Architecture 314
Structures I

Lateral Stability

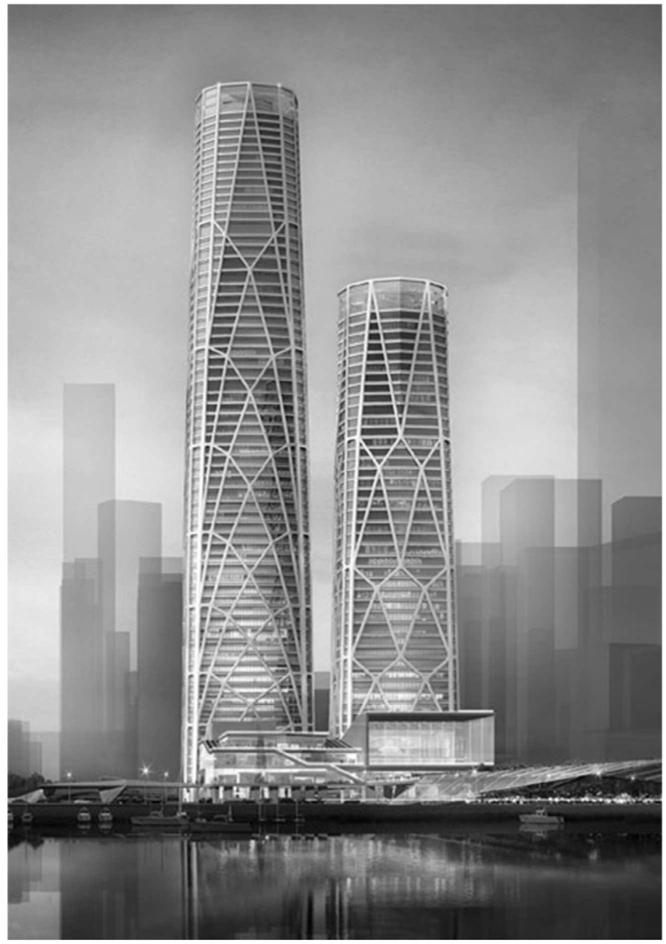
Lateral Loads

Frame Bracing

Shearwalls

Diaphragms

Bracing Configurations



CITIC Financial Center
Shenzhen, China
SOM

Load Combinations

Load Types

- Dead Load - D
- Roof Live Load - Lr
- Floor Live Load - L
- Snow Load - S
- Wind Load - W
- Earthquake – Ev & Eh

Allowable Stress Design (ASD)

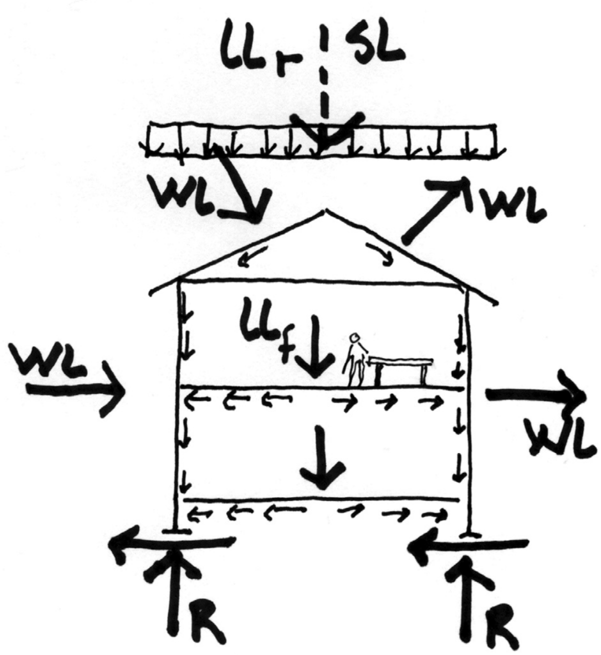
Not factored

- D
- D + L
- D + (Lr or S)
- D + 0.75 L + 0.75 (Lr or S)
- D + (0.6W)
- D + 0.75L + 0.75(0.6W) + 0.75(Lr or S)
- D + 0.7Ev + 0.7Eh

Strength Design (LRFD)

With gamma (γ) safety factors

- 1.4 D
- 1.2 D + 1.6 Lr + 0.5(Lr or S)
- 1.2 D + 1.6(Lr or S) + (L or 0.5W)
- 1.2 D + 1.0W + L + 0.5(Lr or S)
- 0.9D + 1.0W
- 1.2D + Ev + Eh + L + 0.2S
- 0.9D - Ev + Eh

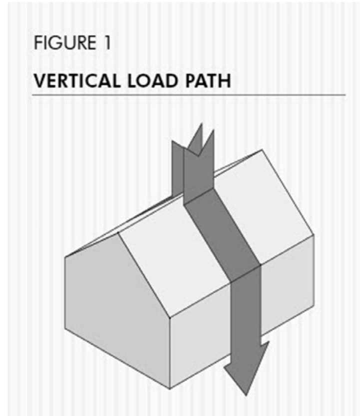


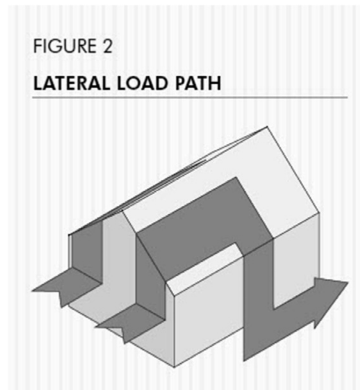
Load Paths

Vertical Loads
- gravity
- D, L, Lr, S

- seismic wind
- Ev Wv

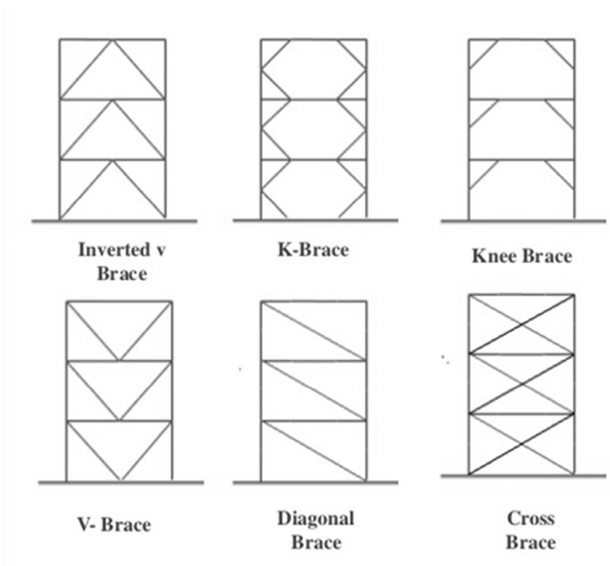
Lateral Loads
- wind Wh
- seismic Eh





Frame Bracing

types of bracing



John Hancock Tower, Chicago
SOM, 1968
Engineer: Fazlur Khan

Lateral Frame Bracing

Lateral Bracing
tension and compression
(Michigan North Quad)

Diagonal Tension Counters (X-Bracing)
(Buck Steel Buildings)

Lateral Stability

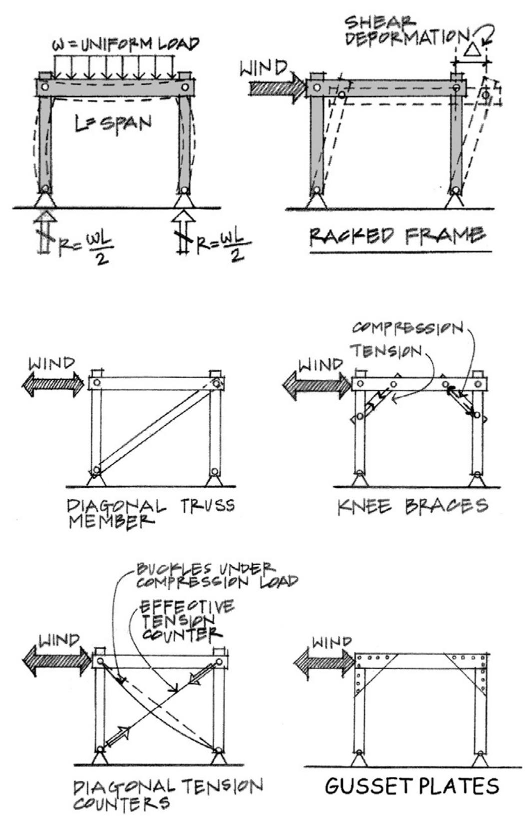
A system needs to be stable in all directions – x, y, and z.

Dead , Live and Snow Loads are vertical due to gravity.

Wind and Seismic Loads are primarily horizontal or lateral, but can also be vertical (usually upward).

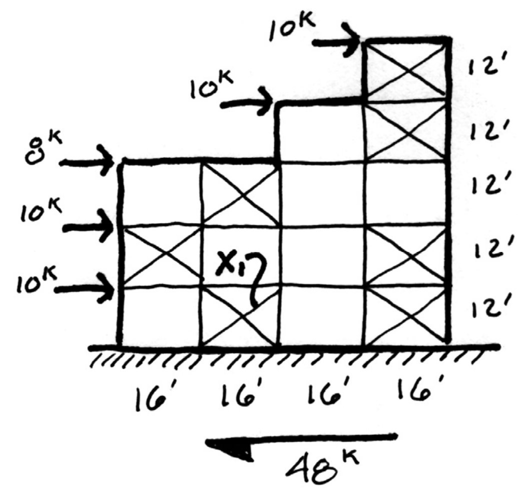
Lateral bracing can be achieved with:

- Diagonal truss member
- X-bracing members
- Knee bracing
- Gusset plates



Example Frame Bracing

- Check for stability. At least one ridged frame per story
- Convert distributed loads to point loads acting at floors.
- Solve the horizontal reaction for the whole system.
- Assume the bracing carries tension only

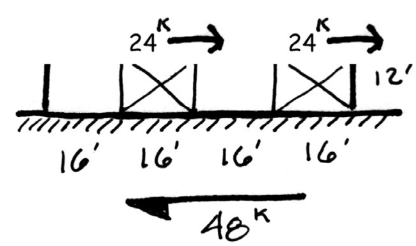


Base shear = 48k

$$\sum F_H = 0$$
$$0 = 10 + 10 + 8 + 10 + 10 - R$$
$$R = 48^k$$

Example Frame Bracing cont.

- Cut a FBD horizontally through the story containing the brace being solved.
- Sum horizontal forces to find the horizontal component in the braces. Assume load is divided evenly among braces in a story.
- In this case only the tension bracing carries load (rods or cables)
- Find the vertical component by proportions or trig function



$$\sum F_H = 0$$
$$0 = -48 + H_1 + H_2$$
$$H_1 = H_2 = 24^K$$

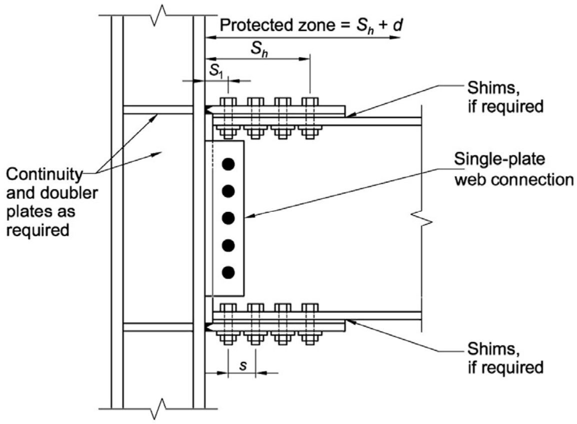
$$\frac{12}{16} : \frac{V}{24}$$
$$V = 18$$
$$X_1 = \sqrt{18^2 + 24^2} = 30^K$$

Lateral Stability

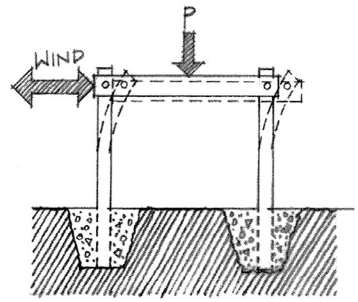
A system needs to be stable in all directions – x, y, and z.

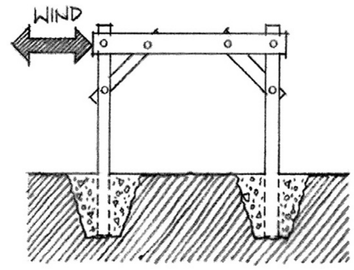
Fixed (moment) connections in a rigid frame can also provide stability.

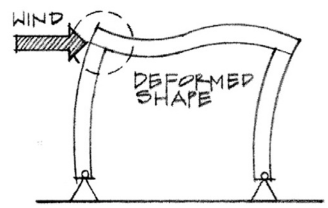
In a fixed frame the members act in both compression and bending.



moment connection

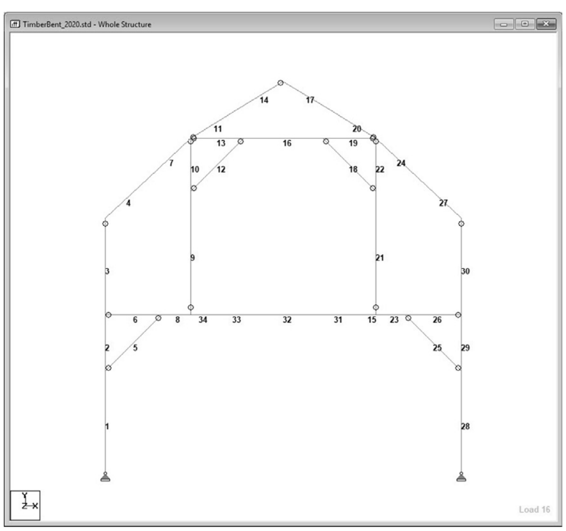




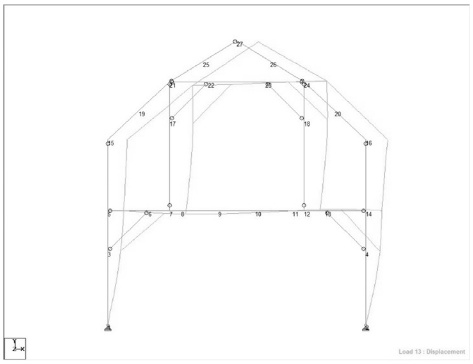


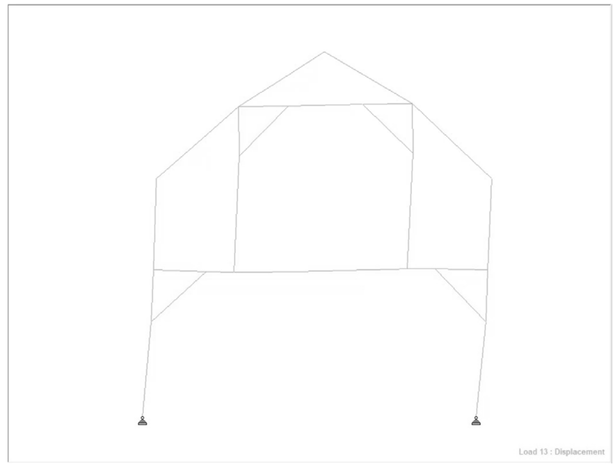
Timber Frame Bracing

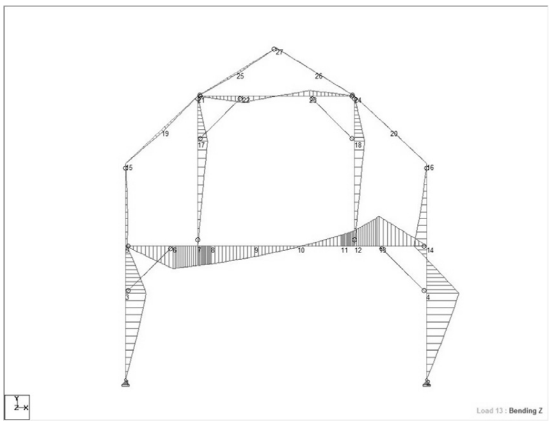
John Pariseau's Timber Frame
Load Case: D + 0.6W

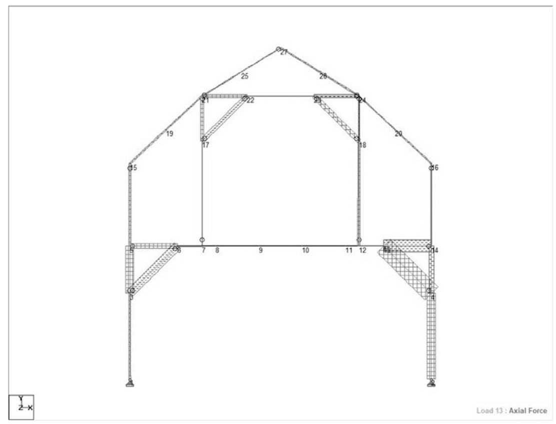


Timber Frame Bracing
John Pariseau's Timber Frame

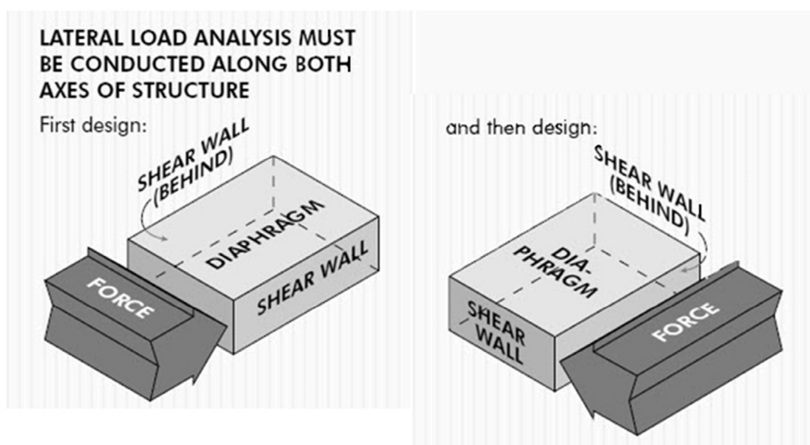


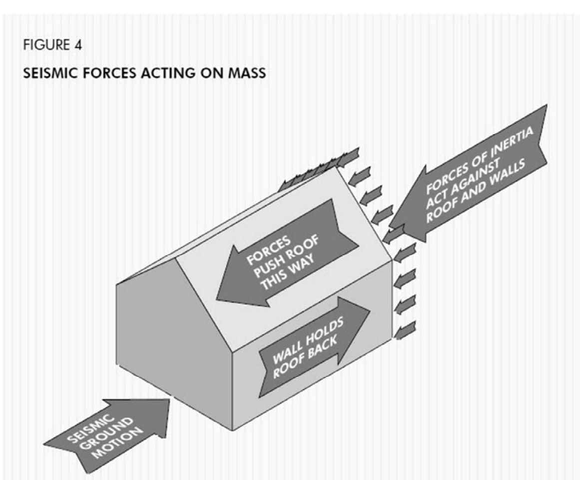


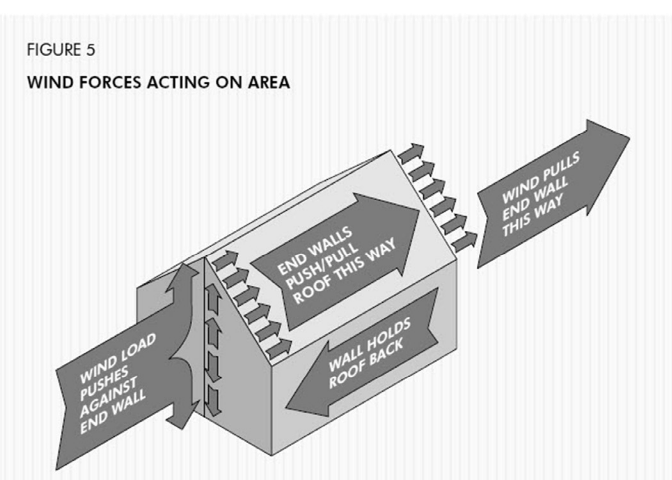




Diaphragms and Shear Walls



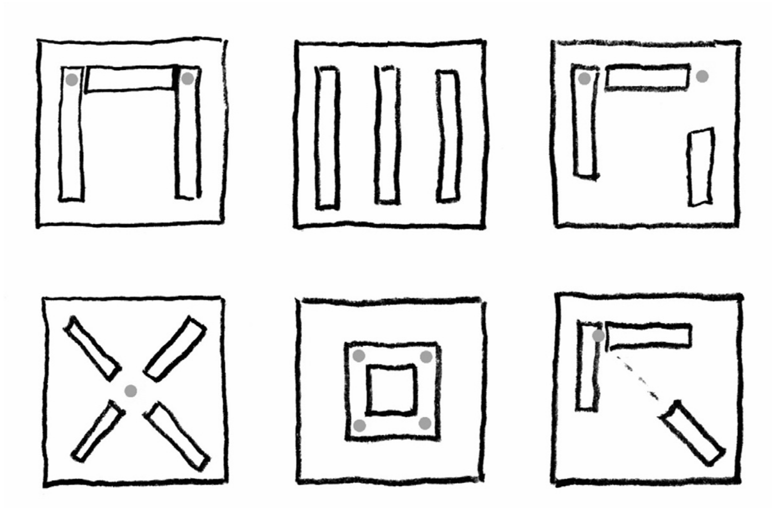




Lateral Force Resistance

Stability requires at least 2 points of intersection.

Force is more evenly resisted with centroid of walls in the kern of slab



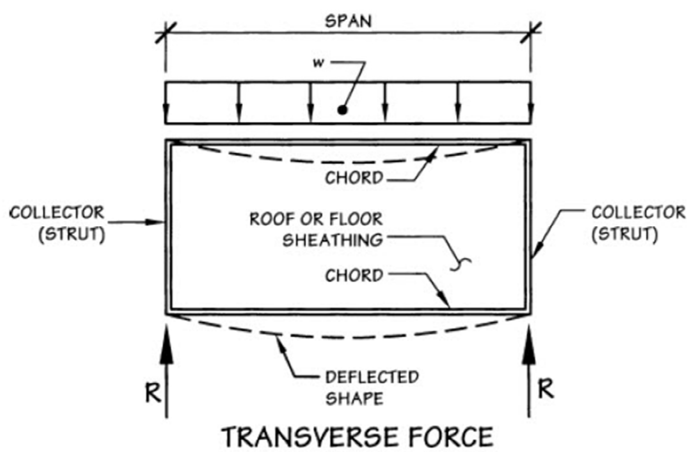
Definitions

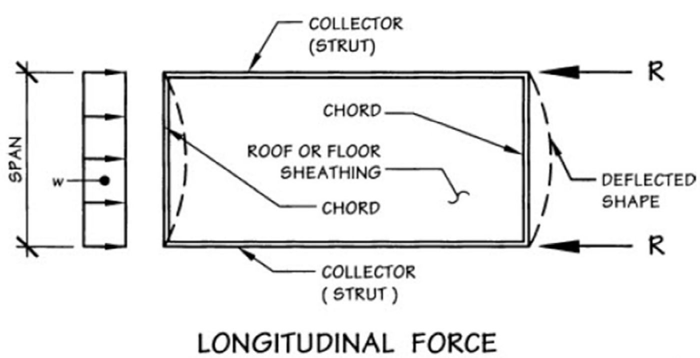
Diaphragm – a flat structure which acts as a deep beam to resist in plane loads.

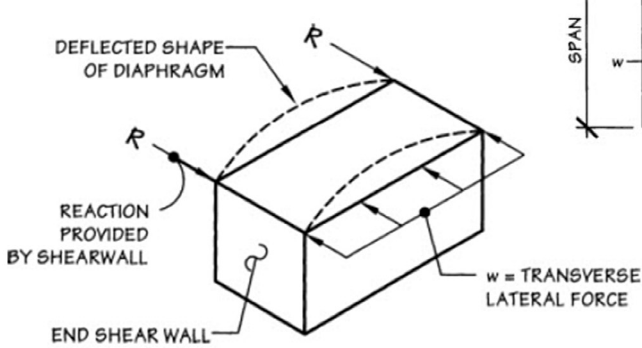
Shear Wall – a vertical structure which acts as a cantilevered diaphragm

Chord – the edge member of a diaphragm

Collector (strut) – transfers the force from the diaphragm to the shear wall



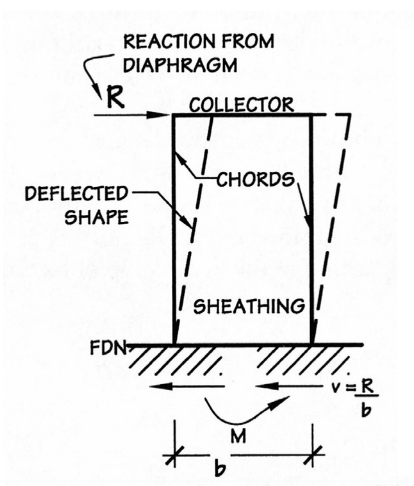


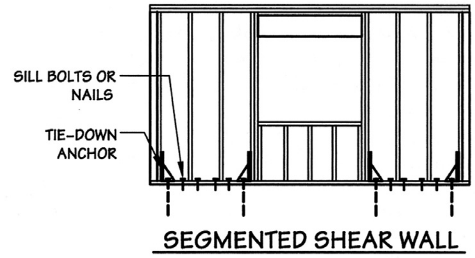


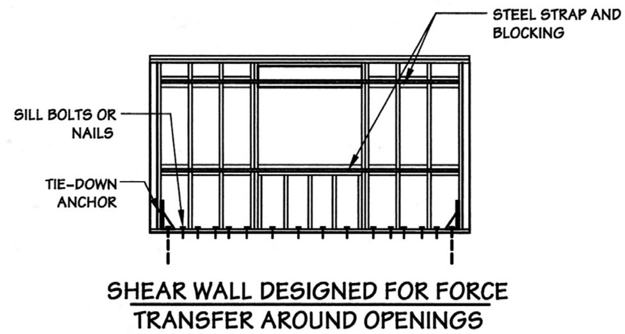
Three Shear Wall Types

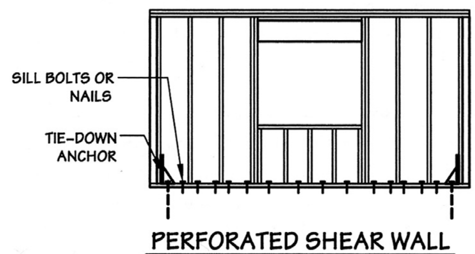
Design considerations:

- Sheathing – type and thickness
- Sheathing nailing – size and spacing
- Chord design – tension and compression
- Collector design – tension and comp.
- Anchorage – hold-downs, shear ties
- Shear panel proportions – h:w
- Deflection









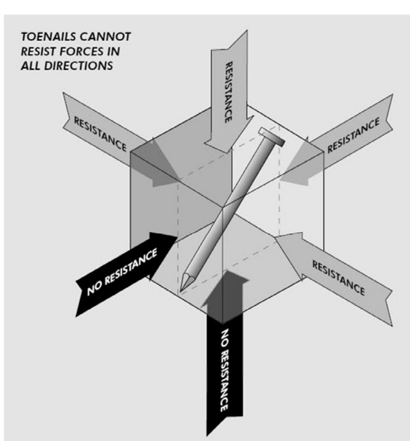
Shear Wall Connections

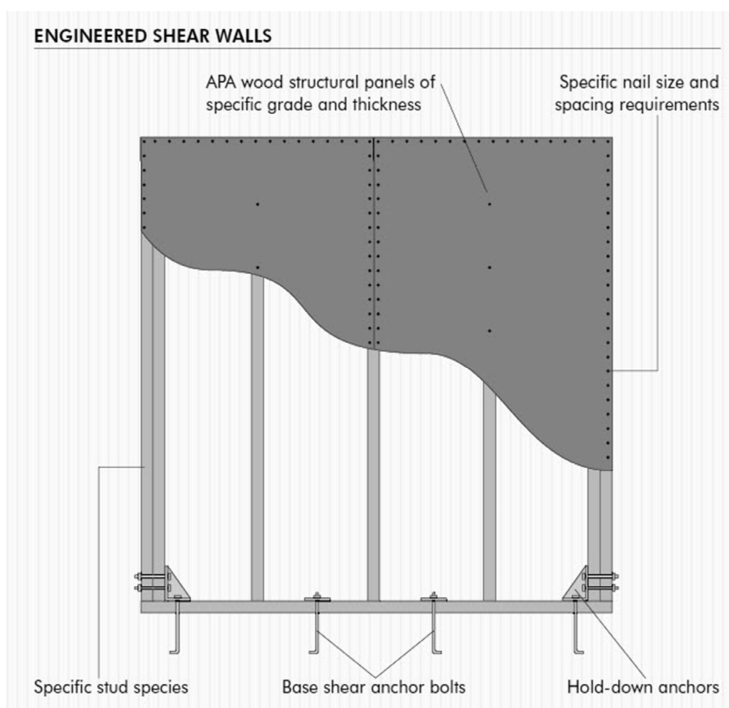
Connections need to transmit force in 6 directions (3 axes)

Toenails – not adequate

Hold–down Anchors

Base Shear Anchors





Shear Wall Types

Acts like a vertical cantilever beam

Let-in Wall Bracing – 45° - limited to single or top story

Wall Board – requires 8 ft length

Wood Structural Panel – requires 4 ft length

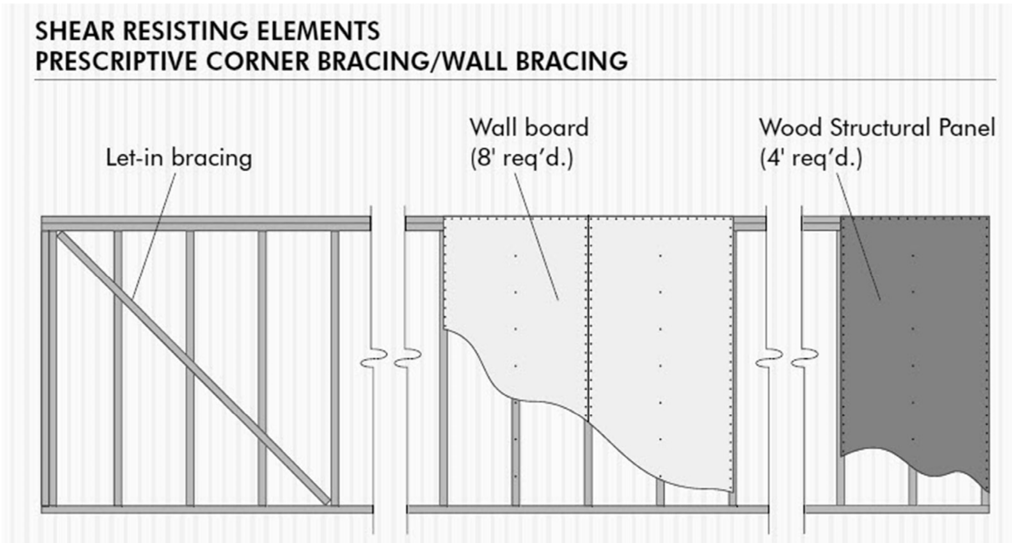
3 times stronger by length

Table 4.3.4 Maximum Shear Wall Aspect Ratios

Shear Wall Sheathing Type	Maximum h/b_s Ratio
Wood structural panels, unblocked	2:1
Wood structural panels, blocked	3.5:1
Particleboard, blocked	2:1
Diagonal sheathing, conventional	2:1
Gypsum wallboard	2:1[1]
Portland cement plaster	2:1[1]
Structural Fiberboard	3.5:1

1 Walls having aspect ratios exceeding 1.5:1 shall be blocked shear walls.

AWC SDPWS 2015 (in 2021 Tab. 4.3.3)



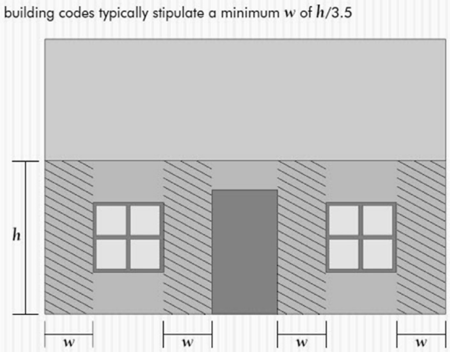
Shear Wall Design Elements

- Panel Thickness
- Panel Grade
- Nail spacing
- Base shear anchors
- Hold down anchors (at ends of each wall)
- Placement for lateral stability
- Fastening at edges (chords)

FIGURE 11

SHEAR WALL SEGMENT

Local building codes typically stipulate a minimum w of $h/3.5$



A Shear Wall...	A Diaphragm...
Is vertical	Is horizontal (or nearly so)
Is designed like a cantilevered beam	Is designed as a simply supported beam
Table has only blocked values, because a shear wall is always blocked*	Table has both blocked and unblocked diaphragm values

*A code requirement.

FIGURE 13

OVERTURNING

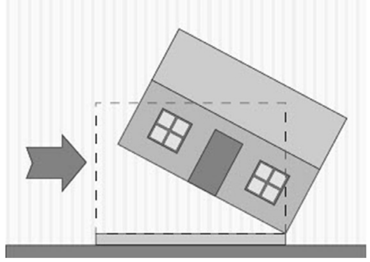
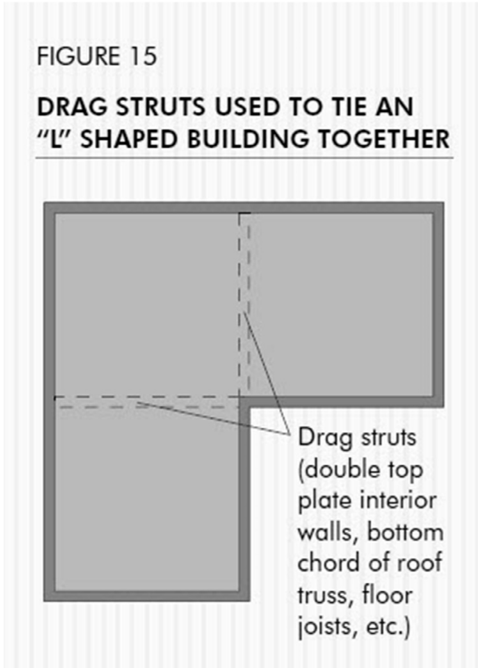


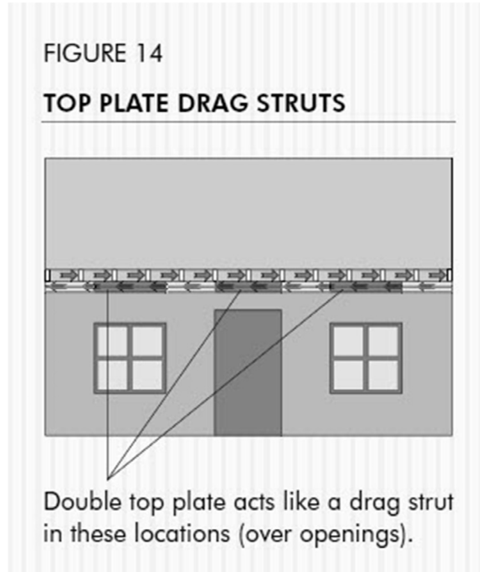
FIGURE 12

BASE SHEAR

Drag Struts

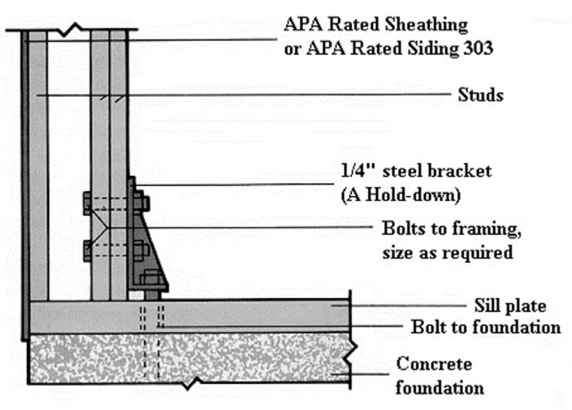
Double Top Plate

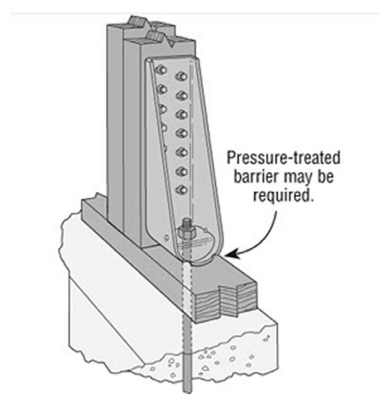


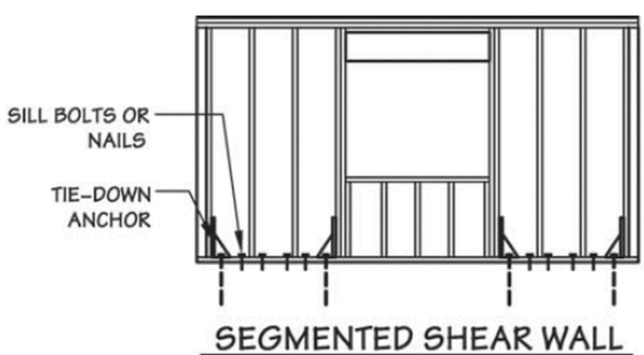


APA X305

Anchors and Tie-downs







Multi-story shear walls

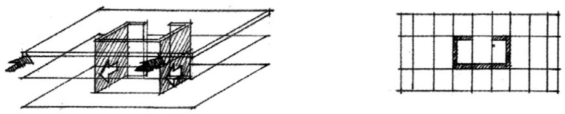


Figure 4.55 *Shearwalls at the central circulation core.*

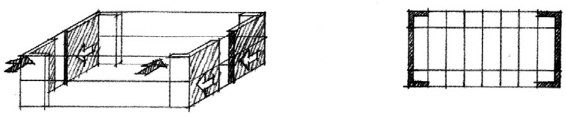


Figure 4.56 *Shearwalls at the exterior corners.*

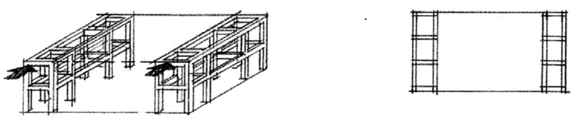


Figure 4.57 *Rigid frames at end bays (can also comprise the entire skeleton).*

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University of British Columbia, Vancouver, Canada