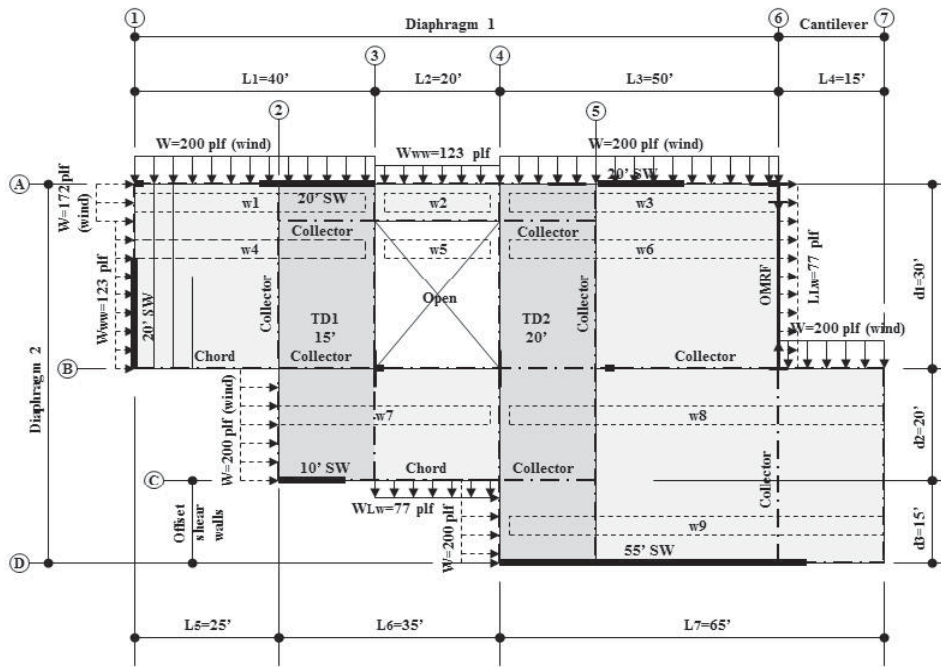


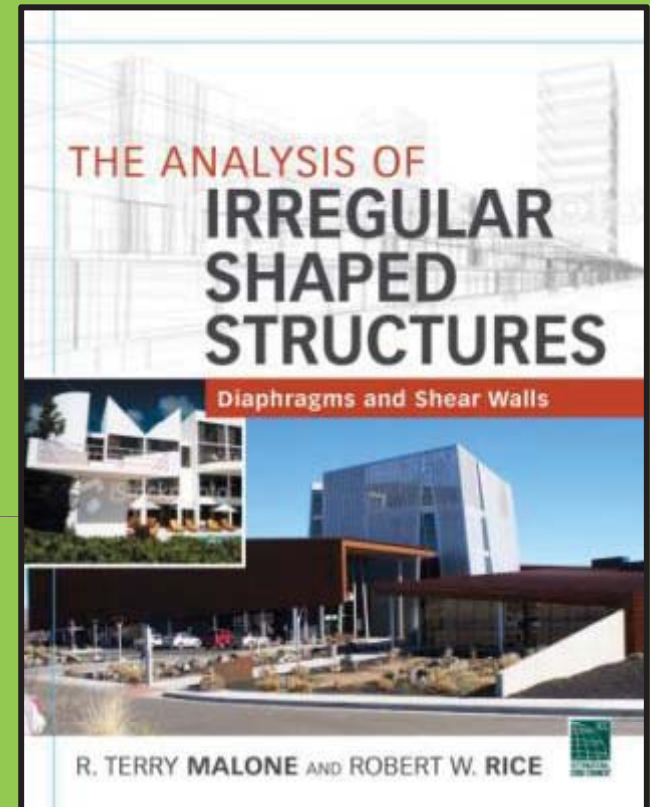


Part 2-Offset Shear Walls



Example-Complex Diaphragm

Based on:



Presentation updated to 2012 IBC, ASCE 7-10
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By: R. Terry Malone, PE, SE
Senior Technical Director
Architectural & Engineering
Solutions

terrym@woodworks.org



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Course Description

A continuation from Part 1, this session will cover how to conduct a preliminary breakdown of a complex diaphragm to better understand the distribution of forces within the diaphragm and assure that complete load paths are being established. Examples will be provided illustrating how to analyze in-plane and out-of-plane offset shear walls that are typically created by these diaphragms.



Learning Objectives

- **Segmentation of a Complex Diaphragm**

Discuss methods of breaking down and analyzing complex diaphragms into manageable segments.

- **In-plane and Out-of-plane Offset Shear Walls**

Discuss the various types of offset shear wall conditions.

- **Out-of-plane Offset Shear Walls**

Examine the method of analyzing a diaphragm with offset shear walls for loading in the longitudinal direction.

- **In-plane Offset Shear Walls**

Examine a two story offset shear wall with varying width.

Presentation Assumptions

Flexible wood sheathed or un-topped steel deck diaphragms
(Also applies to semi-rigid diaphragms)

- Loads to diaphragms and shear walls
 - Strength level or allowable stress design
 - Wind or seismic forces (UNO).
- The loads are already factored for the appropriate load combination.


Code References:

- ASCE 7-10 “Minimum Design Loads for Buildings and Other Structures”
- 2012 IBC

Design references:

- The Analysis of Irregular Shaped Structures: Diaphragms and Shear Walls-
Malone, Rice
- Design of Wood Structures- Breyer, Fridley, Pollock, Cobeen
- SEAOC Seismic Design Manual, Volume 2
- Wood Engineering and Construction Handbook-Faherty, Williamson
- Guide to the Design of Diaphragms, Chords and Collectors-NCSEA

Complete Example with narrative and calculations



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The Analysis of Irregular Shaped Diaphragms


© Tony Mahon, PE, SE • Senior Technical Director • WoodWorks

Several decades ago, the residential and commercial buildings being designed tended to be straightforward, rectangular structures with simple load-out lateral resisting systems. These structures had a minimum number of horizontal and vertical offsets. In contrast, the structural configurations of many modern buildings require complex lateral load paths that incorporate diaphragms at different elevations, multiple re-entrant corners, multiple irregularities and fewer vertical lateral force-resisting elements. It is important to address these design issues and irregularities to ensure complete load paths throughout the structure. However, this doesn't have to be a daunting task.

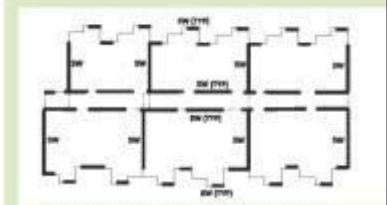
Knowledge regarding the analysis of complex diaphragm layouts varies greatly within engineering and code enforcement communities. In some cases, it has become standard practice to treat all structures as if they were simple rectangular diaphragms, and the absence of continuous load paths, presence of discontinuities, and existing elements such as chases, collectors and drag struts are commonly overlooked. This is largely due to the lack of concrete information on how to design complex diaphragms. While most relevant books and publications provide comprehensive coverage of simple rectangular diaphragms, there is very little guidance on how to analyze and design complex layouts. Further, methods of analysis for simple diaphragms do not easily adapt to the complex layouts in irregularly shaped structures. The purpose of this paper is to bridge that information gap by providing an overview of a method, based on simple statics, which can be used to analyze complex diaphragm structures, while guiding readers to more detailed information through the references.

Principles of Effective Diaphragm Design

Diaphragms, drag chills, collectors and shear walls function the same way regardless of whether the loads applied to the diaphragm are from wind, seismic, soil or other sources. Principles of engineered design require that complete load paths with adequate strength and stiffness be provided to transfer all forces from the point of origin to the final point of resistance. The 2012 *International Building Code* (IBC) describes this design principle in Section 1604.4, stating:

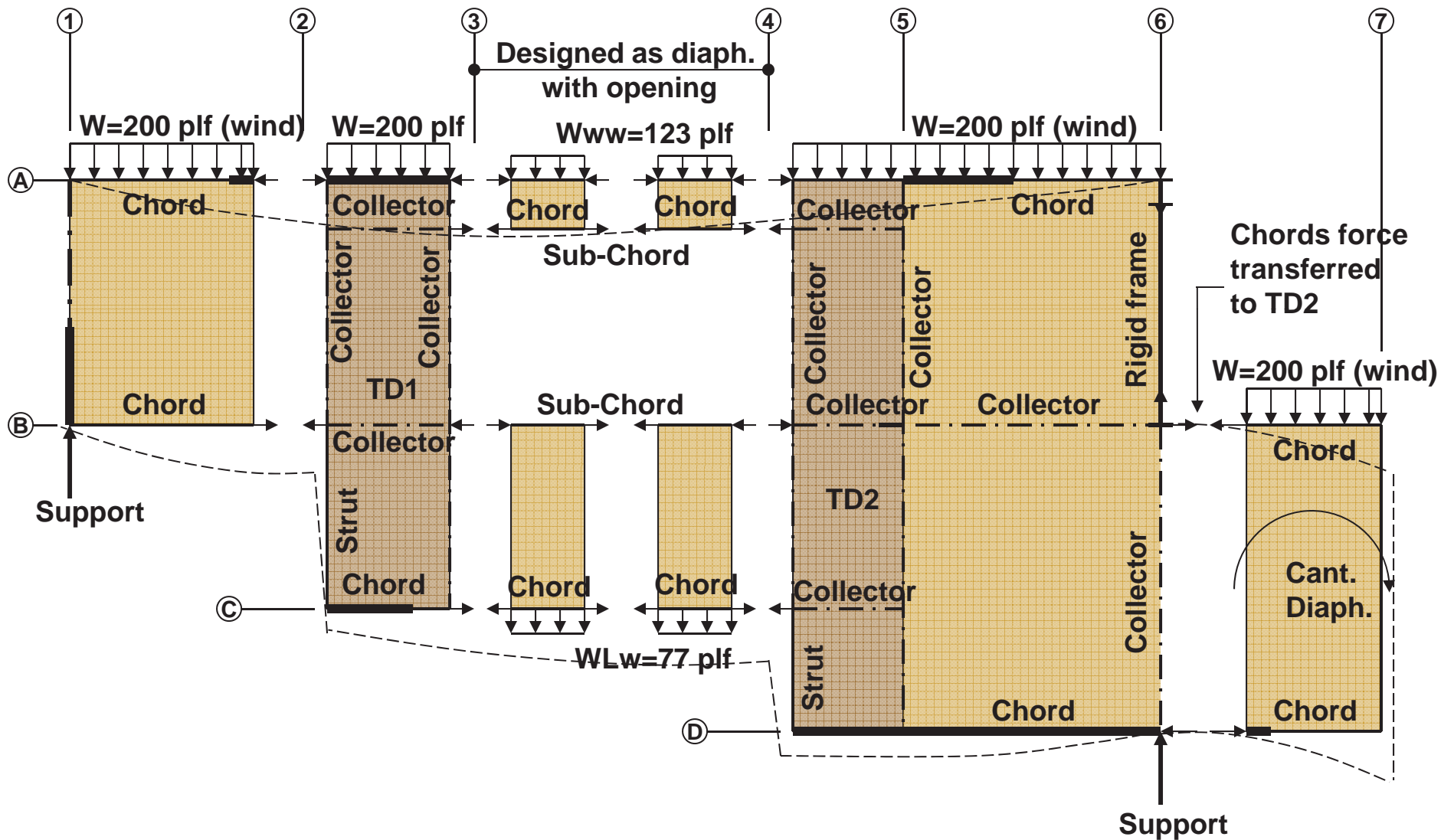


Massive Diaphragms
Five stories of wood construction plus a wood frame mezzanine over six levels of concrete, two of which are above ground. (Source: B&B Services, Inc. & Timberlake, LLC.)

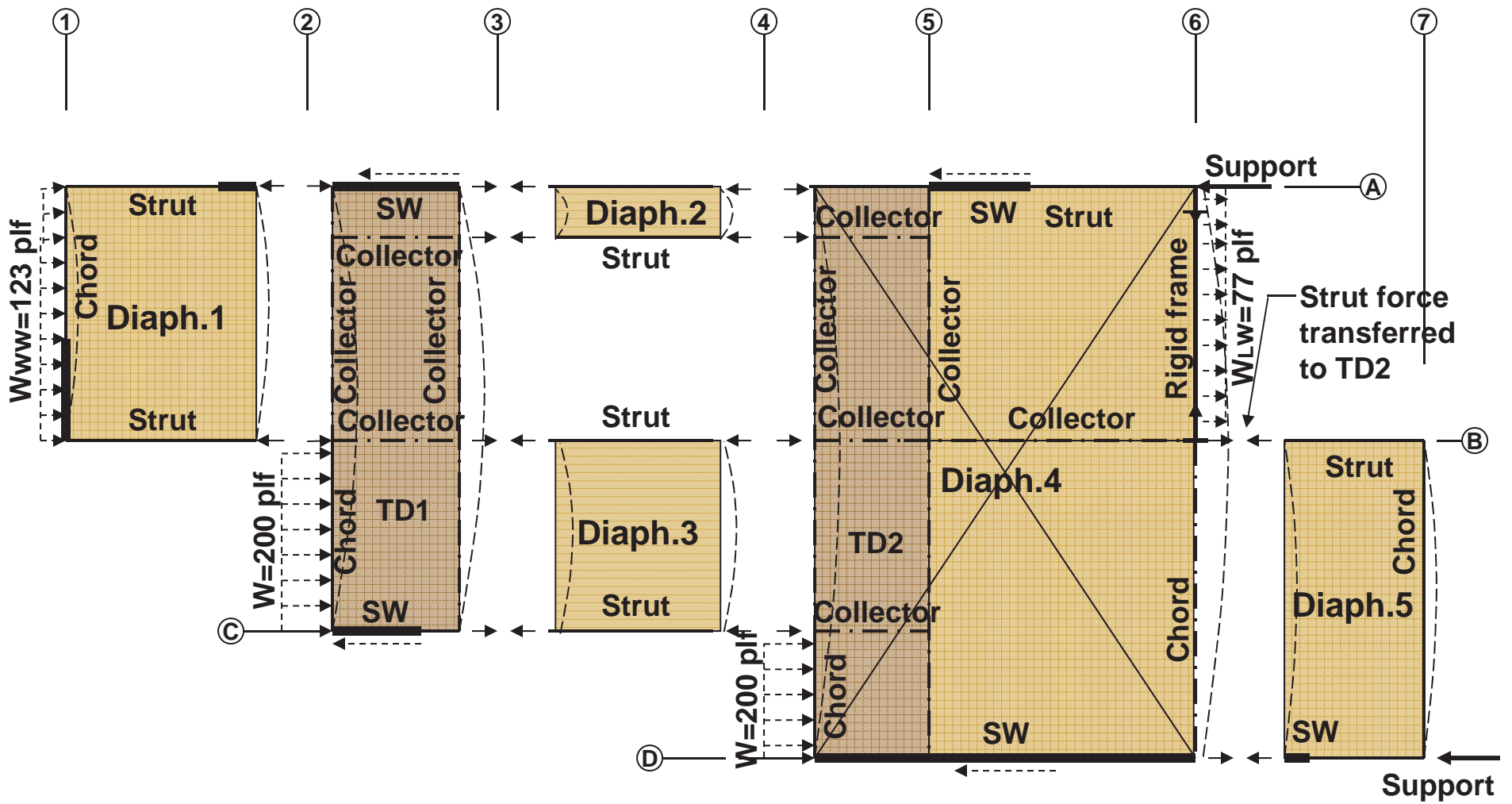


Typical plan with horizontal offsets in the diaphragm chills and struts.

<http://www.woodworks.org/education-publications/research-papers/#>

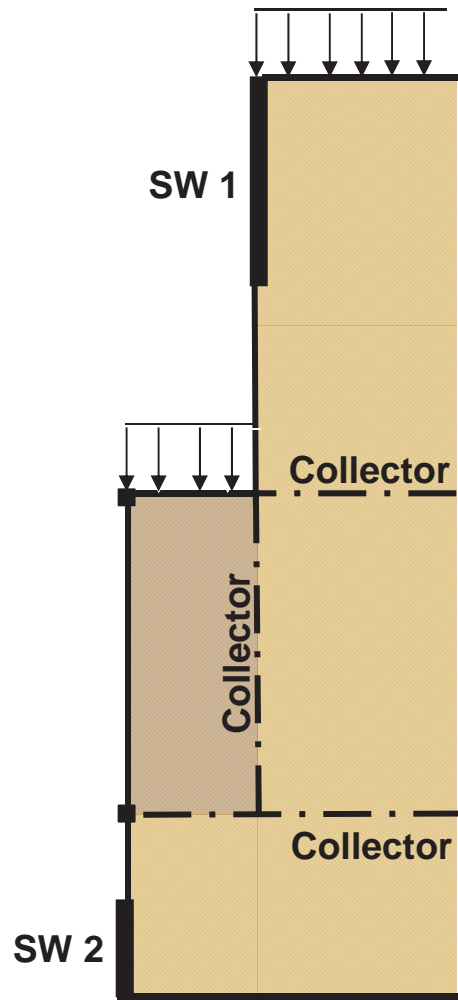


Segmentation of the Diaphragm for Transverse Loading

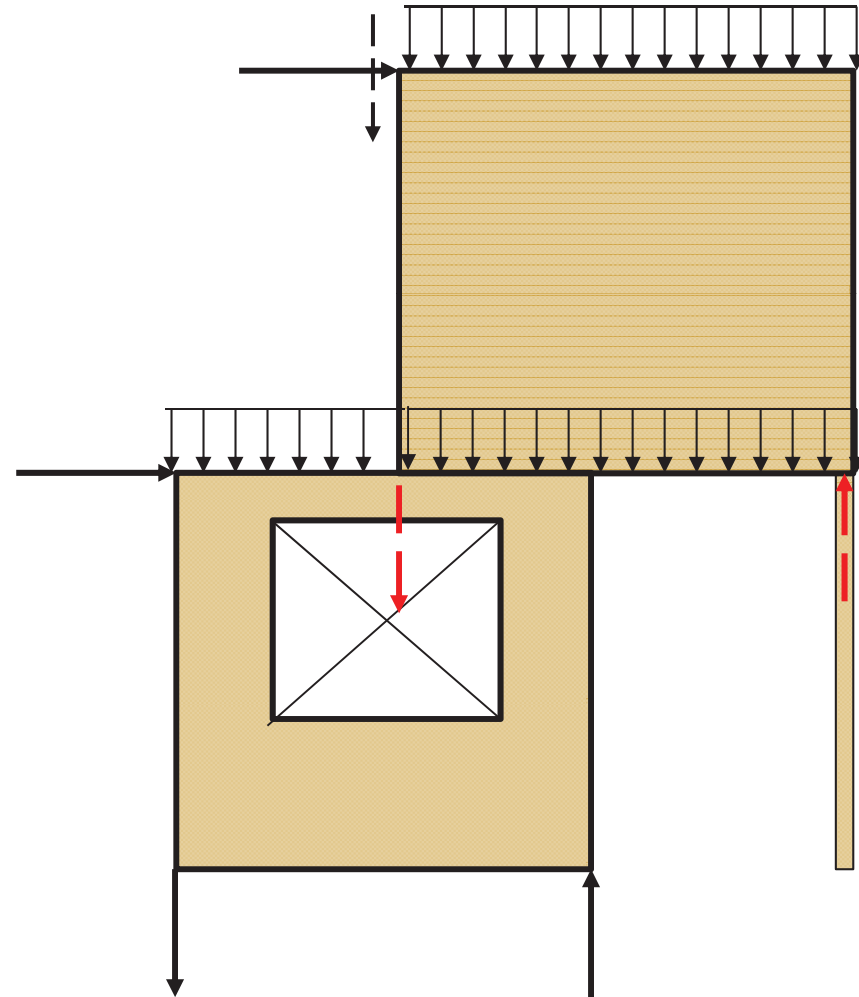


Segmentation of the Diaphragm for Longitudinal Loading

Offset Shear Walls



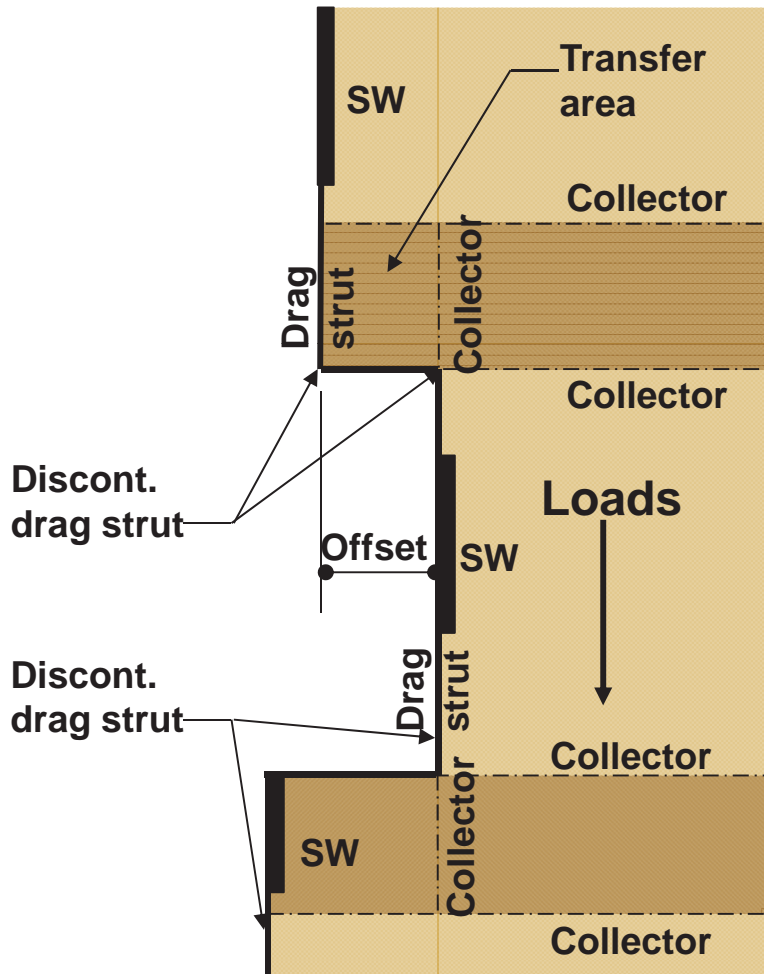
Out-of-plane Offsets



In-plane Offsets

Out-of-Plane Offset Shear Walls

Assumed to act in the Same Line of Resistance



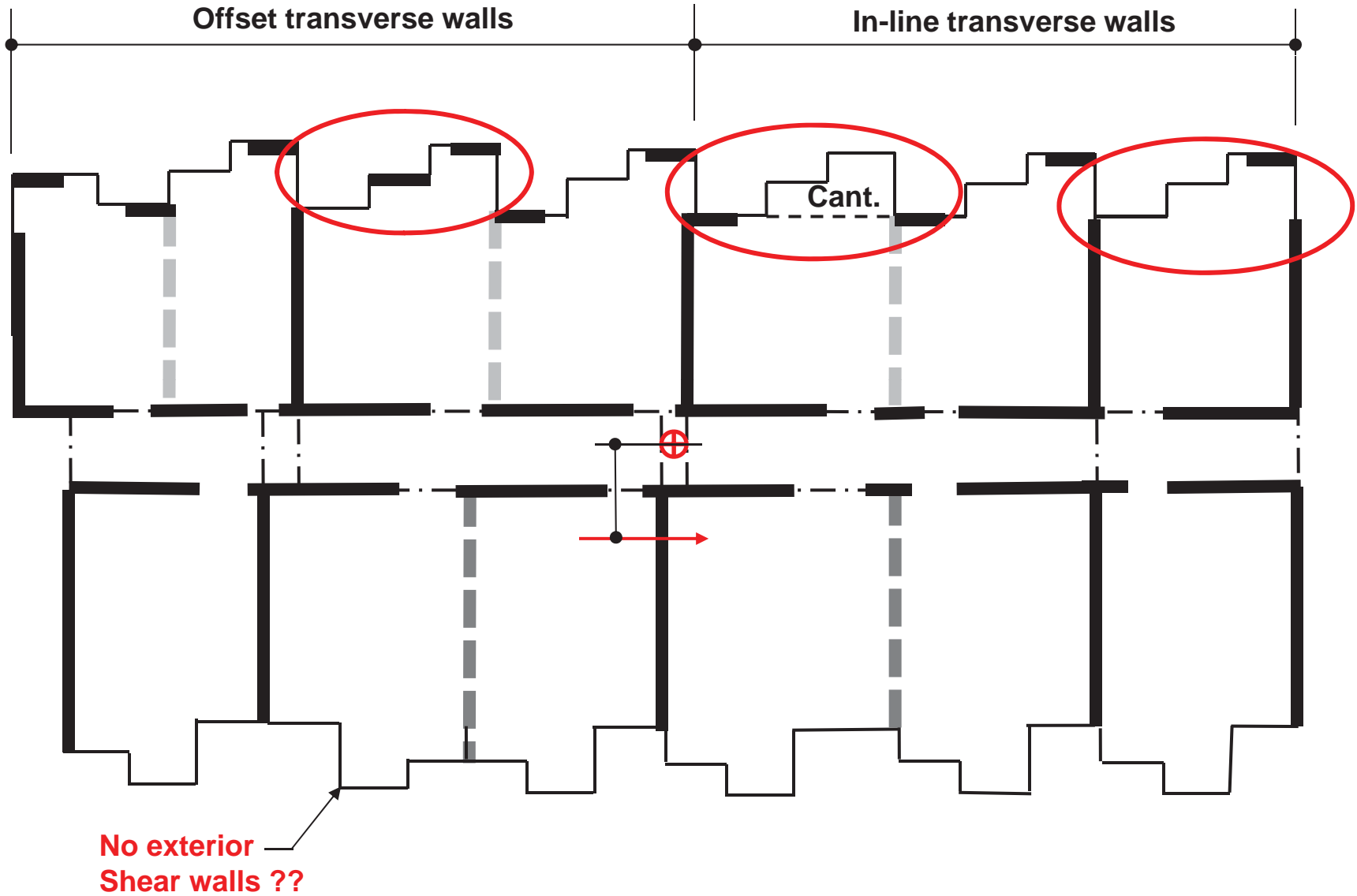
Typical mid-rise multi-family structure at exterior wall line

- Offset walls are typically assumed to act in the same line of lateral-force-resistance.
- Calculations are rarely provided showing how the walls are interconnected to act as a unit, or to verify that a complete lateral load path has been provided.
- Collectors are often not installed to transfer the disrupted forces across the offsets.

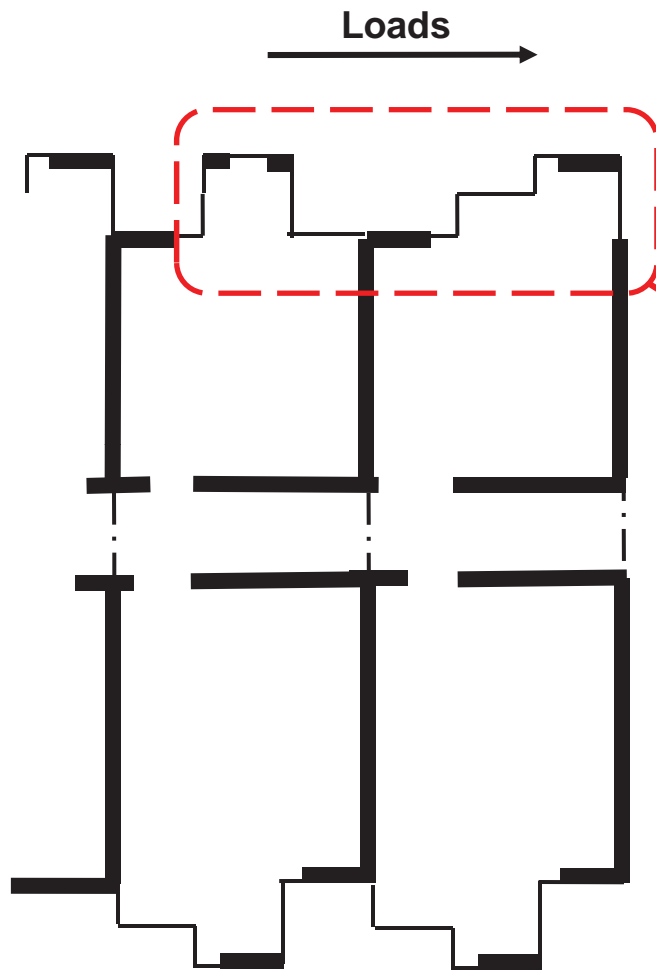
ASCE 7-10 Section 14.5.2

Where offset walls occur in the wall line, portions of the shear wall on each side of the offset shall be considered as separate shear walls unless provisions for force transfer around the offset are provided.

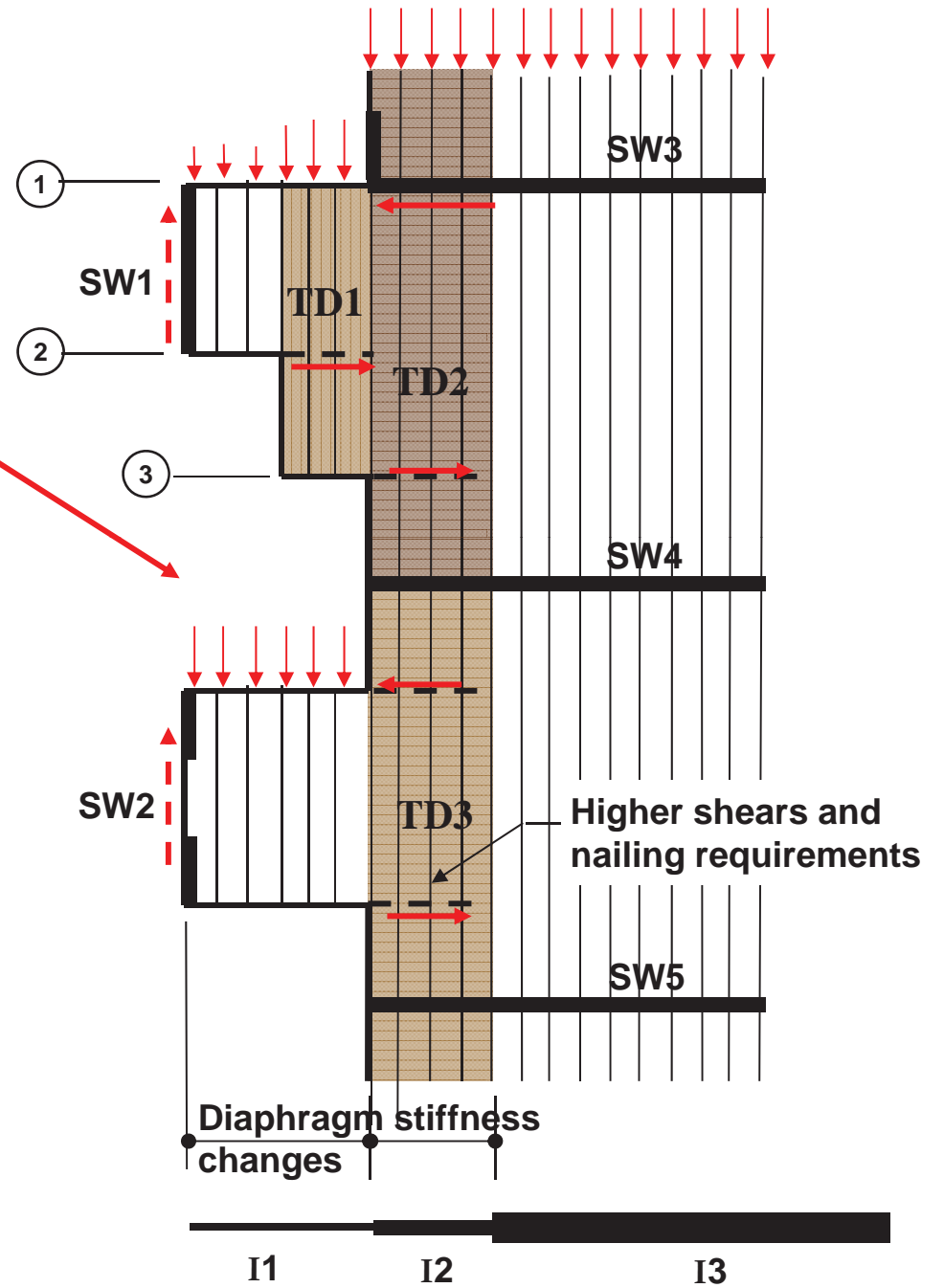
Longitudinal Loading



Flexible, semi-rigid, or rigid???

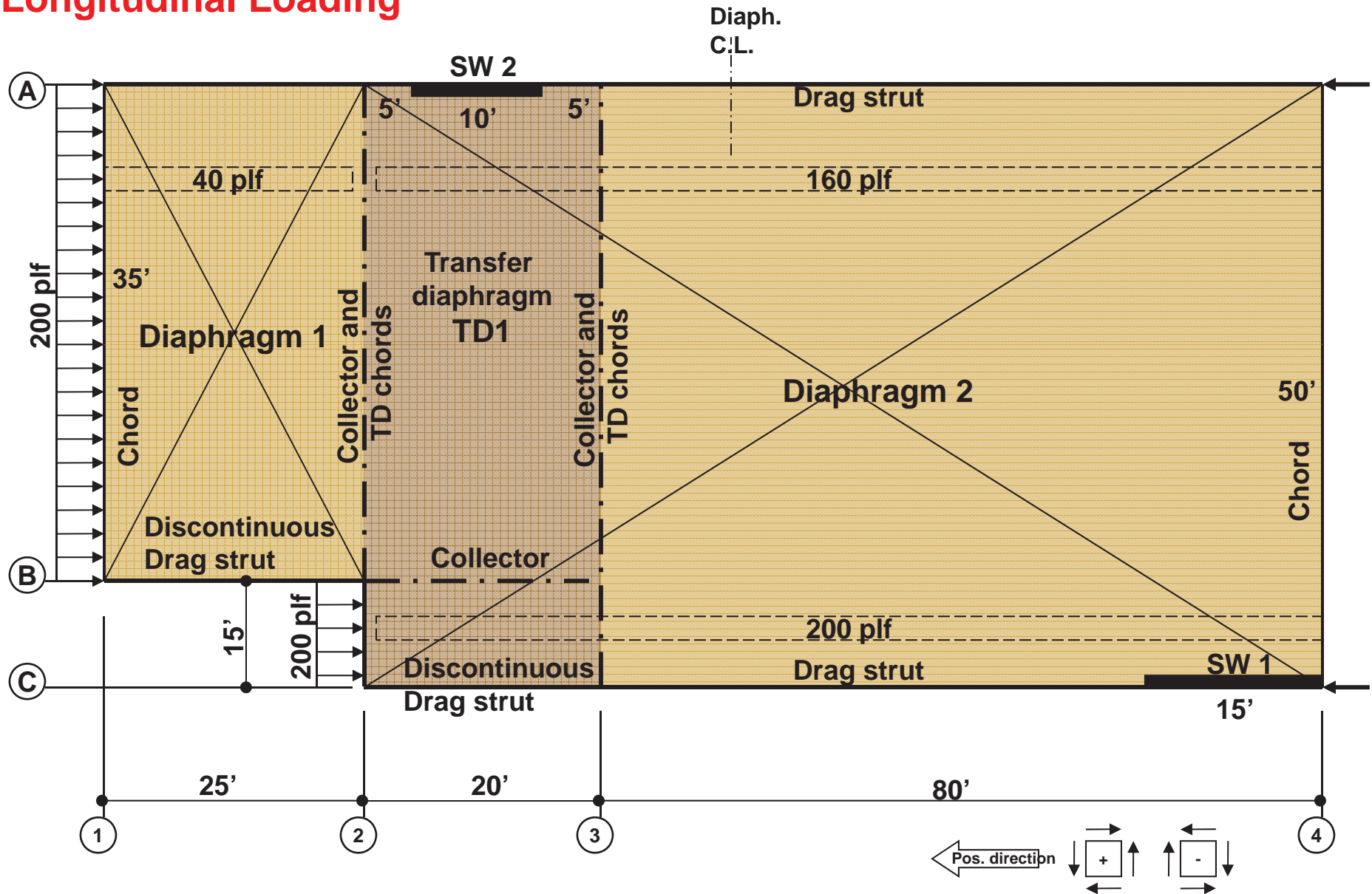


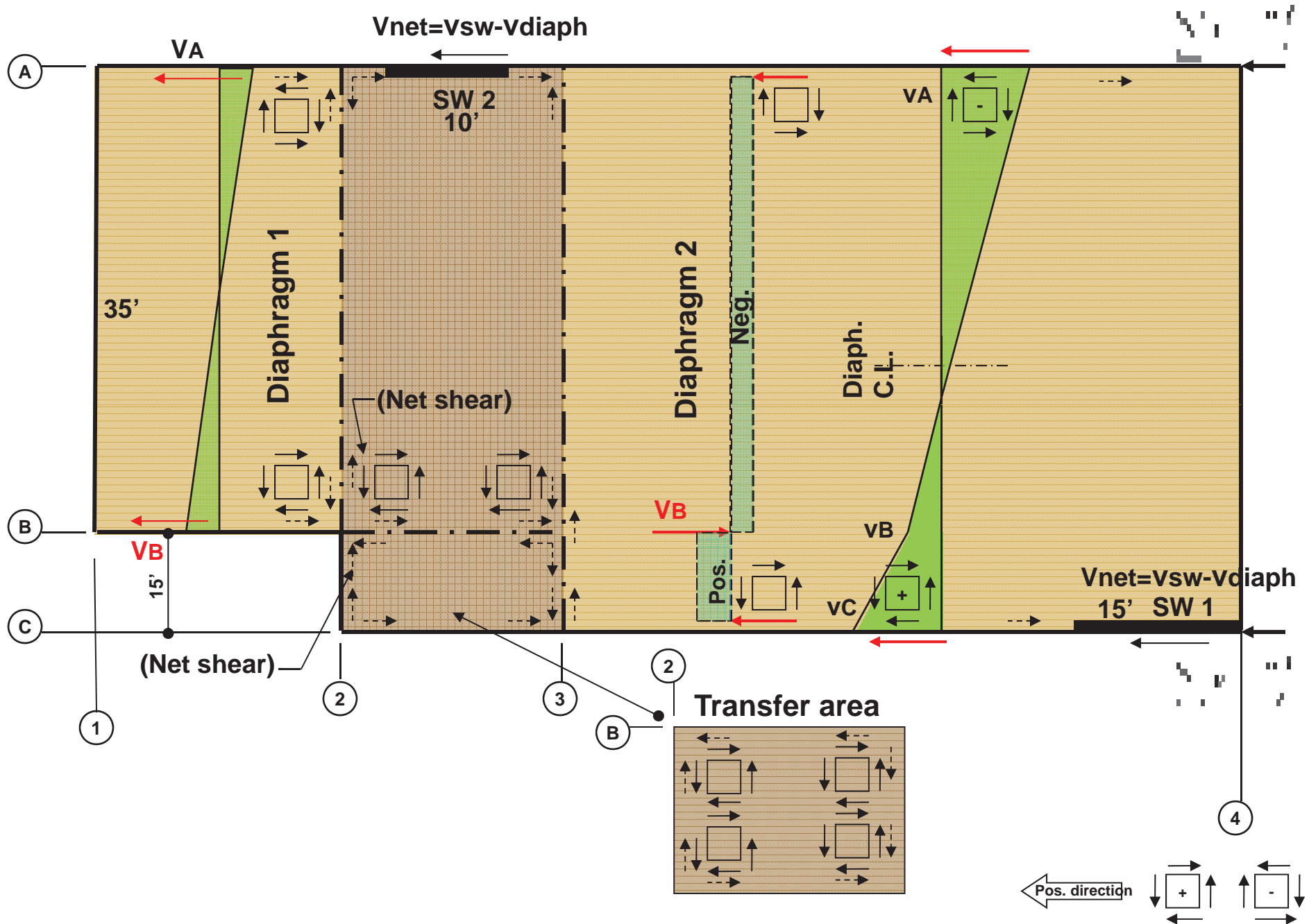
**Multi Story, Multi-family
Wood Structure**



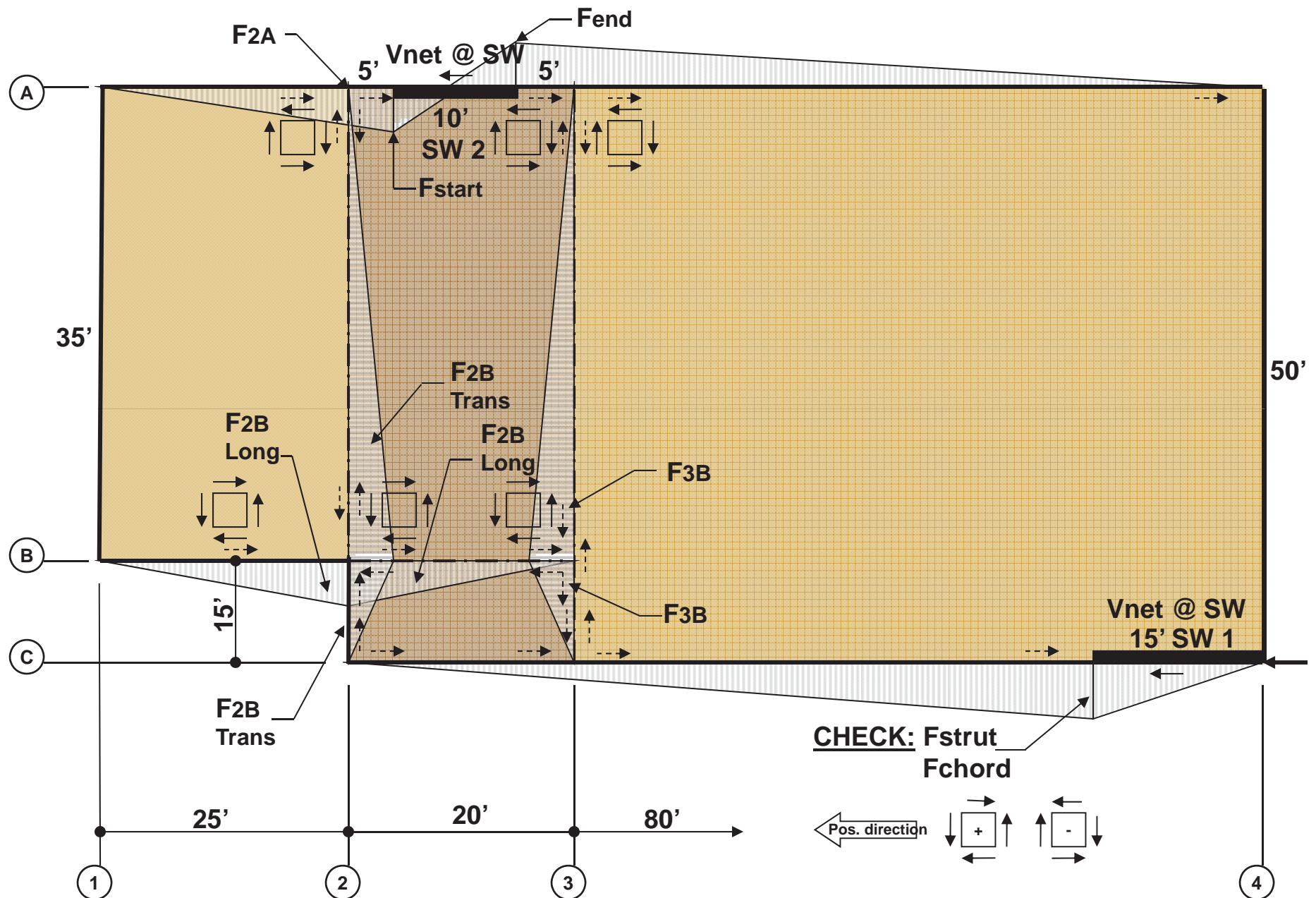
Example 2-Diaphragm with Horizontal End Offset

Longitudinal Loading



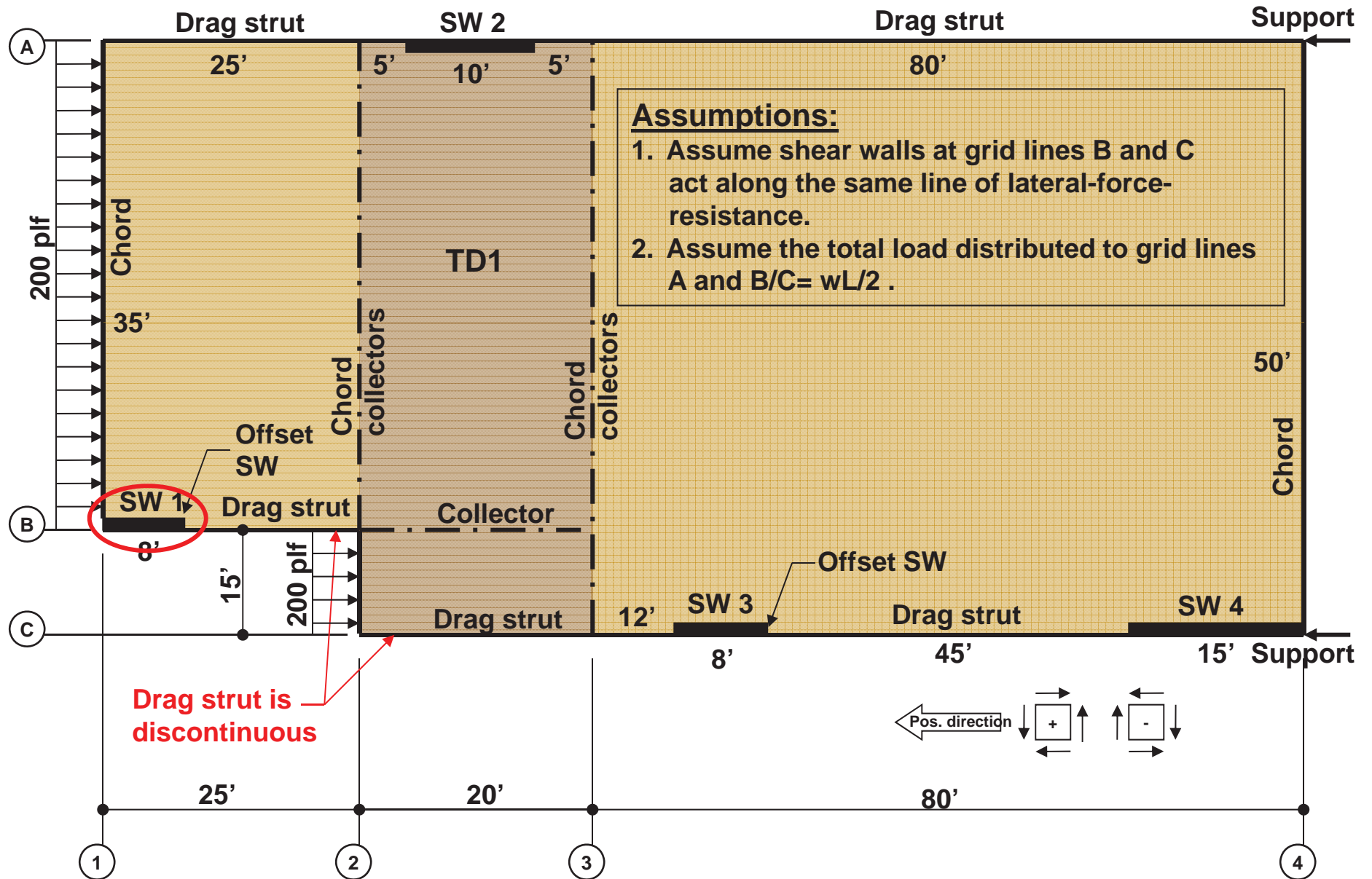


Transfer Diaphragm and Net Diaphragm Shear



Longitudinal and Transverse Collector/Strut Force Diagrams

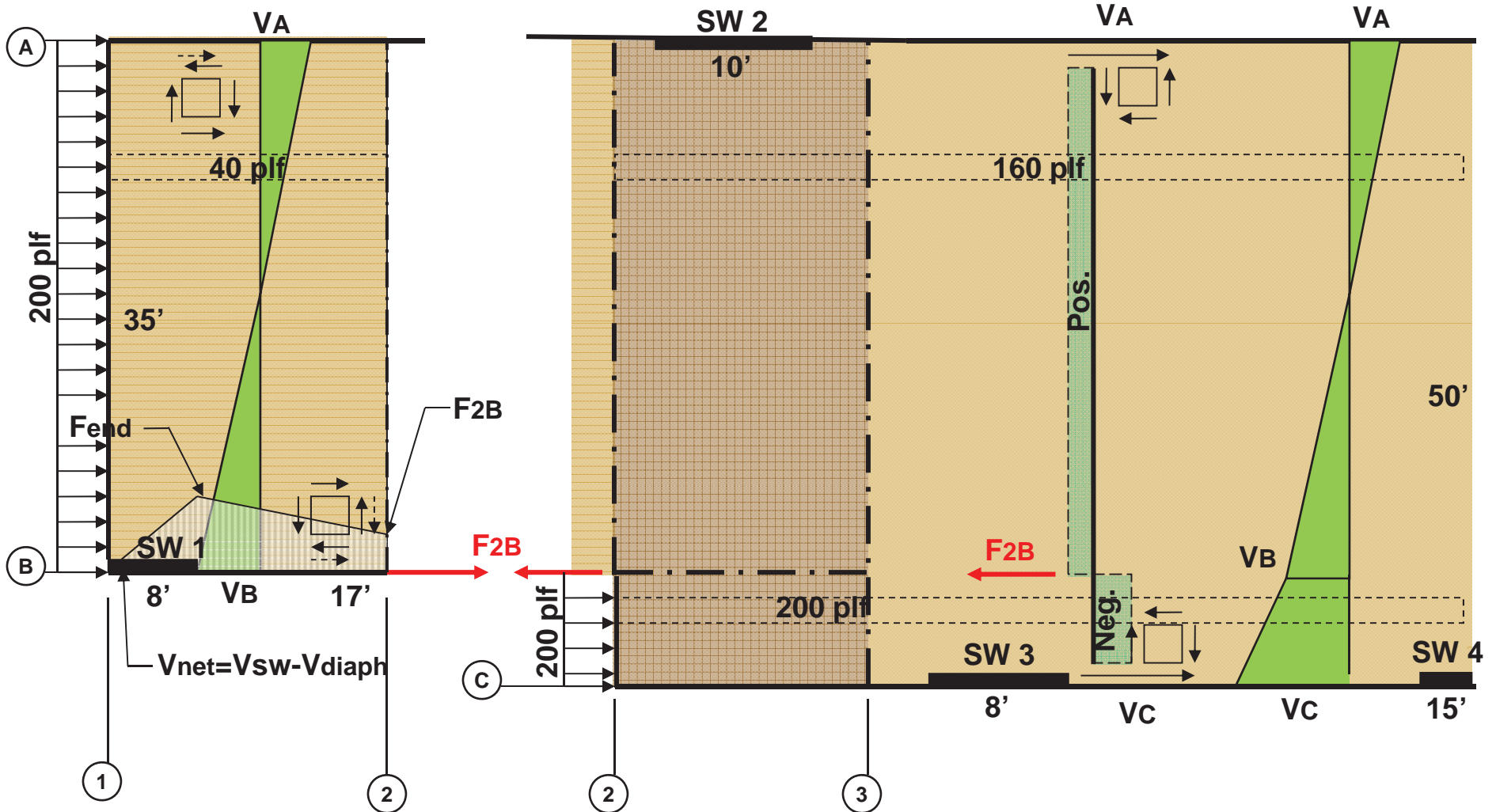
Example 3-Diaphragm with Horizontal End Offset Longitudinal Loading-Offset Shear Walls



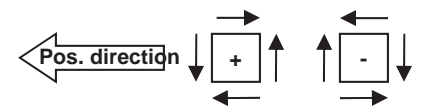
Total Shear to Shear Walls (Assumed)

$V_{sw2} = wL/2$ plf

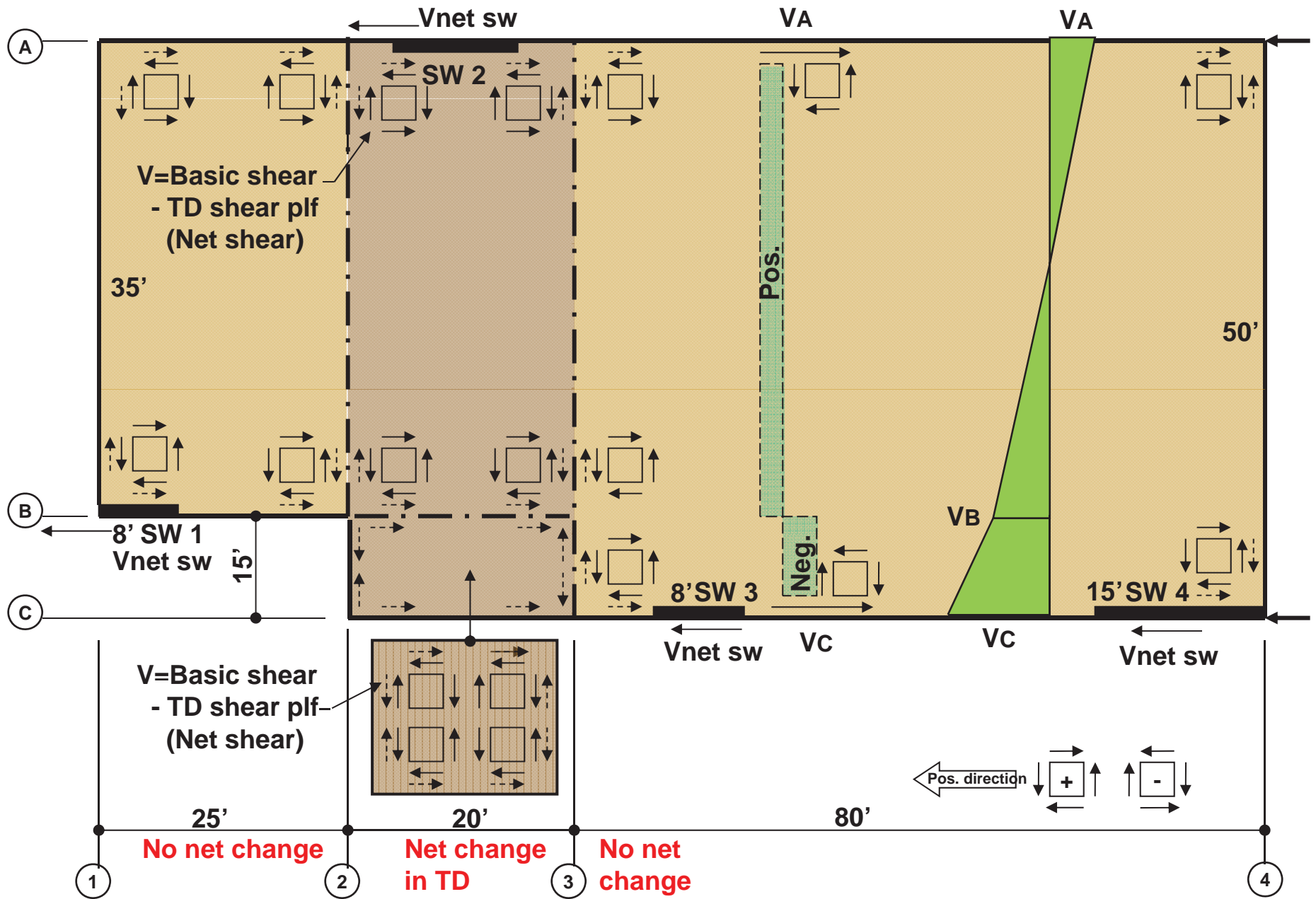
$\sum V_{sw1, sw3, sw4} = wL/2, v_{sw} = \sum V_{1,3,4} / (L_{sw1} + L_{sw3} + L_{sw4})$ plf



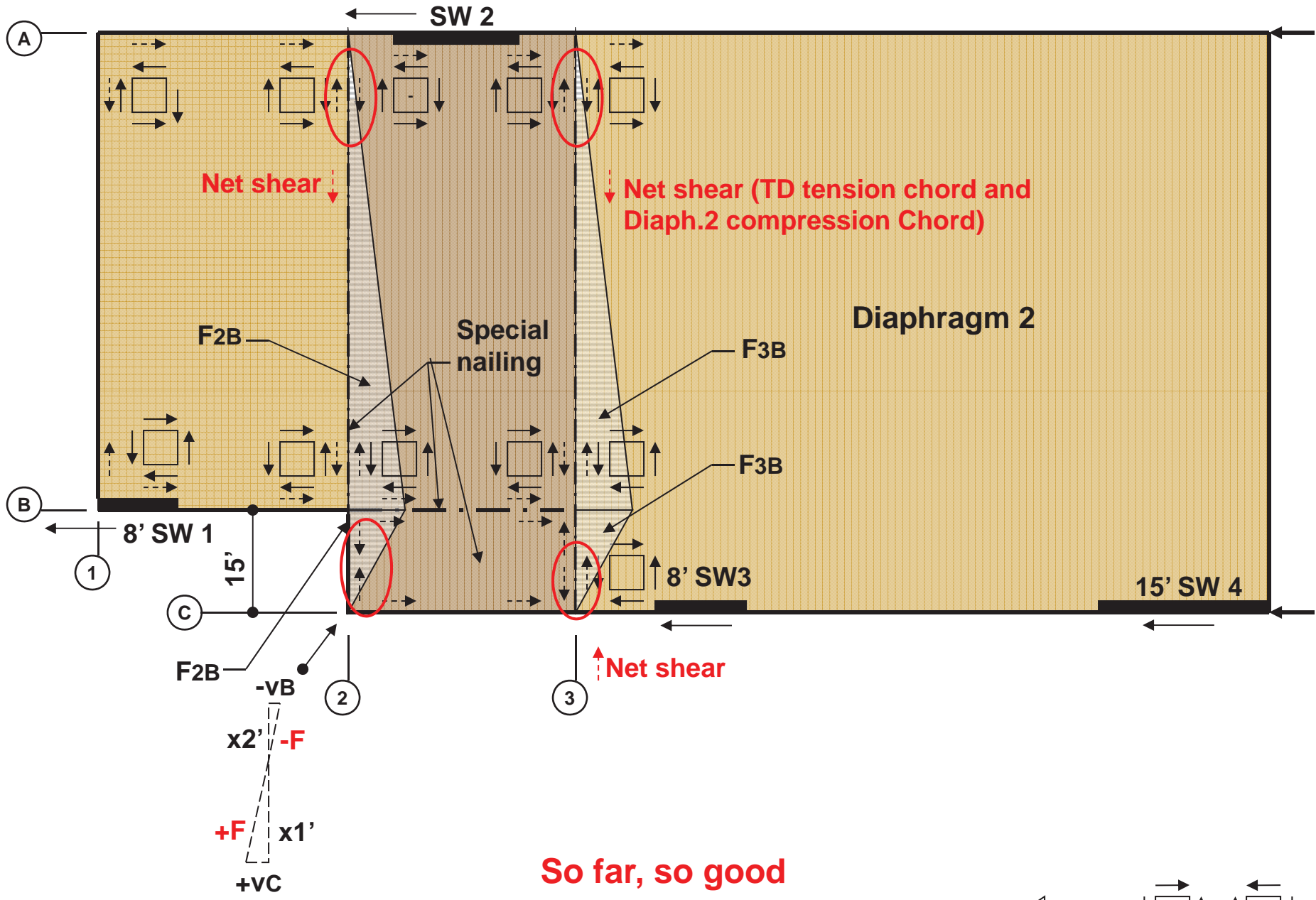
Determine Force transferred Into Transfer Diaphragm



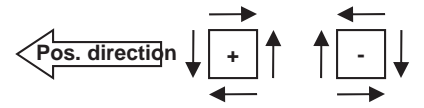
Basic Diaphragm Shears and Transfer Diaphragm Shear

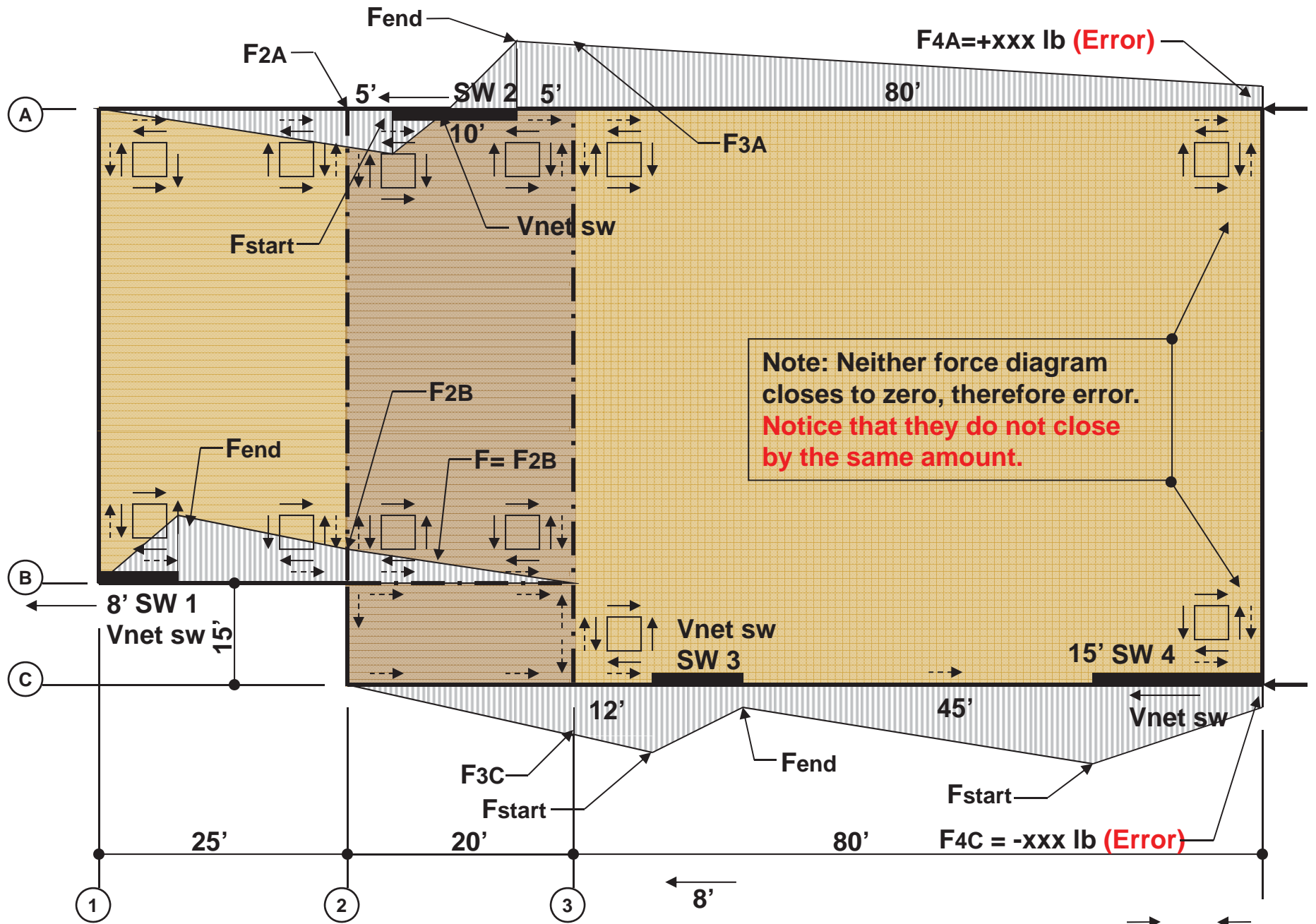


Net Diaphragm Shears

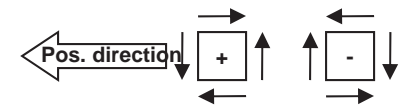


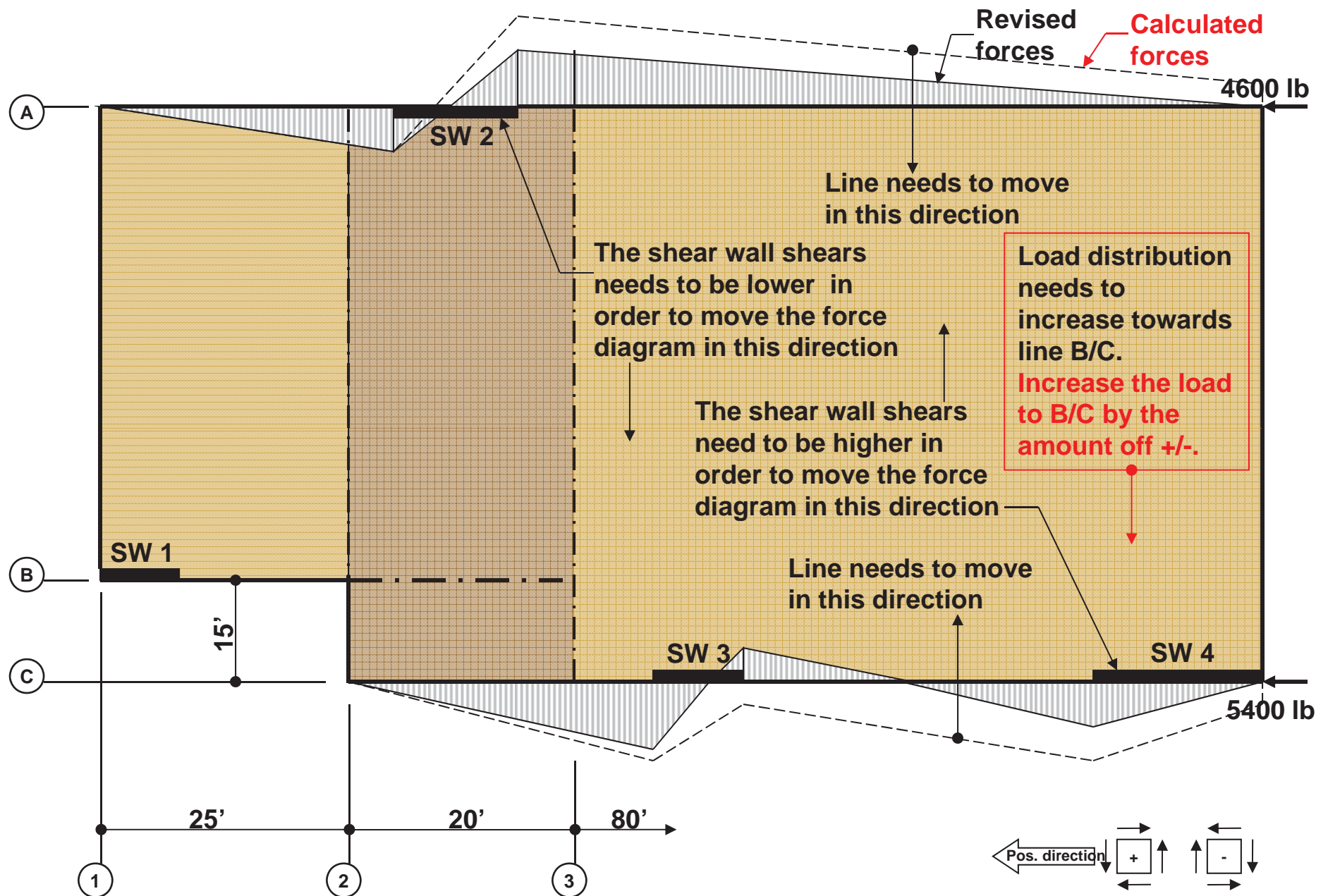
So far, so good
Transverse Collector Force Diagrams





Longitudinal Strut Force Diagrams

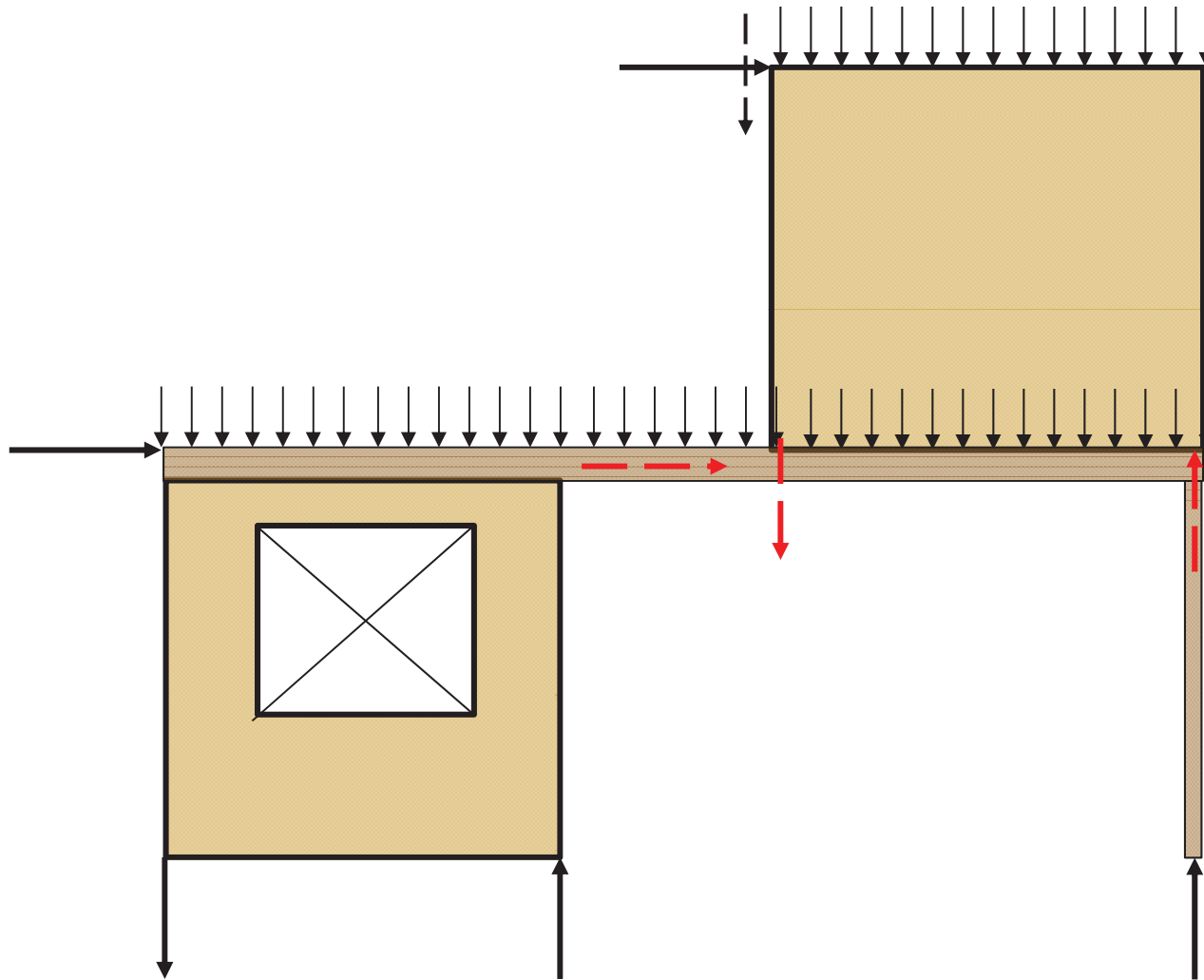


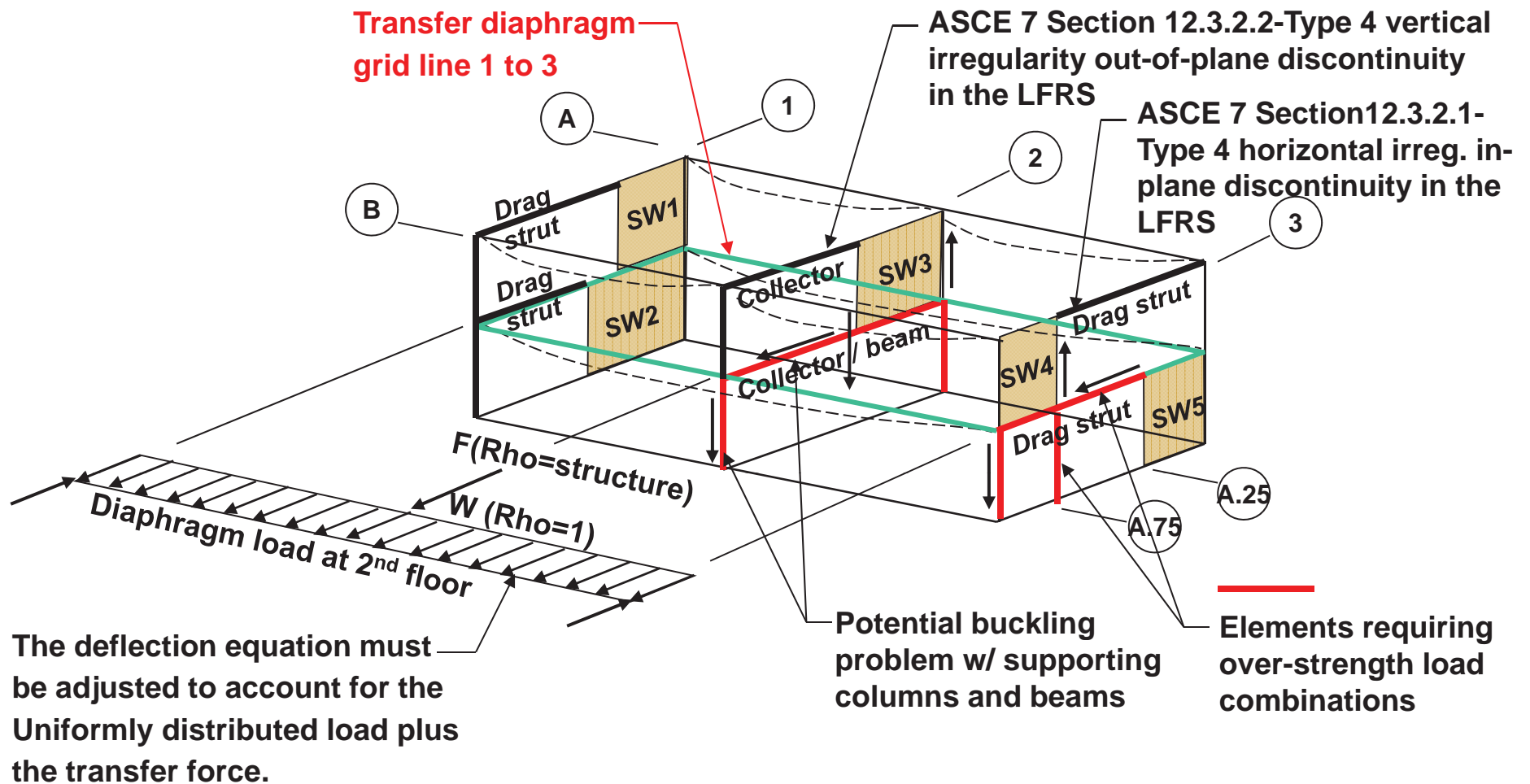


Adjusted Longitudinal Strut Force Diagrams (8% increase to B/C)

[Amount shifted to B/C depends on the offset to span ratio of the transfer diaphragm]

In-plane Offset Shear Walls





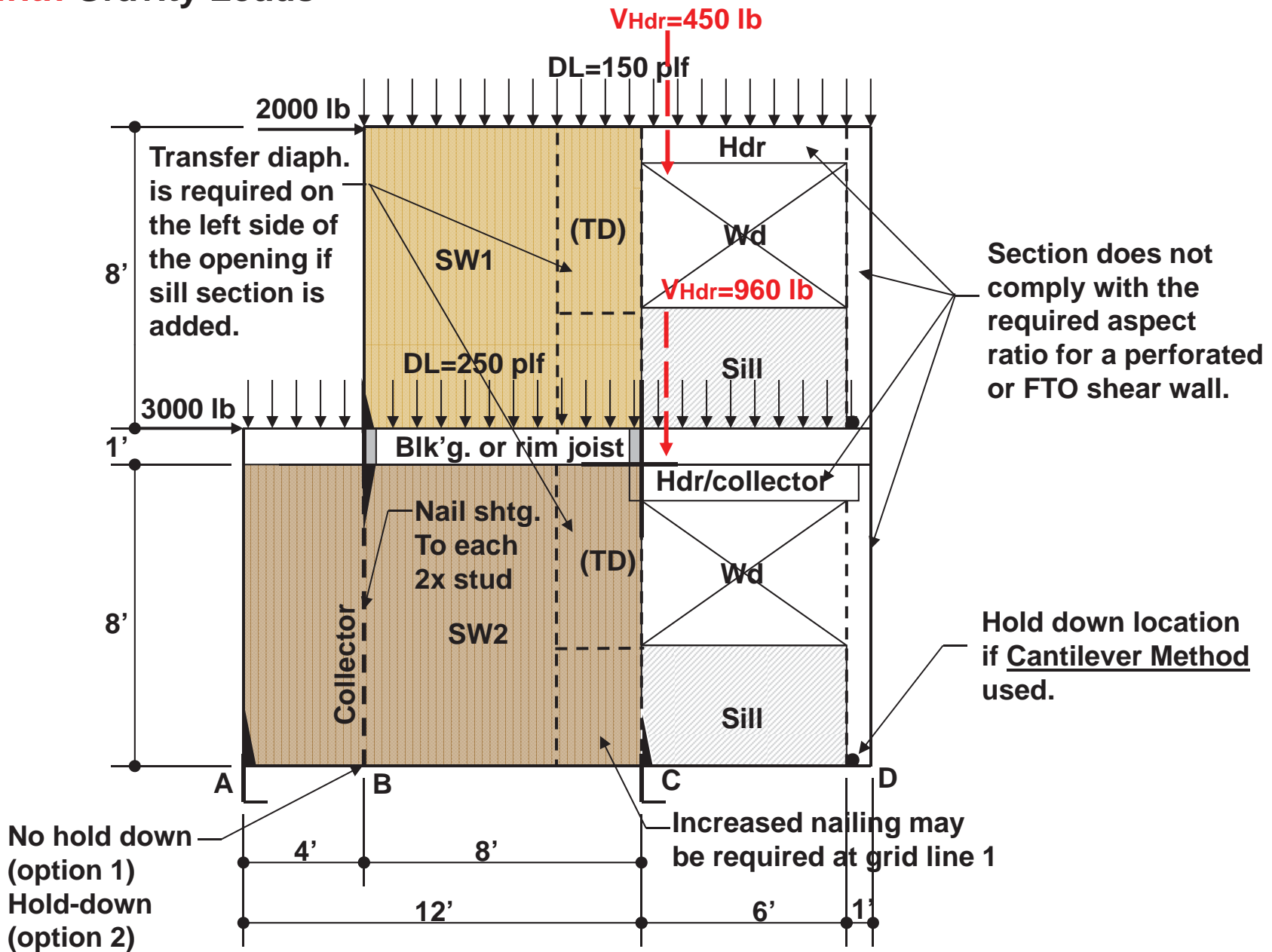
ASCE 7 Section 12.3.3.4-Type 4 vertical or horizontal irregularity in SDC D, E, F design forces determined from Section 12.10.1.1 (F_{px}) shall be increased 25% (See section for details)

ASCE 7 section 12.3.3.3

Elements supporting discontinuous walls and frames (Rho required if SDC D thru F)

Example 4-In-plane Offset Segmented Shear Wall

-with Gravity Loads



Ends of wall panels do not line up.
Requires special nailing of sheathing
into stud below.



Requires same
number of studs
above and below
with boundary
nailing each stud

Solid blocking
required

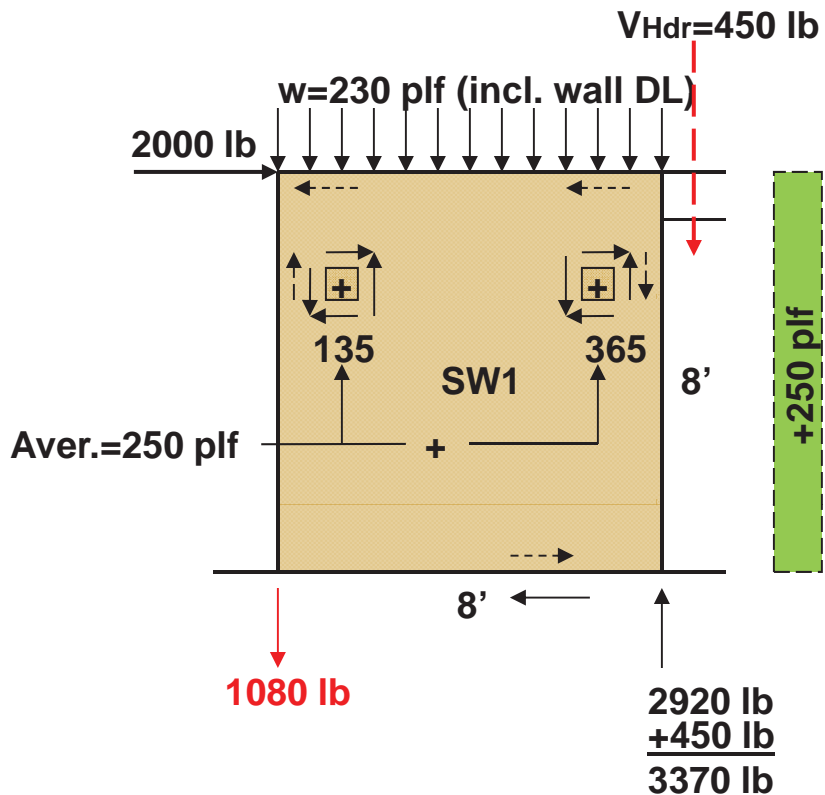
Hold down

Nailing found
in field was 12"
o.c.

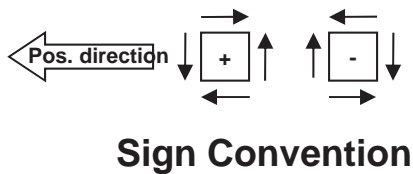
No hold-down below

Hold down

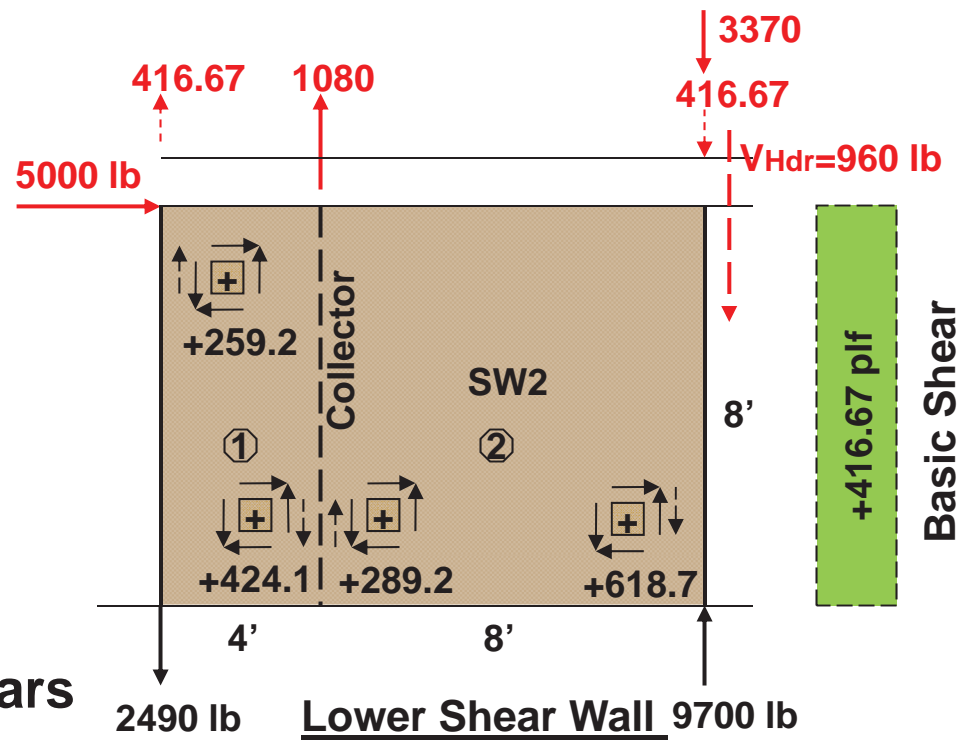
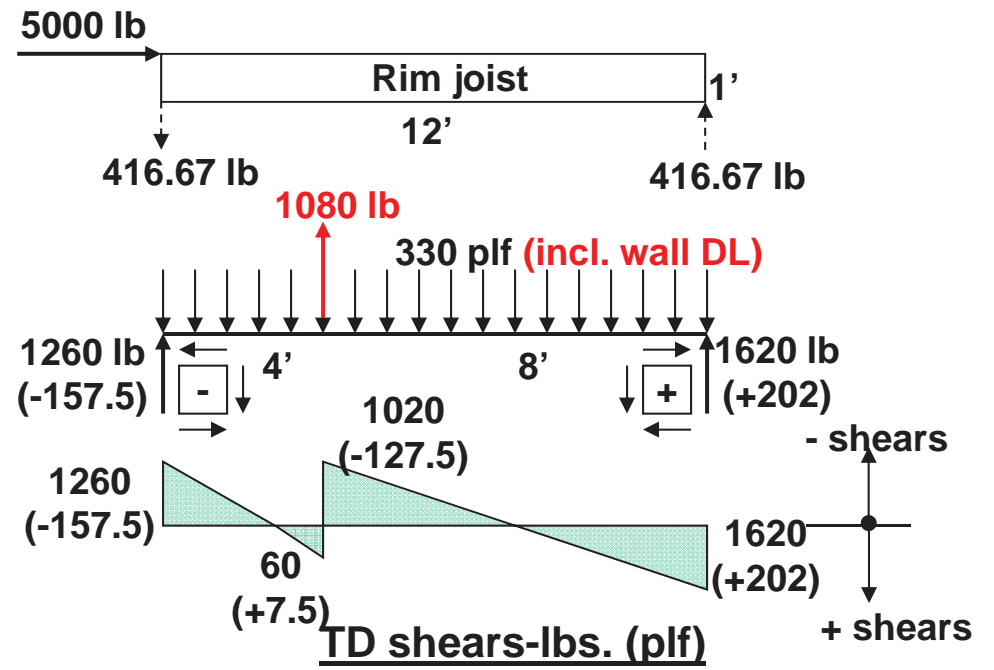
Photo-In-plane Offset Segmented Shear Walls



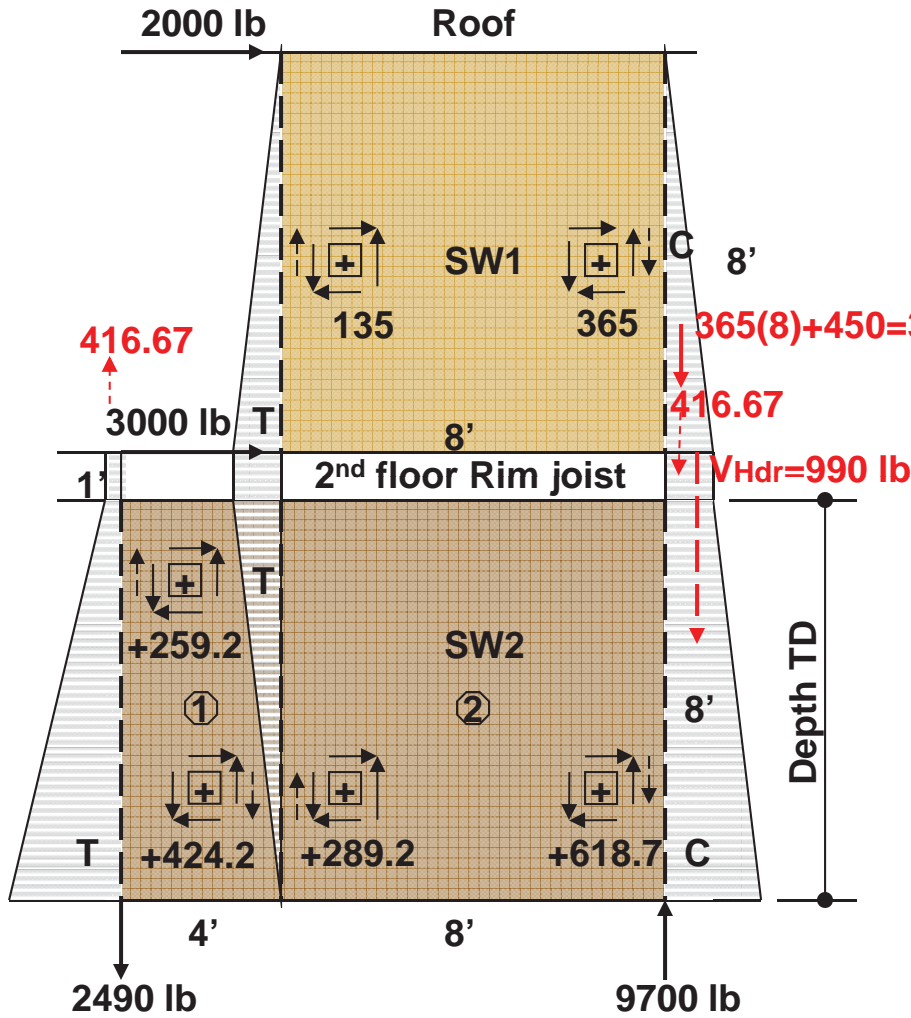
Upper Shear Wall



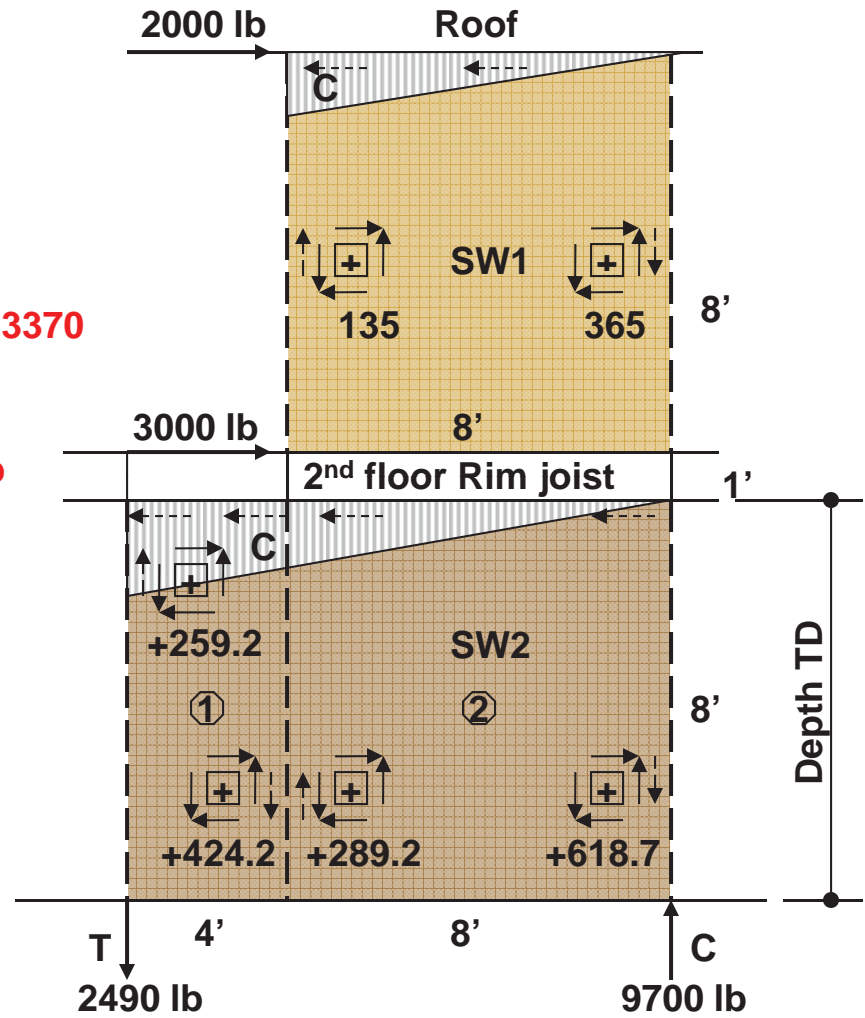
Wall and Transfer Diaphragm Shears



Lower Shear Wall

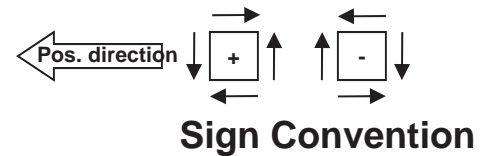


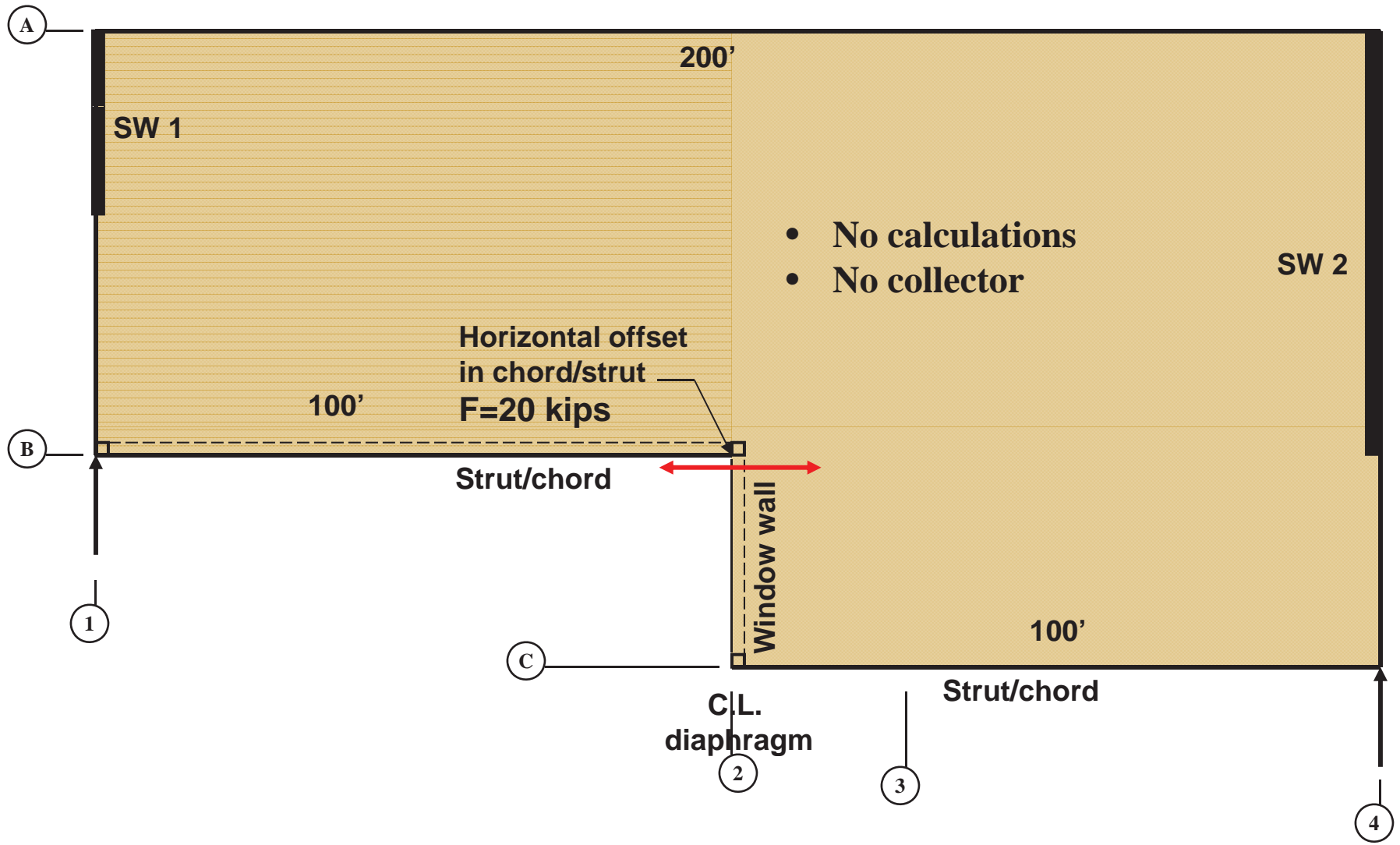
Vertical Collector Forces



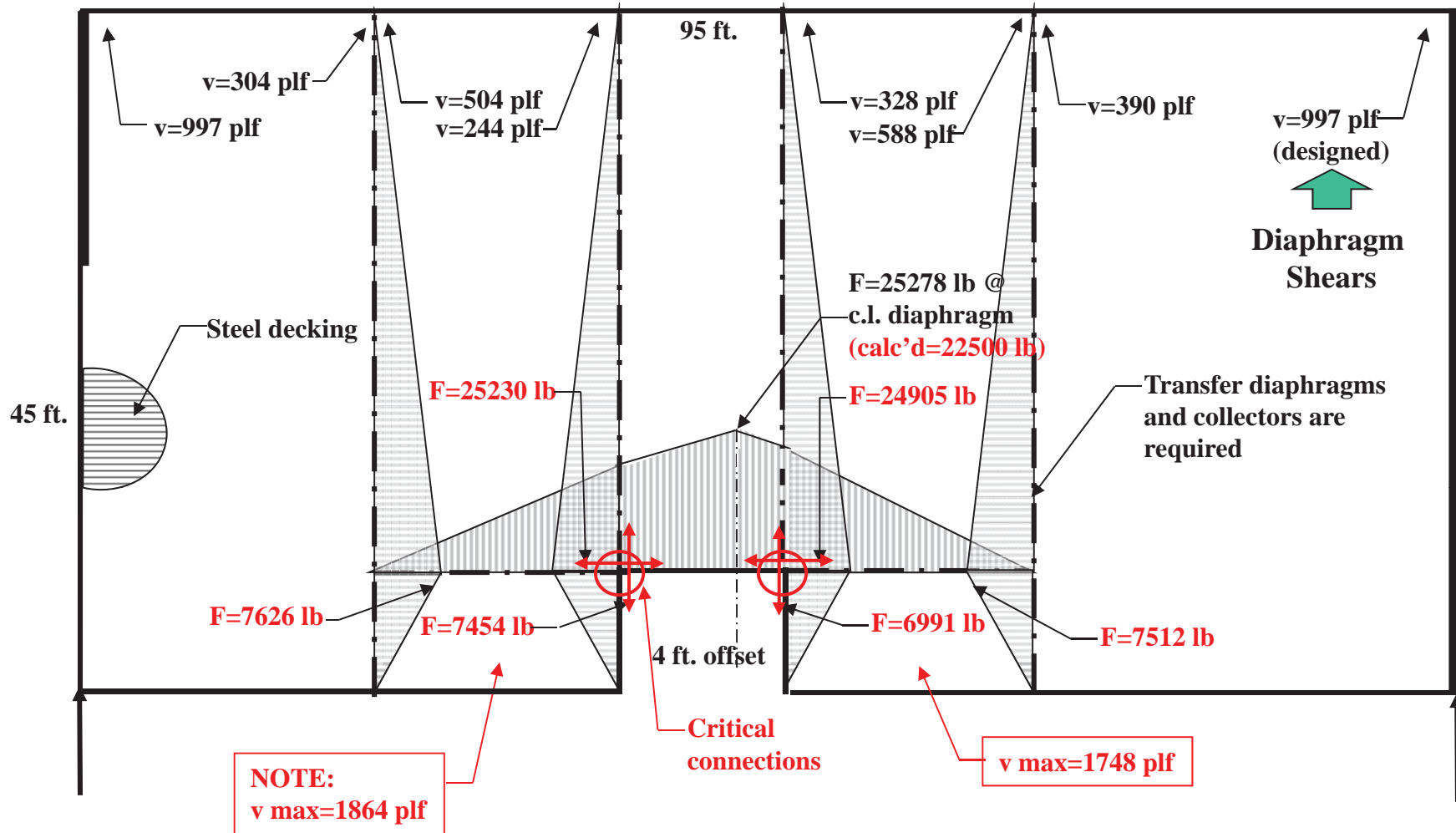
Horizontal Collector Forces

Collector Force Diagrams





Actual Project



- Diaphragm designed as a simple rectangular diaphragm, no offset, using only a spreadsheet.
- Checked only diaphragm shear and chord force (maximum depth, not offset depth).
- No collectors, connection designs or details at re-entrant corners.
- Forces on trusses at collectors were not called out on drawing.

Actual Project

QUESTIONS?

This concludes The American Institute of Architects
Continuing Education Systems Course

Part 2- Offset Shear Walls

R. Terry Malone, P.E., S.E.
Senior Technical Director
WoodWorks.org

Contact Information:
terrym@woodworks.org

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