Lateral Load Resistance

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

Load Direction

- layout

Figure 1.14  Earthquake loads on a structure.
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

- masonry
- concrete
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
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

![Diagram of long-span member precluding frame action](image1)

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

![Diagram of shear walls combined with bearing walls](image2)

Building Height and Resistance

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

![Building height and resistance](image3)

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

![High-rise building example](image4)

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 building example](image5)

Multistory Buildings

• overturning, rigidity

![Diagram of overturning and rigidity](image6)

(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

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