# Lateral Stability

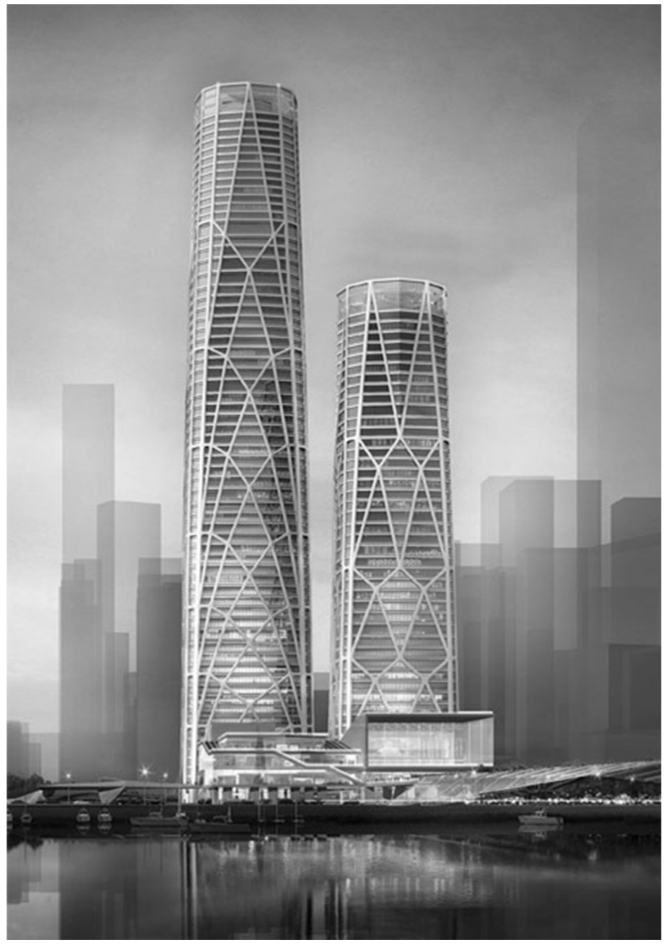
Lateral Loads

Frame Bracing

Shearwalls

Diaphragms

Bracing Configurations



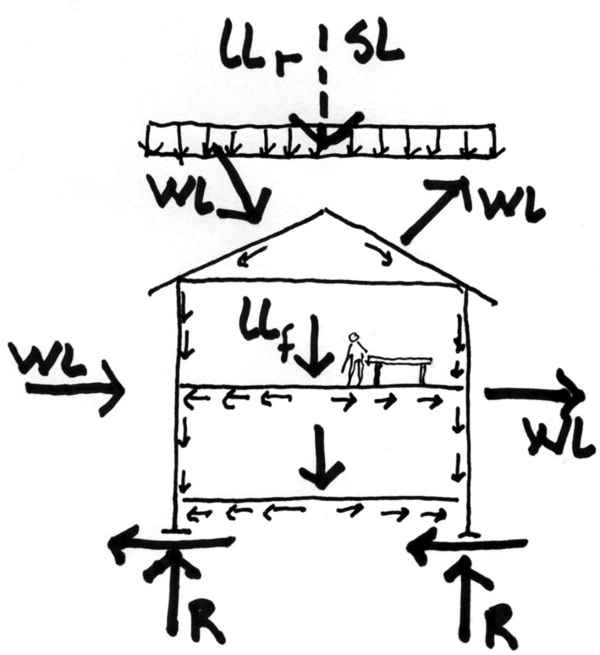
CITIC Financial Center
Shenzhen, China
SOM



## 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

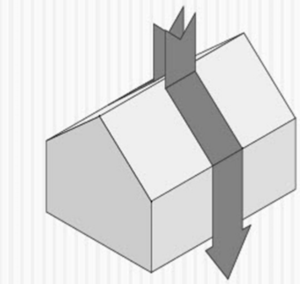
- 1.4 D
- 1.2 D + 1.6 Lr + 0.5(Lr or S)
- 1.2 D + 1.6(Lr or S) + (L or 0.5W)
- 1.2 D + 1.0W + L + 0.5(Lr or S)
- 0.9D + 1.0W
- 1.2D + Ev + Eh + L + 0.2S
- 0.9D - Ev + Eh

# Load Paths

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

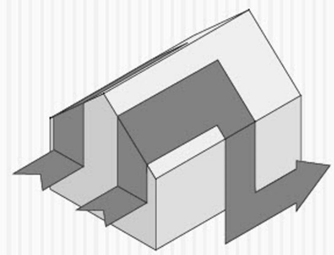
seismic wind
Ev Wv

FIGURE 1
VERTICAL LOAD PATH



Lateral Loads
- wind Wh
- seismic Eh

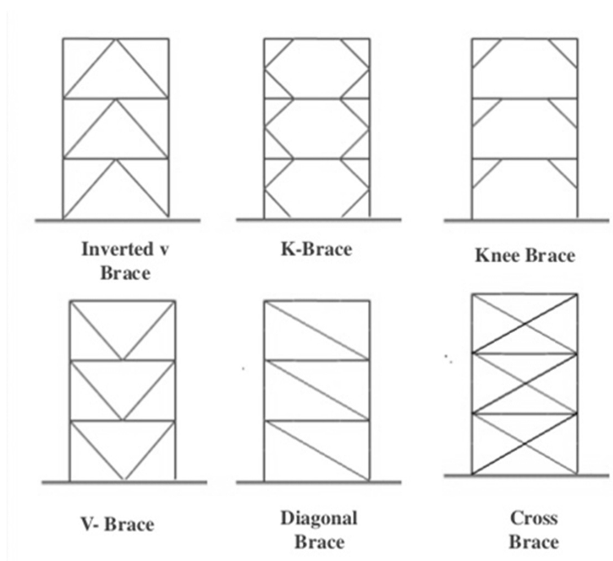
FIGURE 2
LATERAL LOAD PATH





# 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

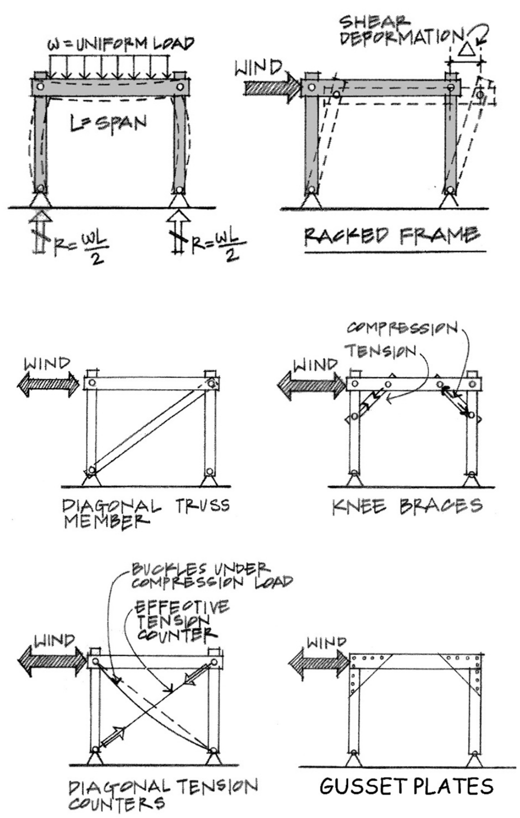
A system needs to be stable in all directions – x, y, and z.

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).

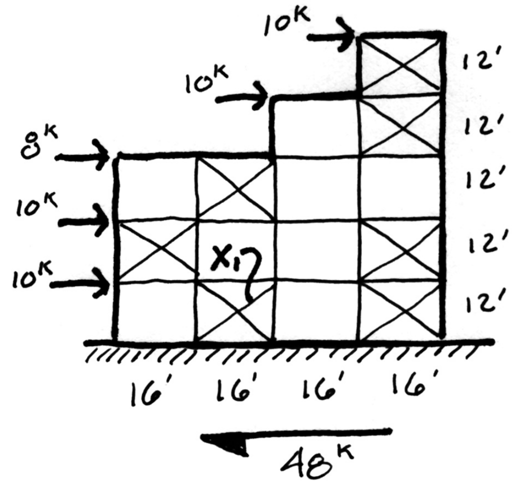
Lateral bracing can be achieved with:

- 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



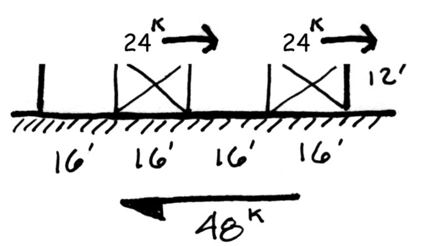

Base shear = 48k

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



# 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




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

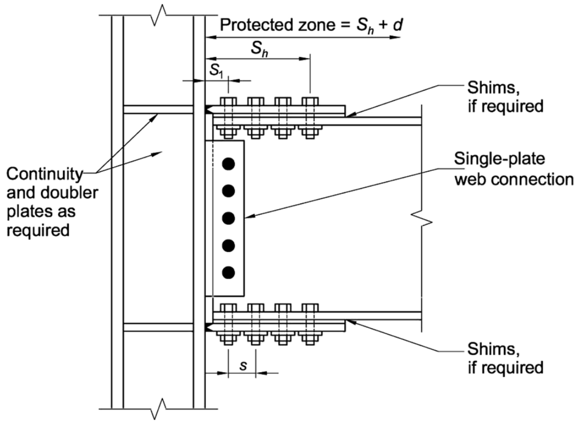
$$\frac{12}{16} : \frac{V}{24}$$
$$V = 18$$
$$X_1 = \sqrt{18^2 + 24^2} = 30^K$$

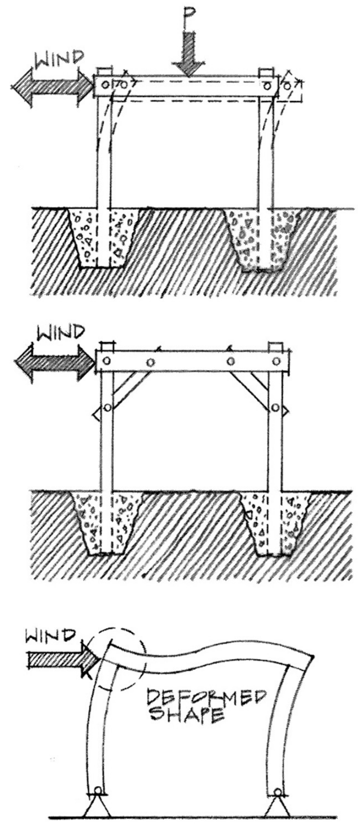
# Lateral Stability

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.



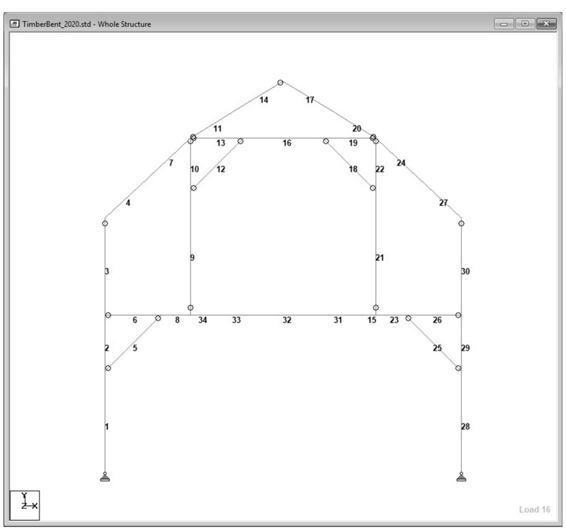




moment connection

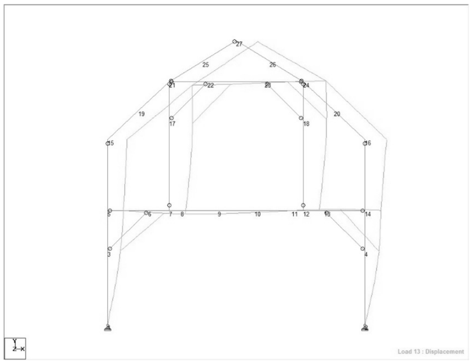


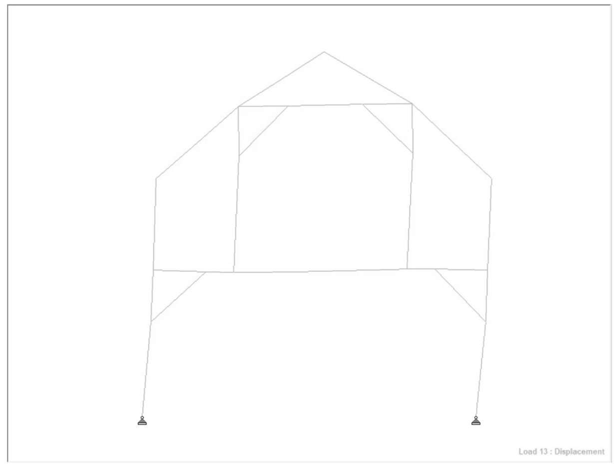
# Timber Frame Bracing

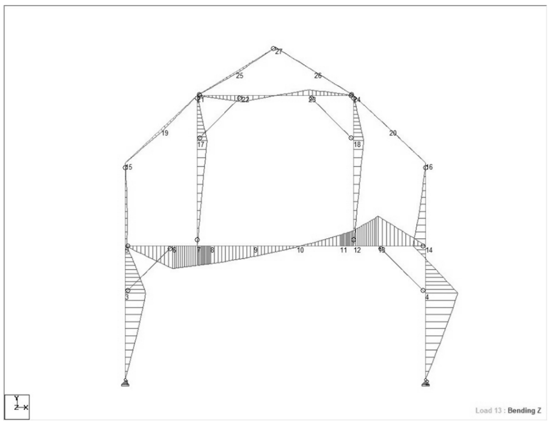
John Pariseau's Timber Frame
Load Case: D + 0.6W

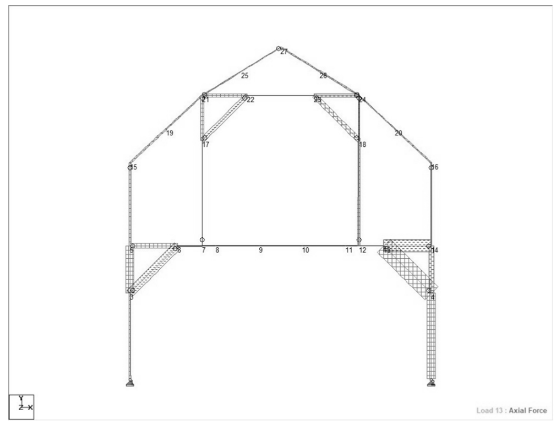



# Timber Frame Bracing
## John Pariseau's Timber Frame











# Diaphragms and Shear Walls

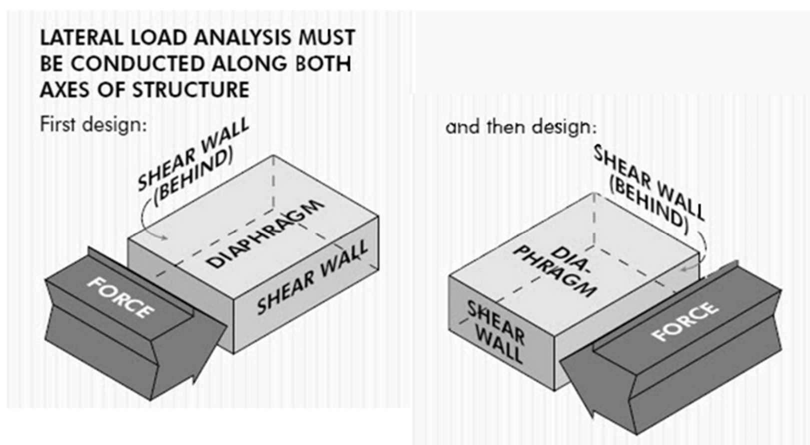



FIGURE 4

SEISMIC FORCES ACTING ON MASS

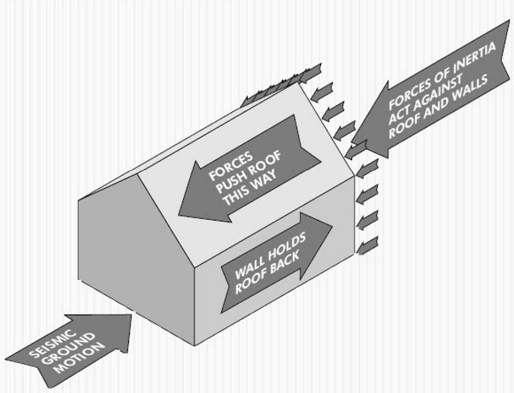
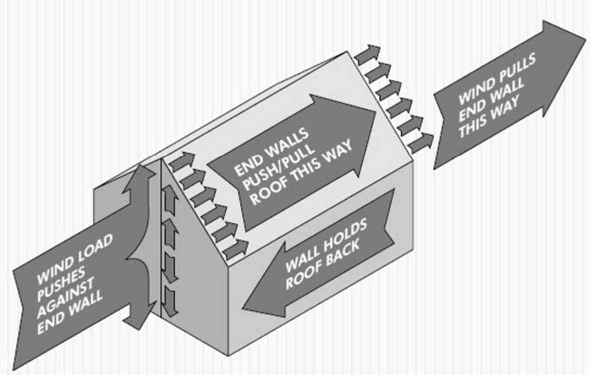



FIGURE 5

WIND FORCES ACTING ON AREA



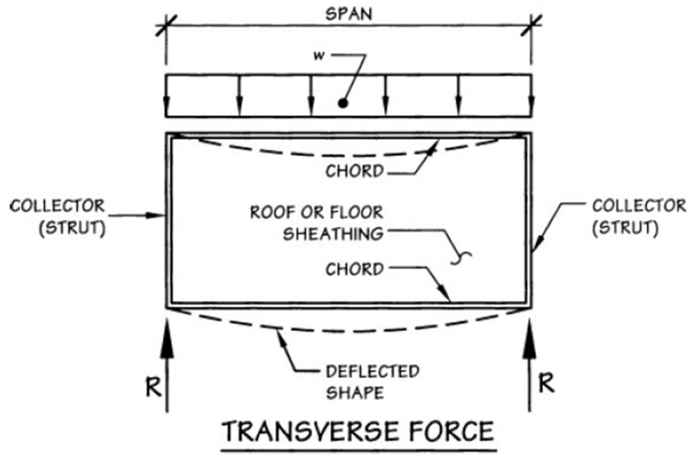
# Definitions

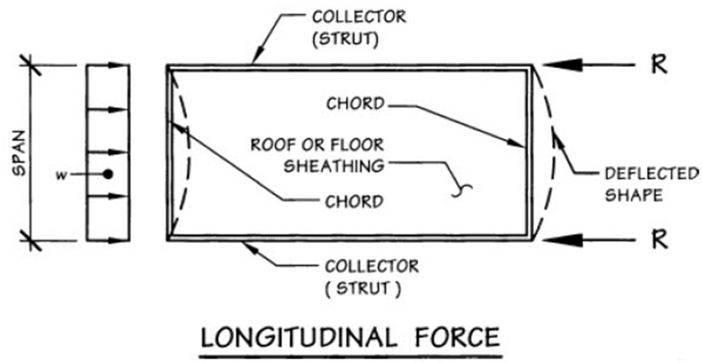
Diaphragm – a flat structure which acts as a deep beam to resist in plane loads.

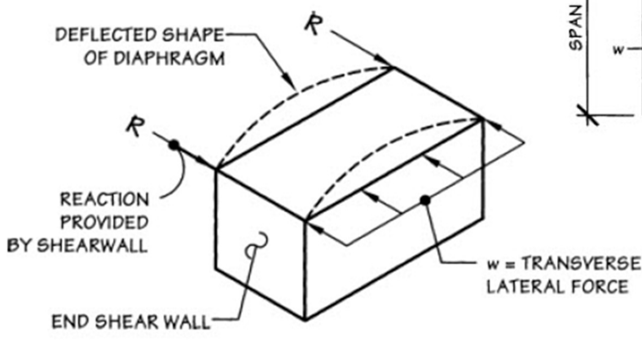
Shear Wall – a vertical structure which acts as a cantilevered diaphragm

Chord – the edge member of a diaphragm

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



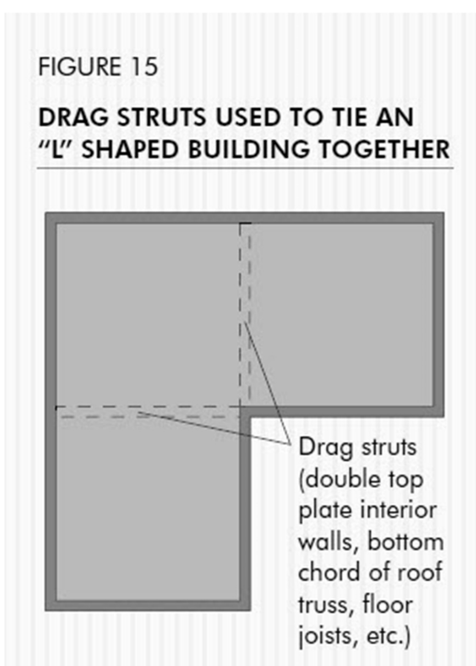



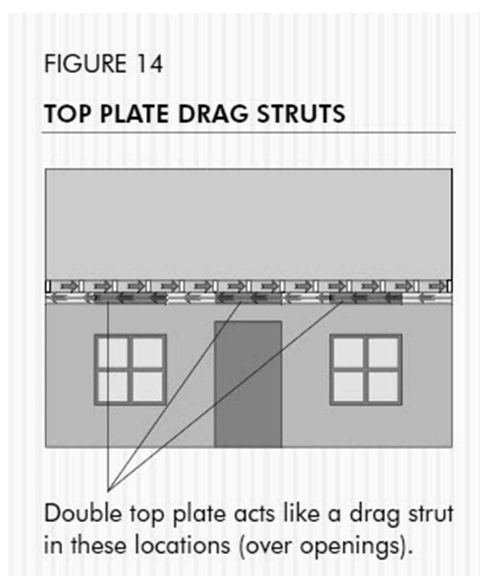






# Drag Struts

Double Top Plate



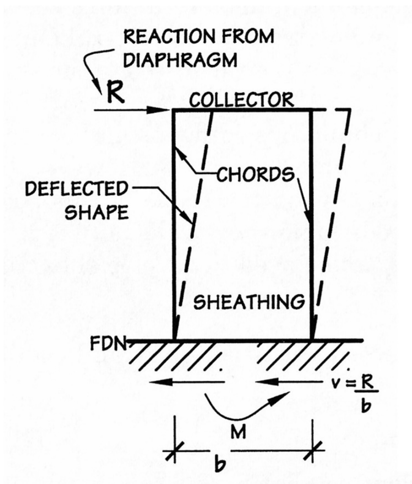



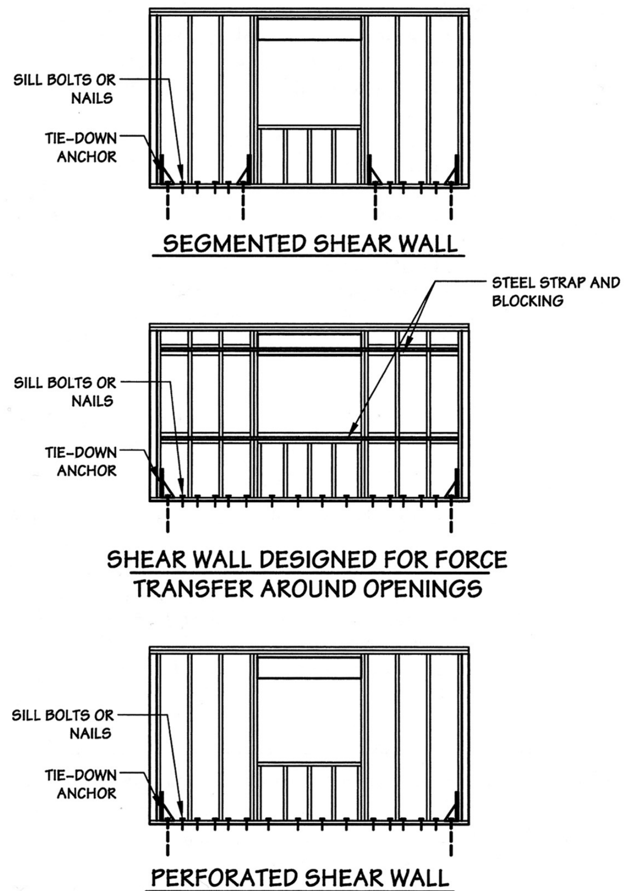

APA X305

# 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





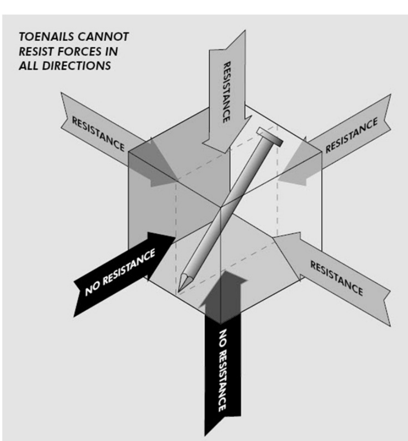

# Shear Wall Connections

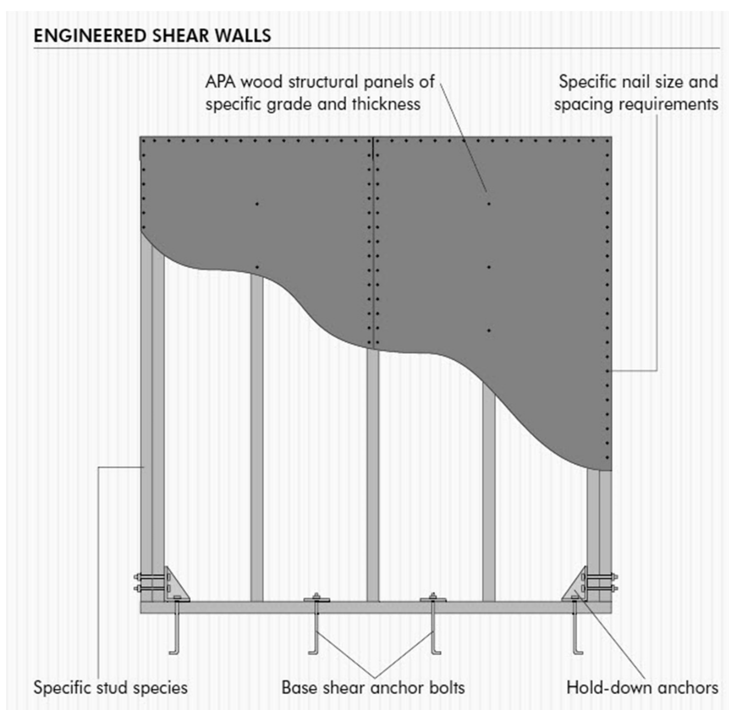
Connections need to transmit force in 6 directions (3 axes)

Toenails – not adequate

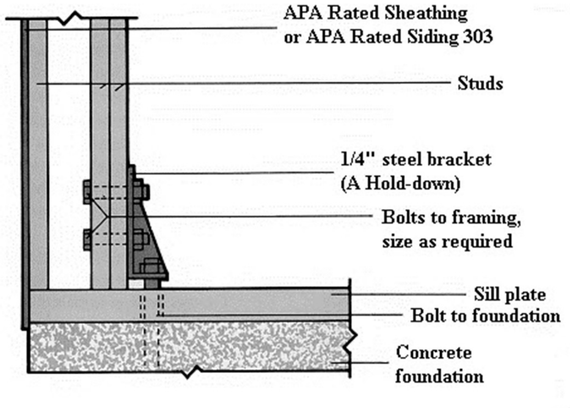
Hold–down Anchors

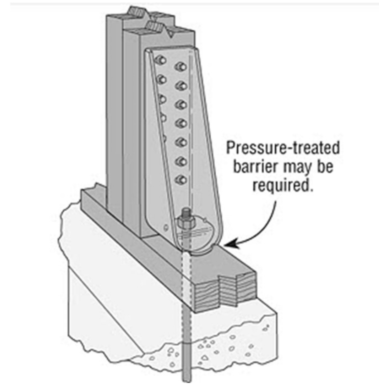
Base Shear Anchors

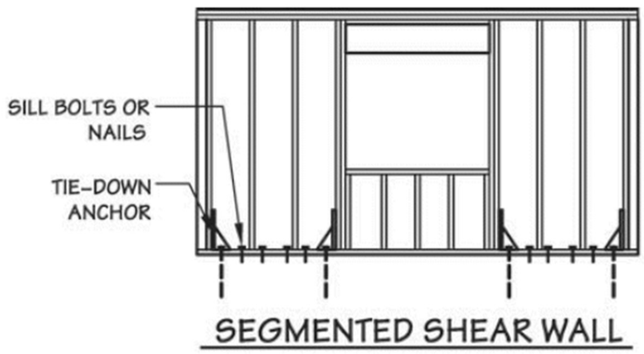


# Anchors and Tie-downs






# 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

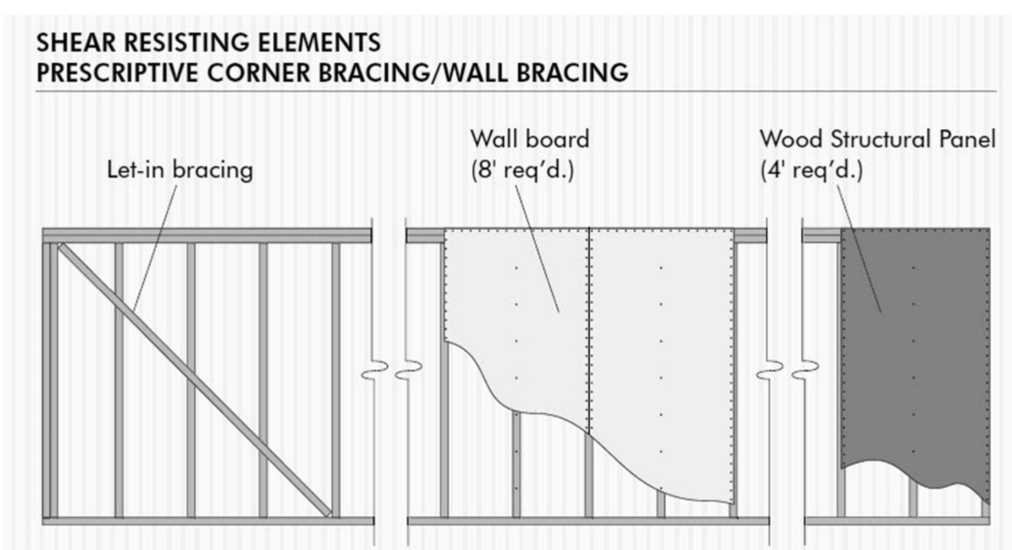
3 times stronger by length

**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)

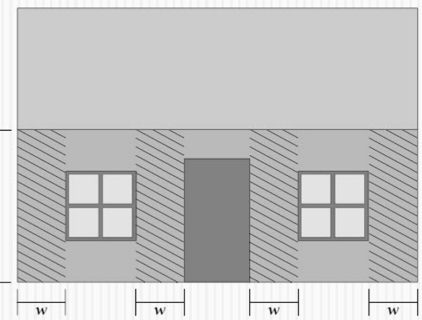


FIGURE 11
SHEAR WALL SEGMENT
Local building codes typically stipulate a minimum $w$ of $h/3.5$

| 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.

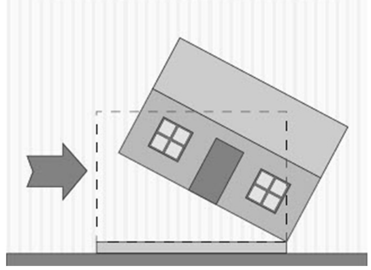


FIGURE 13
OVERTURNING

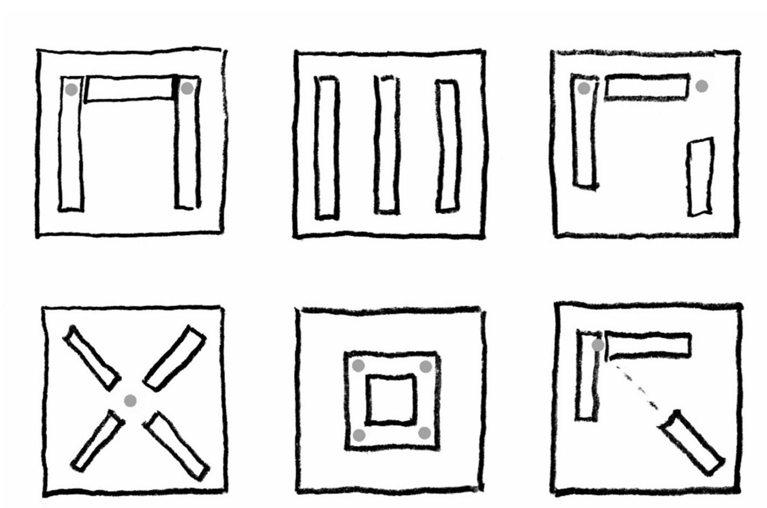

FIGURE 12
BASE SHEAR



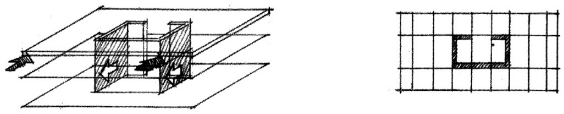
# Lateral Force Resistance

Stability requires at least 2 points of intersection.

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

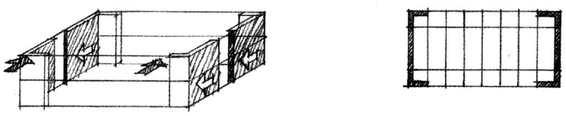


# Multi-story shear walls



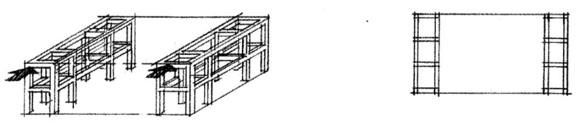
(a) (b) Plan diagram.

*Figure 4.55 Shearwalls at the central circulation core.*



(a) (b) Plan diagram.

*Figure 4.56 Shearwalls at the exterior corners.*



(a) (b) Plan diagram.

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

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University of British Columbia, Vancouver, Canada