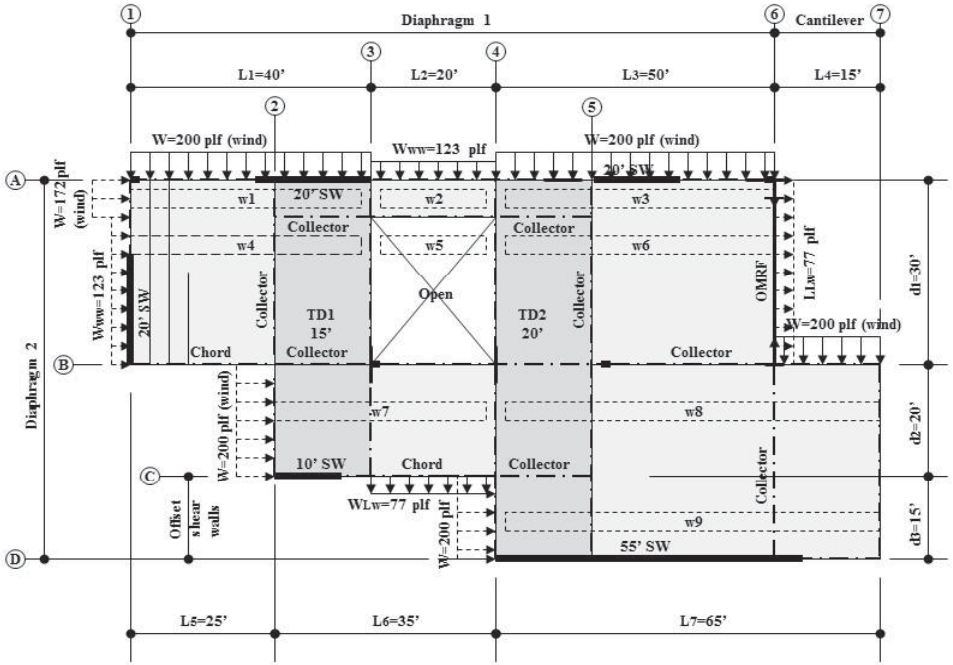
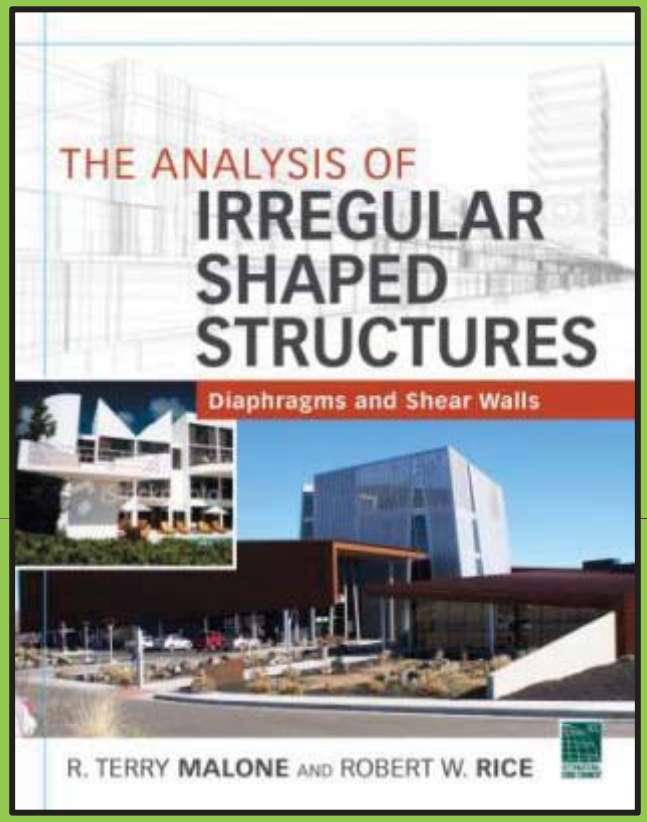
WoodWorks

Part 1-Offset Diaphragms



Example-Complex Diaphragm

Based on:



Presentation updated to 2012 IBC, ASCE 7-10

By: R. Terry Malone, PE, SE

Senior Technical Director

Architectural & Engineering Solutions

terrym@woodworks.org

"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.

Course Description

Lateral force resisting systems in today's structures are much more complex than they were several decades ago, incorporating multiple horizontal and vertical offsets in the diaphragms, multiple irregularities, and fewer lateral resisting elements. This two part presentation will provide a brief review of the method used to analyzed these complex structures. In part 1, topics will include code requirements, how to recognize diaphragm irregularities and discontinuities, how shears are distributed through complex diaphragms, the method of analysis used to solve the transfer of forces across areas of discontinuity, and the analysis of flexible wood sheathed or untopped steel decking diaphragms with horizontal offsets.

Learning Objectives

- **Basic Information**

  Discuss boundary elements, complete lateral resisting load path requirements and related code sections.

- **Examine Common Types of Discontinuities**

  Examine common types of discontinuities and irregularities and discuss how to establish complete lateral load paths across areas of discontinuity.

- **Discuss the Analytical Method of Analysis**

  Review an analytical method used for solving complex diaphragms and shear walls using “Transfer Diaphragms” and the “Visual Shear Transfer Method.”

- **Offset Diaphragms-Examples**

  Review the analysis of flexible offset diaphragms for loading in the transverse direction.

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.

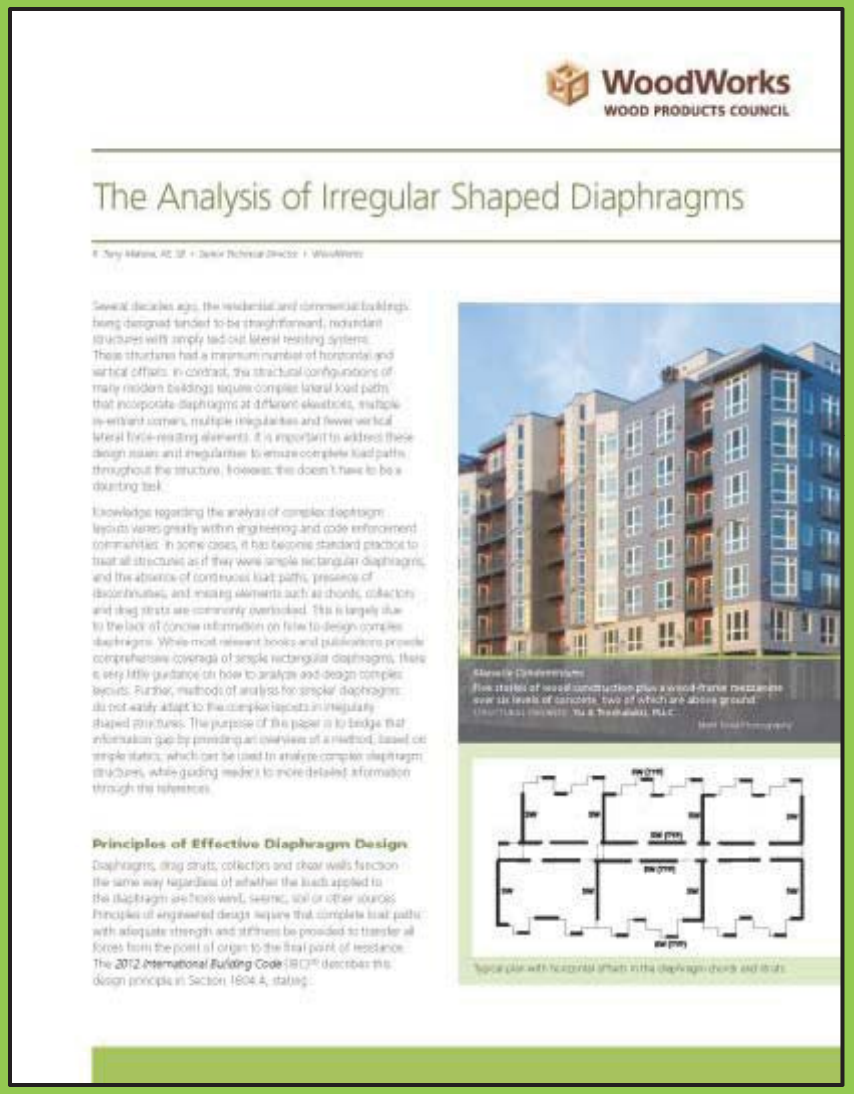
Code References:

- 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



WoodWorks
WOOD PRODUCTS COUNCIL

The Analysis of Irregular Shaped Diaphragms

Principles of Effective Diaphragm Design

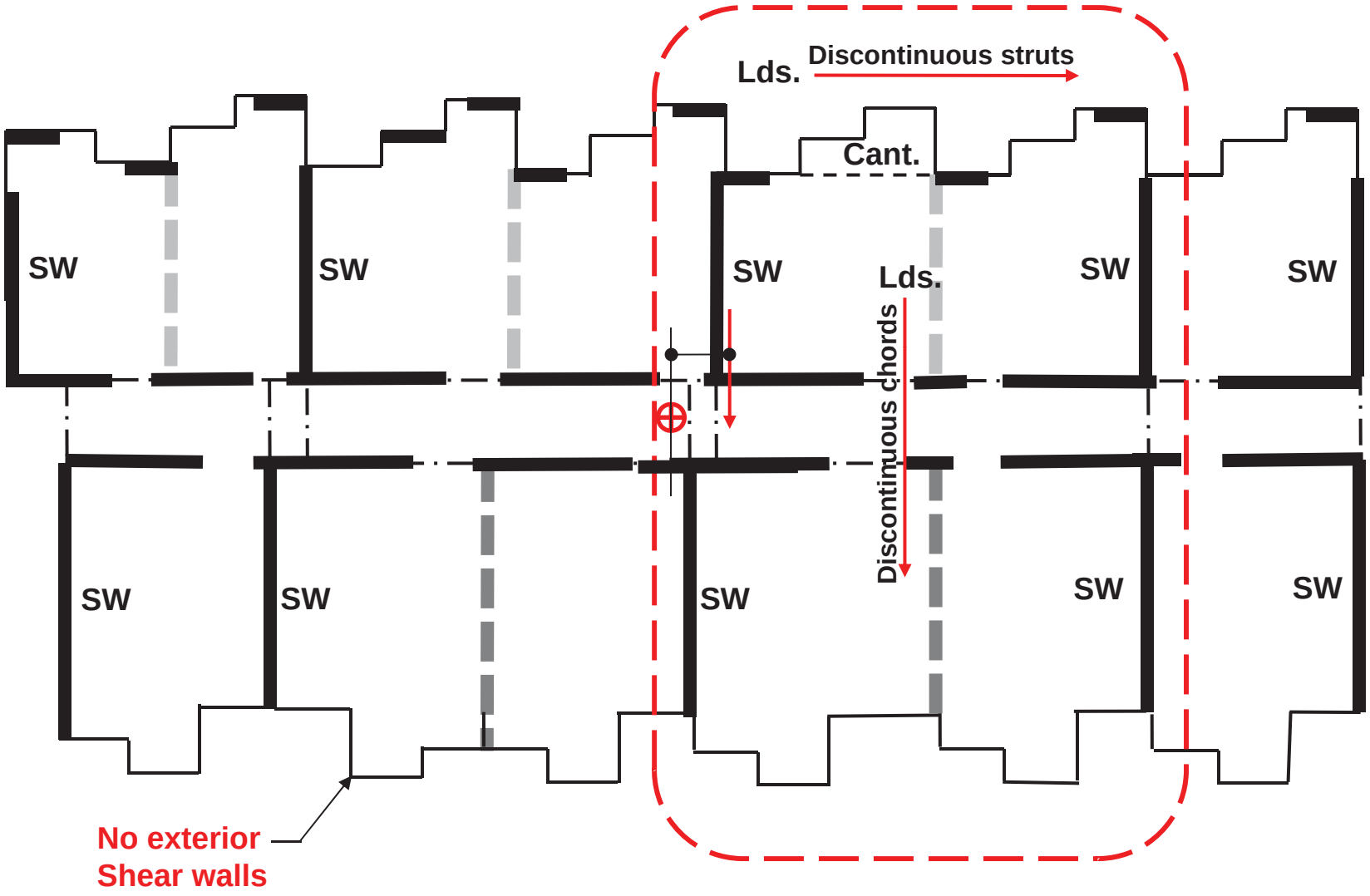
http://www.woodworks.org/education-publications/research-papers/#

Mid-rise Multi-family

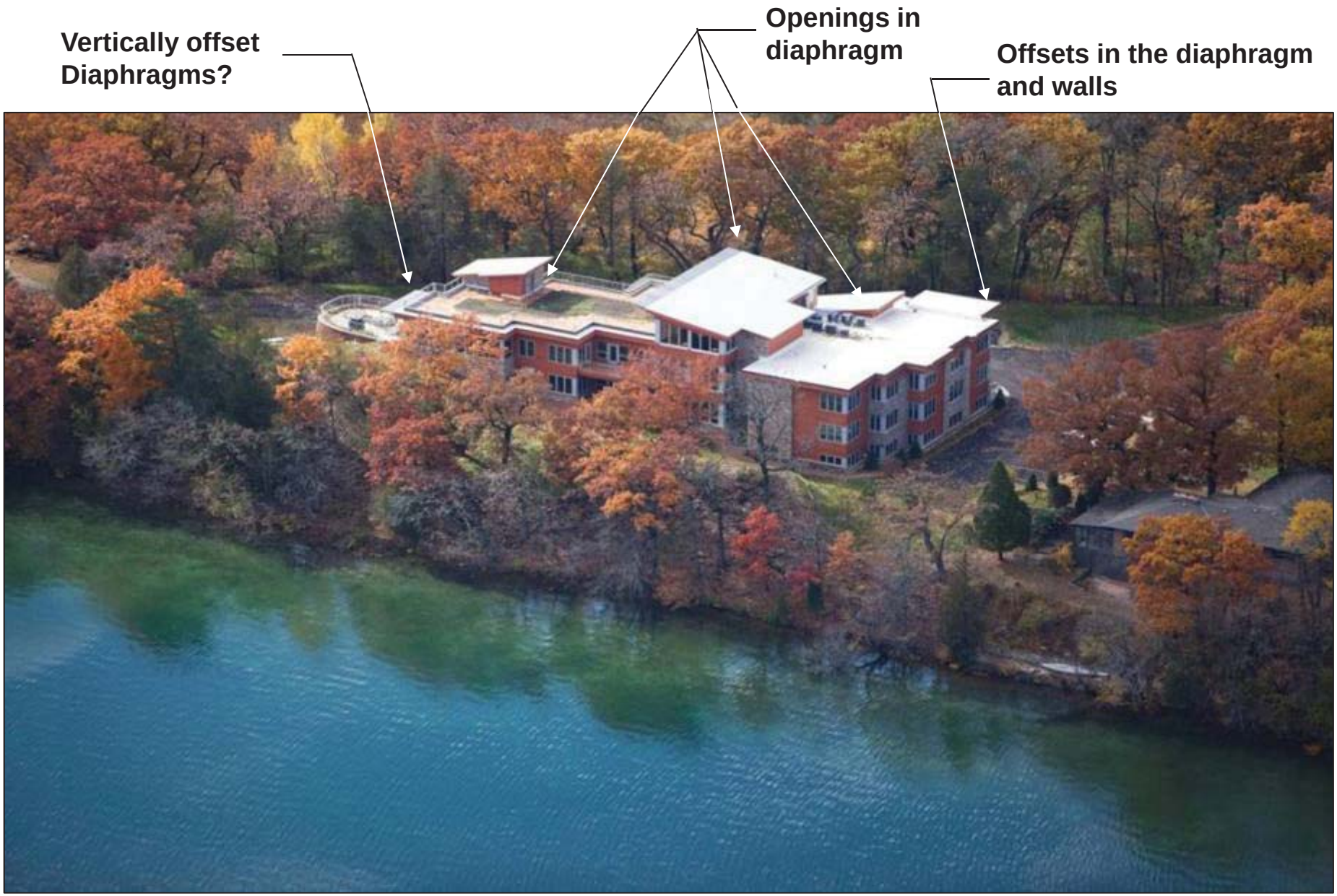
Marselle Condominiums
Structural Engineer engineer: Yu & Trochalakis, PLLC
Photographer: Matt Todd Photographer

5 stories of wood over 6 stories concrete (podium) 2 above grade

Mid-rise Multi-family



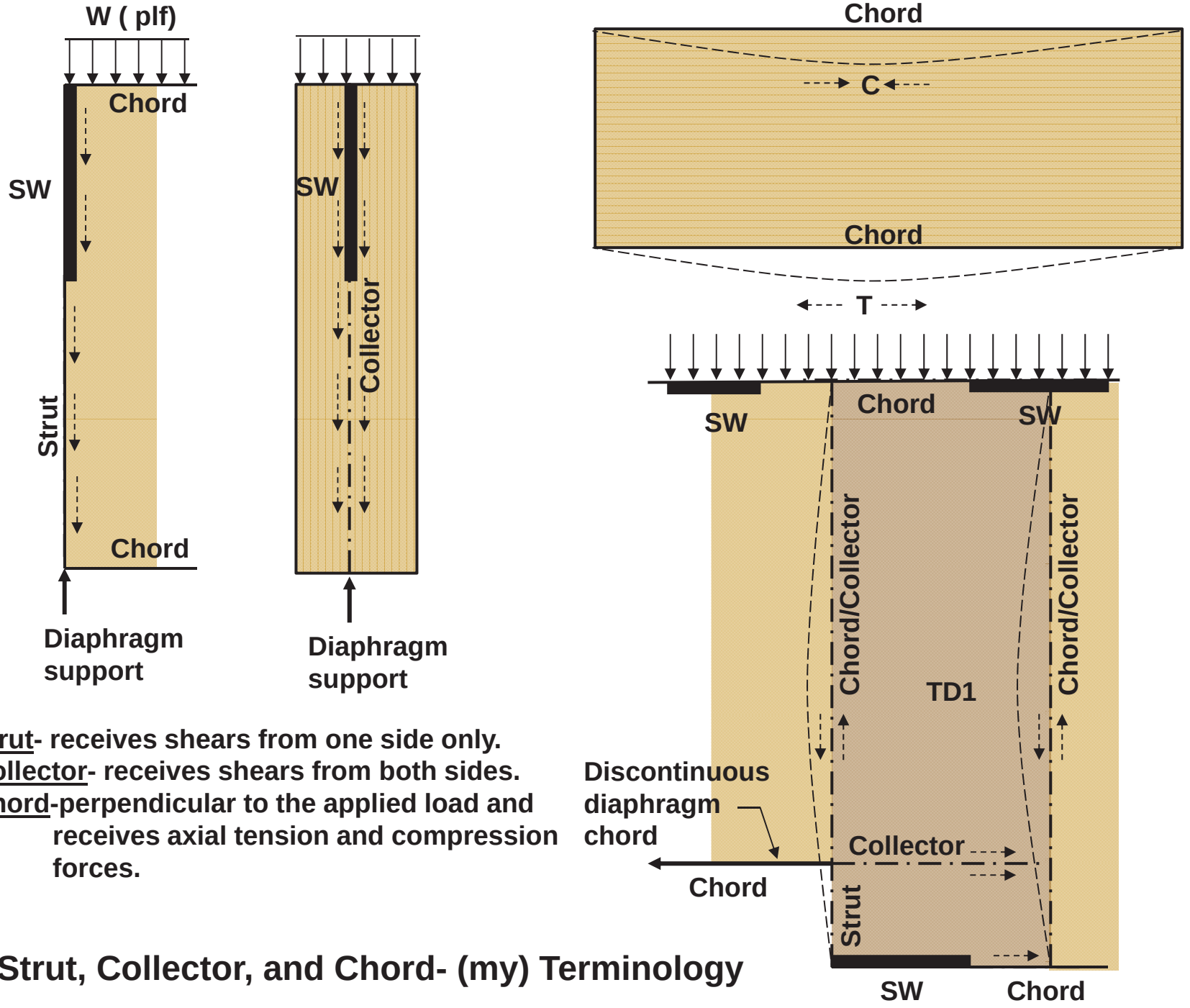
Flexible, semi-rigid, or rigid???



Harrington Recovery Center
Structural engineer: Pujara Wirth Torke, Inc.
Photographer: Curtis Walz

Basic Information

- **Boundary Elements**
- **Complete Load Paths**
- **Method of Analysis**



Strut- receives shears from one side only.
Collector- receives shears from both sides.
Chord-perpendicular to the applied load and receives axial tension and compression forces.

Strut, Collector, and Chord- (my) Terminology

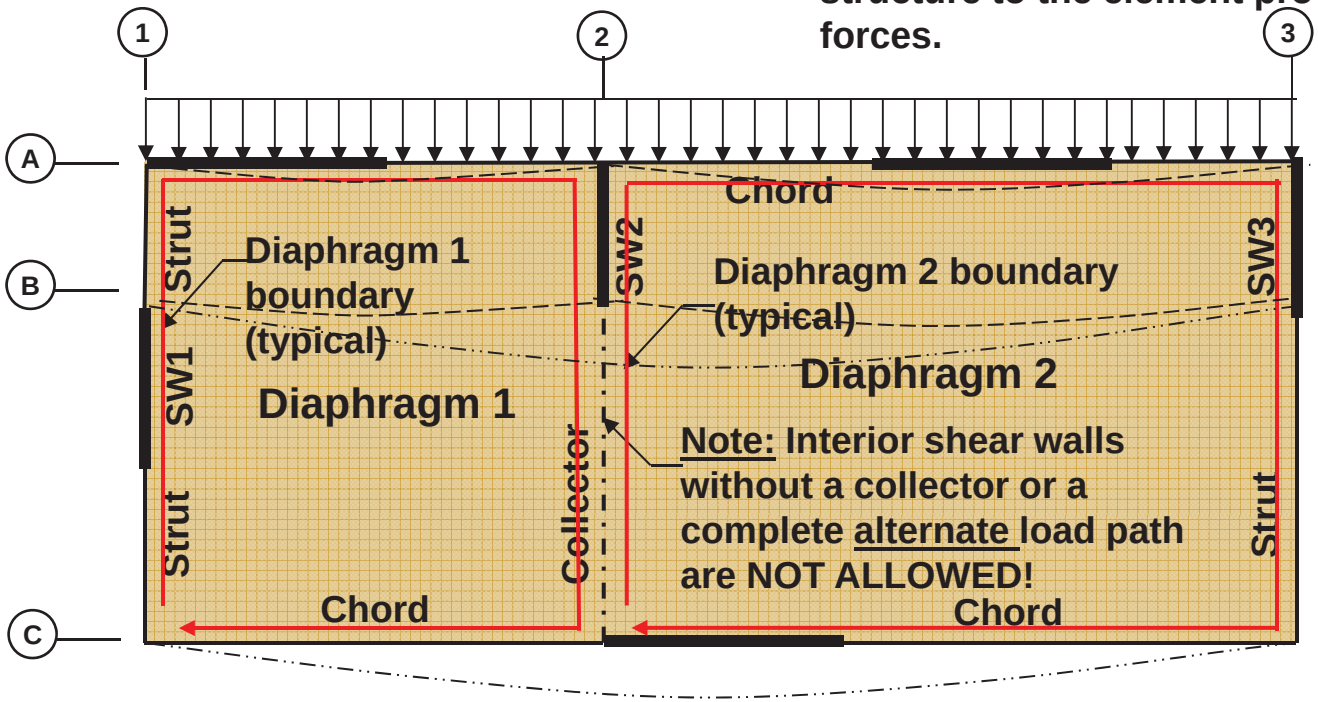
Diaphragm Boundary Elements

Fundamental Principles:

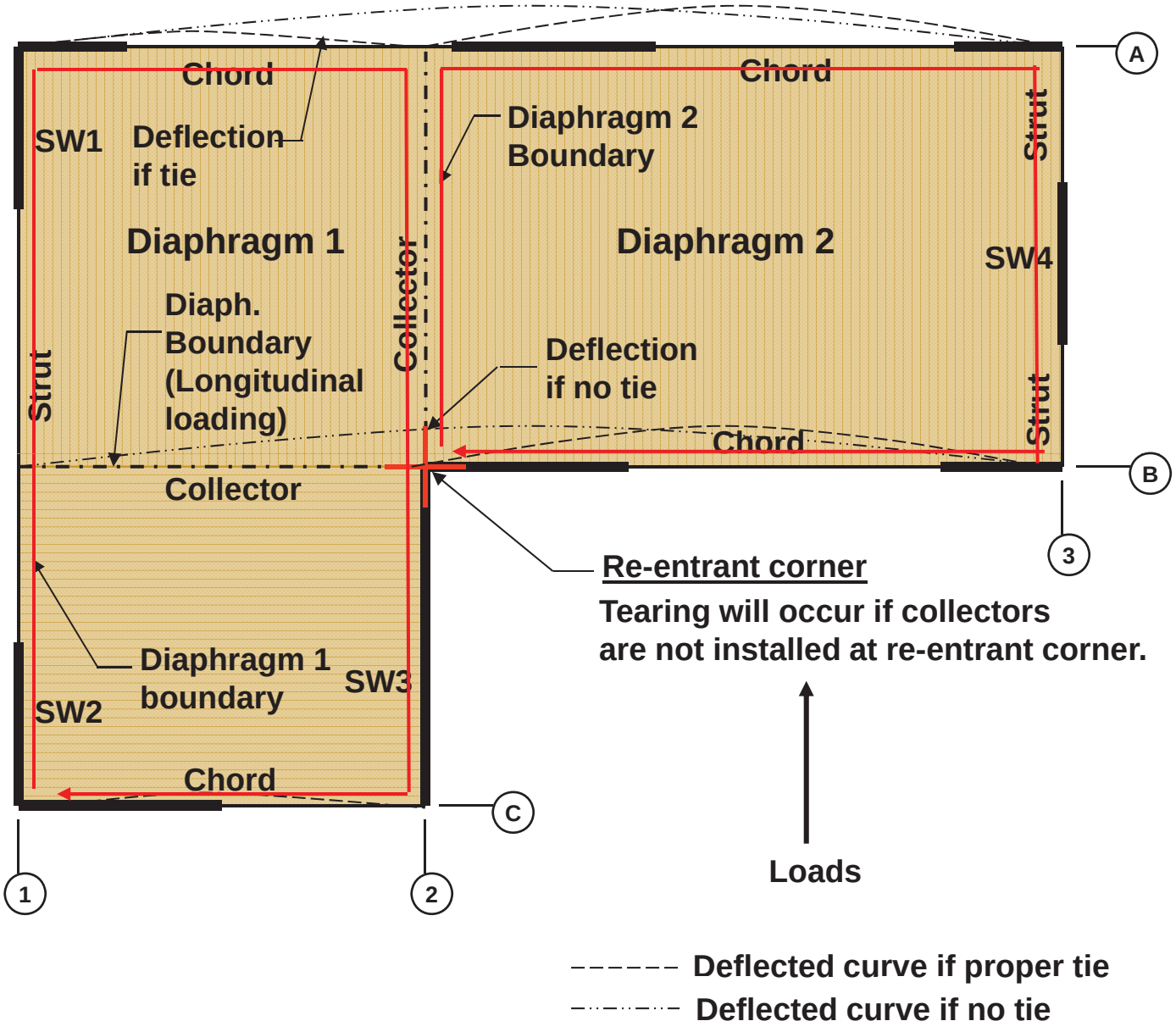
A shear wall is a location where diaphragm forces are resisted (supported), and therefore defines a diaphragm boundary location.

Note: All edges of a diaphragm shall be supported by a boundary element.

- **Diaphragm Boundary Elements:**
  - **Chords, drag struts, collectors, Shear walls, frames**
  - **Boundary member locations:**
    - **Diaphragm and shear wall perimeters**
    - **Interior openings**
    - **Areas of discontinuities**
    - **Re-entrant corners.**
- **Diaphragm and shear wall sheathing shall not be used to splice boundary elements.**
- **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.**



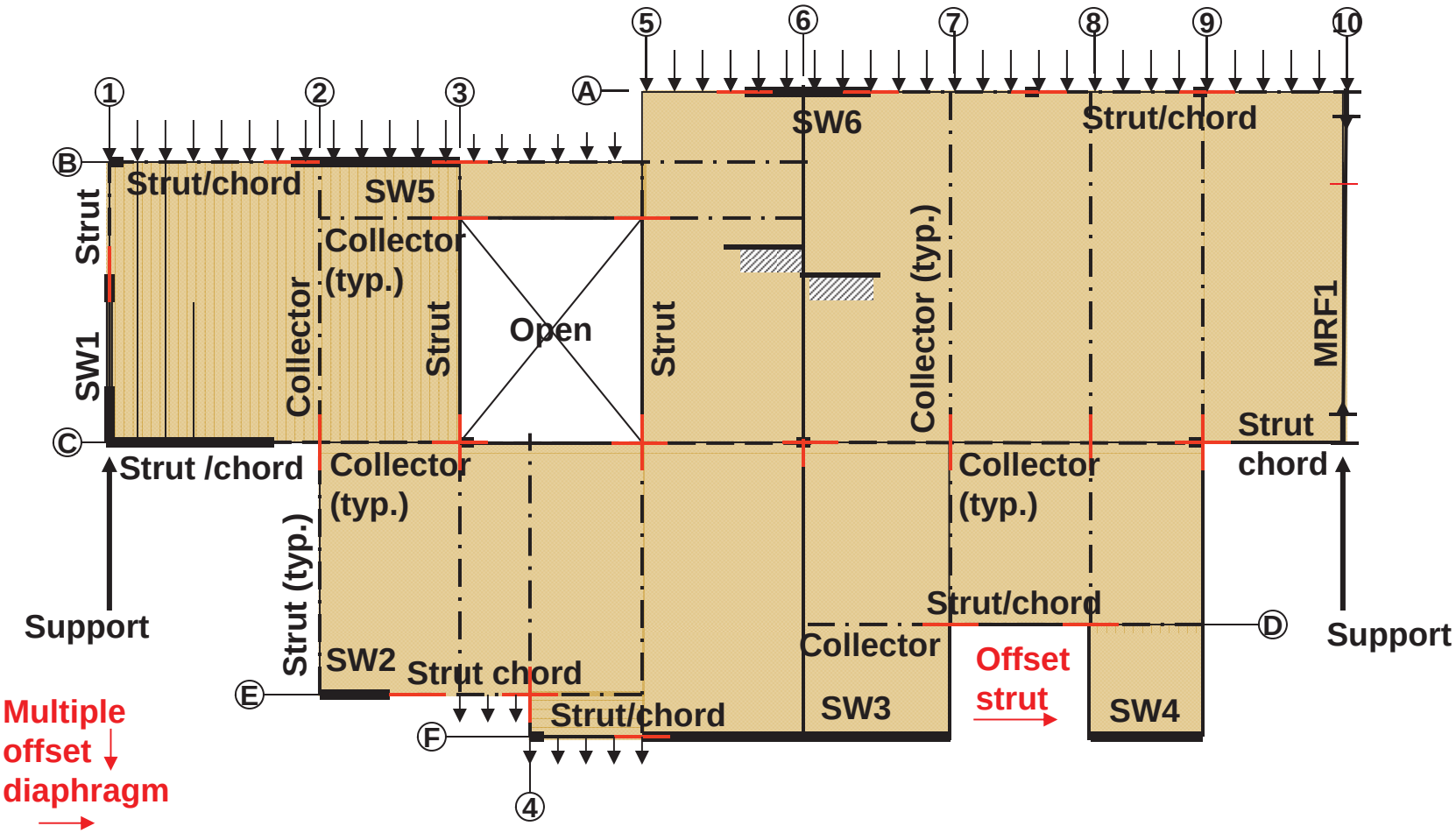
Required for all SDC and wind



Boundary Elements “L” Shaped Buildings-Transverse Loading

Basic Information

- Boundary Elements
- **Complete Load Paths**
- Method of Analysis

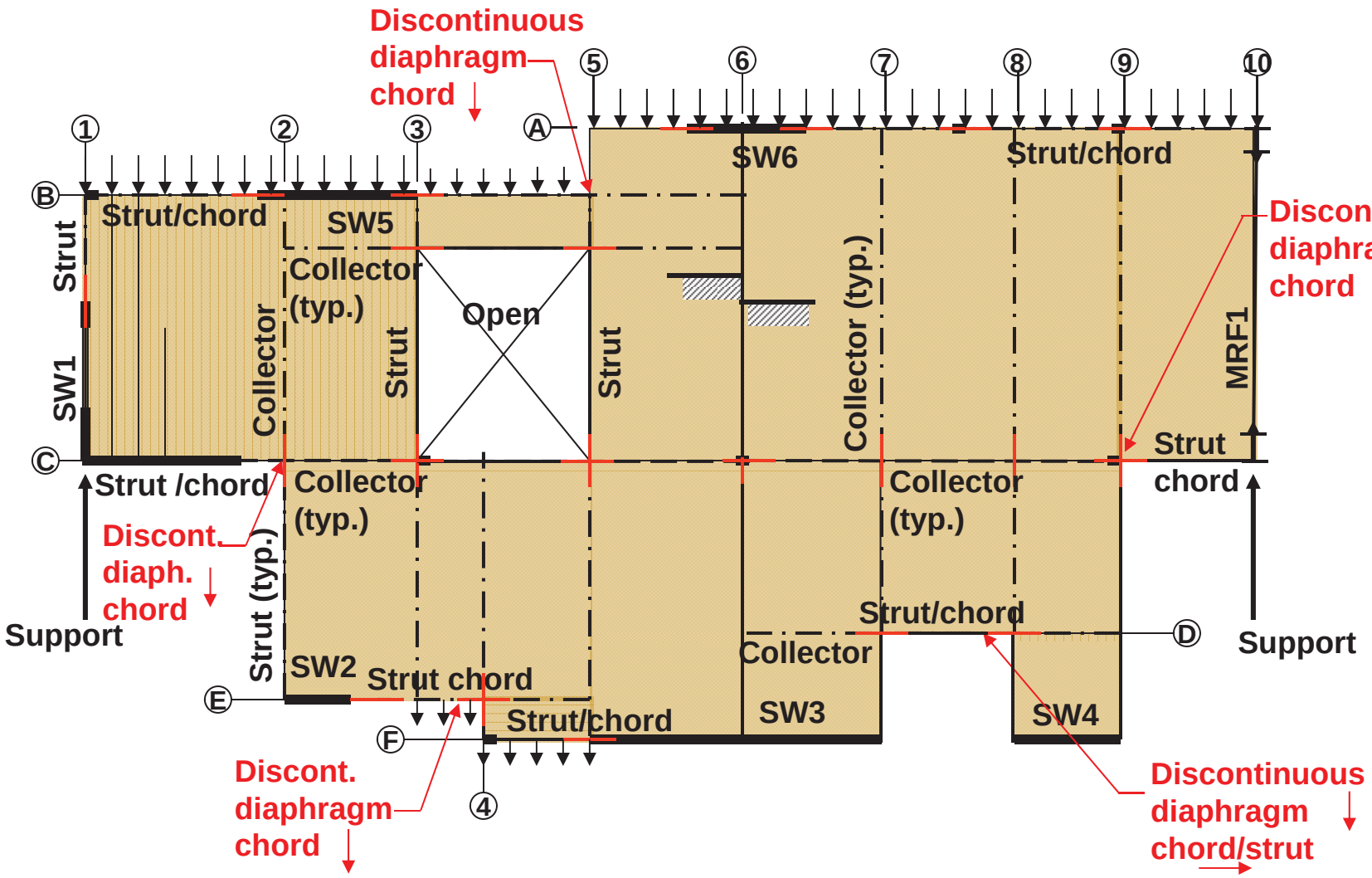


Analysis:

- Design shall be based on a rational analysis
- 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.

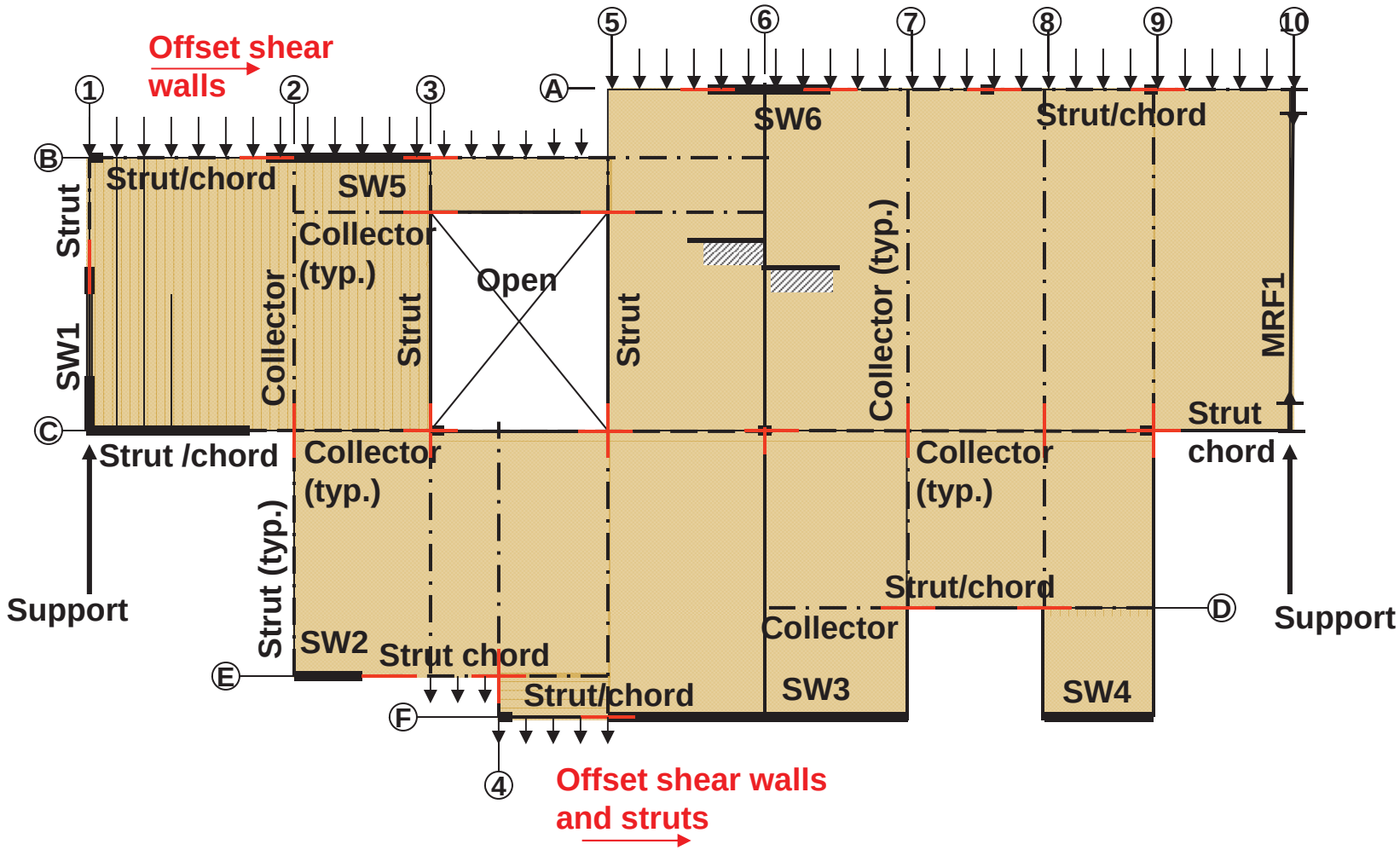
What does this mean?

Complete Continuous Lateral Load Paths



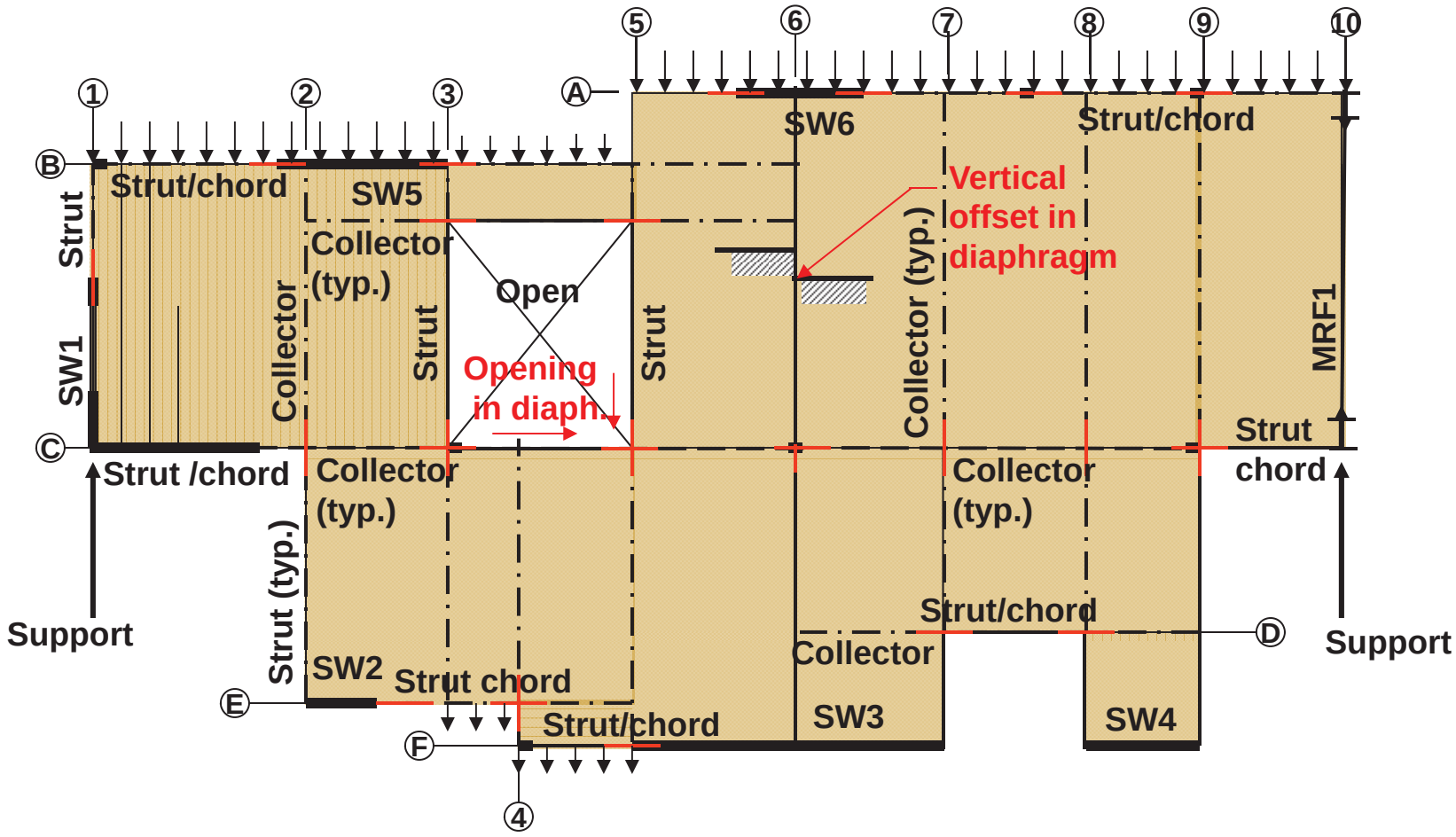
Design: Complete load paths are required including members and their splice connections

Complete Continuous Lateral Load Paths



Design: Complete load paths are required including member and their splice connections

Complete Continuous Lateral Load Paths



Design:

- **Openings in shear panels that materially effect their strength shall be fully detailed on the plans and shall have their edges adequately reinforced to transfer all shear stresses.**

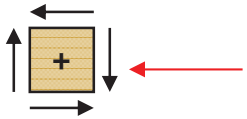
Complete Continuous Lateral Load Paths

Basic Information

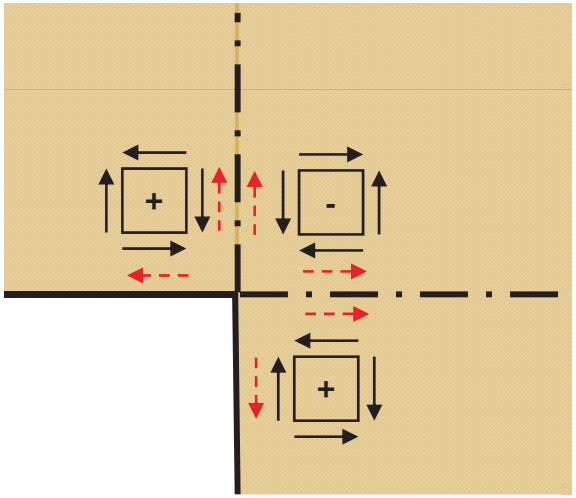
- Boundary Elements
- Complete Load Paths
- **Method of Analysis**

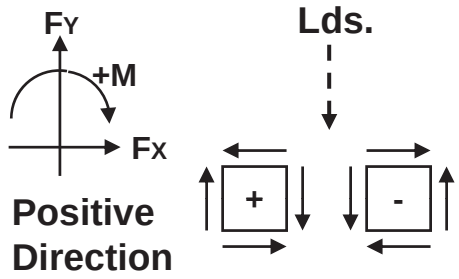
Method of Analysis

The Visual Shear Transfer Method



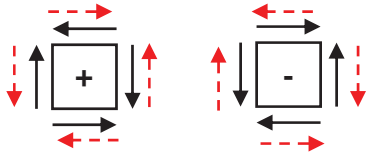
Symbol for 1 ft x 1 ft square piece of sheathing in static equilibrium (typ.)





Transverse Direction (shown)

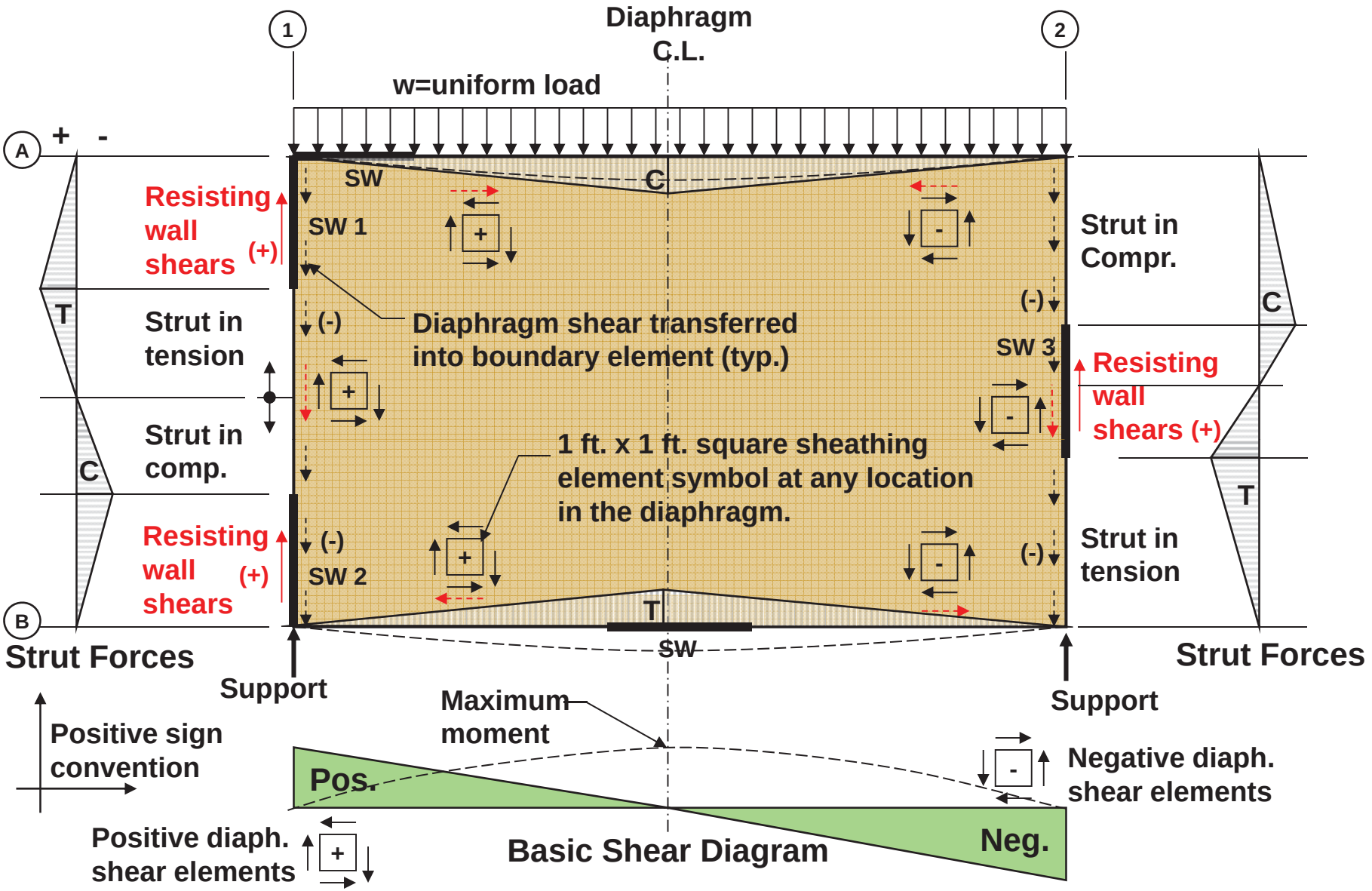
Shears Applied to Sheathing Elements



Unit shear acting on sheathing element (plf)

Unit shear transferred from the sheathing element into the boundary element (plf)

Shears Transferred Into Boundary Elements

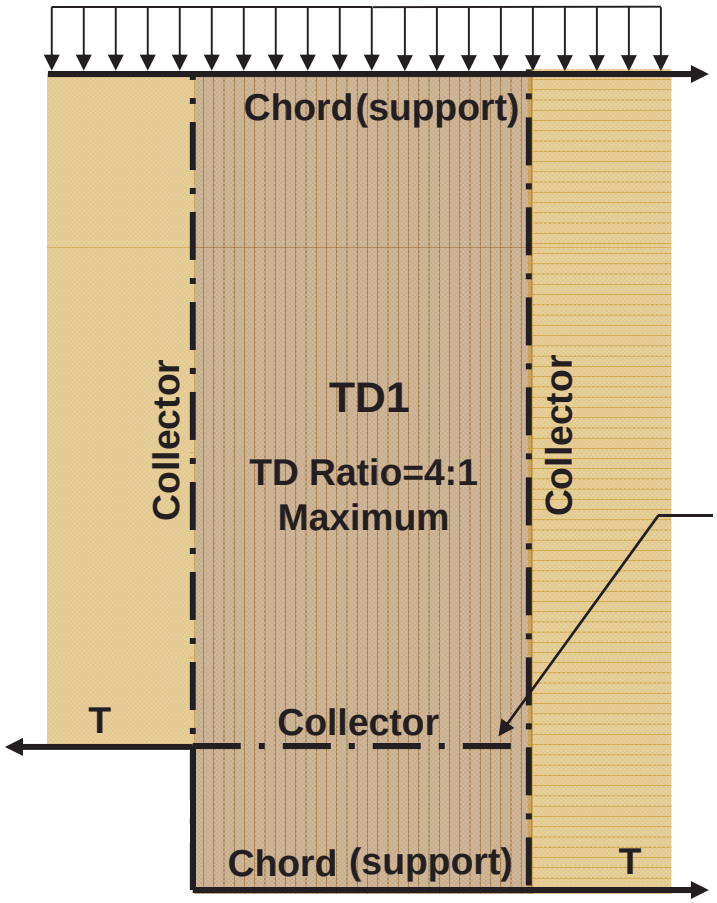


All edges of a diaphragm shall be supported by a boundary element (chord, strut, collector) or other vertical lateral force resisting element (shear wall, frame).

Shear Distribution Into a Simple Diaphragm

The Visual Shear Transfer Method

Introduction to Transfer Diaphragms and Transfer Areas

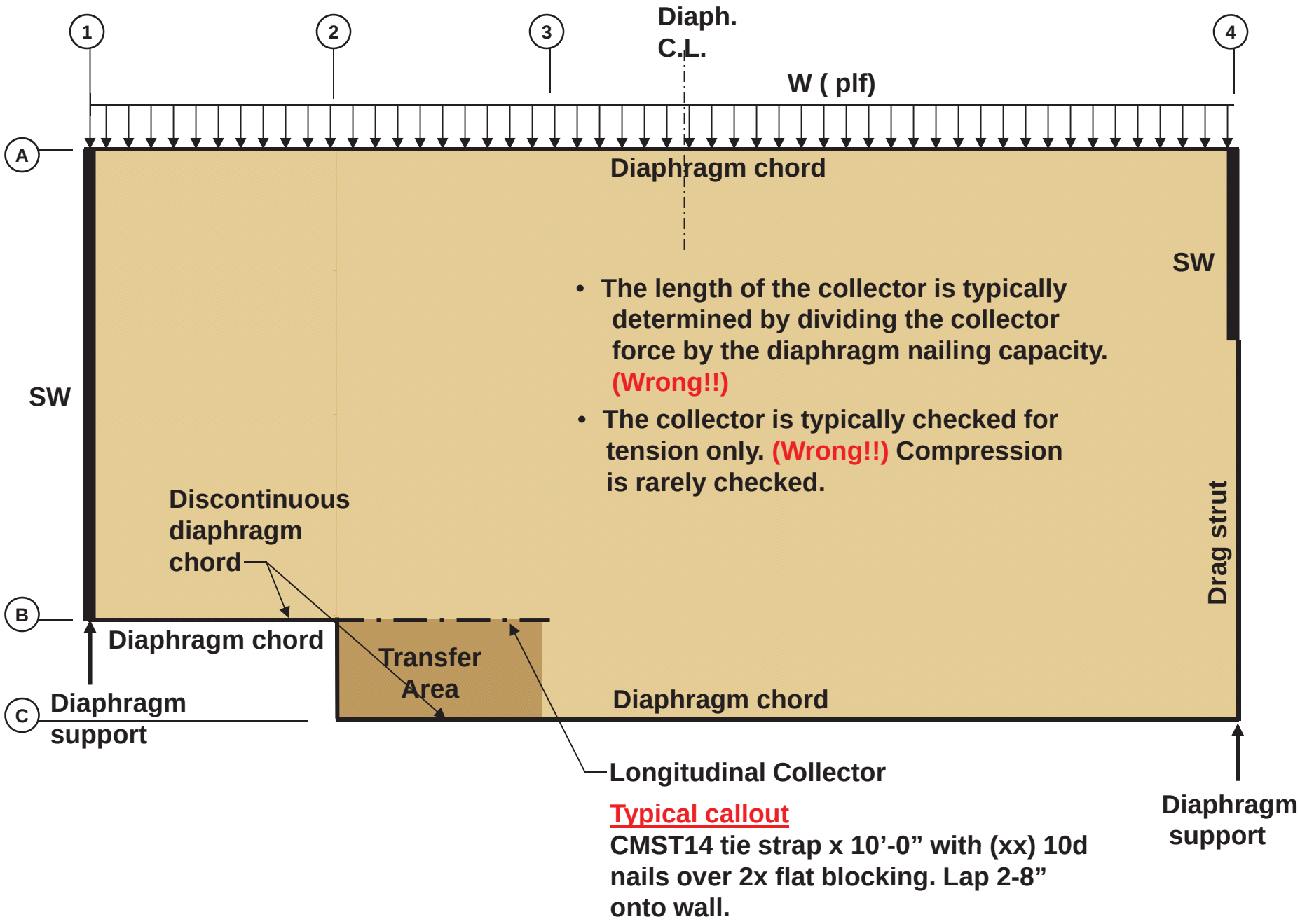


Transfer Diaphragm

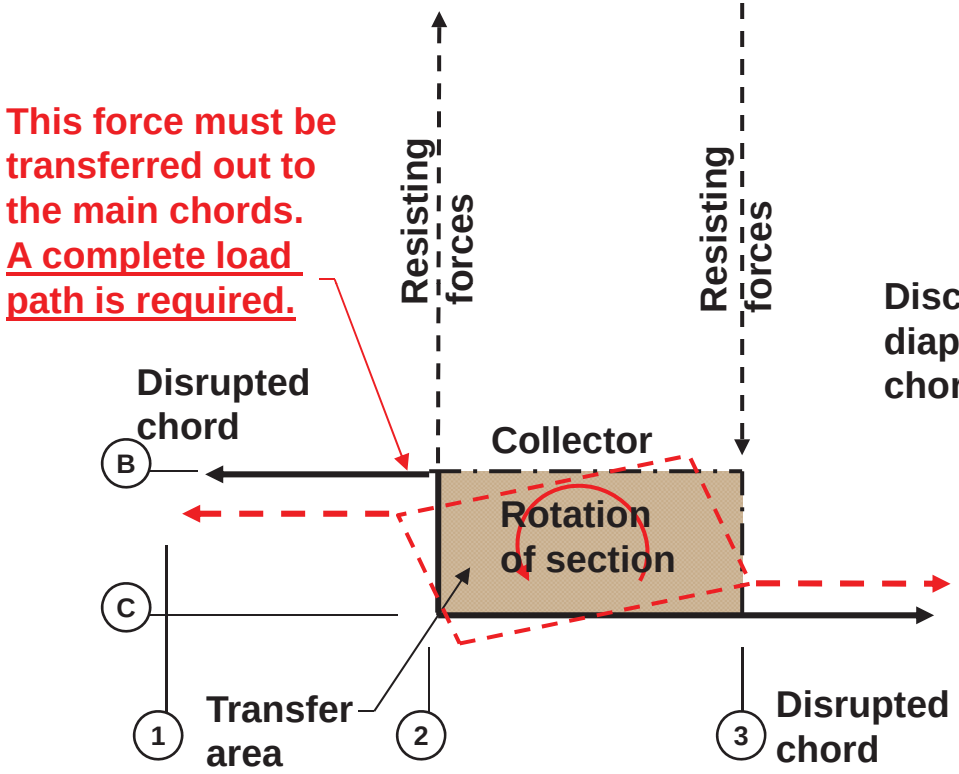
- sub-diaphragm
- Transfers local forces out to primary chords/struts of the main diaphragm.

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

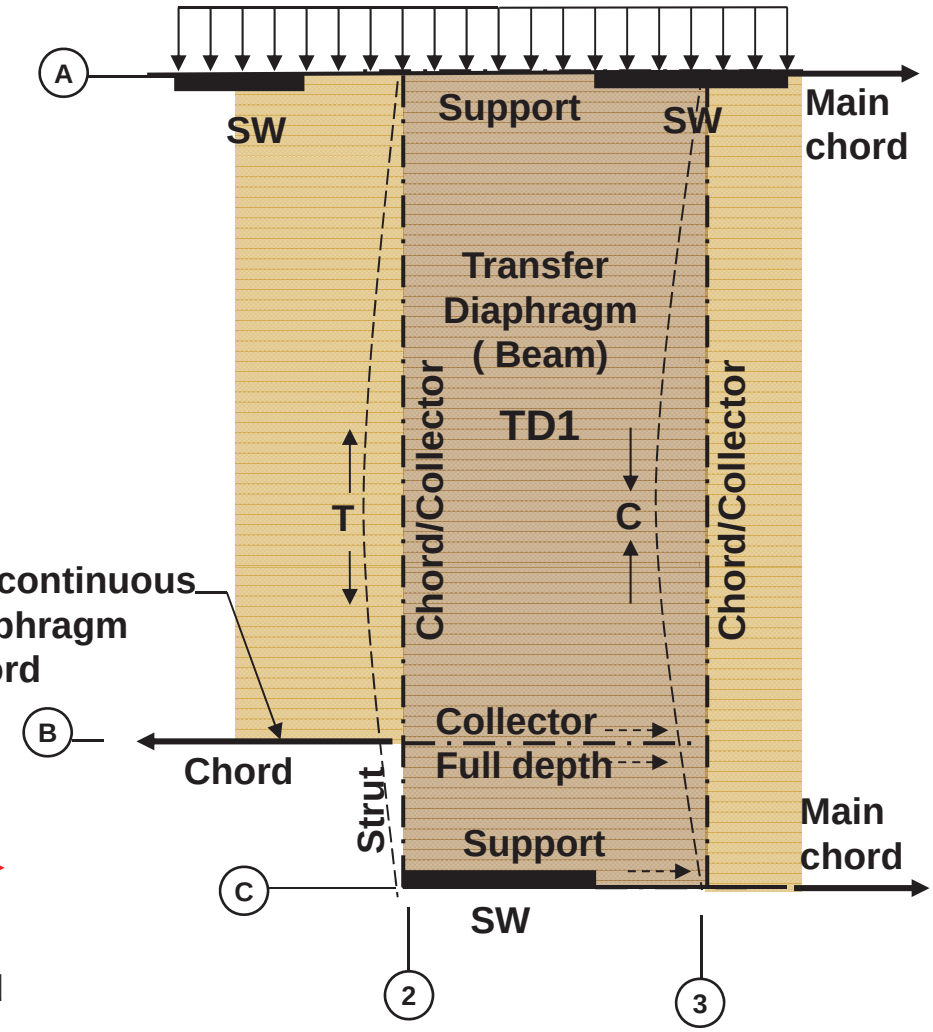
What does this mean?



Transfer Diaphragm Members and Elements



Transfer area without transverse collectors

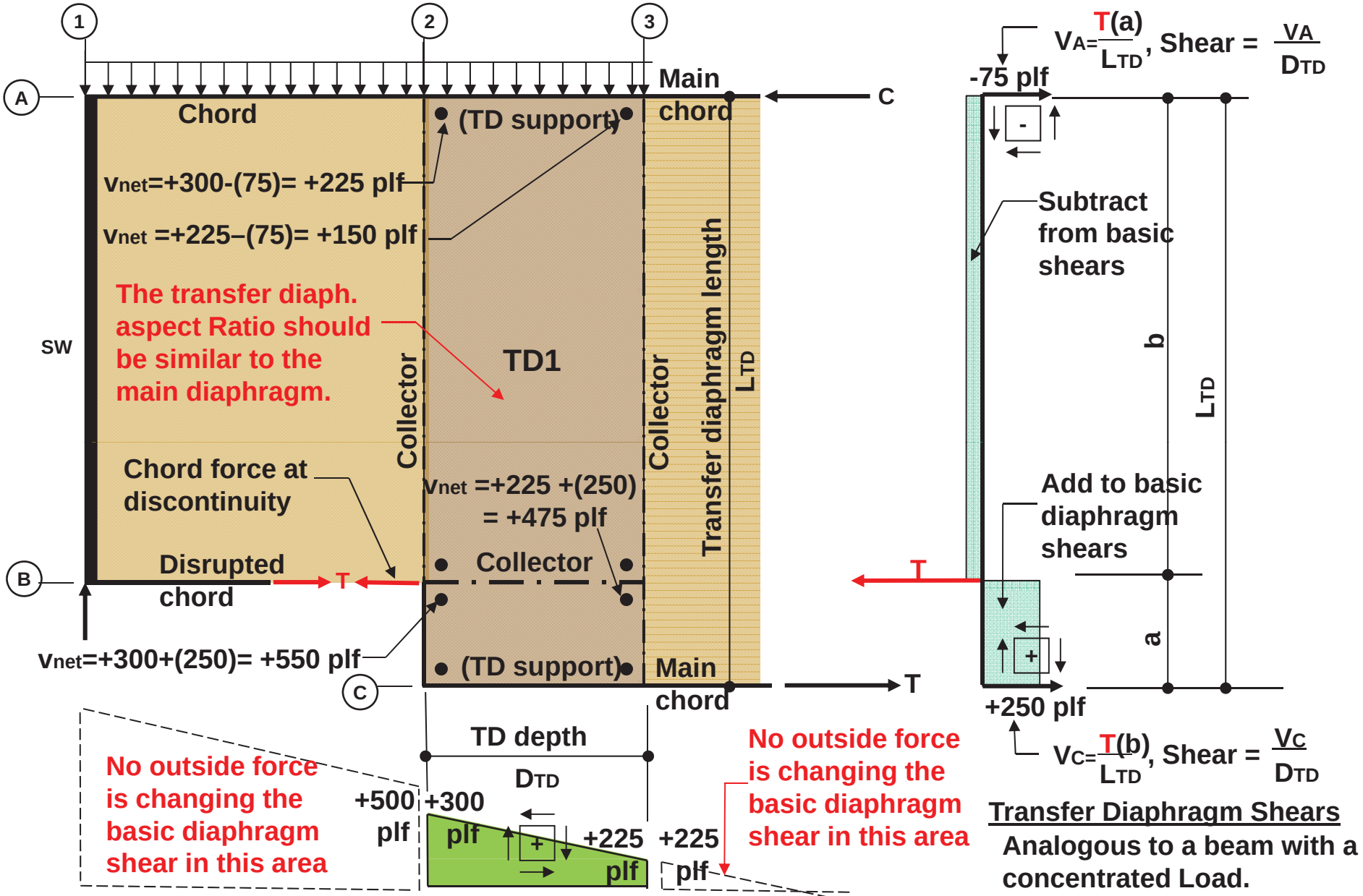


NOTE:

Collector must extend the full depth of the transfer diaphragm

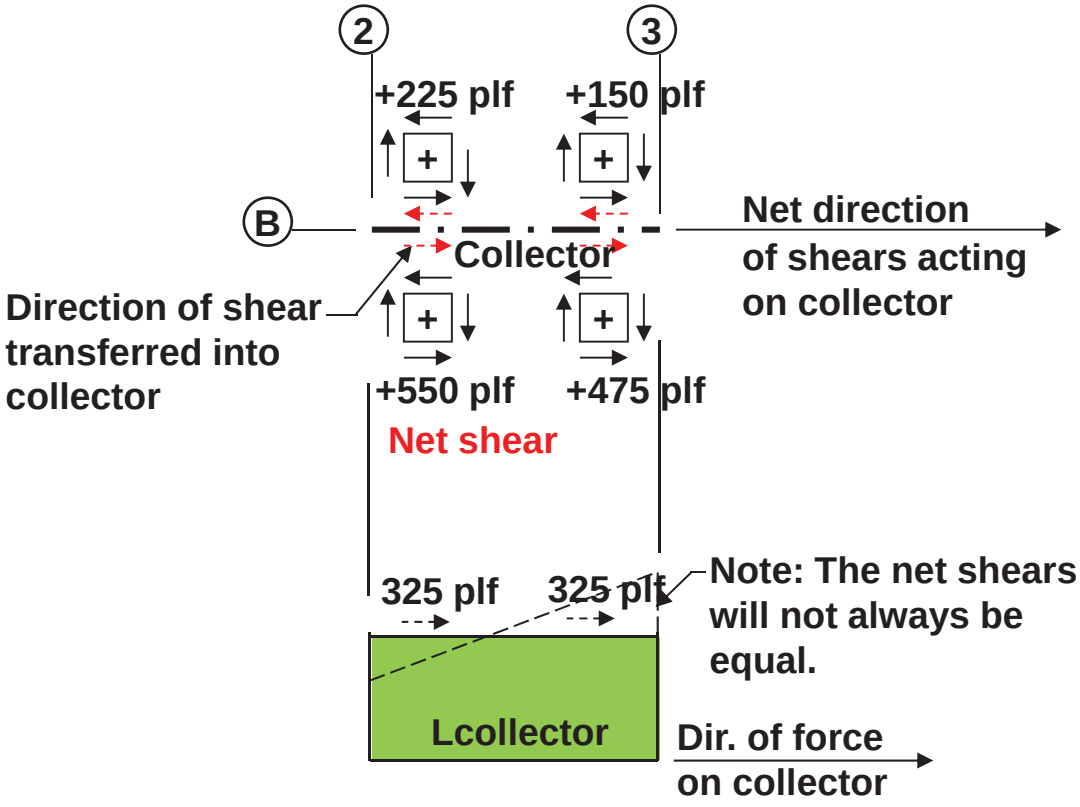
Transfer using beam concept

Transfer Mechanism



Basic Procedure

Method by Edward F. Diekmann



Resulting net shear diagram on collector

- 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).

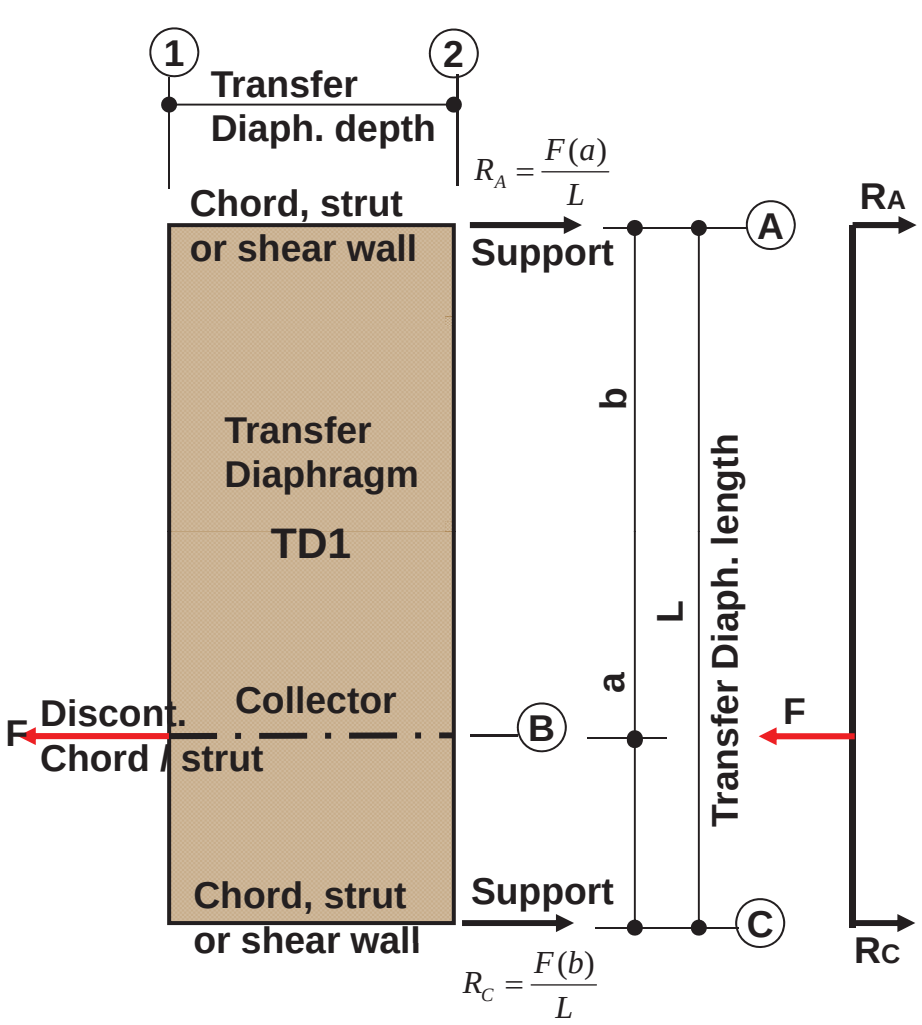
  Shear left=+550-225= +325 plf

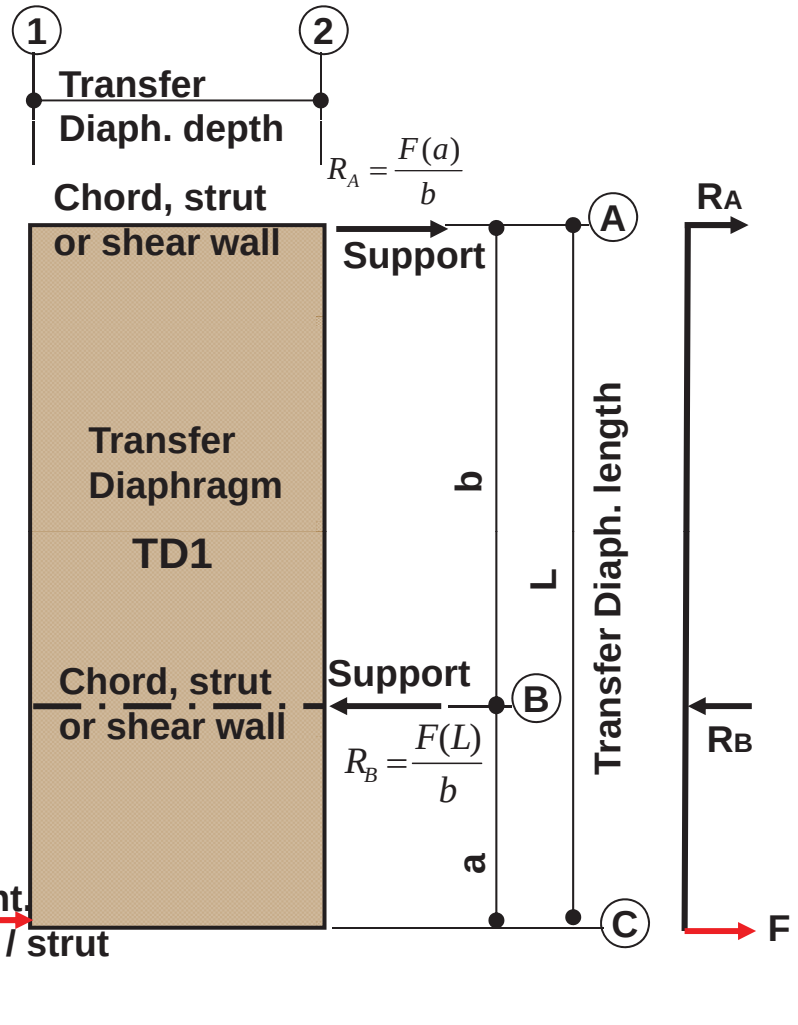
  Shear right=+475-150=+325 plf

- Collector force=area of shear diagram

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

Shear Distribution Into The Collector





Simple Span Transfer Diaphragm

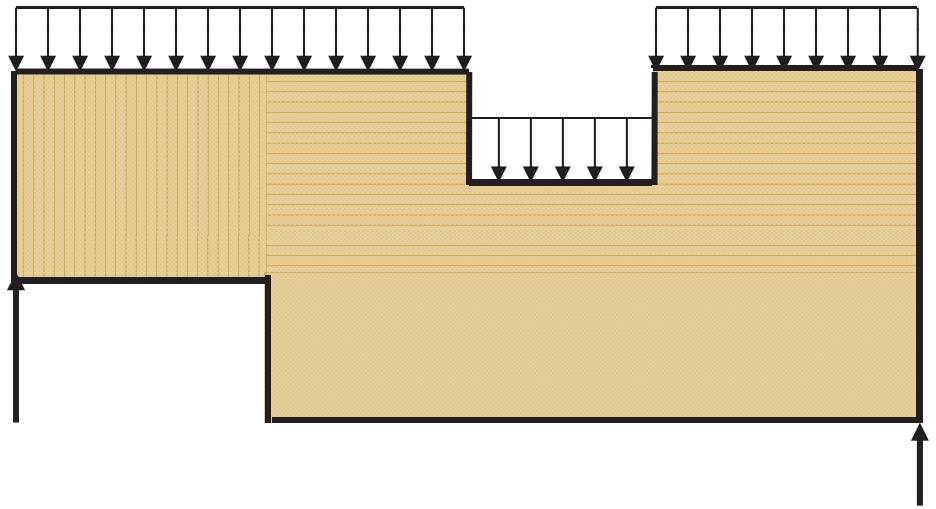
Analogous to a simple span beam with a concentrated load

Propped Cantilever Transfer Diaphragm

Analogous to a propped cantilever beam with a concentrated load

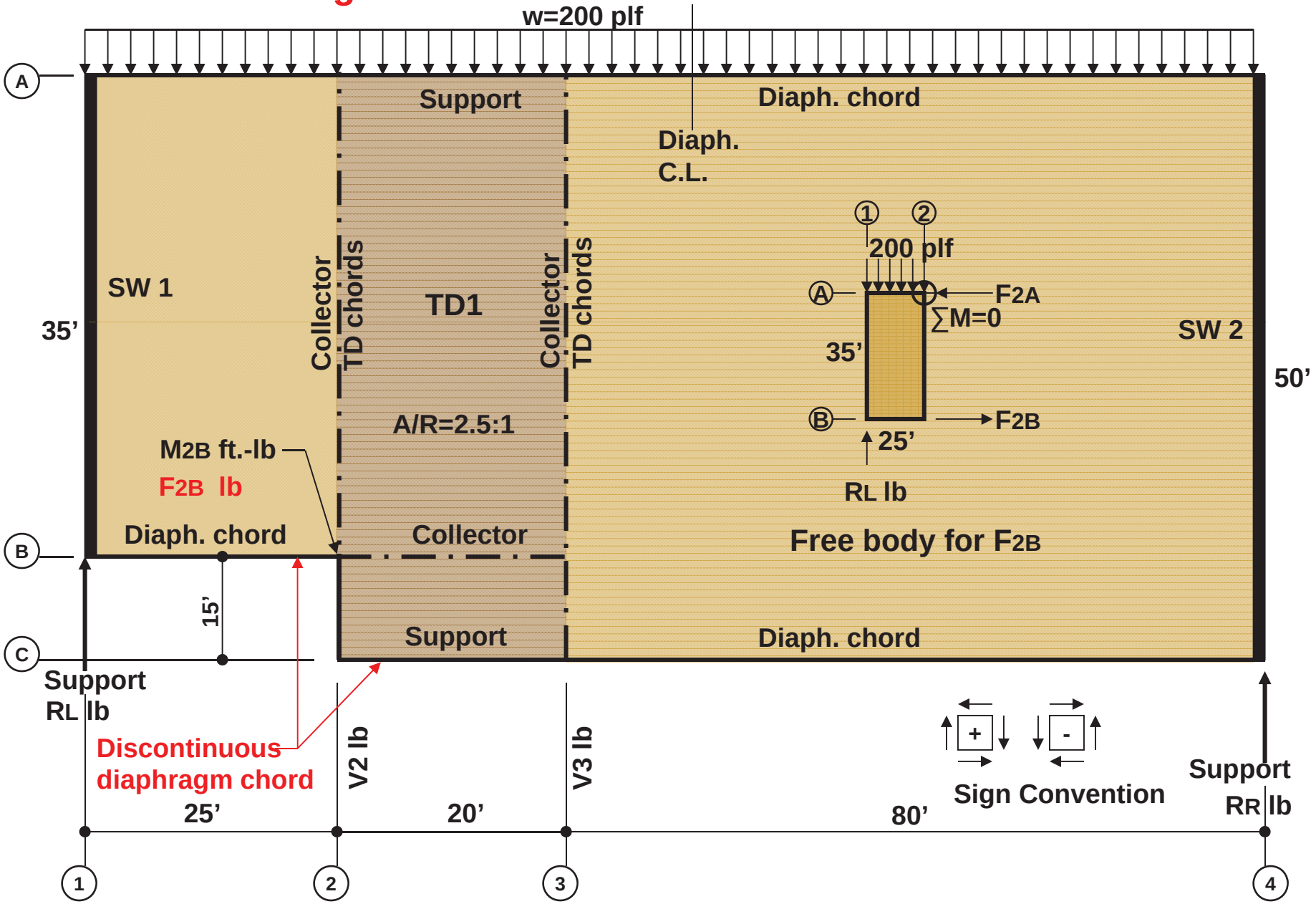
Simple Span and Propped Cantilever Transfer Diaphragms

Diaphragms with Horizontal Offsets

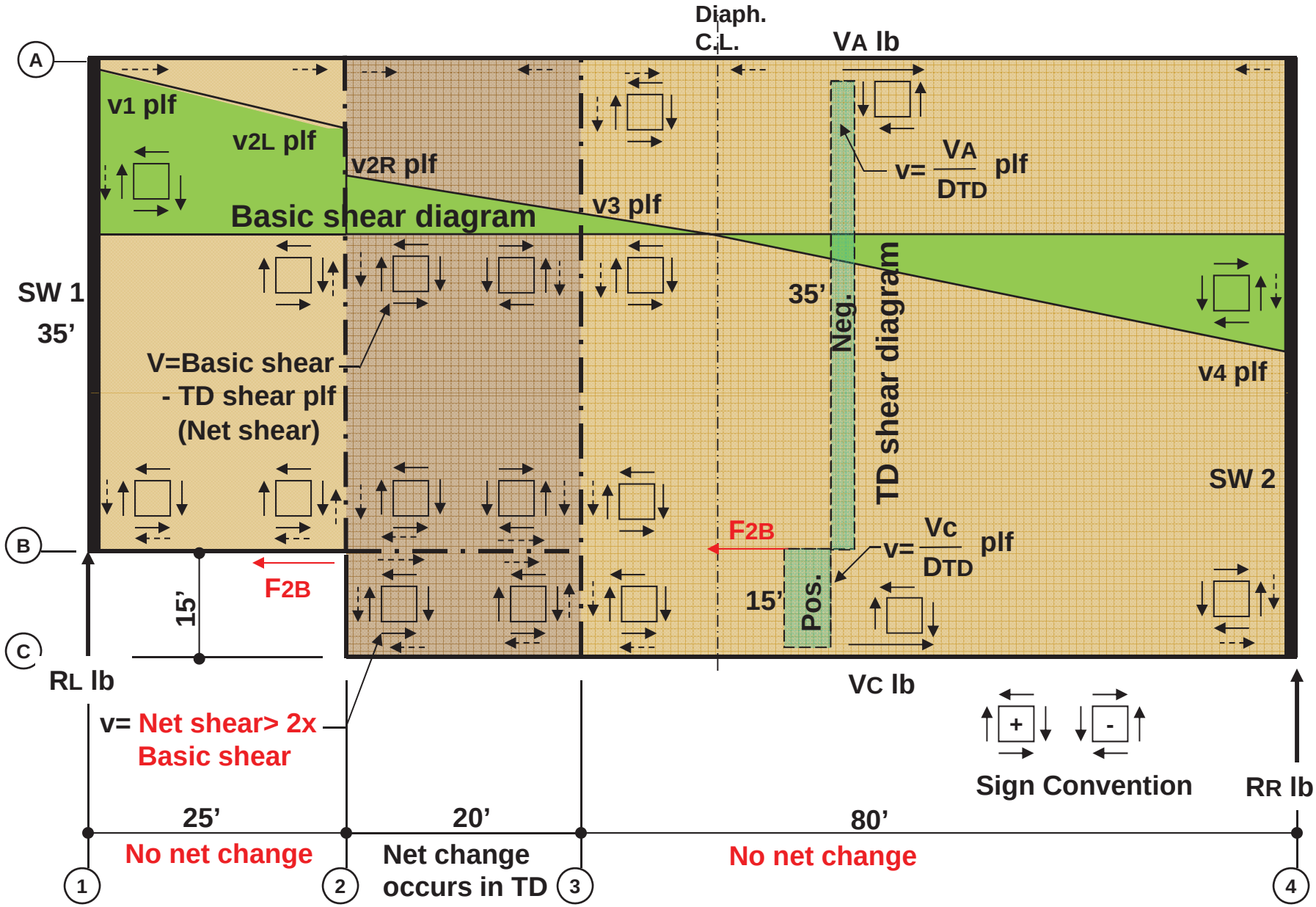


Example 1-Diaphragm with Horizontal End Offset

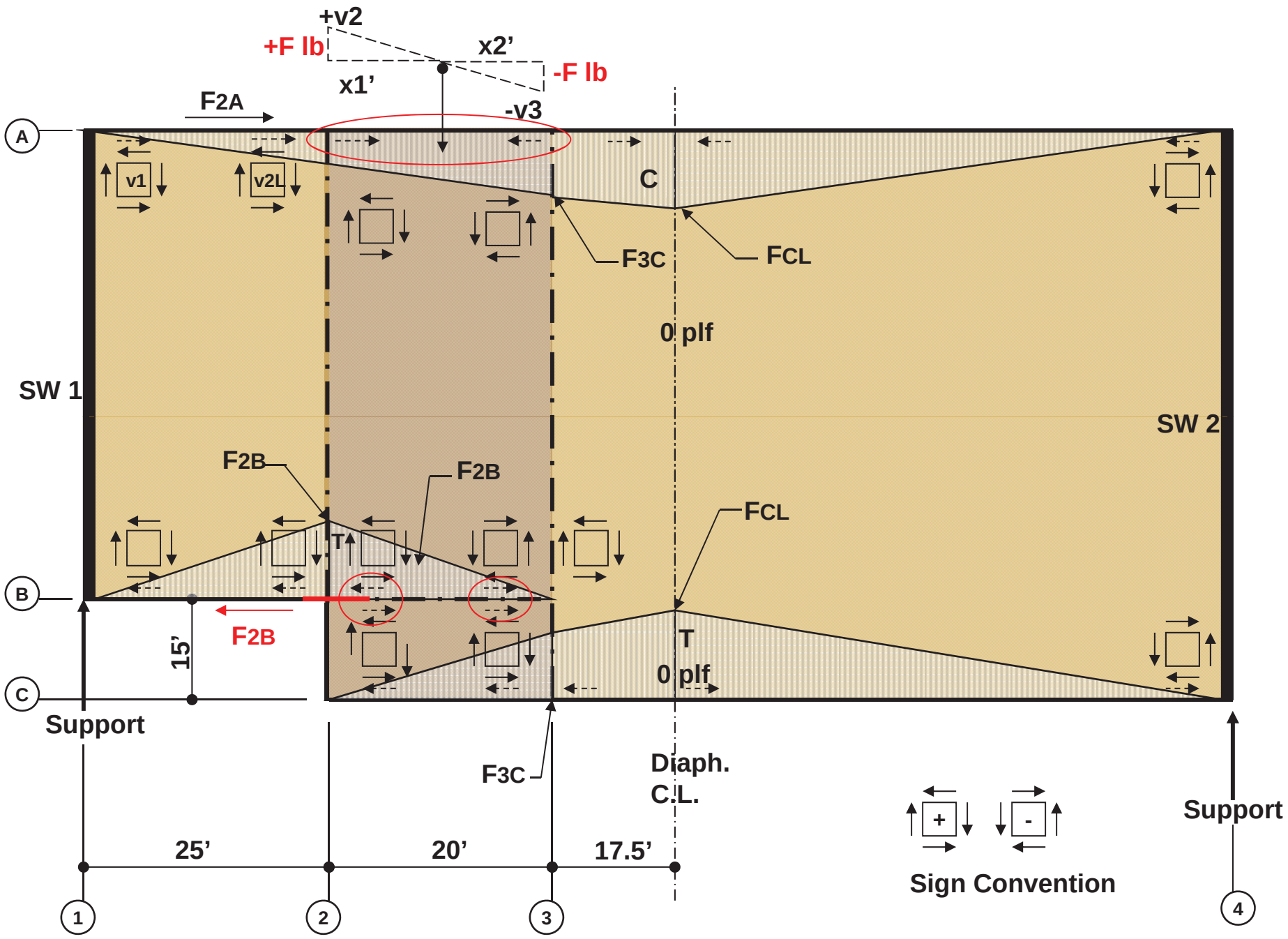
Transverse Loading



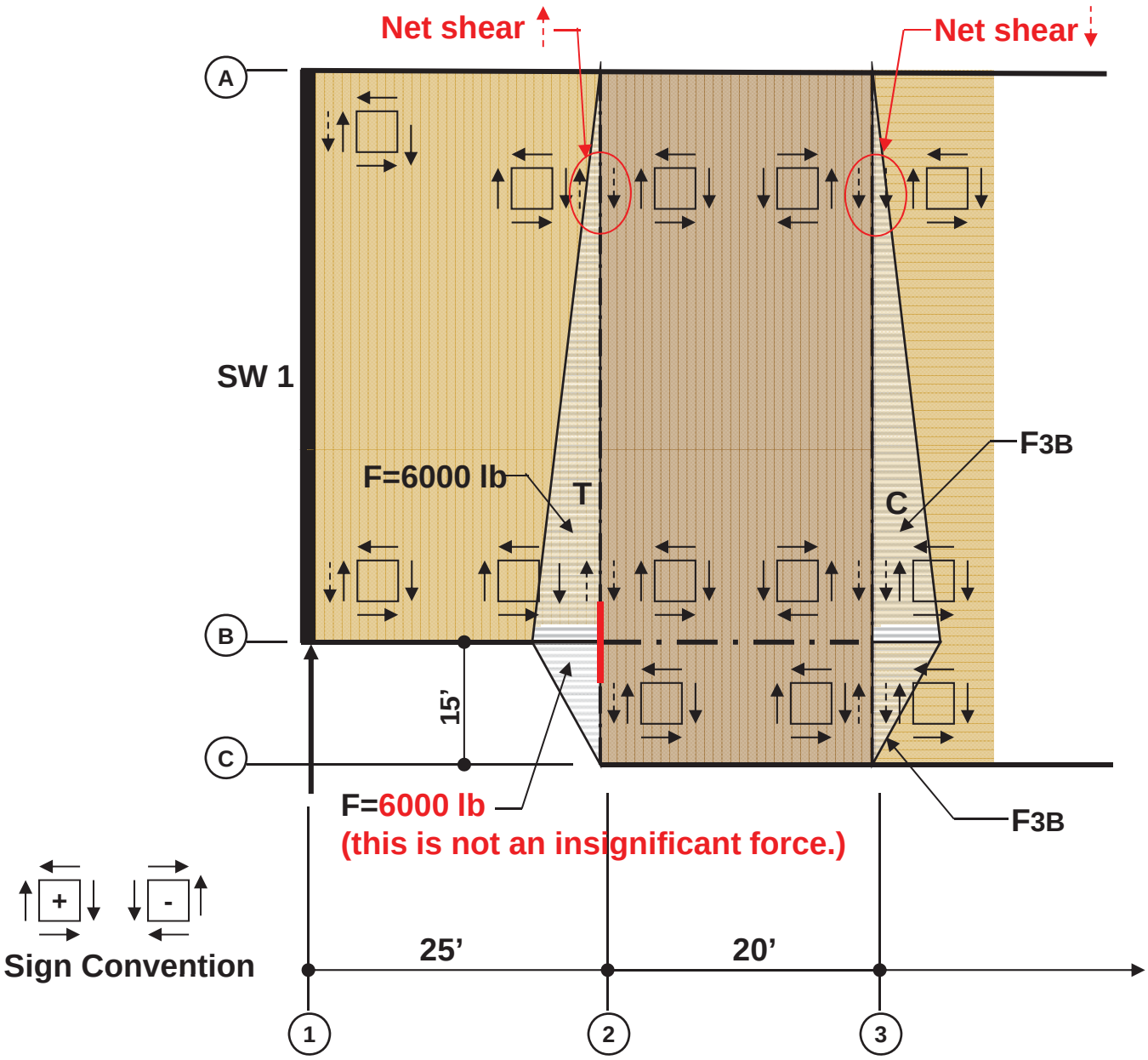
Transfer Diaphragm and Net Diaphragm Shear



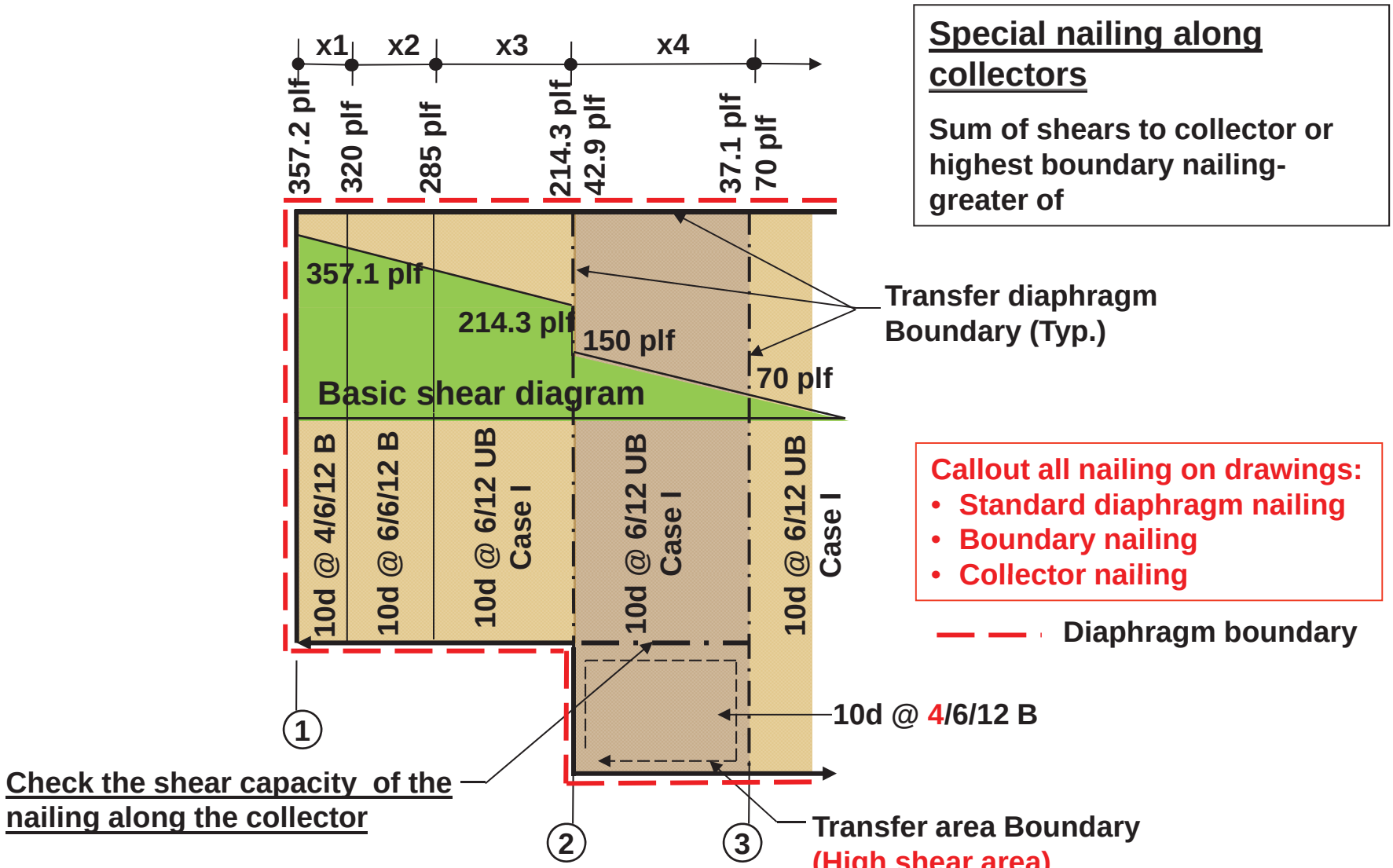
Net TD shears (basic shear +/- transfer diaph. shears)



Longitudinal Chord Force Diagrams



Transverse Collector Force Diagrams



Diaphragm Nailing Callouts

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

Part 1- Offset Diaphragms

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

Contact Information:
terrym@woodworks.org

Events/Presentation Archives (slide handouts)-free

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