

Lateral Stability

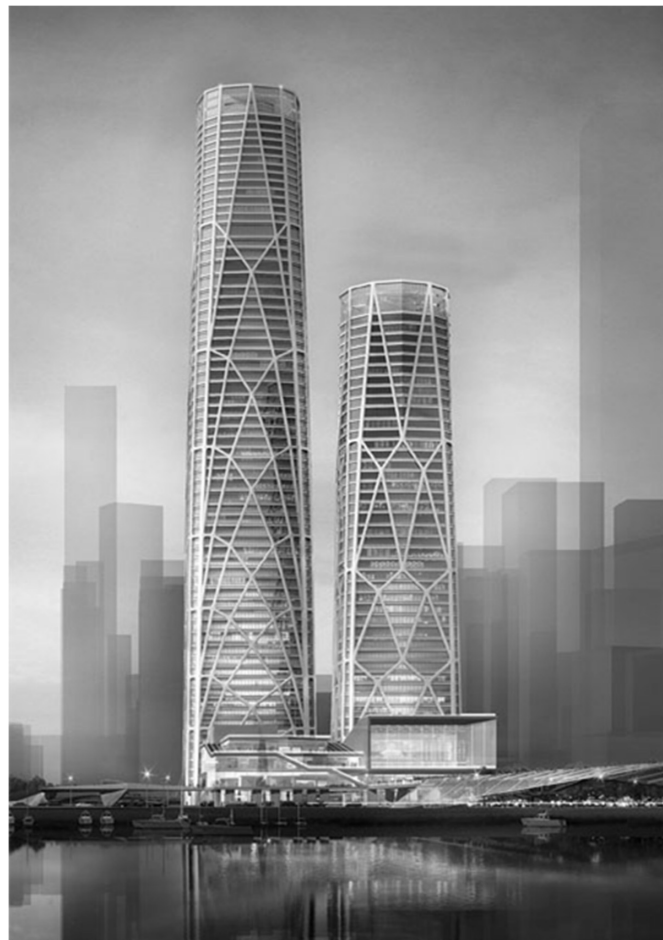
Lateral Loads

Frame Bracing

Shearwalls

Diaphragms

Bracing Configurations



CITIC Financial Center
Shenzhen, China
William Baker
SOM

Peter von Buelow

University of Michigan, TCAUP

Slide 1 of 21

Load Combinations

Load Types

- Dead Load - D
- Roof Live Load - L_r
- Floor Live Load - L
- Snow Load - S
- Wind Load - W
- Earthquake - E_v & E_h

Allowable Stress Design (ASD)

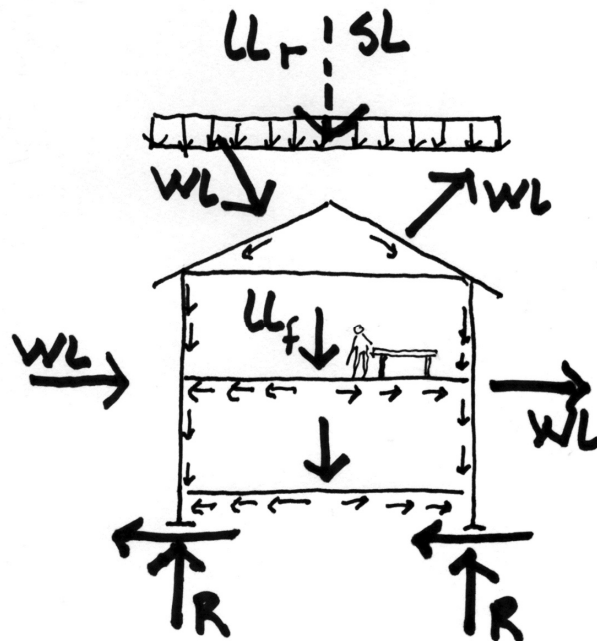
Not factored

- D
- D + L
- D + (L_r or S)
- D + 0.75 L + 0.75 (L_r or S)
- D + (0.6W)
- D + 0.75L + 0.75(0.6W) + 0.75(L_r or S)
- D + 0.7E_v + 0.7E_h

Strength Design (LRFD)

With gamma (γ) safety factors

- 1.4 D
- 1.2 D + 1.6 L_r + 0.5(L_r or S)
- 1.2 D + 1.6(L_r or S) + (L or 0.5W)
- 1.2 D + 1.0W + L + 0.5(L_r or S)
- 0.9D + 1.0W
- 1.2D + E_v + E_h + L + 0.2S
- 0.9D - E_v + E_h



Load Paths

Vertical Loads

gravity

D, L, Lr, S

seismic wind

Ev Wv

Lateral Loads

wind Wh

seismic Eh

FIGURE 1

VERTICAL LOAD PATH

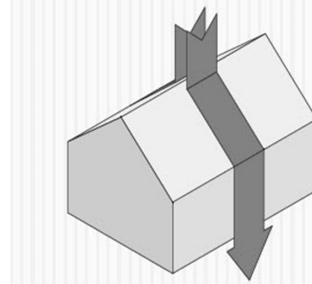
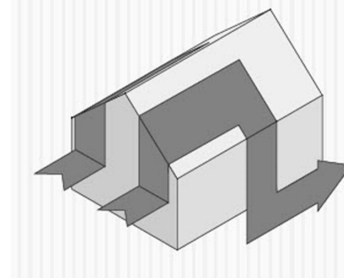


FIGURE 2

LATERAL LOAD PATH



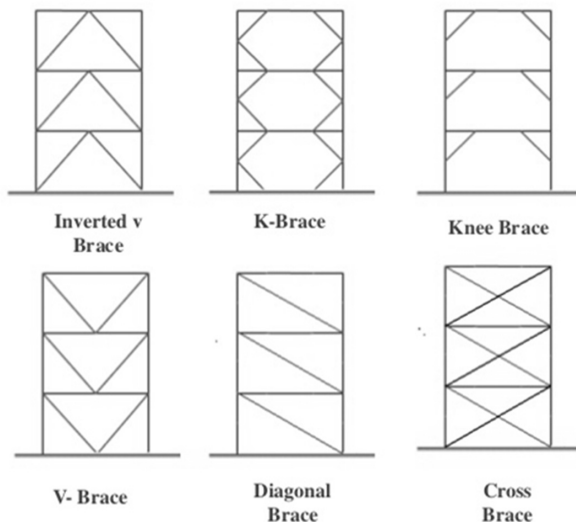
Peter von Buelow

University of Michigan, TCAUP

Slide 3 of 21

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

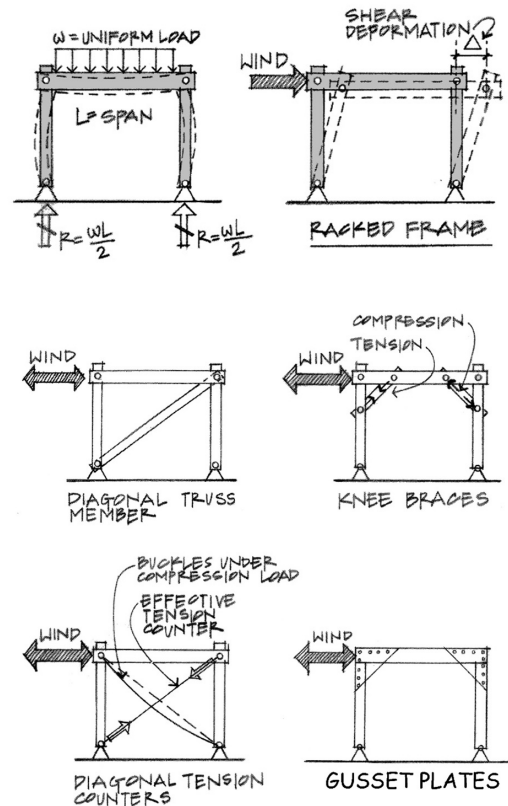
A system needs to be stable in all directions – x, y, and z.

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

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

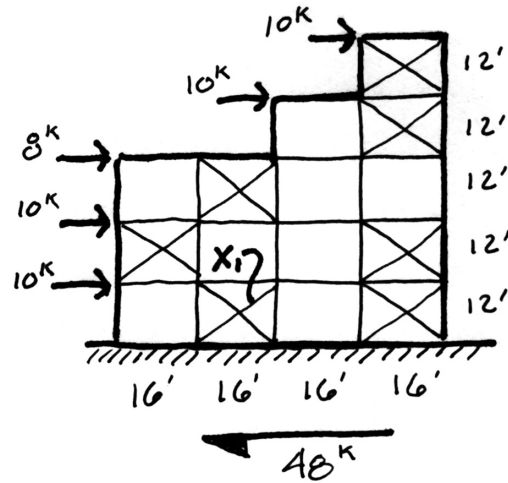
Lateral bracing can be achieved with:

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



Frame Bracing - Example

- Check for stability. At least one rigid 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 in this case.



Base shear = 48k

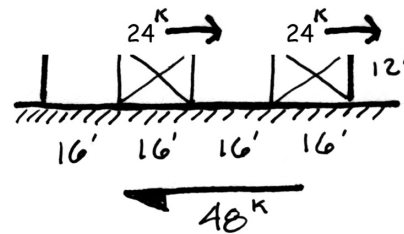
$$\sum F_H = 0$$

$$0 = 10 + 10 + 8 + 10 + 10 - R$$

$$R = 48^k$$

Frame Bracing - Example 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



$$\sum F_H = 0$$

$$0 = -48 + H_1 + H_2$$

$$H_1 = H_2 = 24^k$$

$$\frac{12}{16} : \frac{V}{24}$$

$$V = 18$$

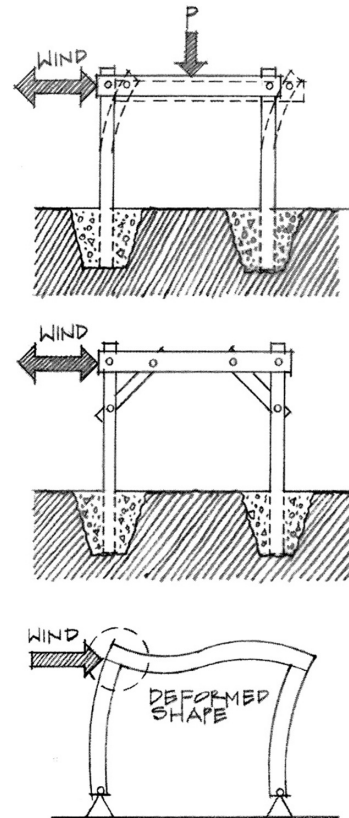
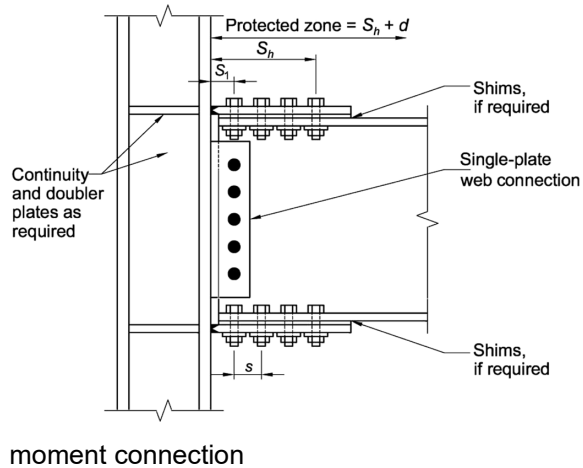
$$X_1 = \sqrt{18^2 + 24^2} = 30^k$$

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.

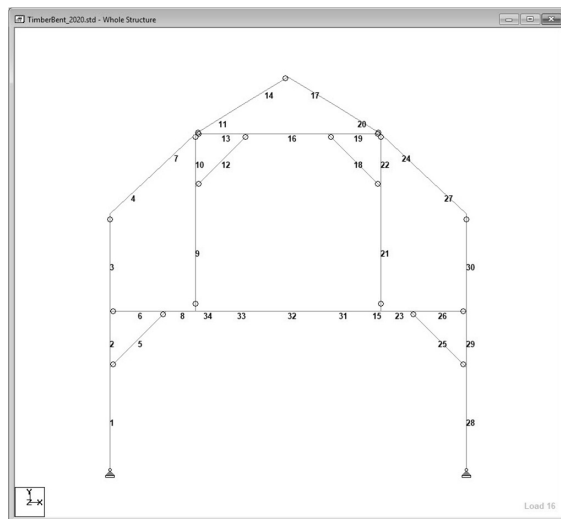
In a fixed frame the members act in both compression and bending.



Timber Frame Bracing

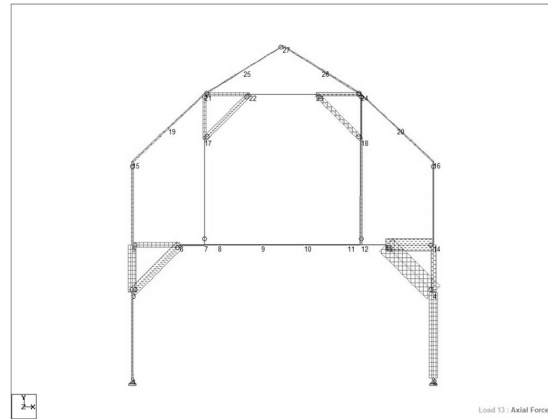
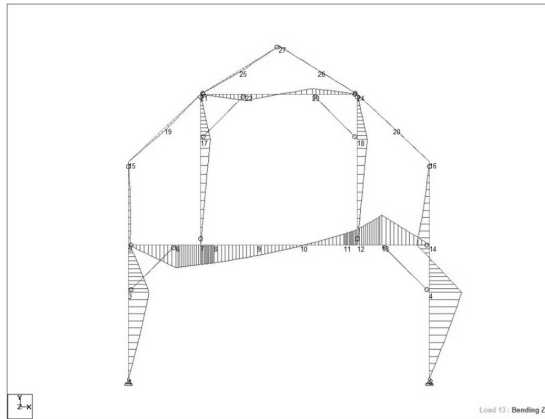
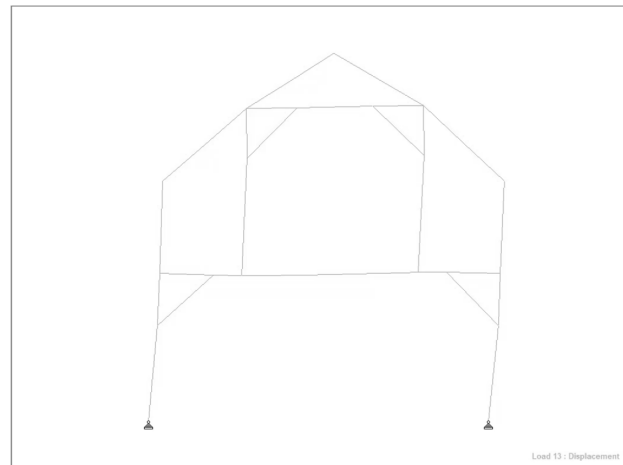
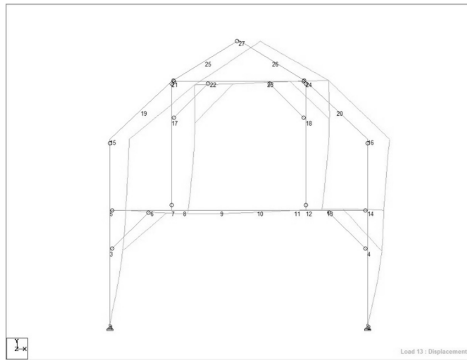
John Pariseau's Timber Frame

Load Case: D + 0.6W



Timber Frame Bracing

John Pariseau's Timber Frame



University of Michigan, TCAUP

Structures I

Slide 11 of 21

Diaphragms and Shear Walls

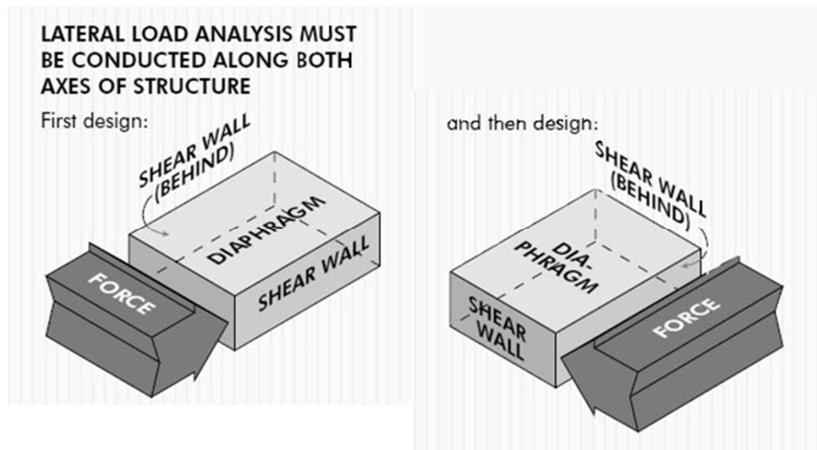


FIGURE 4
SEISMIC FORCES ACTING ON MASS

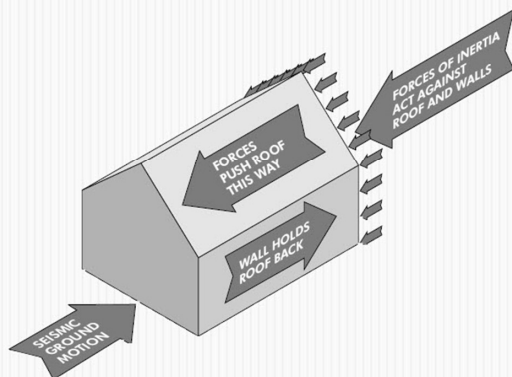
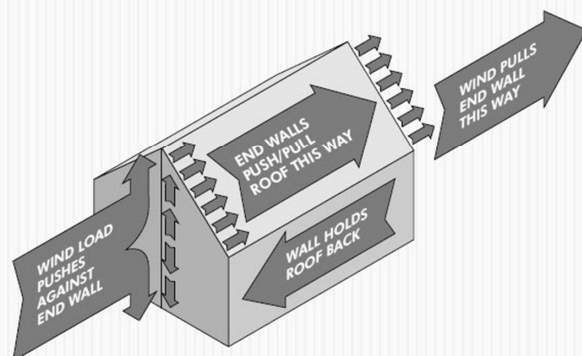


FIGURE 5
WIND FORCES ACTING ON AREA



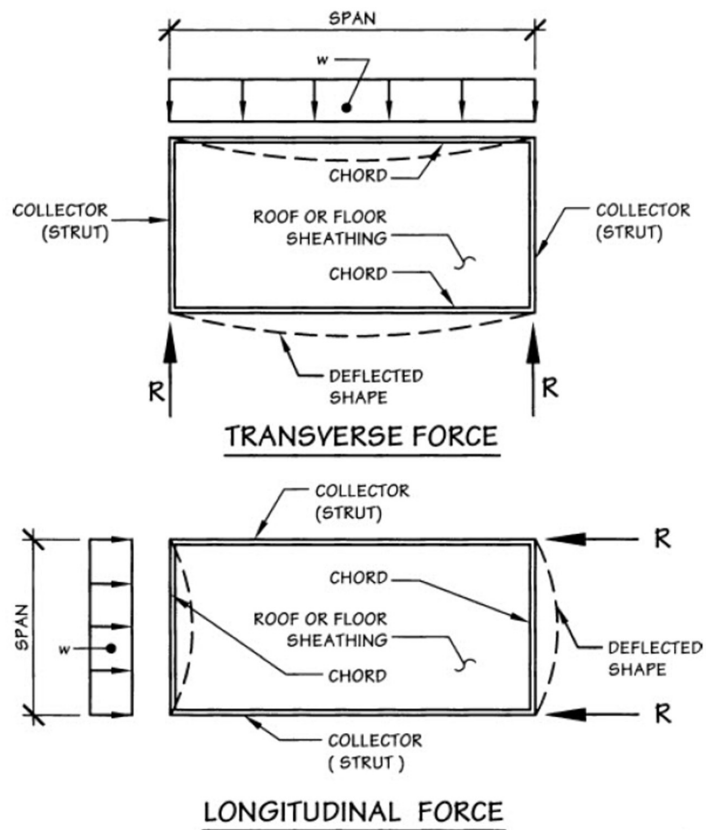
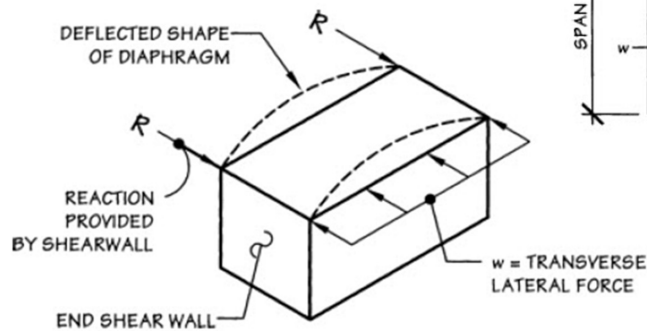
Definitions

Diaphragm – a flat horizontal 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



Peter von Buelow

University of Michigan, TCAUP

Slide 13 of 21

Drag Struts

Double Top Plate

FIGURE 15

DRAG STRUTS USED TO TIE AN "L" SHAPED BUILDING TOGETHER

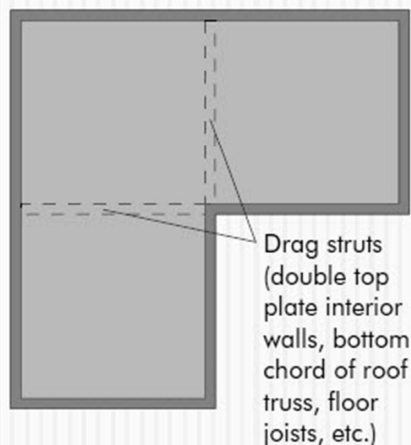
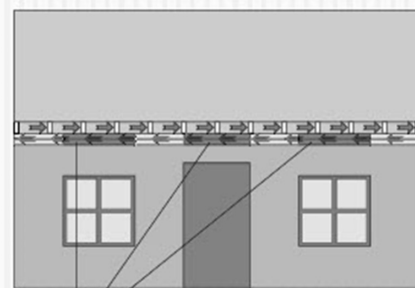


FIGURE 14

TOP PLATE DRAG STRUTS



Double top plate acts like a drag strut in these locations (over openings).

APA X305

Peter von Buelow

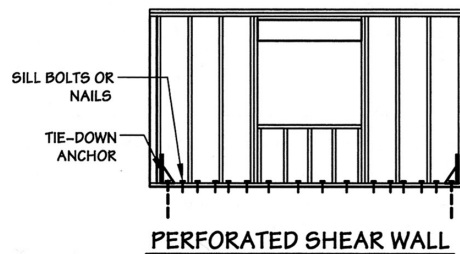
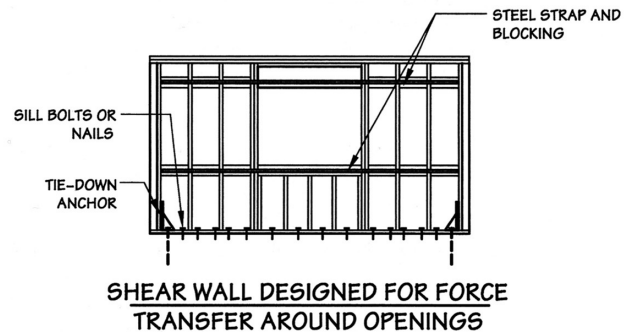
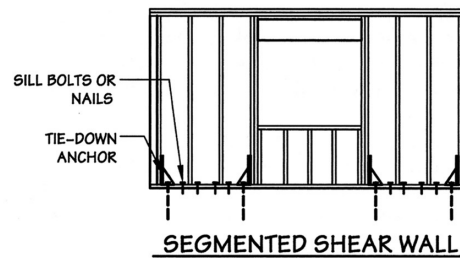
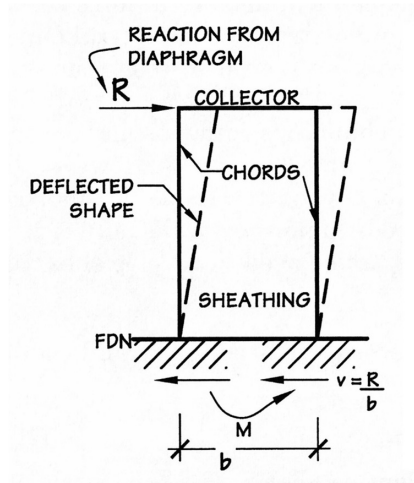
University of Michigan, TCAUP

Slide 14 of 21

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



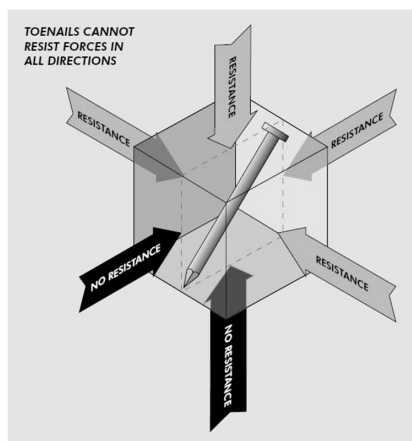
Shear Wall Connections

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

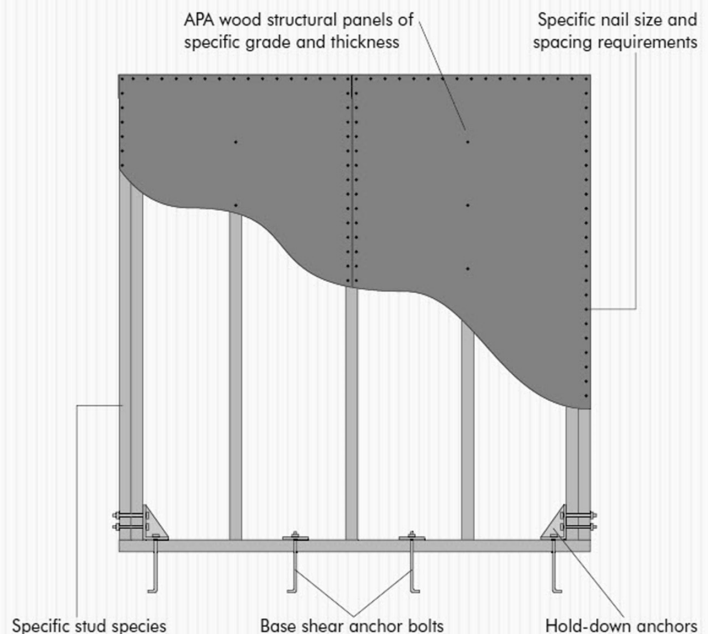
Toenails – not adequate

Hold-down Anchors

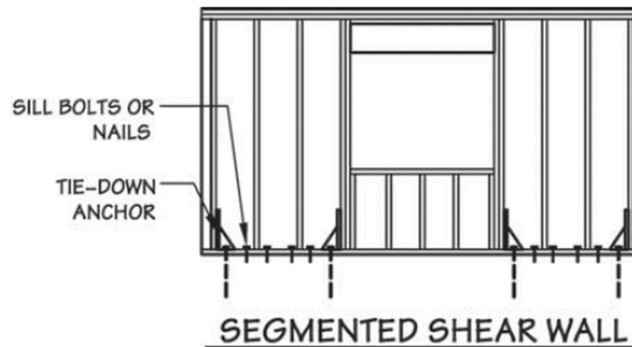
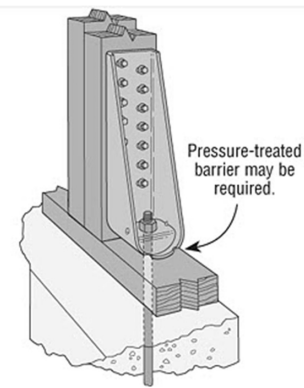
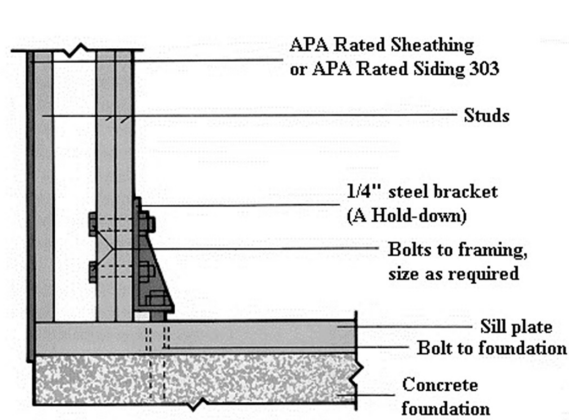
Base Shear Anchors



ENGINEERED SHEAR WALLS



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

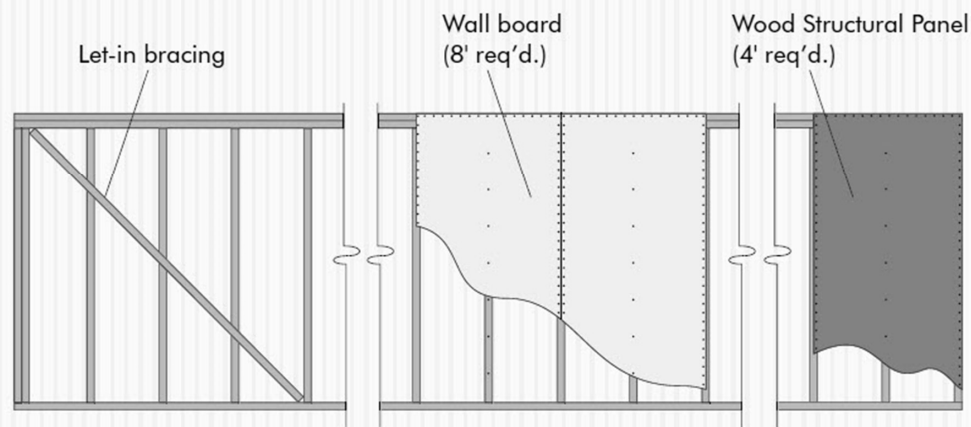
Table 4.3.4 Maximum Shear Wall Aspect Ratios

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 RESISTING ELEMENTS PRESCRIPTIVE CORNER BRACING/WALL BRACING



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)

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 11

SHEAR WALL SEGMENT

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

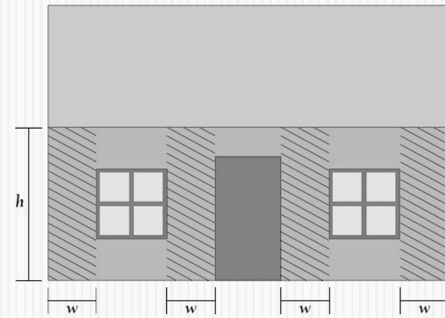


FIGURE 13

OVERTURNING

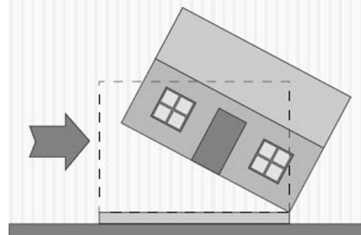


FIGURE 12

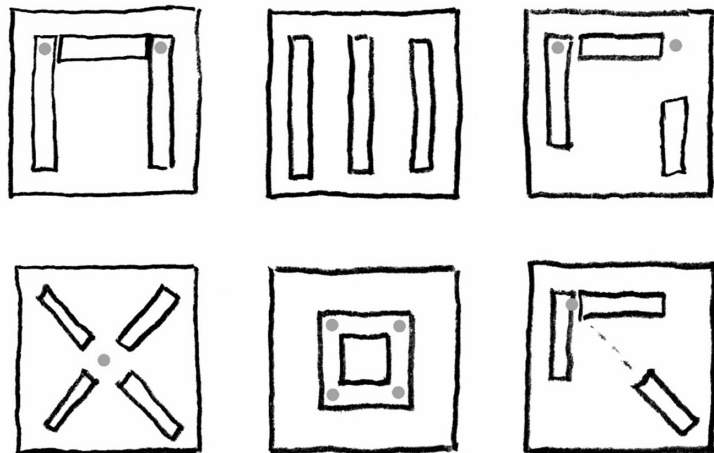
BASE SHEAR



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

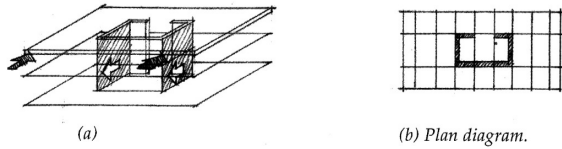


Figure 4.55 Shearwalls at the central circulation core.

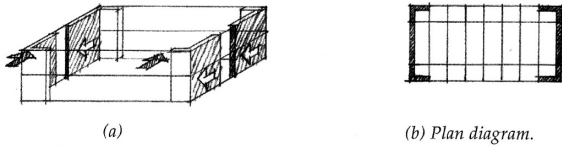


Figure 4.56 Shearwalls at the exterior corners.

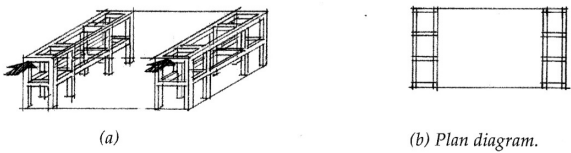


Figure 4.57 Rigid frames at end bays (can also comprise the entire skeleton).



Brock Commons Tallwood House
University of British Columbia, Vancouver, Canada