design for lateral loads

Lateral Load Resistance

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

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

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

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

**Rigid Framing and Bracing**
Rigid Framing and Bracing

Frame Action

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

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)
- 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

Multistory Buildings

- overturning, rigidity
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

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

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

**Flood Design**

- **loads**
  - hydrostatic pressure
    - up, down, lateral
  - impact velocities
    - scour
  - impact from debris

- **design**
  - elevation, proper site
  - shear walls with caution
  - concrete recommended