APPLIED ARCHITECTURAL STRUCTURES:
STRUCTURAL ANALYSIS AND SYSTEMS
ARCH 631
DR. ANNE NICHOLS
FALL 2013

lecture
fifteen

design for lateral loads

Lateral Load Resistance

- stability important for any height
- basic mechanisms
  - shear walls
  - diaphragms
  - diagonal bracing
  - frame action
- resist <u>any</u> direction laterally without excessive movement

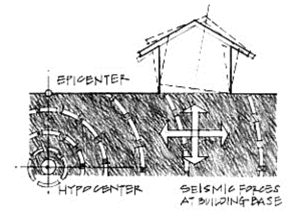
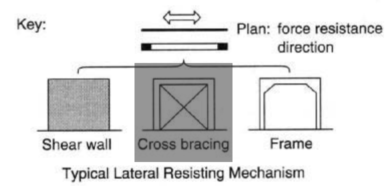
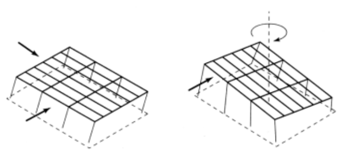


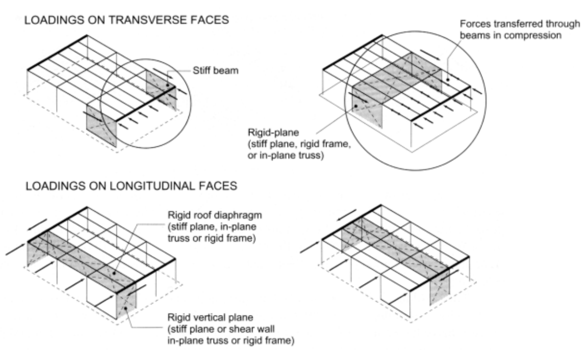
Figure 1.14 Earthquake loads on a structure.



Lateral Load Resistance

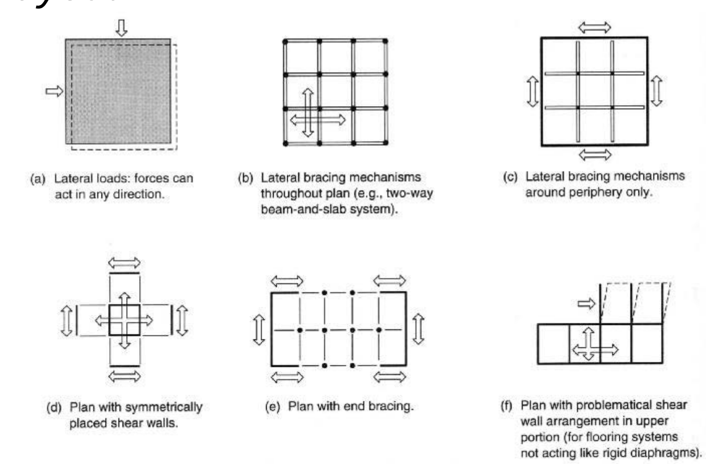
- deformations
- load transfer & in-plane forces





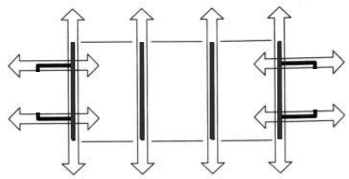
Load Direction

- layout



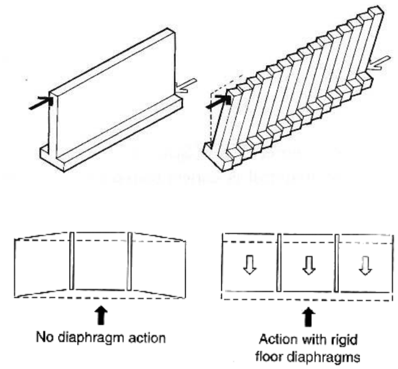
Rectangular Buildings

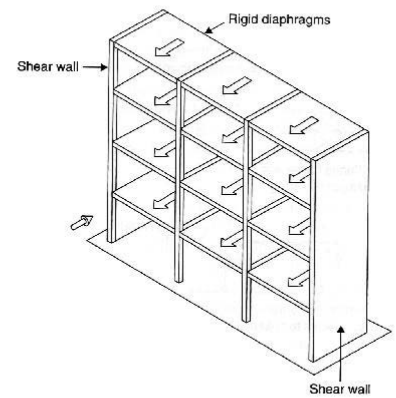
- *short side (in red)*
  - *needs to resist most wind*
  - *bigger surface area*
  - *shear walls common*
- *long side*
  - *other mechanisms*
- *long & low*
  - *may only need end bracing*
- *symmetry important*
  - *avoid distortions, ex. twisting*



Shear Walls

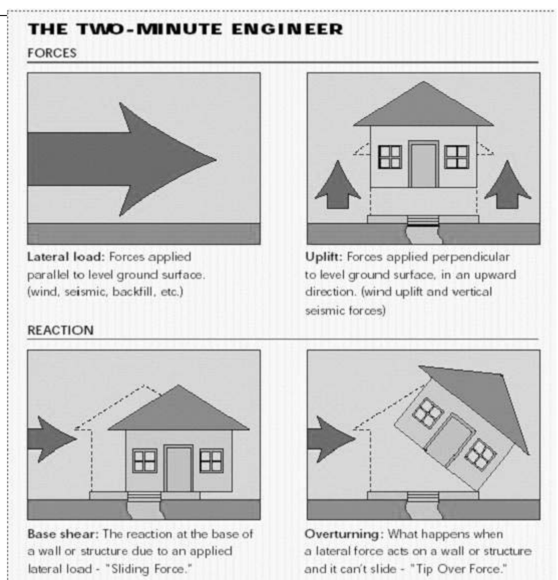
- *resist lateral load in plane with wall*





Shear Walls

- *lateral resistance*


THE TWO-MINUTE ENGINEER

FORCES

Lateral load: Forces applied parallel to level ground surface. (wind, seismic, backfill, etc.)

Uplift: Forces applied perpendicular to level ground surface, in an upward direction. (wind uplift and vertical seismic forces)

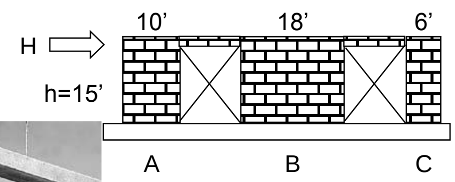
REACTION

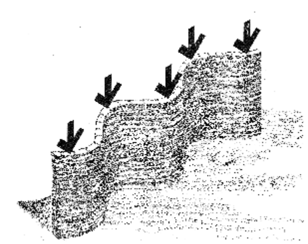
Base shear: The reaction at the base of a wall or structure due to an applied lateral load - "Sliding Force."

Overturning: What happens when a lateral force acts on a wall or structure and it can't slide - "Tip Over Force."

Shear Walls

- *masonry*
- *concrete*





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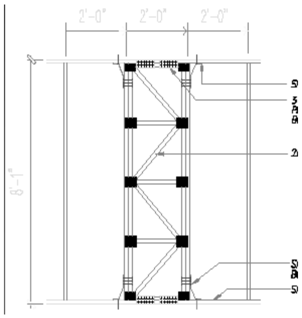
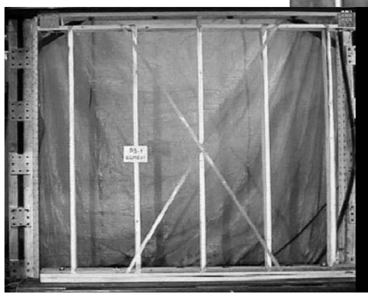
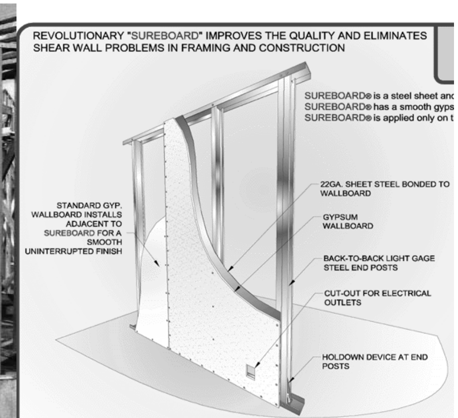
Shear Walls

- *timber*
  - *– wall studs with sheathing*
  - *– vertical trusses*

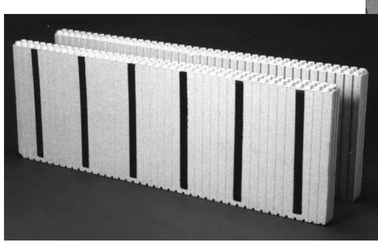
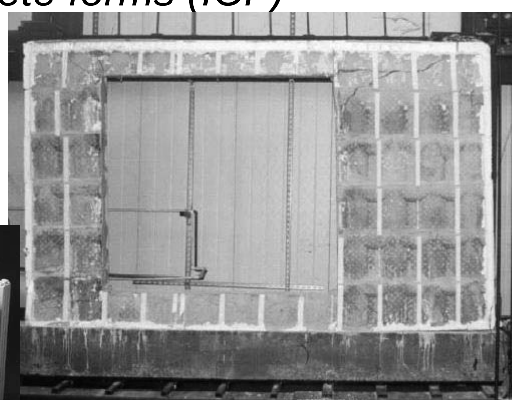

Shear Walls

- *steel*

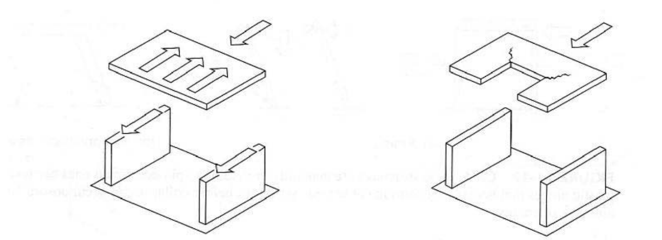
Shear Walls

- *insulated concrete forms (ICF)*

Diaphragms

- *– roof and floor framing and decks*
- *– relative stiffness*
- *– necessary in pin connected beam-column frames with no horizontal resisting elements*

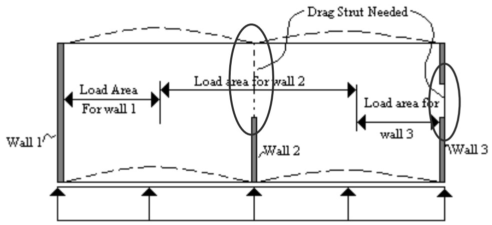


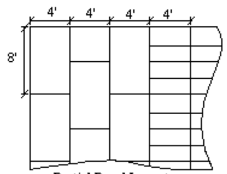
(a) Typical diaphragm action: the horizontal plane acts like a beam in carrying earthquake-induced forces to shear walls or other lateral-load-carrying mechanisms.

(b) If diaphragms are improperly designed, failure can result in floor or roof planes.

Diaphragms

- *connections critical*
- *drag struts*





Partial Panel Layout

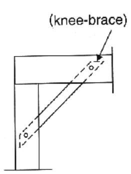
Braced Frames

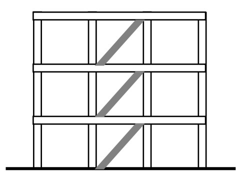
- *pin connections*
- *bracing to prevent lateral movements*

http:// nisee.berkeley.edu/godden

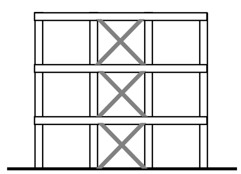
Braced Frames

- *types of bracing*
  - *knee-bracing*
  - *diagonal*
  - *X (cross)*
  - *K, V or chevron*
  - *shear walls*

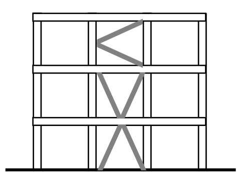




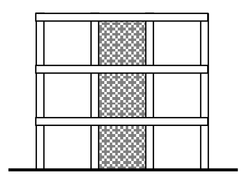
diagonal



X

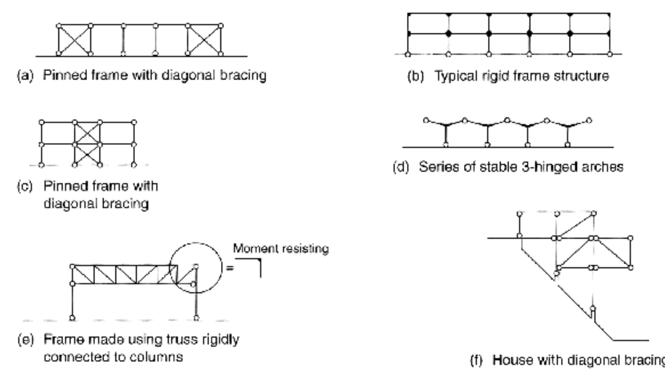


K, V & chevron



shear walls

Rigid Framing and Bracing



Rigid Framing and Bracing

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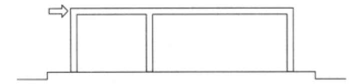
Frame Action

- choice influenced by ease of rigid joint construction by system
  - concrete
  - steel
  - timber braces

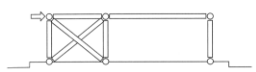


(b) Frame action (joints must be rigid)

- bending moments mean larger members

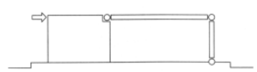
Shear Walls & Diagonal Bracing

- use with pin connected members
  - steel common
  - concrete rare



(a) Diagonal bracing (joints can be pin-connected)

- solid shear walls
  - concrete
  - masonry

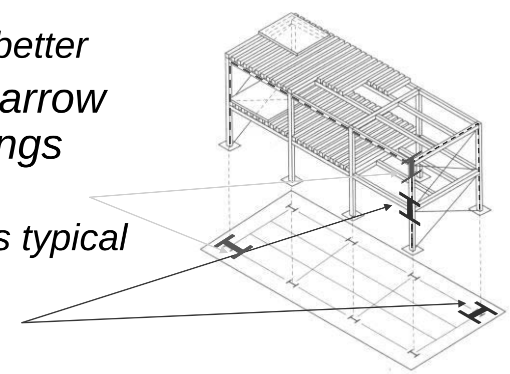


(c) Shear wall (joints can be pin-connected)

- wide spaced shear walls or diagonal bracing requires floor diaphragms
  - timber, steel or composite

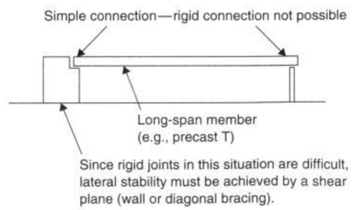
Member Orientation

- strong axis
  - biggest I in a non-doubly-symmetric section
  - resists bending better
- frame action & narrow dimension buildings
  - deep direction parallel to long is typical
  - <u>very narrow</u> parallel to short

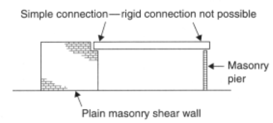


Member Characteristics

- long span members preclude frame action



- shear walls can be combined with bearing walls
  – use determines orientation



Building Height and Resistance

- low-medium rise
  – easier to accommodate
  – ex. residential
    - shear walls
    - diagonal bracing
    - floor diaphragms (panels)

http://gardenopolis.files.wordpress.com

- high rise
  – shear walls & bracing hinder functions
  – frames useful or with shear walls

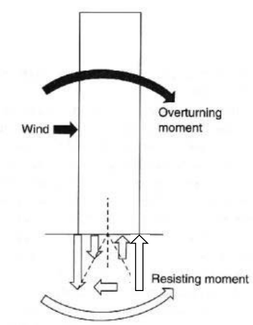
Multistory Buildings

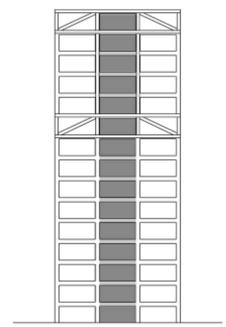
- strength design
  – frame action efficient up to ~ 10 stories
  – steel systems
  – reinforced concrete
    - flat plate & columns
      – lower lateral capacity
      – edge moments can't be resisted
      – end walls offer shear resistance
    - flat slab
    - one-way
    - two-way
      – higher resistance
  – elevator cores

www.allaboutskyscrapers.com

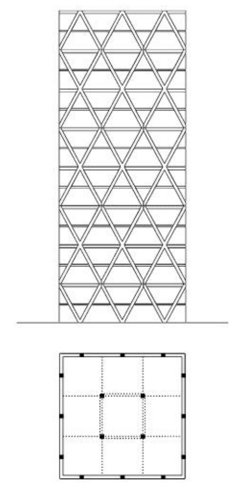
Multistory Buildings

- overturning, rigidity





(c) Frame and core are connected with outrigger trusses for additional stiffness.



(f) Diagrid. Gravity and lateral forces are transferred through a triangulated column grid.

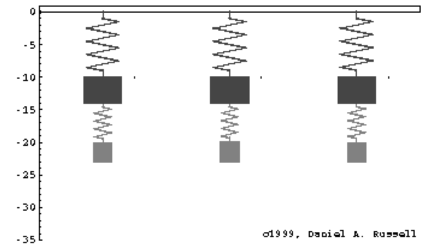
Strength Design

- *moments like cantilever beam*
- *tube action – bigger I*
- *elements*
  - *rigid at exterior resist lateral loads*
  - *interior can only carry gravity loads*
- *"stiffen" narrow shaped plans with shape*

http://darkwing.uoregon.edu/~struct/resources/applets/pencil.html

Deflection and Motion Control

- *serviceability issues*
  - *vibration*
  - *deflection*
  - *displacement*
- *mechanisms*
  - *stiffness*
  - *tuned mass dampers*
- *rule of thumb:*
  - *limit static wind load deflections to h/500*



Wind Design

- *codes*
  - *based upon minimum wind speed with 90% probability of 50 yr non-exceedance*
- *loads*
  - *pressure*
  - *drag*
  - *rocking*
  - *harmonic*
  - *uplift*
  - *torsion*

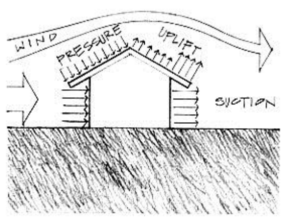
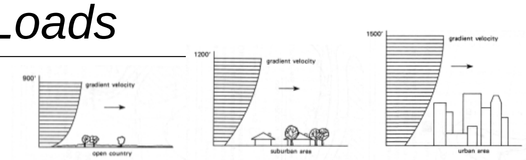


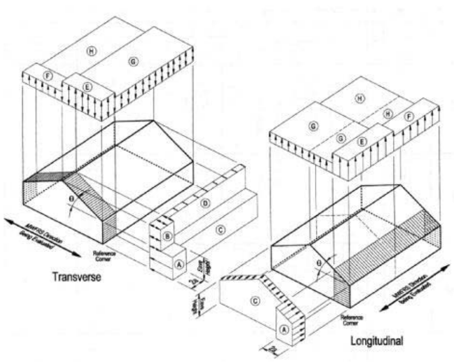
Figure 1.13 Wind loads on a structure.

Wind Design Loads

- *exposure*
  - *non-linear*
  - *equivalent static pressure based on wind speed*

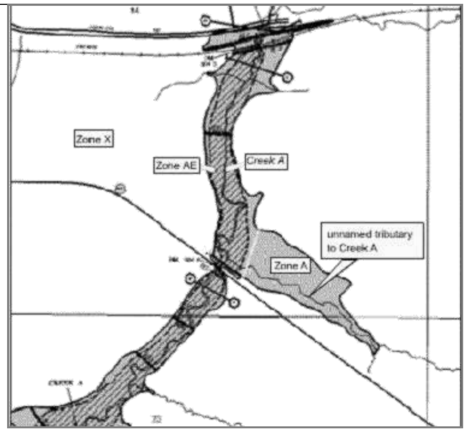


$$F_W = C_d q_h A$$
$$= pA$$



Flood Design

- know your risk
  - zone A
    - 100 year flood, no data available
  - zone AE
    - 100 year flood, detailed analysis
  - zone E
    - outside 100 year flood, minimal depths



http://youtu.be/TkfhuvOGbml - Lake Delton, WI 2008

Flood Design

- loads
  - hydrostatic pressure
    - up, down, lateral
  - impact velocities
    - scour
  - impact from debris
- design
  - elevation, proper site
  - shear walls with caution
  - concrete recommended