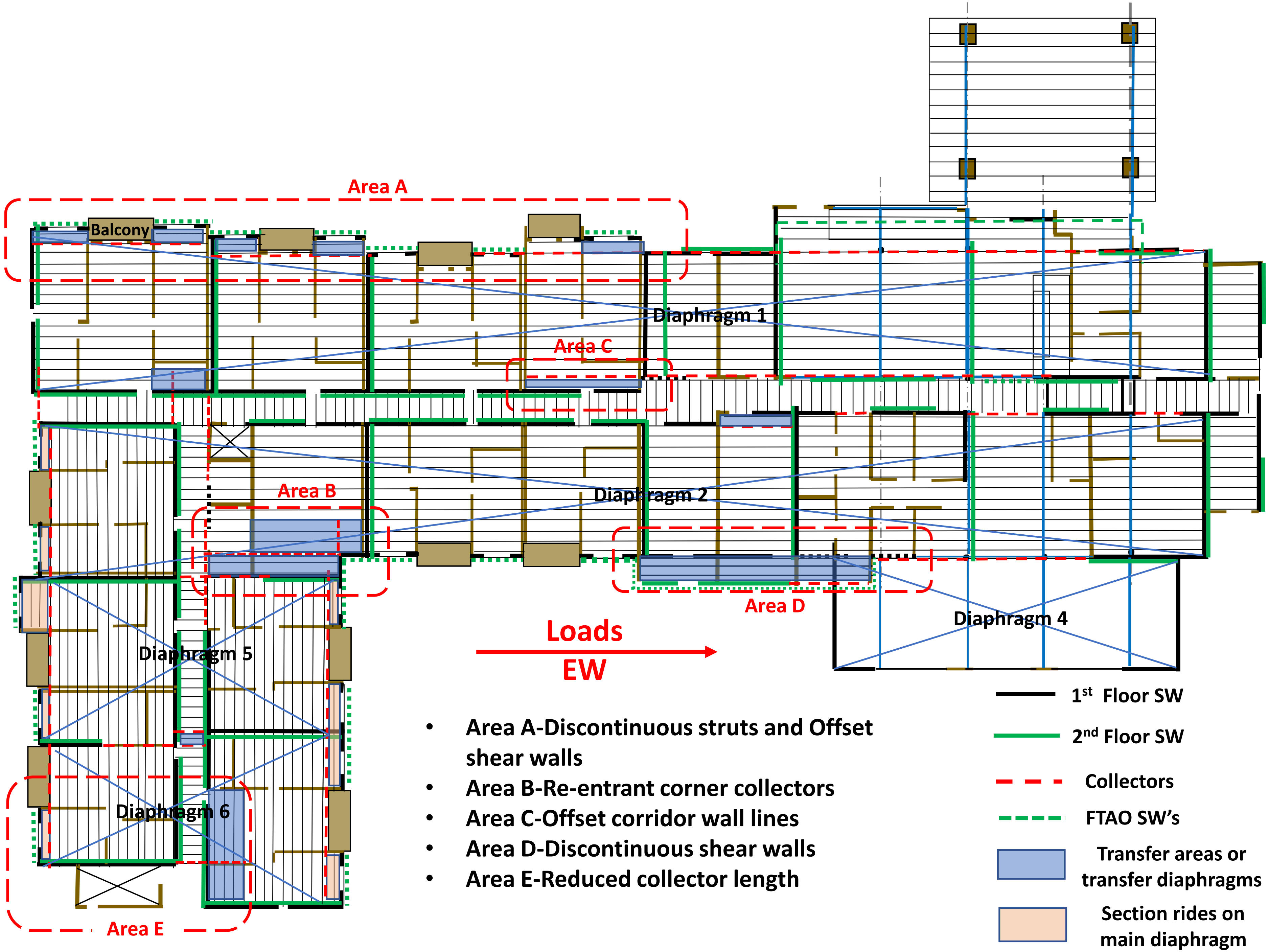


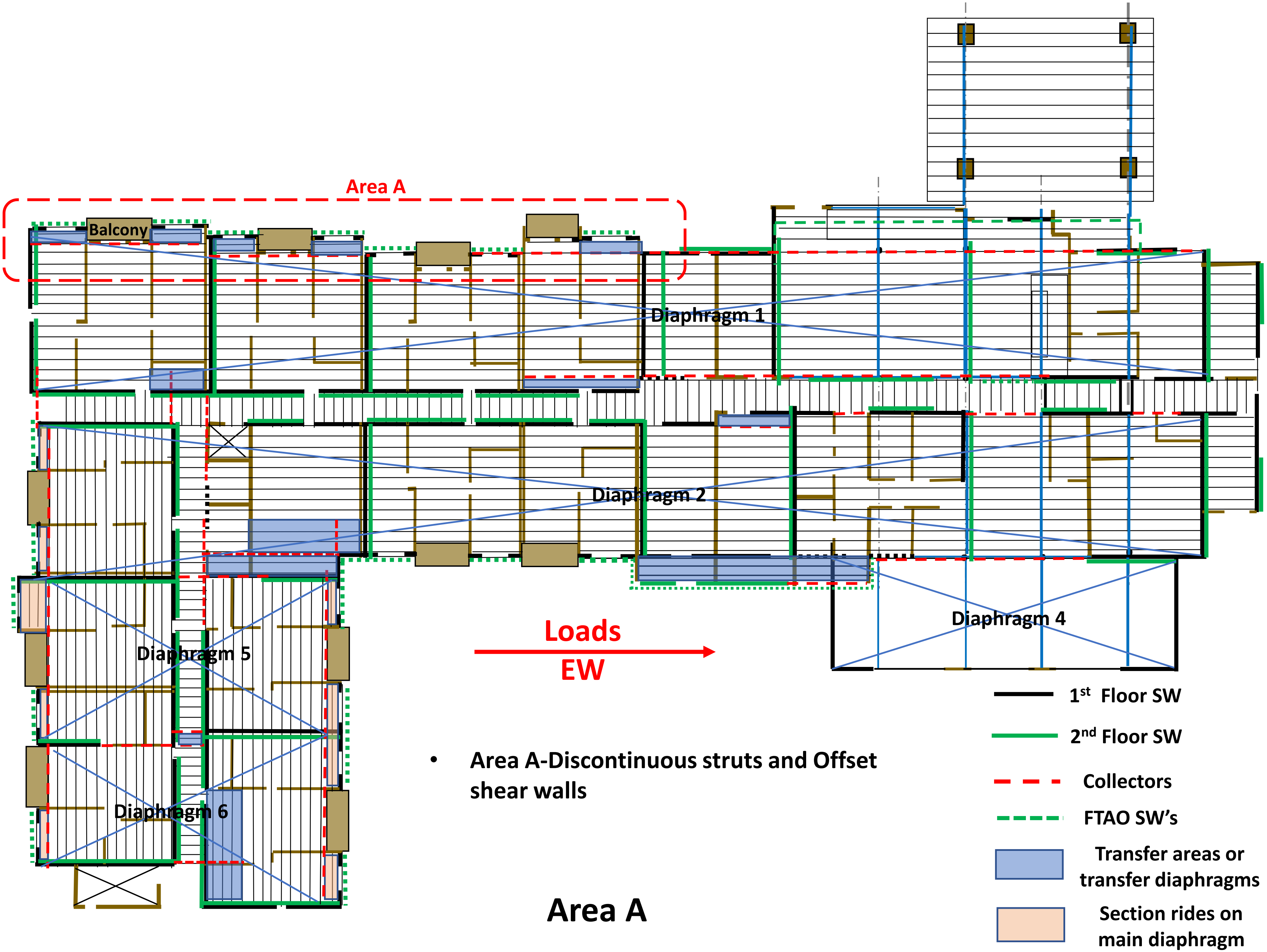
Area G

Diaphragm Layout if 1st floor SW not installed

ASCE 7-16:

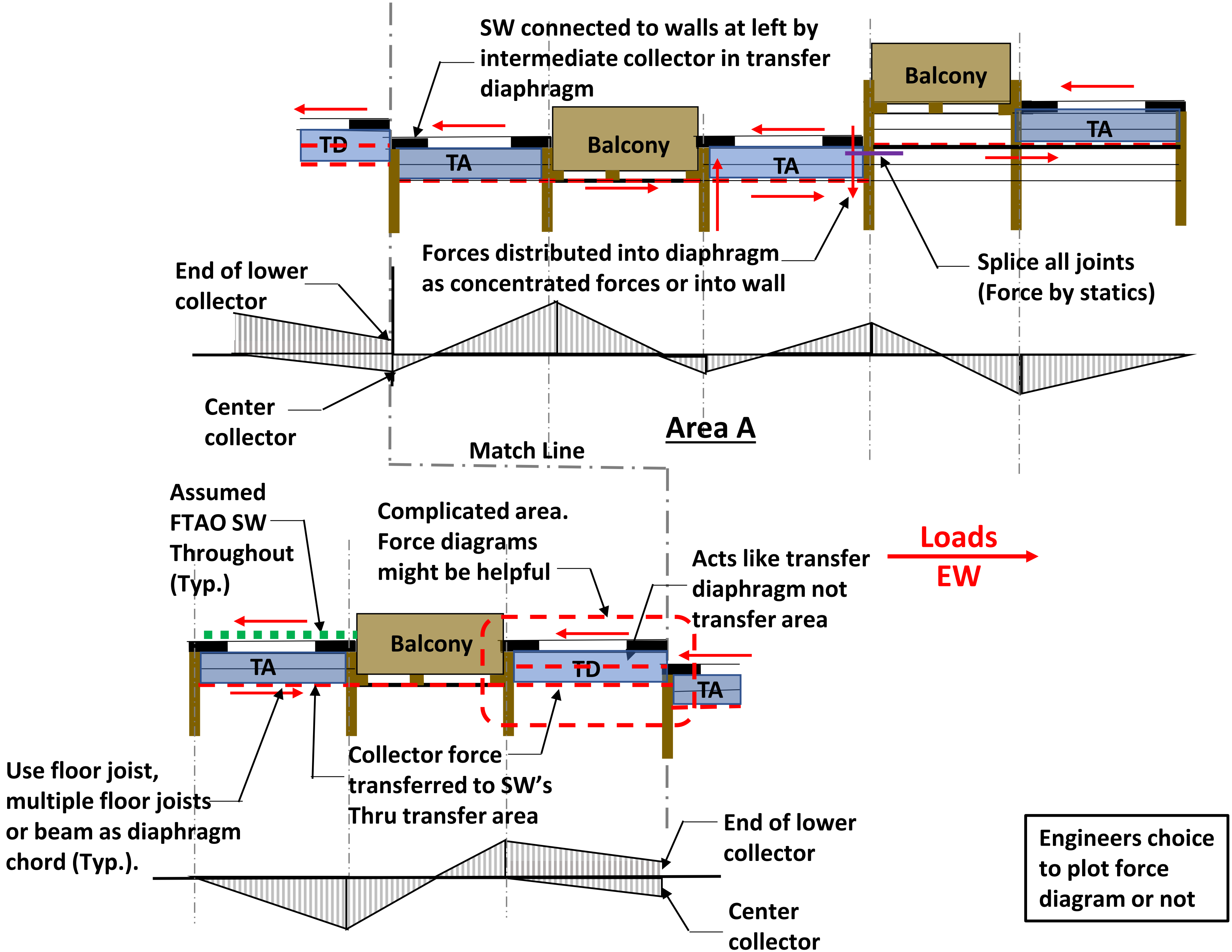
- 12.3.3.3-Discontinuous SW, SDC B-F
- 12.3.3.4-Increase forces, SDC D-F
- 12.10.1.1-Diaphragm inertial design forces, transfer forces

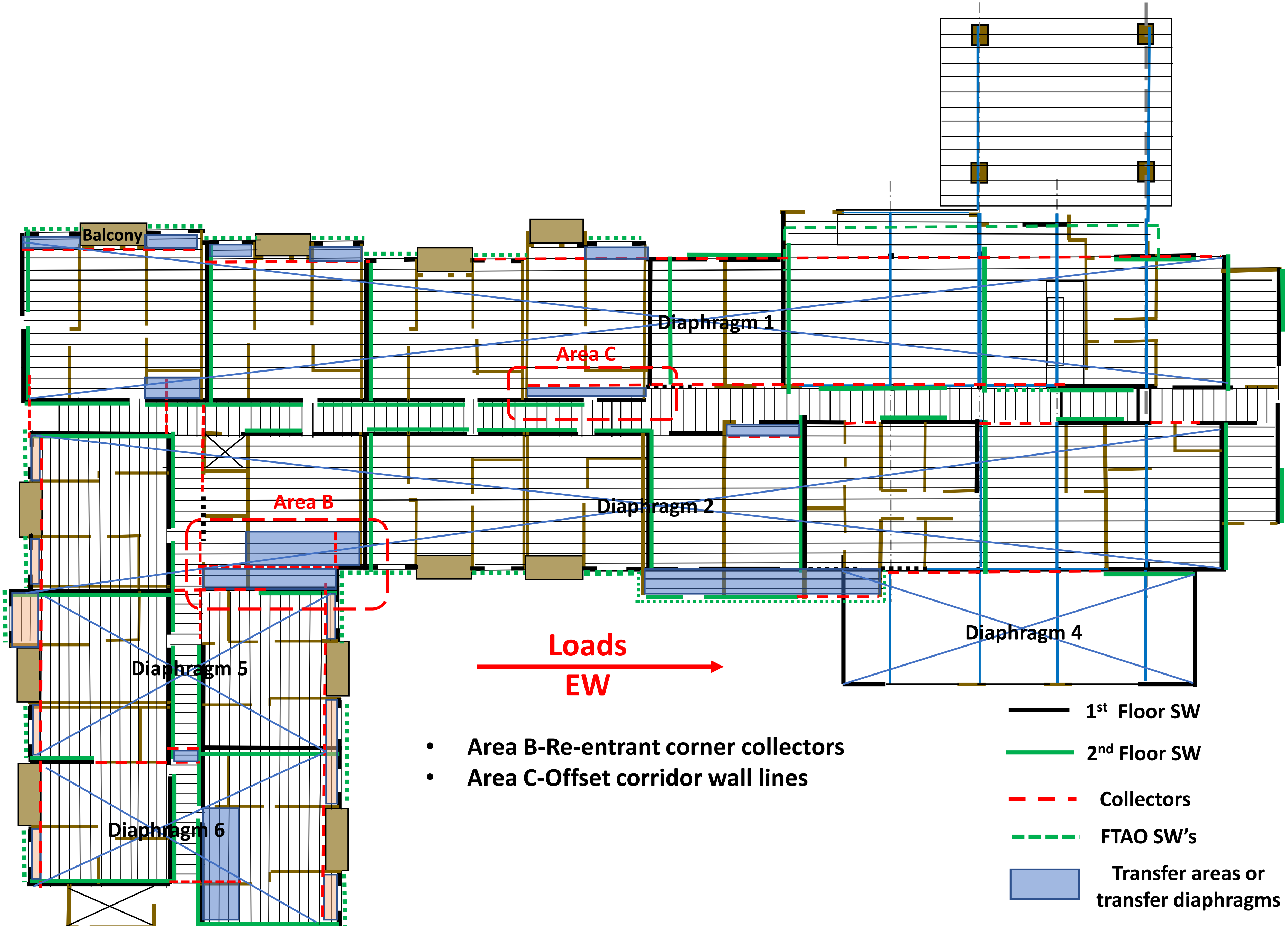

Area A
Balcony
Diaphragm 1
Area C
Diaphragm 2
Area B
Area D
Diaphragm 4
Loads
EW
Diaphragm 5
Diaphragm 6
Area E
• Area A-Discontinuous struts and Offset shear walls
• Area B-Re-entrant corner collectors
• Area C-Offset corridor wall lines
• Area D-Discontinuous shear walls
• Area E-Reduced collector length
1st Floor SW
2nd Floor SW
Collectors
FTAO SW's
Transfer areas or transfer diaphragms
Section rides on main diaphragm



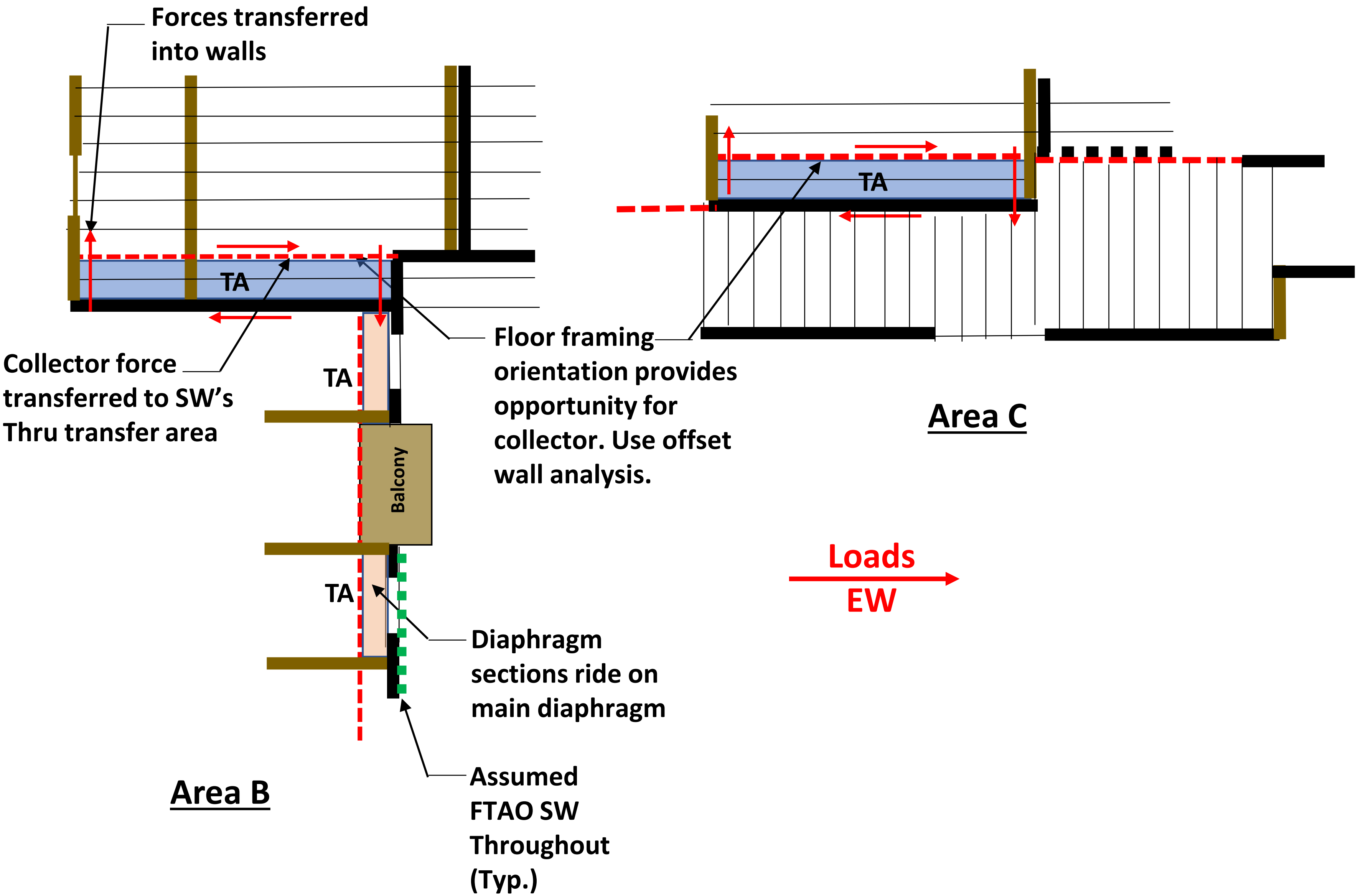
- **Area A-Discontinuous struts and Offset shear walls**

Area A


SW connected to walls at left by intermediate collector in transfer diaphragm
TD
TA
Balcony
TA
Balcony
TA
End of lower collector
Forces distributed into diaphragm as concentrated forces or into wall
Splice all joints (Force by statics)
Center collector
Area A
Match Line
Assumed FTAO SW Throughout (Typ.)
Complicated area. Force diagrams might be helpful
Acts like transfer diaphragm not transfer area
Loads
EW
TA
Balcony
TD
TA
Use floor joist, multiple floor joists or beam as diaphragm chord (Typ.).
Collector force transferred to SW's Thru transfer area
End of lower collector
Center collector
Engineers choice to plot force diagram or not

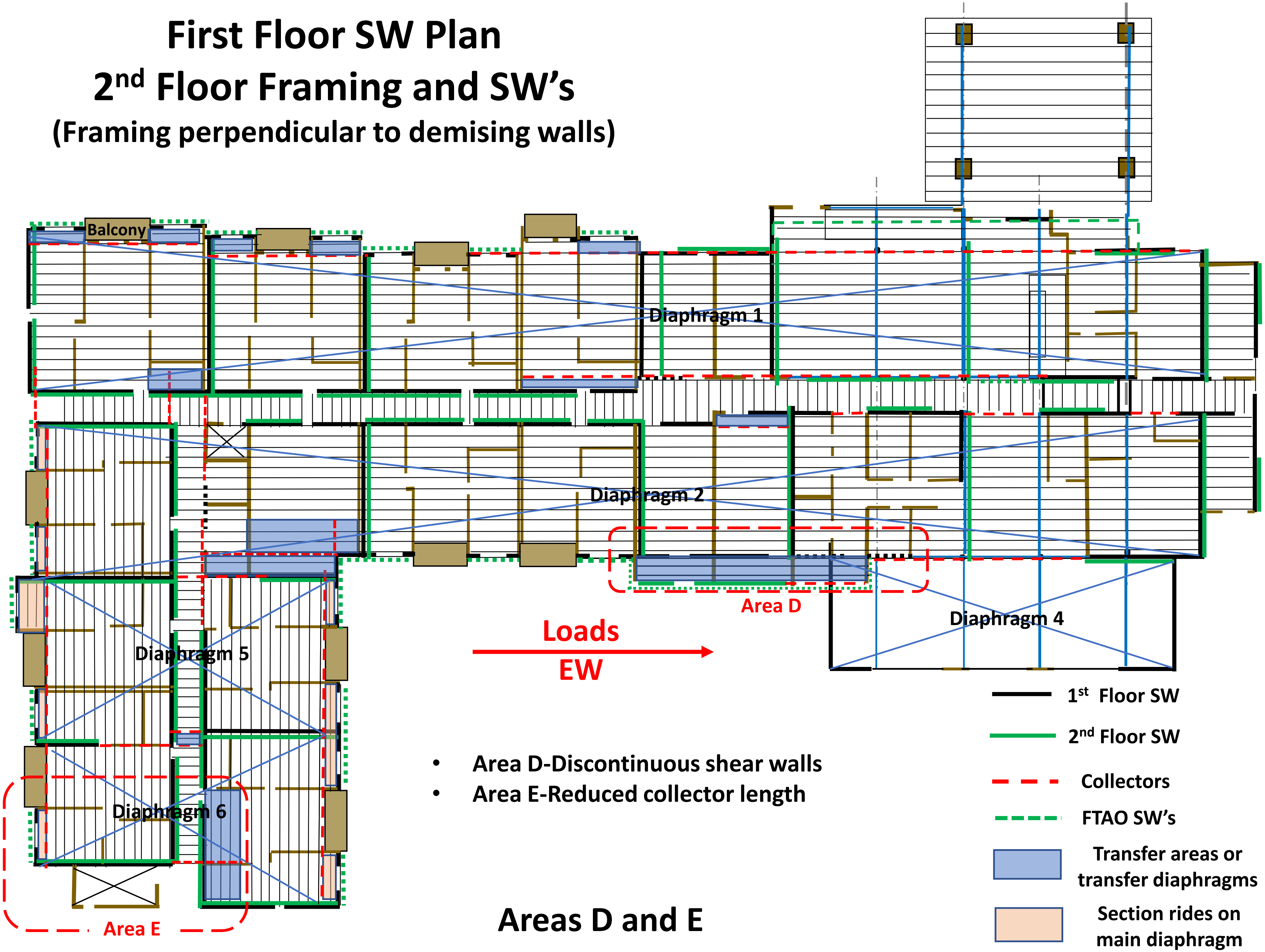

Balcony
Diaphragm 1
Area C
Area B
Diaphragm 2
Diaphragm 4
Diaphragm 5
Diaphragm 6
Loads
EW
• Area B-Re-entrant corner collectors
• Area C-Offset corridor wall lines
1st Floor SW
2nd Floor SW
Collectors
FTAO SW's
Transfer areas or transfer diaphragms
Section rides on main diaphragm

Areas B and C



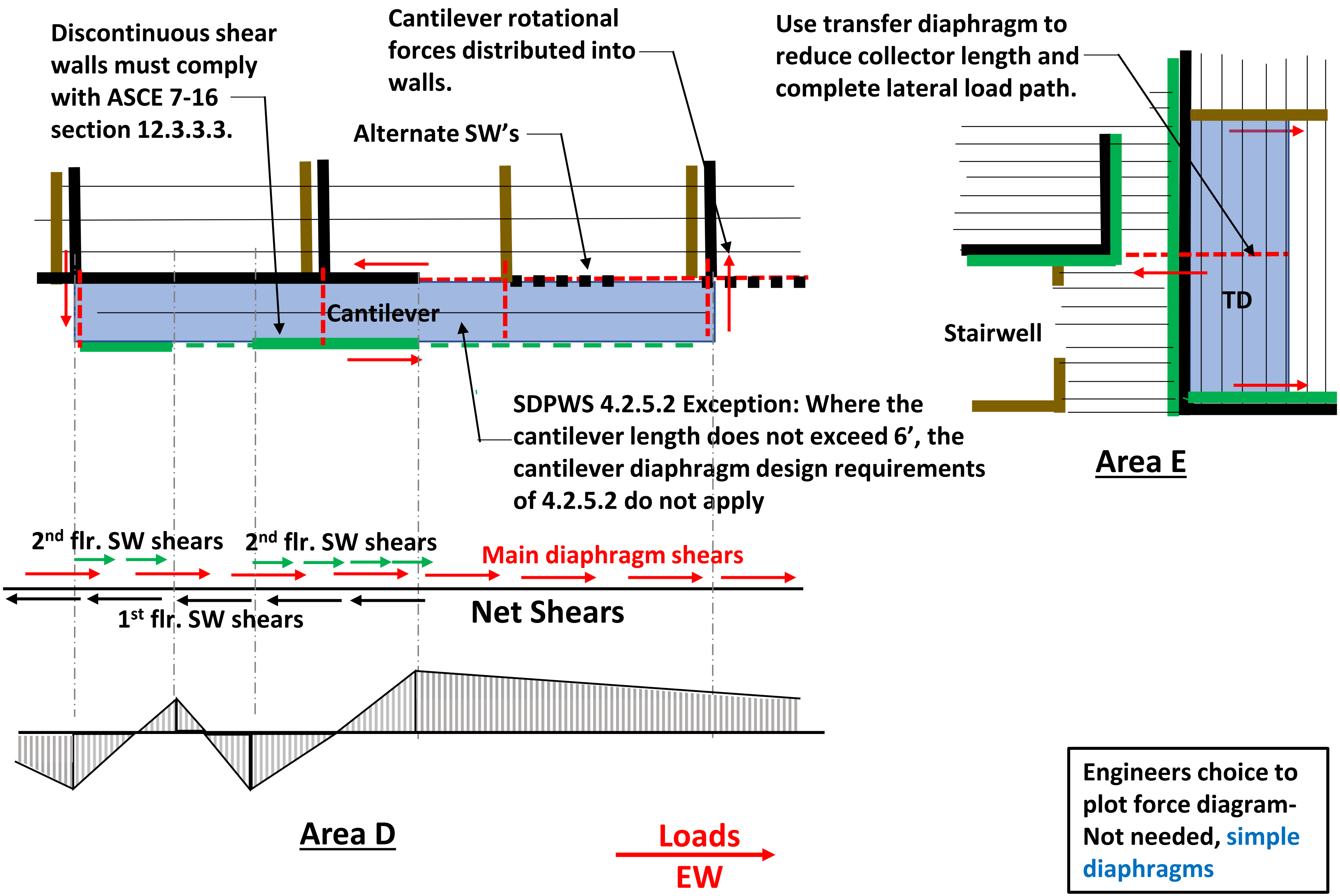
Forces transferred into walls
TA
Collector force transferred to SW's Thru transfer area
TA
Balcony
TA
Floor framing orientation provides opportunity for collector. Use offset wall analysis.
Diaphragm sections ride on main diaphragm
Assumed FTAO SW Throughout (Typ.)
Area B
TA
Area C
Loads
EW

First Floor SW Plan
2nd Floor Framing and SW's
(Framing perpendicular to demising walls)



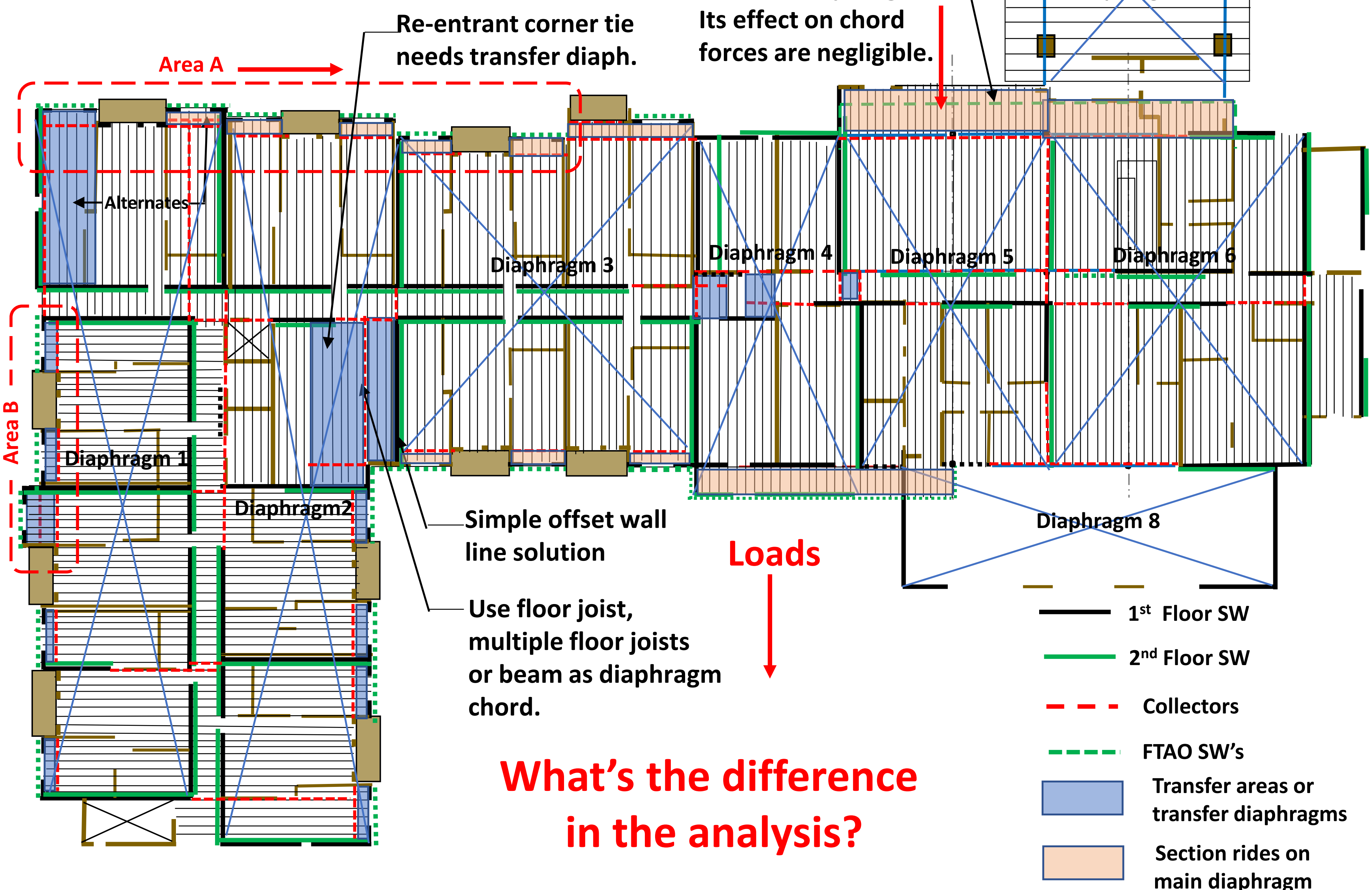
- Area D-Discontinuous shear walls
- Area E-Reduced collector length

Areas D and E

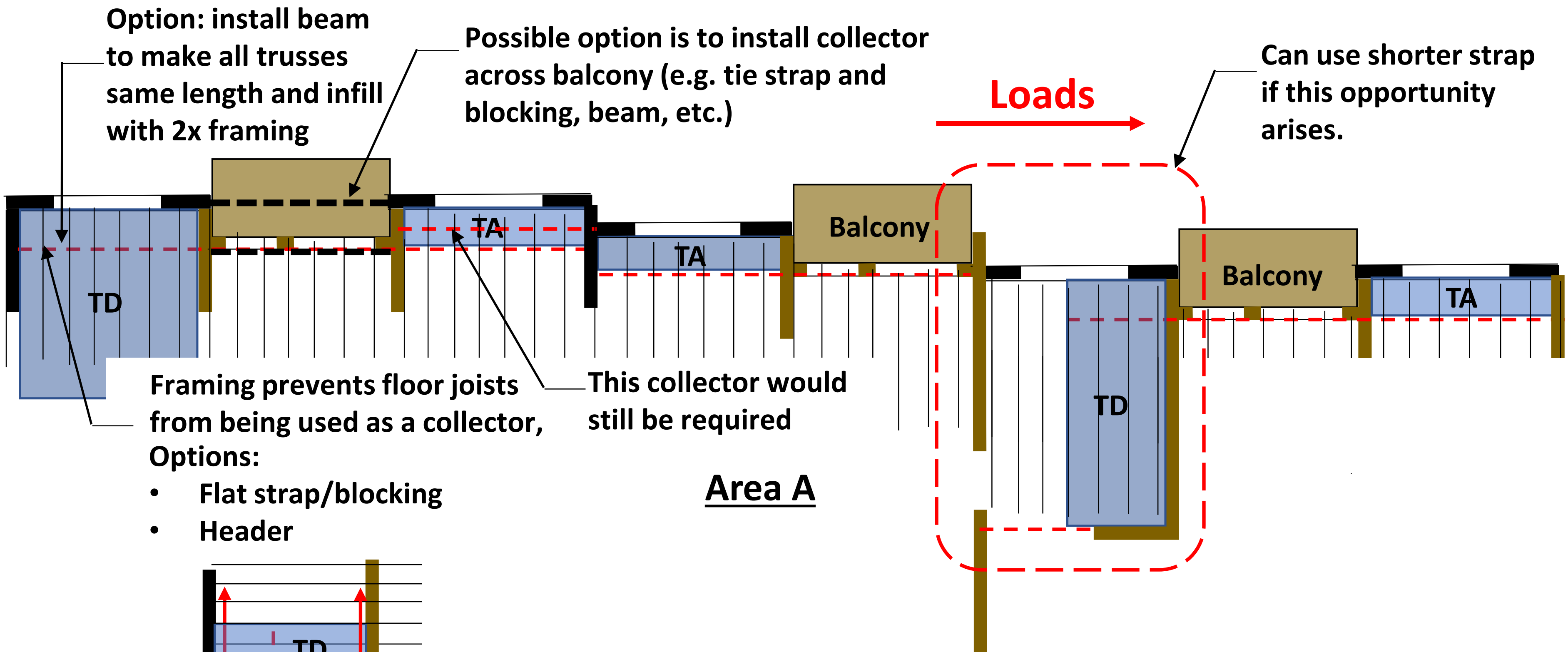

Discontinuous shear walls must comply with ASCE 7-16 section 12.3.3.3.
Cantilever rotational forces distributed into walls.
Alternate SW's
Use transfer diaphragm to reduce collector length and complete lateral load path.
Cantilever
TD
Stairwell
SDPWS 4.2.5.2 Exception: Where the cantilever length does not exceed 6', the cantilever diaphragm design requirements of 4.2.5.2 do not apply
Area E
2nd flr. SW shears
2nd flr. SW shears
Main diaphragm shears
Net Shears
1st flr. SW shears
Area D
Loads
EW
Engineers choice to plot force diagram- Not needed, simple diaphragms

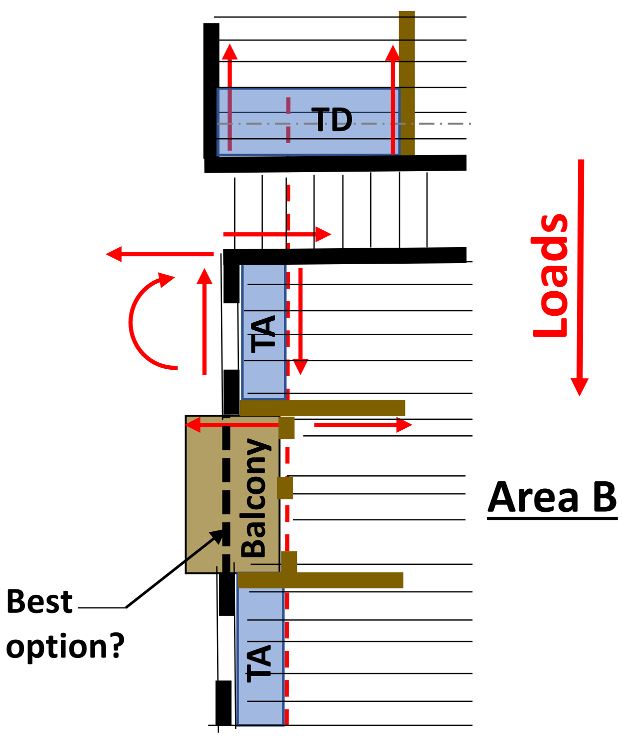
First Floor SW Plan, 2nd Floor Framing and SW's or Roof

(Framing parallel to demising walls)



What's the difference in the analysis?





- The framing orientation in this direction is commonly used at the roof but has also been used (on occasion) for floor framing.

- The lateral analysis for offset walls for this condition is the same as that for framing in the opposite direction, with the exception of what can be used for the collectors.

- Strap lengths will be longer (short straps connecting members across joint vs. longer strap/blocking.

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Q & A

The area of the plan under discussion is noted at the bottom of the slide.

Please note the area and direction of load, NS or EW, at the start of your question.

Example: “B-NS”… question

This concludes Woodworks Presentation on:

A Master Class on Wood Lateral-Resisting Systems

Your comments and suggestions are valued. They will make a difference.

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Thank You