APPLIED ARCHITECTURAL STRUCTURES:
STRUCTURAL ANALYSIS AND SYSTEMS

ARCH 631

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FALL 2012

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

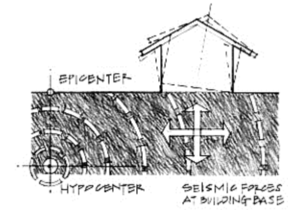
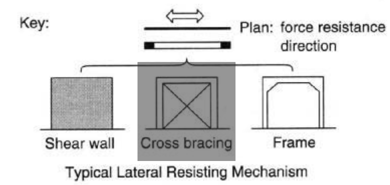
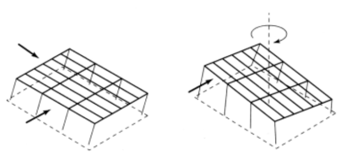


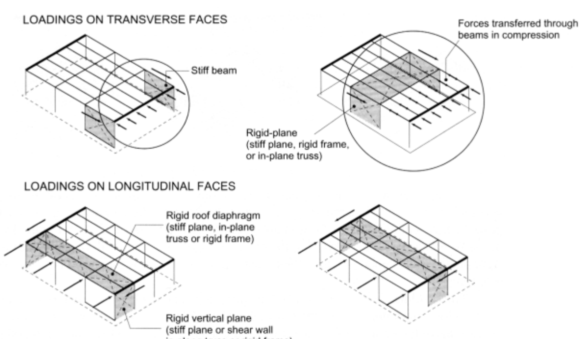
Figure 1.14 Earthquake loads on a structure.



Lateral Load Resistance

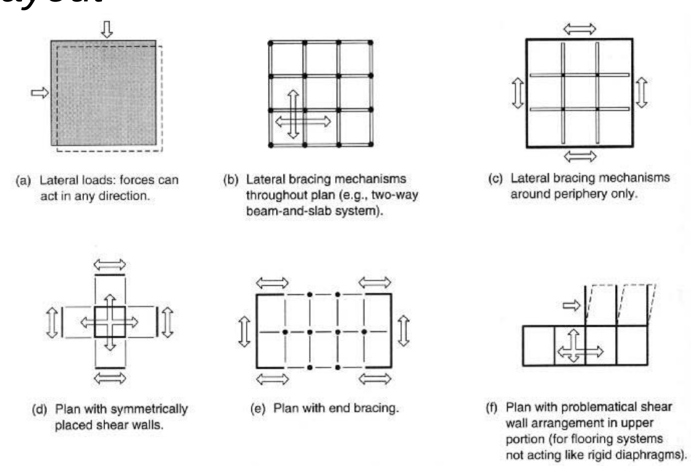
- deformations
- load transfer & in-plane forces





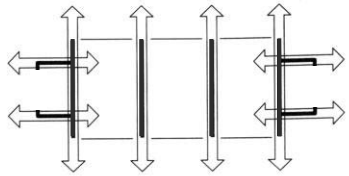
Load Direction

- layout



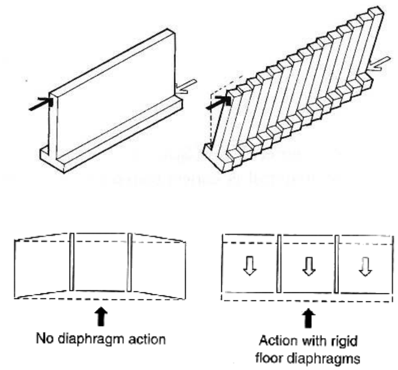
Rectangular Buildings

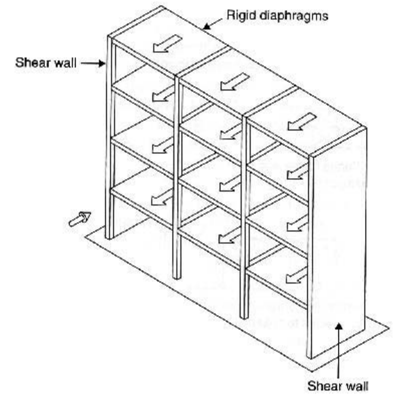
- *short side (in red)*
  - *needs to resist most wind*
  - *bigger surface area*
  - *shear walls common*
- *long side*
  - *other mechanisms*
- *long & low*
  - *may only need end bracing*
- *symmetry important*
  - *– avoid distortions, ex. twisting*



Shear Walls

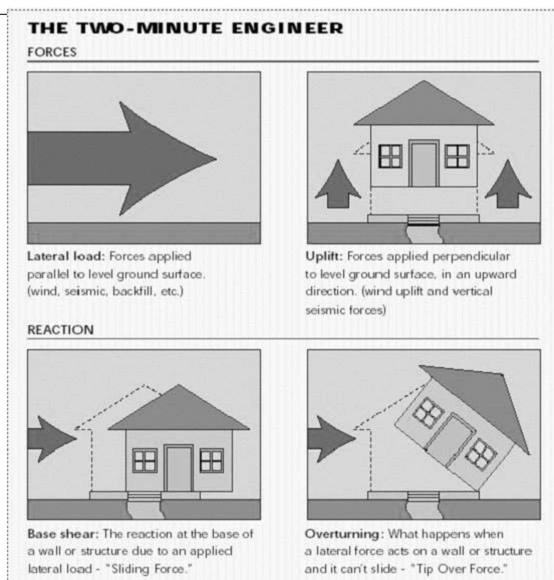
- *resist lateral load in plane with wall*





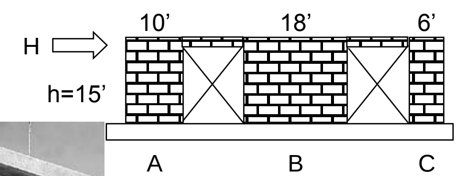
Shear Walls

- *lateral resistance*

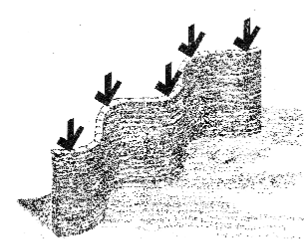


Shear Walls

- *masonry*
- *concrete*

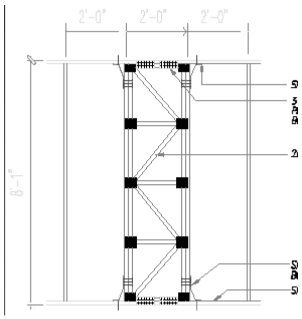
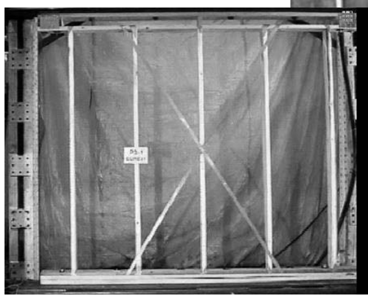


http:// nisee.berkeley.edu/godden



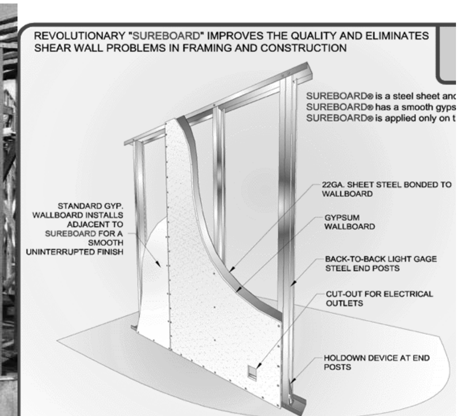
Shear Walls

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

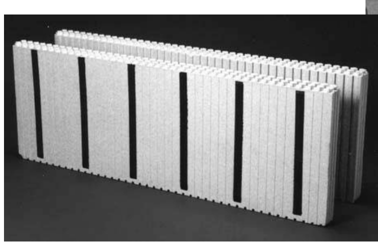
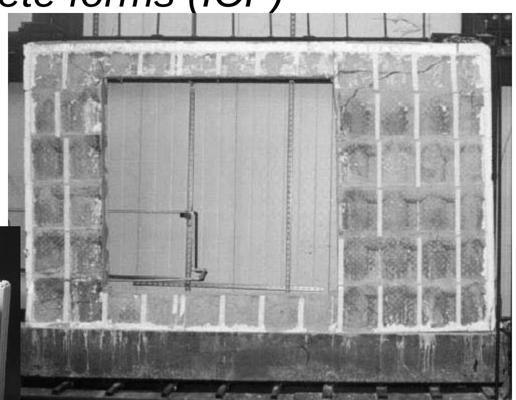

Shear Walls

- *steel*

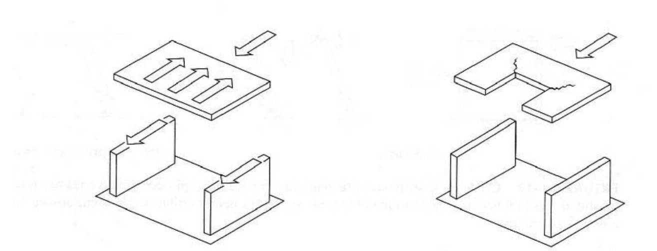
Shear Walls

- *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*

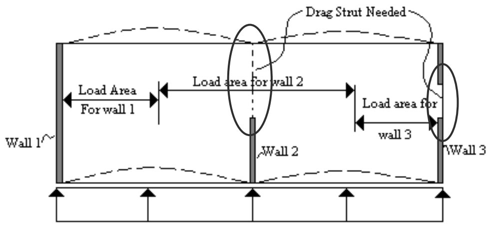


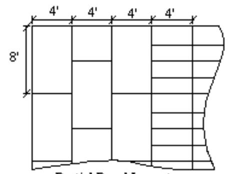
(a) Typical diaphragm action: the horizontal plane acts like a beam in carrying earthquake-induced forces to shear walls or other lateral-load-carrying mechanisms.

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

Diaphragms

- connections critical
- drag struts





Partial Panel Layout

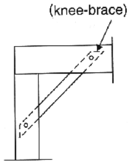
Braced Frames

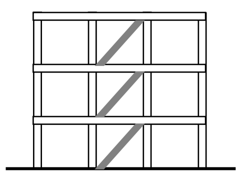
- pin connections
- bracing to prevent lateral movements

http:// nisee.berkeley.edu/godden

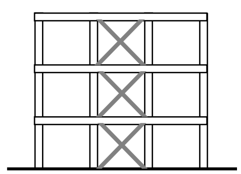
Braced Frames

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

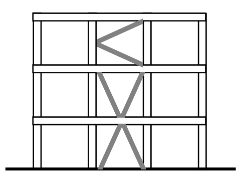




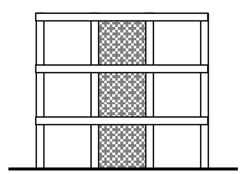
diagonal



X

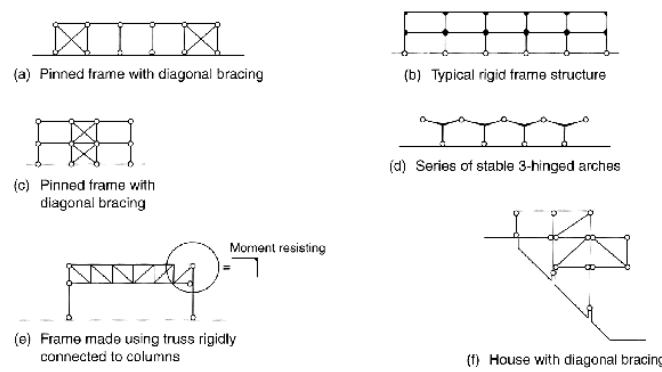


K, V & chevron



shear walls

Rigid Framing and Bracing



Rigid Framing and Bracing

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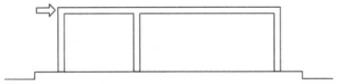
Frame Action

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

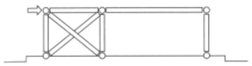


(b) Frame action (joints must be rigid)

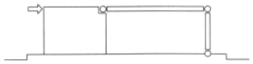
- bending moments mean larger members

Shear Walls & Diagonal Bracing

- use with pin connected members
  - steel common
  - concrete rare
- solid shear walls
  - concrete
  - masonry
- wide spaced shear walls or diagonal bracing requires floor diaphragms
  - timber, steel or composite



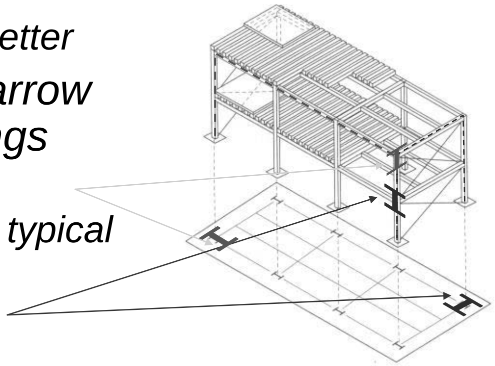
(a) Diagonal bracing (joints can be pin-connected)



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

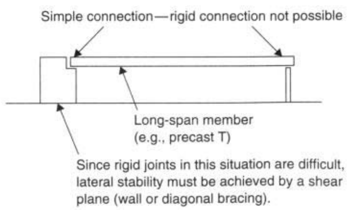
Member Orientation

- 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
  - very narrow parallel to short

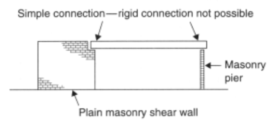


Member Characteristics

- 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

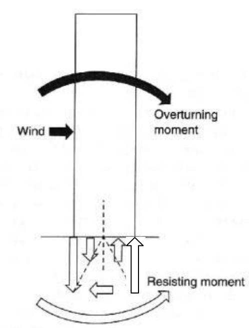
Multistory Buildings

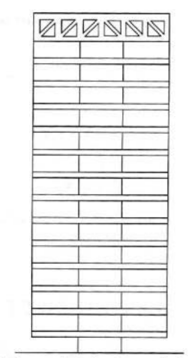
- strength design
  - frame action efficient up to ~ 10 stories
  - steel systems
  - reinforced concrete
    - flat plate & columns
      - lower lateral capacity
      - edge moments can't be resisted
      - end walls offer shear resistance
    - flat slab
    - one-way
    - two-way
      - higher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

www.allaboutskyscrapers.com

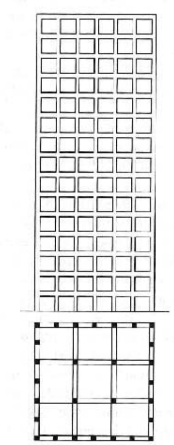
Multistory Buildings

- overturning, rigidity





(c) Suspended structure, reinforced concrete core.



(c) Tube structure. The exterior columns are closely spaced. Horizontal spandrel beams are rigidly connected to columns to form an exterior tube, which carries all lateral forces and some gravity forces. Interior columns carry only vertical forces.

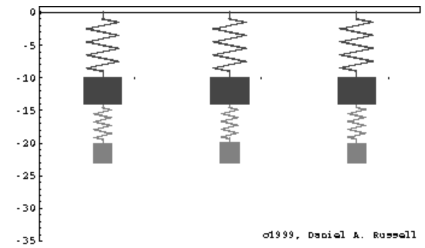
Strength Design

- 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

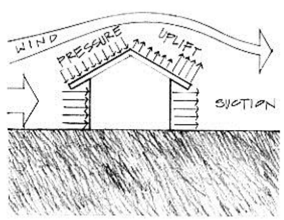
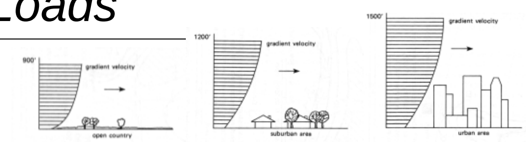


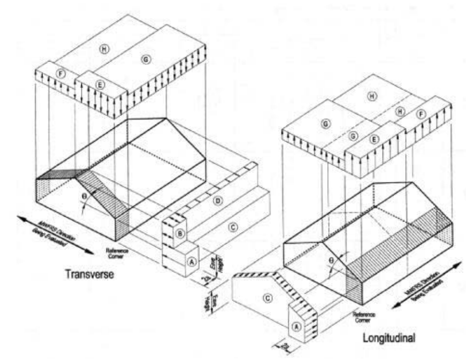
Figure 1.13 Wind loads on a structure.

Wind Design Loads

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

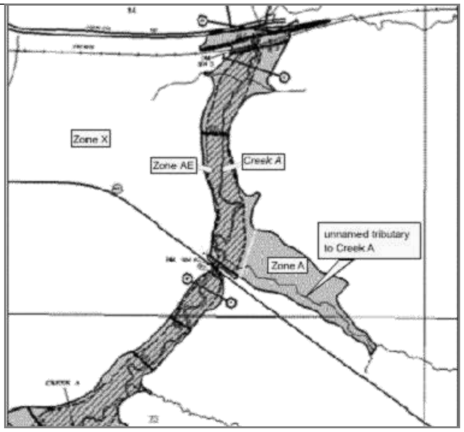


$$F_W = C_d q_h A$$
$$= pA$$



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/TkfhuvOGbmI - 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