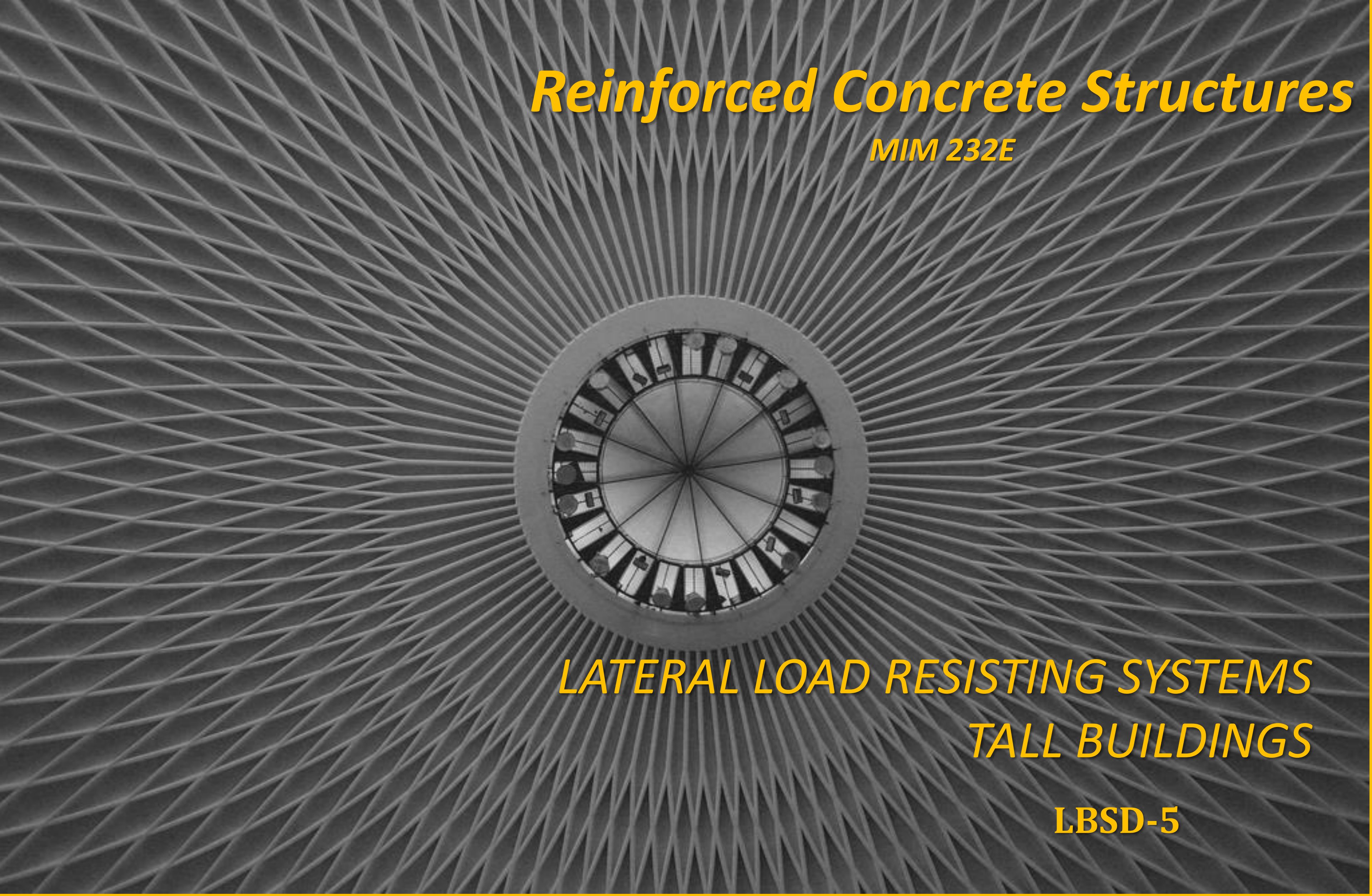


Reinforced Concrete Structures

MIM 232E

LATERAL LOAD RESISTING SYSTEMS
TALL BUILDINGS

LBSD-5

Dr. Haluk Sesigür
I.T.U. Faculty of Architecture
Structural and Earthquake Engineering WG

General

- High Rise Bldgs, h>20~40m
- Lateral loads are more effective (rather than vertical loads)
  - The most important lateral load is EQ effect for RC
- RC, Steel or Composite
- Optimum solution;
  LBS+Arch.+Installation etc.
- Alternative solutions are prepared and investigated

General

- Additional problems due to increase of the heigth
- Principle;
  Resistance against lateral loads
  Transferring vertical loads to soil, safely.
- Special design is required for vertical/lateral load carrying, installation etc.
- Site selection; depends on weather and soil condition etc.
- For areas with heavy wind ; this effect should be considered precisely

General

- There is an installation storey (in almost all high rise building)
- Arch. Project; aesthetics and compatible with function
- LBS; compatible with installation
- Multi-diciplinary work

History

High Rise Steel buildings;

- End of 19th Century; 118 m (Park Row. New York)
- 1913; 242 m (Woolworth Bld., New York)
- 1929; 313m (Chrysler)
- 1931; 381m (Empire state)
- 1972; 415m (World Trade Center)
- 1975; 445m (Chicago Sears)

History

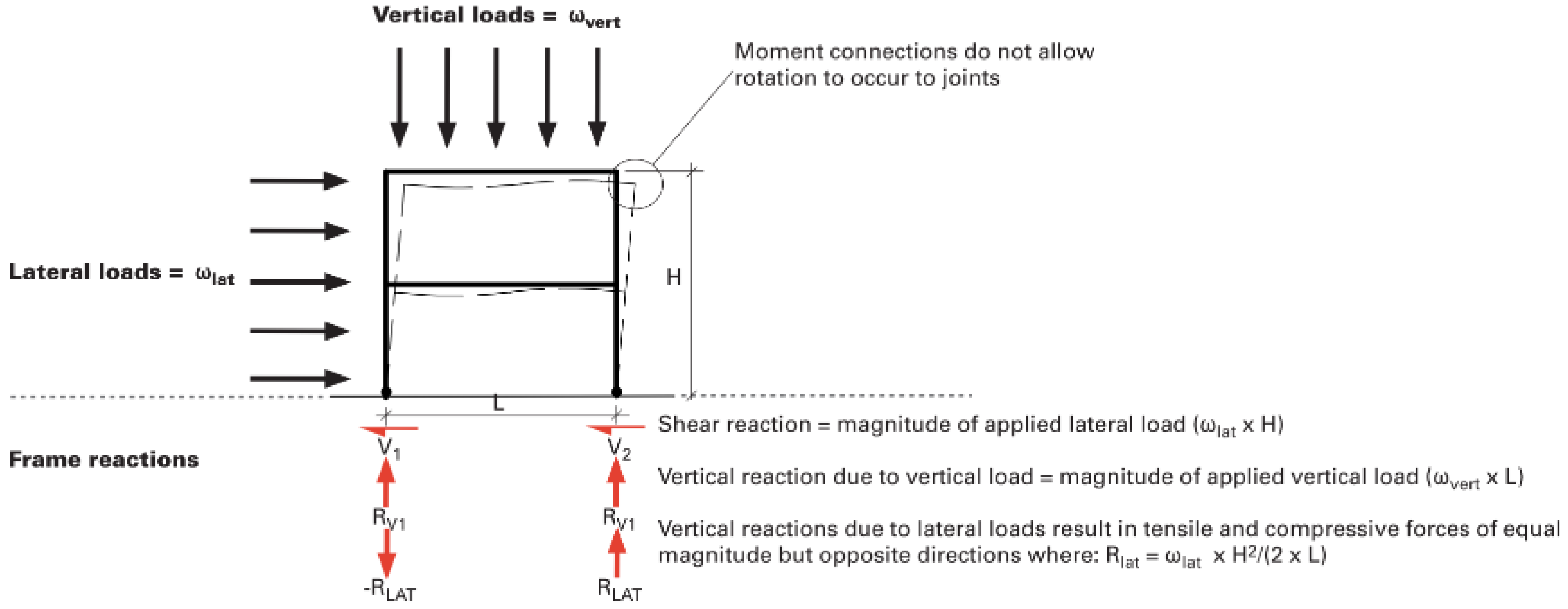
- RC high rise buildings; ~1960s
- Development of RC High Rise Bldgs;

  By new material tech., high-strength concrete, new formwork techs.

- In Turkey; 1950; 40m
  1958; 80m
  1987; 176m (Mersin)
  2011; 234m (Sapphire, İstanbul)
  2014; 200m (Folkart towers, İzmir)

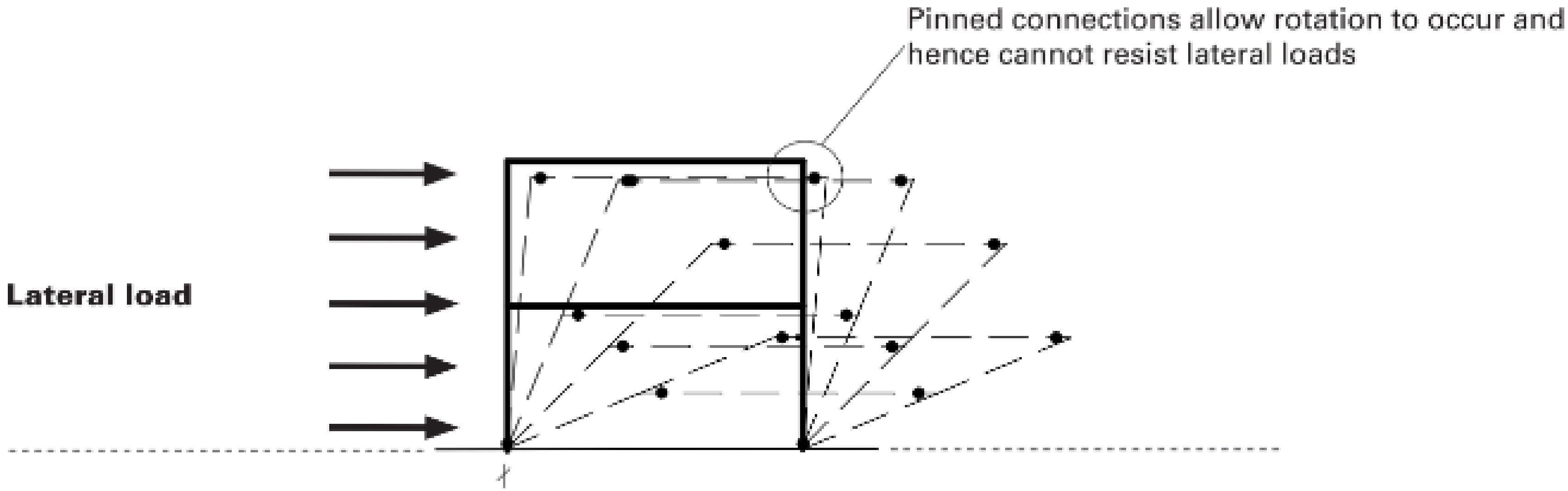
LBS types

Rigid frame under vertical and lateral loads



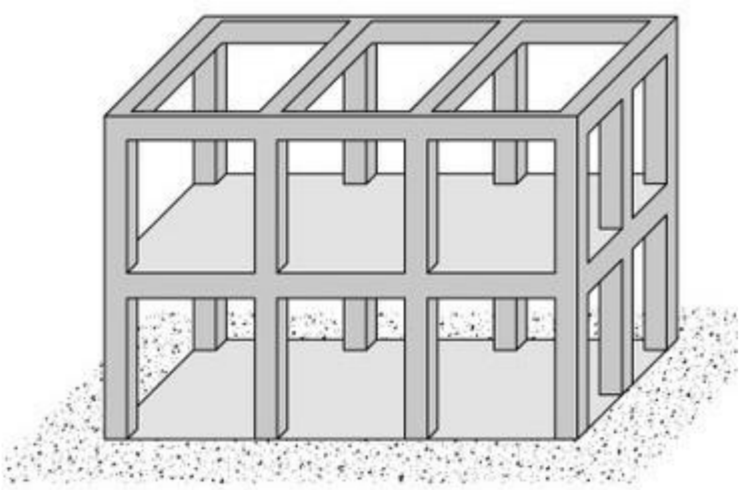
LBS types

Pinned frame under lateral loads forming mechanism



LBS types

Frame LBS
(Moment Resisting Frame; column+beam)

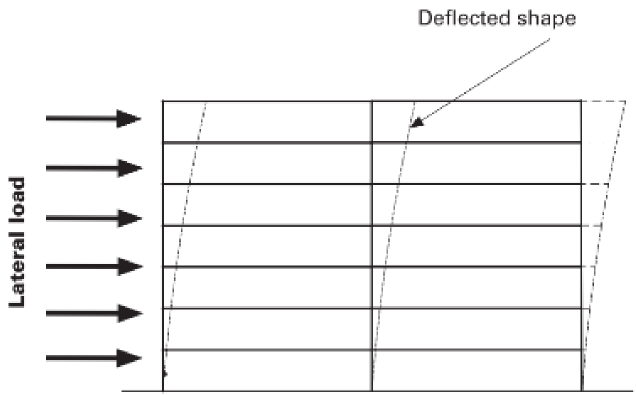


http://www.nexus.globalquakemodel.org/gem-building-taxonomy/overview/glossary/moment-frame--lfm

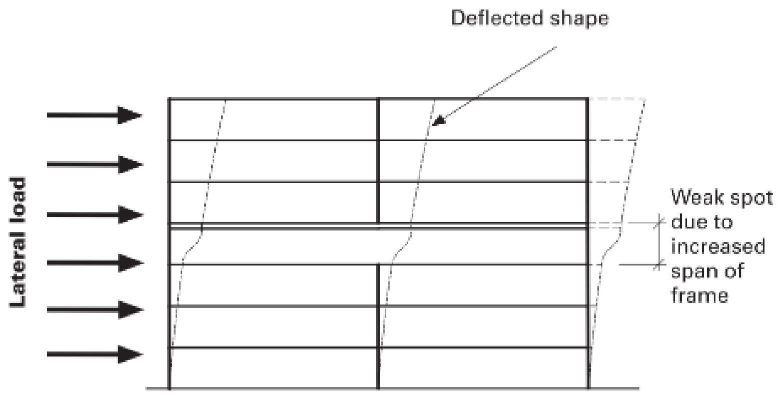
LBS types

Rigid frames under lateral loads

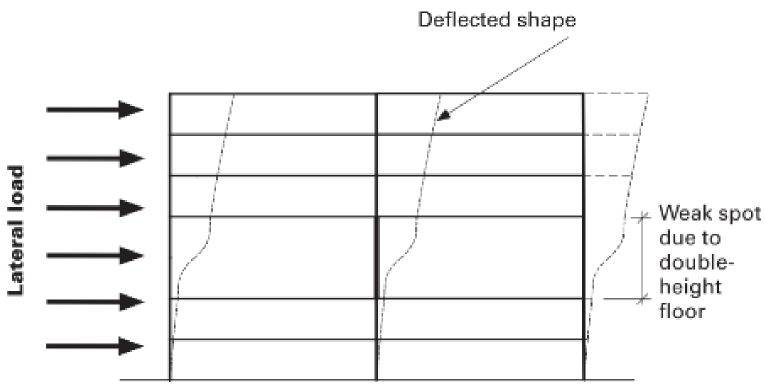
Regular rigid frame under lateral load



Rigid frame with increased floor span at 3rd floor level



Rigid frame with double-height floor under lateral load



LBS types

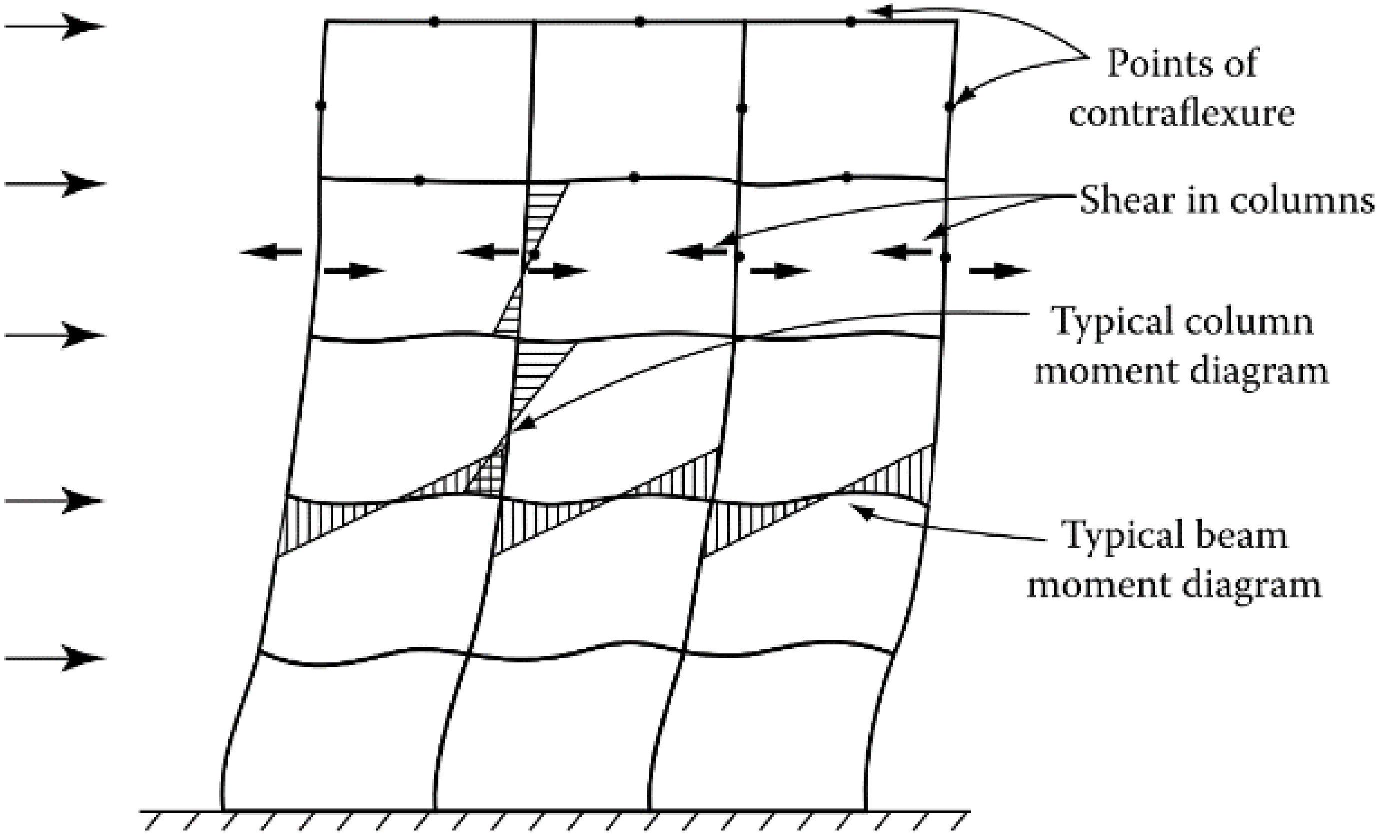
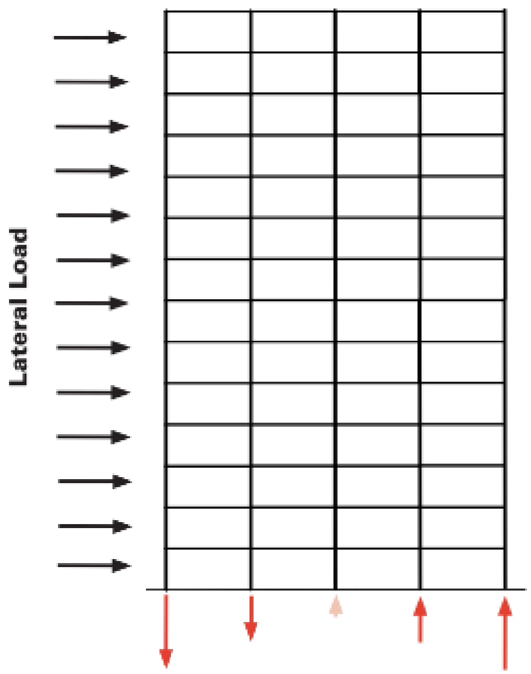


FIGURE 3.7 Rigid frame: Forces and deformations.

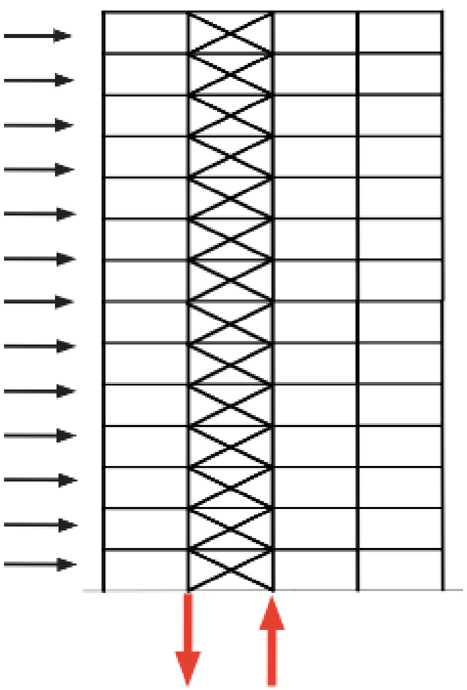
LBS types

Rigid frame under lateral load



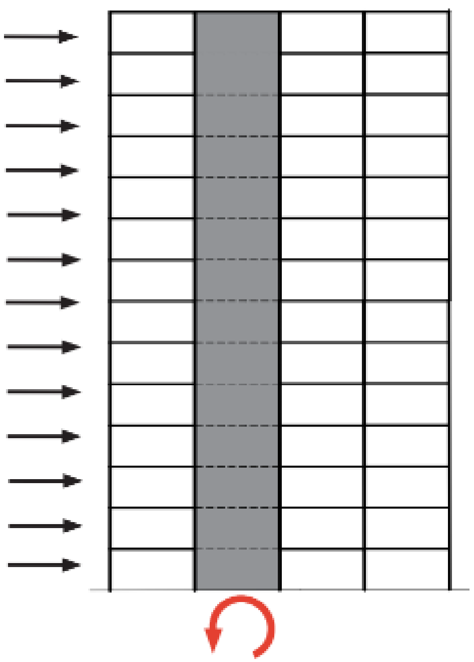
Bending moment due to lateral loads induces vertical tensile and compressive forces at the bases of the rigid frames

Braced frame with cross bracing under lateral load



Bending moment due to lateral loads induces vertical tensile and compressive forces at the base of the cross-braced wall, adjacent columns support vertical loads only

Braced frame with shear wall under lateral load



Bending moment due to lateral loads induces a bending moment at the base of the shear wall, adjacent columns support vertical loads only

LBS types

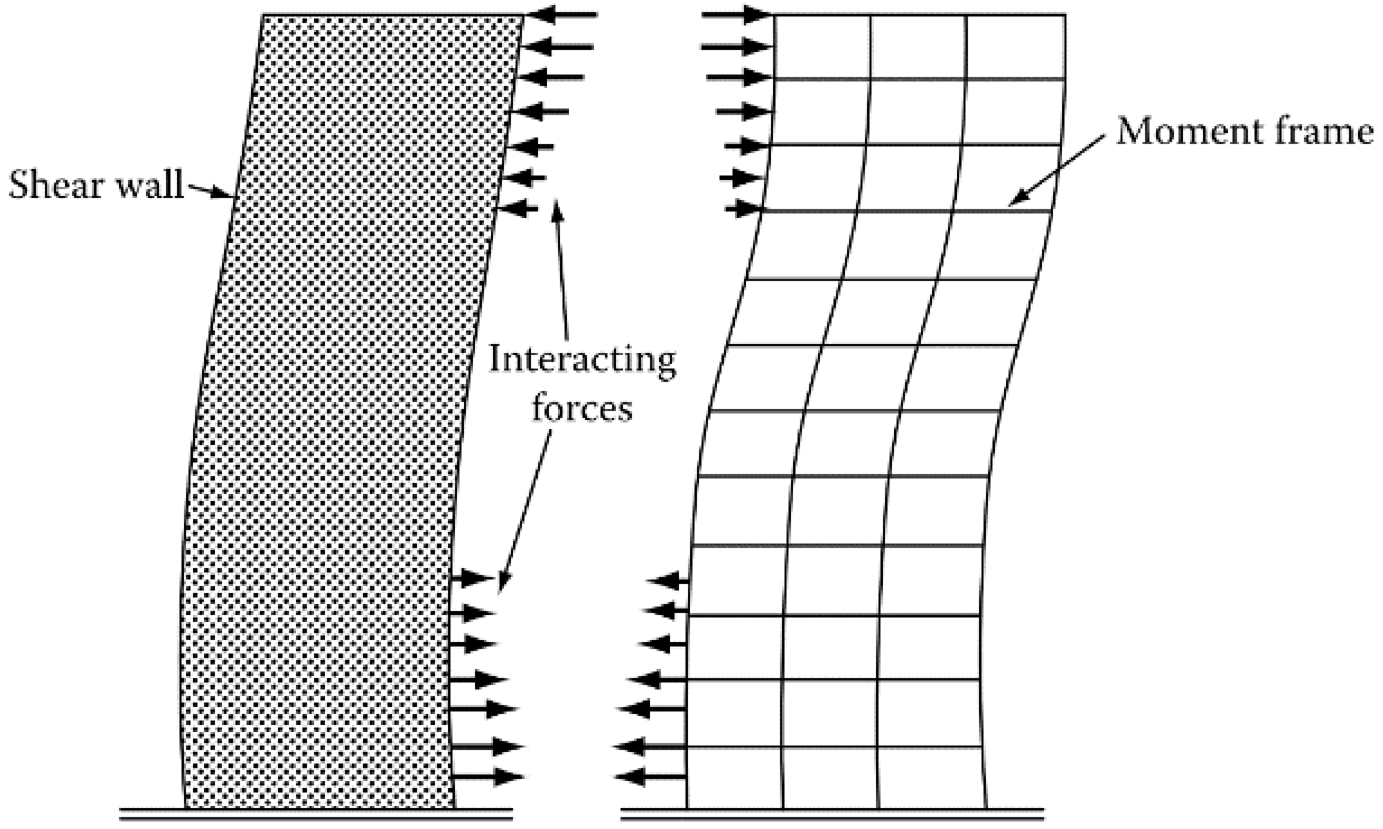
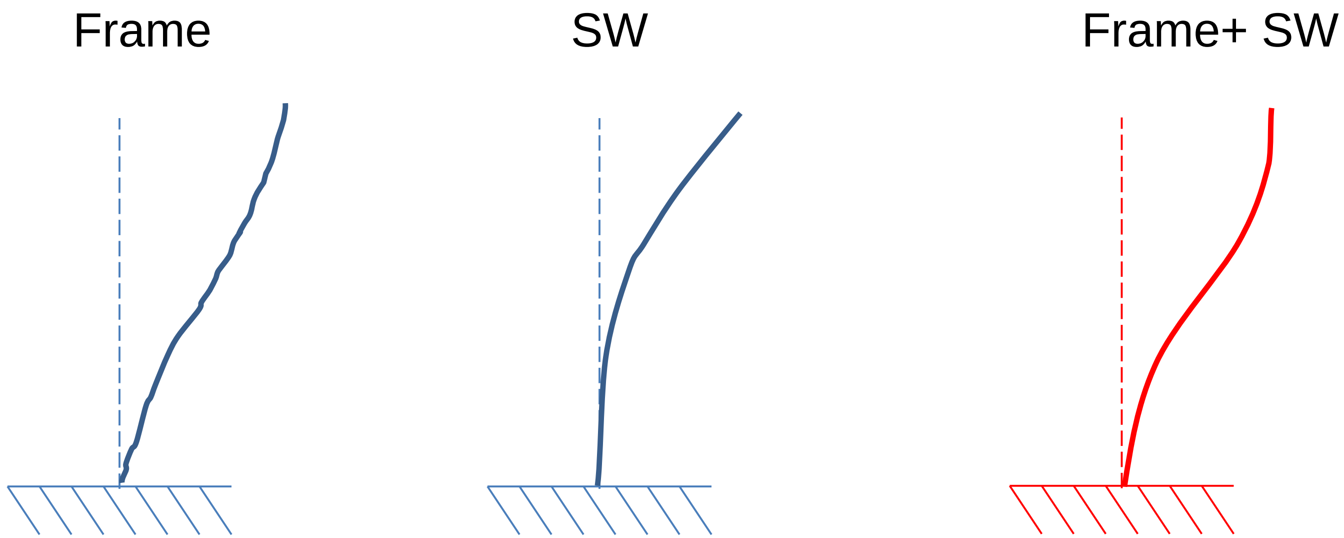


FIGURE 3.8 Shear wall–frame interaction.

Lateral loads at the top are resisting by frames whereas the loads acting at the Bottom are resisting by shear walls.

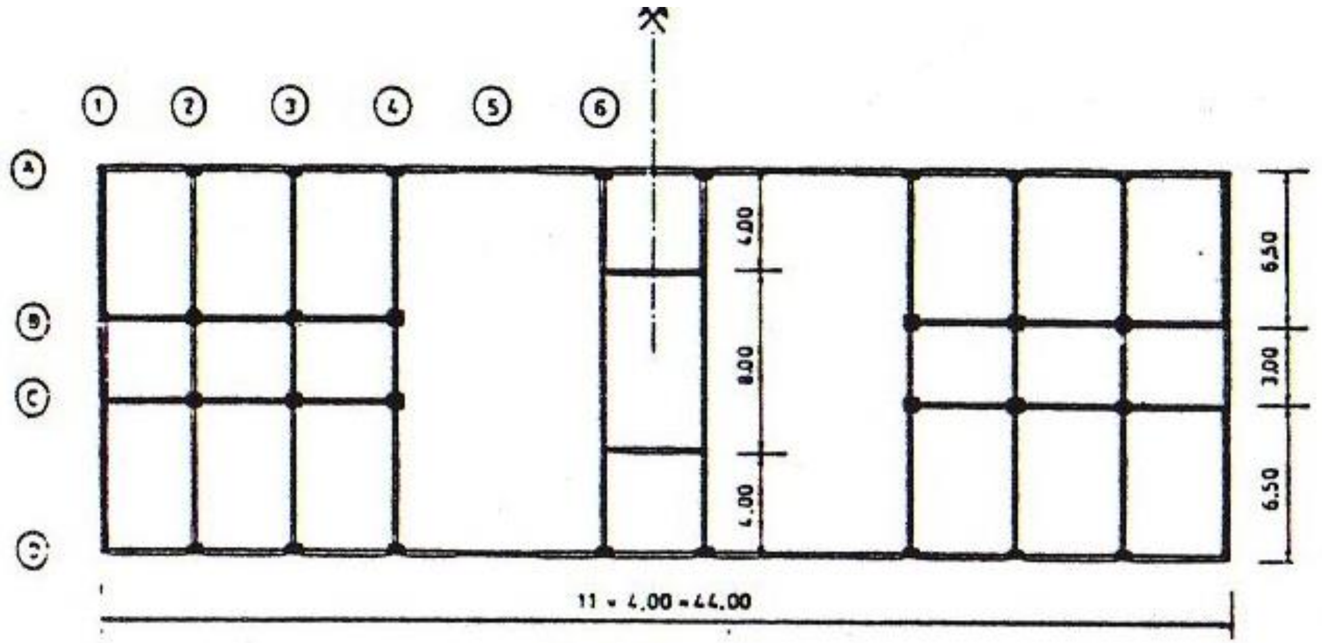
Frame+Shear Wall system

- Different displacement (behavior) of frame and SW



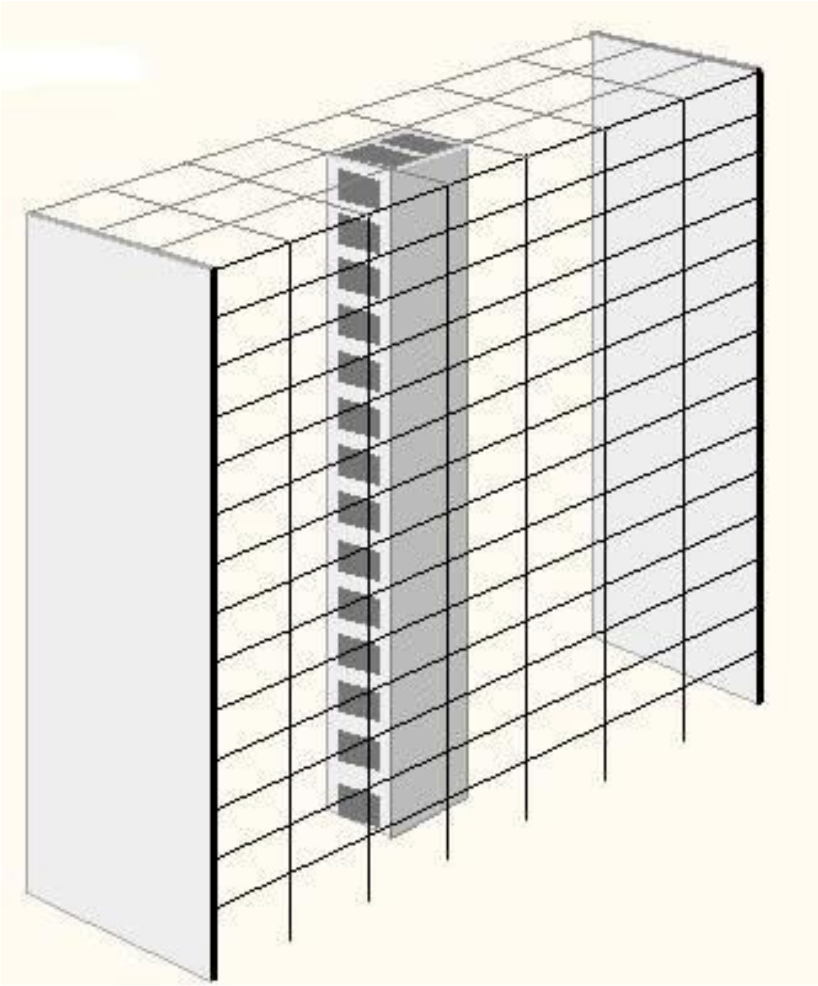
LBS types

- Up to 1960s, Frame+Shear wall LBS



LBS types

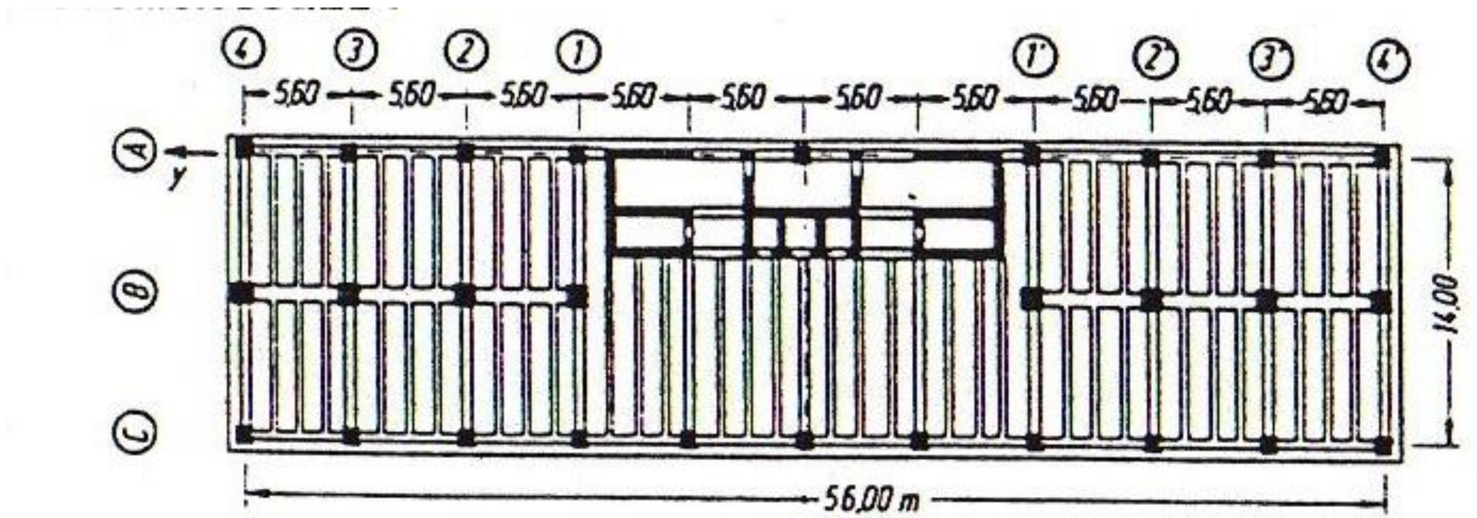
Frame+Shear wall + (Core) LBS



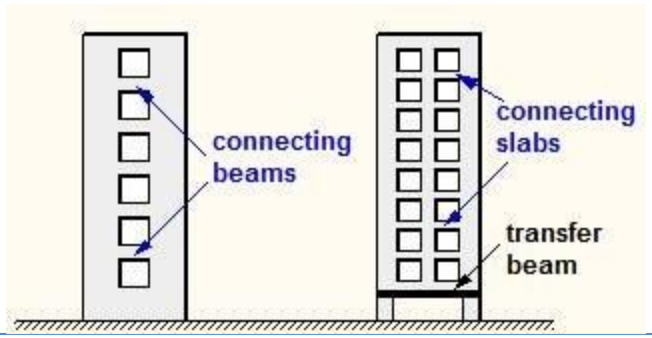
http://theconstructor.org/structural-engg/shear-walls-structural-forms-positioning/6235/

LBS types

- 1964; Fazlur Khan-
  a basic calculation method for frame+shear wall LBS



Beck; coupled shear wall (SW)

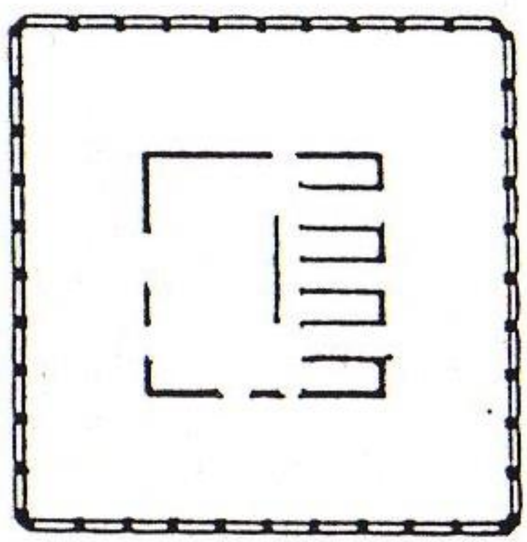


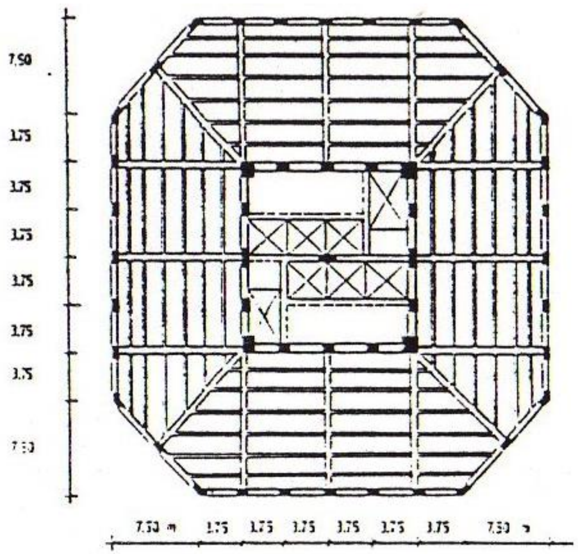
http://theconstructor.org/structural-engg/shear-walls-structural-forms-positioning/6235/

LBS types

- Use of tubes arranged by surrounding frames (Hohlkasten system)

  3D LBS model





High Strength Concrete

- High Rise Bldgs → large column CS

  solution: High strength concrete

- Fc > 42Mpa

- 1962; Chicago 1000 Lake Shore; 41.4Mpa
- 1988; Seatle P.F.C. ; 131 Mpa

- It is expensive;
  but more economical compared to total cost for high rise buildings

High Strength Concrete

- Rapid construction
- However;
  strength  brittleness 

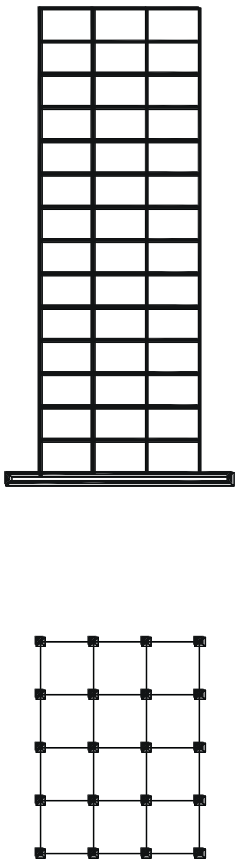
  (should be considered)
- High strength concrete;
  generally used for only bottom levels

Lateral load resisting members

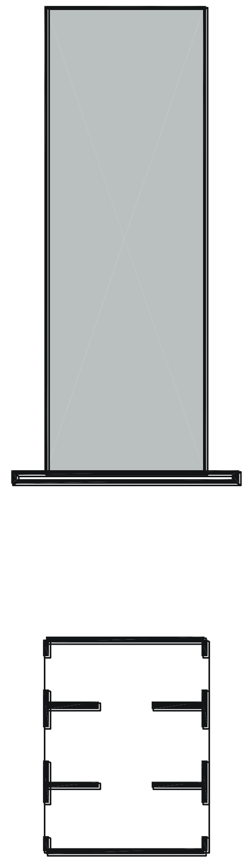
Lateral load resisting members:

a) 2D members;
   - moment resisting frame
   - shear wall
   - coupled shear walls
   - MR frame + shear wall system

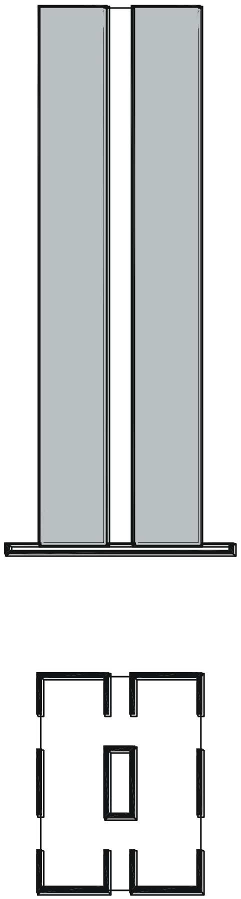
b) 3D members;
   - Tube-frame
   - Core



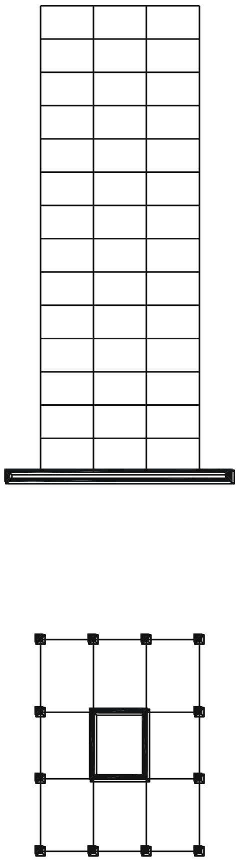
Frame: Column+Beam



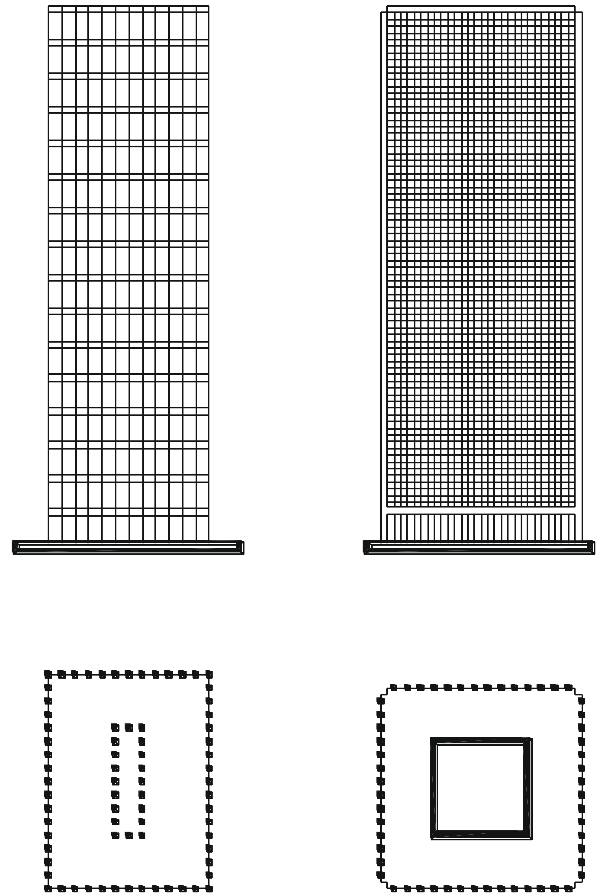
Shear Wall:
In CS; rectangular cantilever members with b/h>1/7 and having vertical axis



Coupled Shear wall:
Shear wall with opening (for door, window etc.)



Frame+ Shear Wall: Frame and Shear Wall are connected to each other by link beams



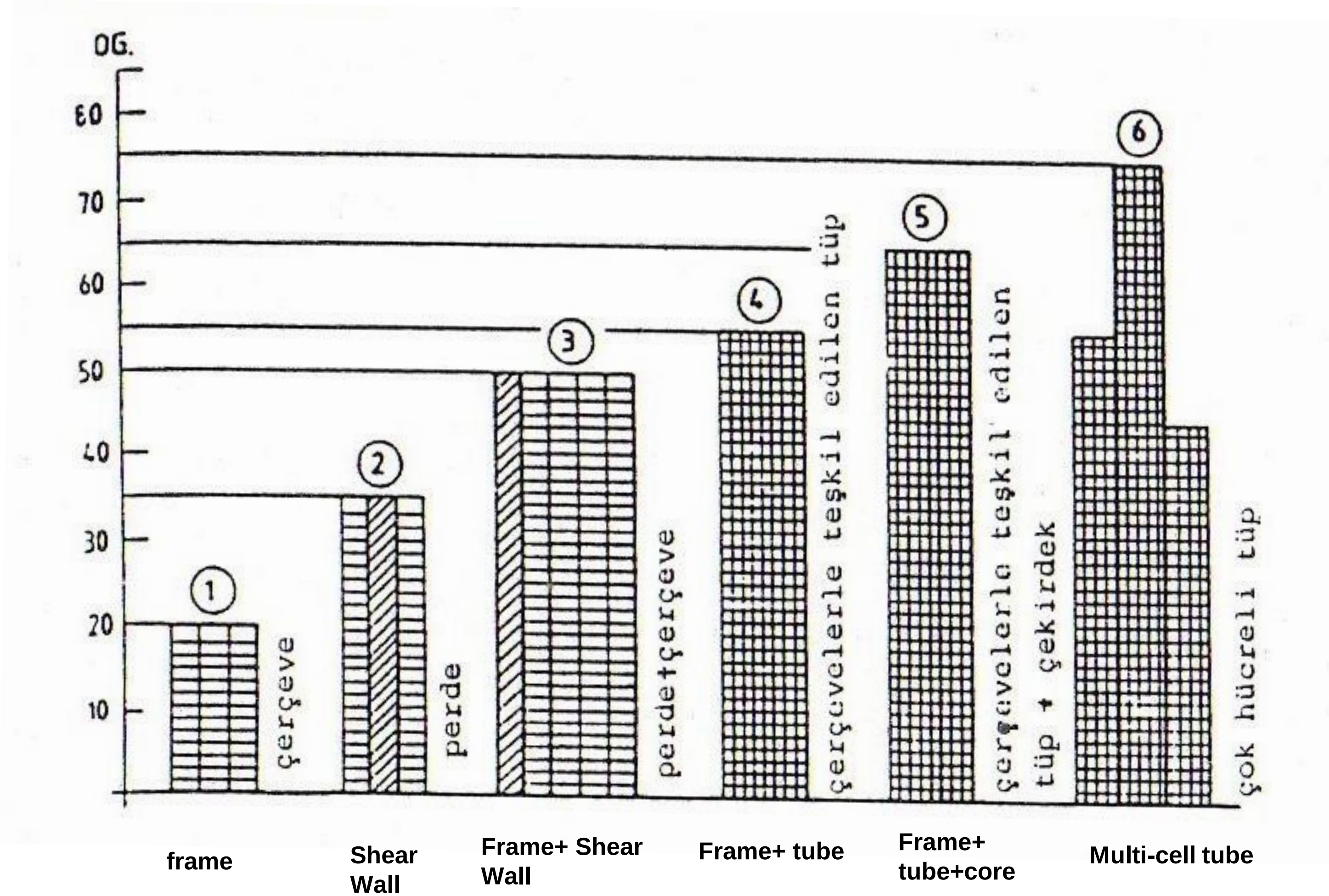
Tube - Frames;

Frequent column arrangement along 4 façades + beams

column distance $\leq 3m$

Lateral load resisting members

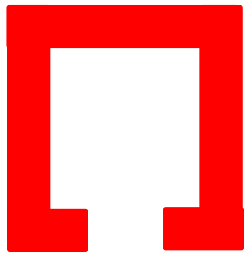
- Usage of lateral load bearing system in RC high rise buildings



Lateral load resisting members

Core:

has thin wall, close formed shear wall members
Generally; arranged around staircase/elevators

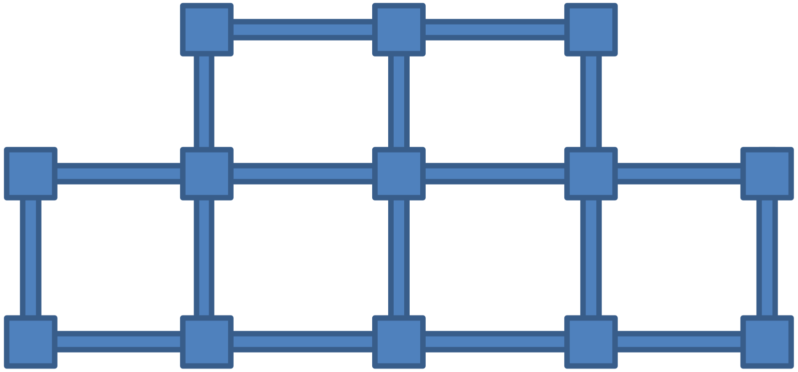


Lateral load resisting system:

Combination of lateral load resisting members given above + beams+ slabs

(Moment Resisting) Frame system

- Used for buildings with ~8-10 storey; to resist/carry vertical+lateral load
- For taller bldgs;
  displacements/Cıre System area of members increase.
  Therefore, Shear wall and/or Core systems are considered



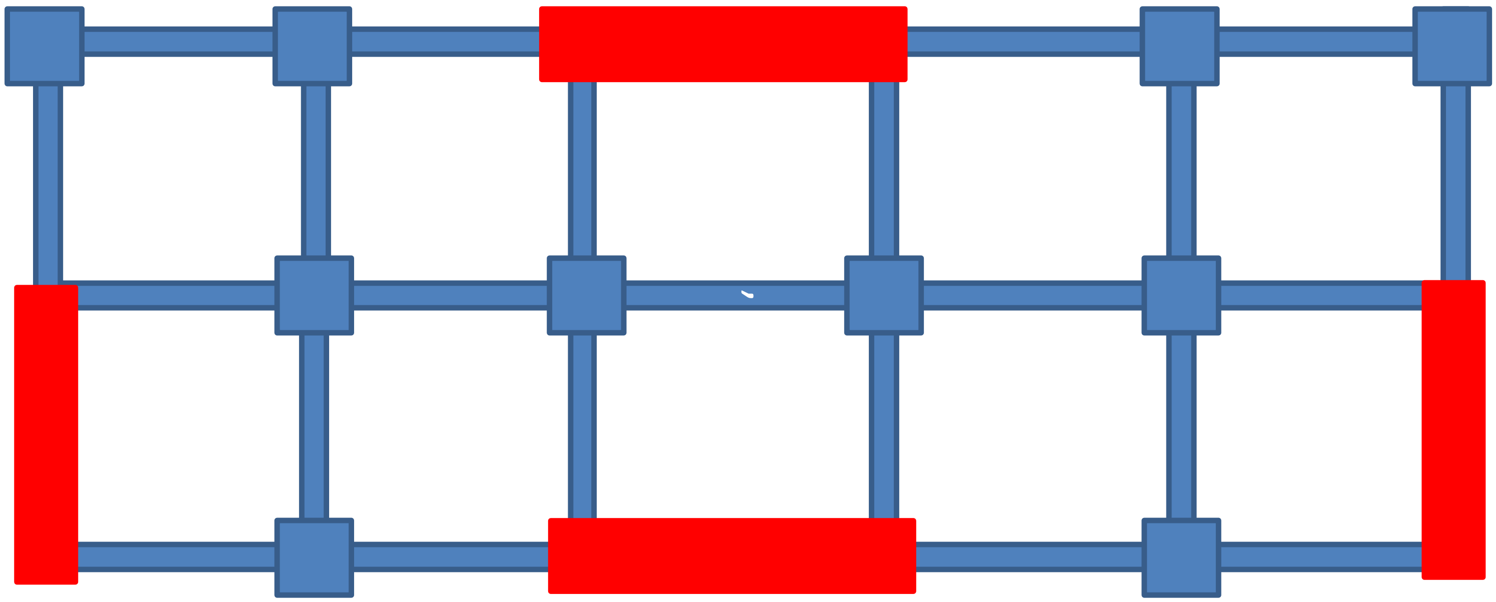
Frame+Shear Wall system

- Displacement of SW and frame are different under lateral load

- Displacement under lateral load;
  SW; small disp. at bottom; large at upper lever

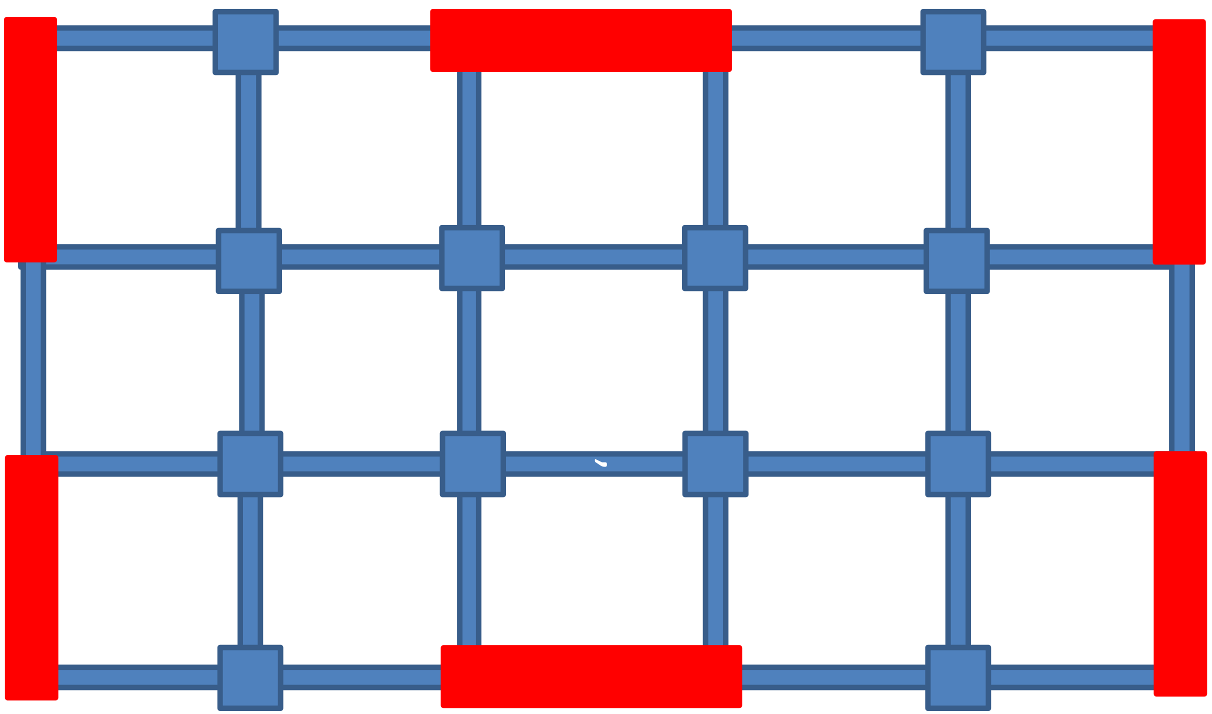
-In a frame+shear wall system;
  at bottom storeys; all lateral force is resisted by SW
  at upper storeys; shear force is resisted by Frame.

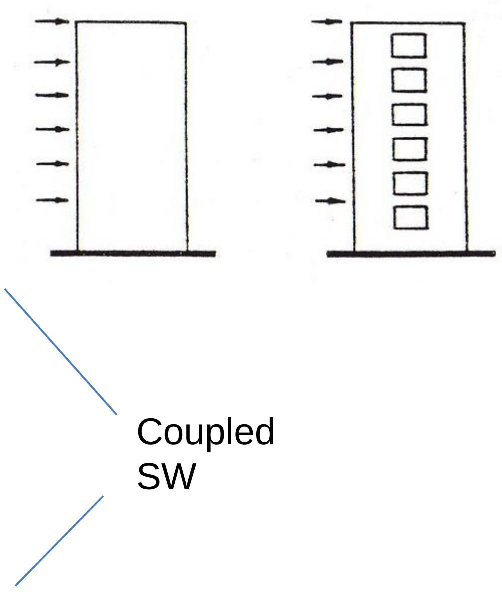
Frame+Shear Wall system



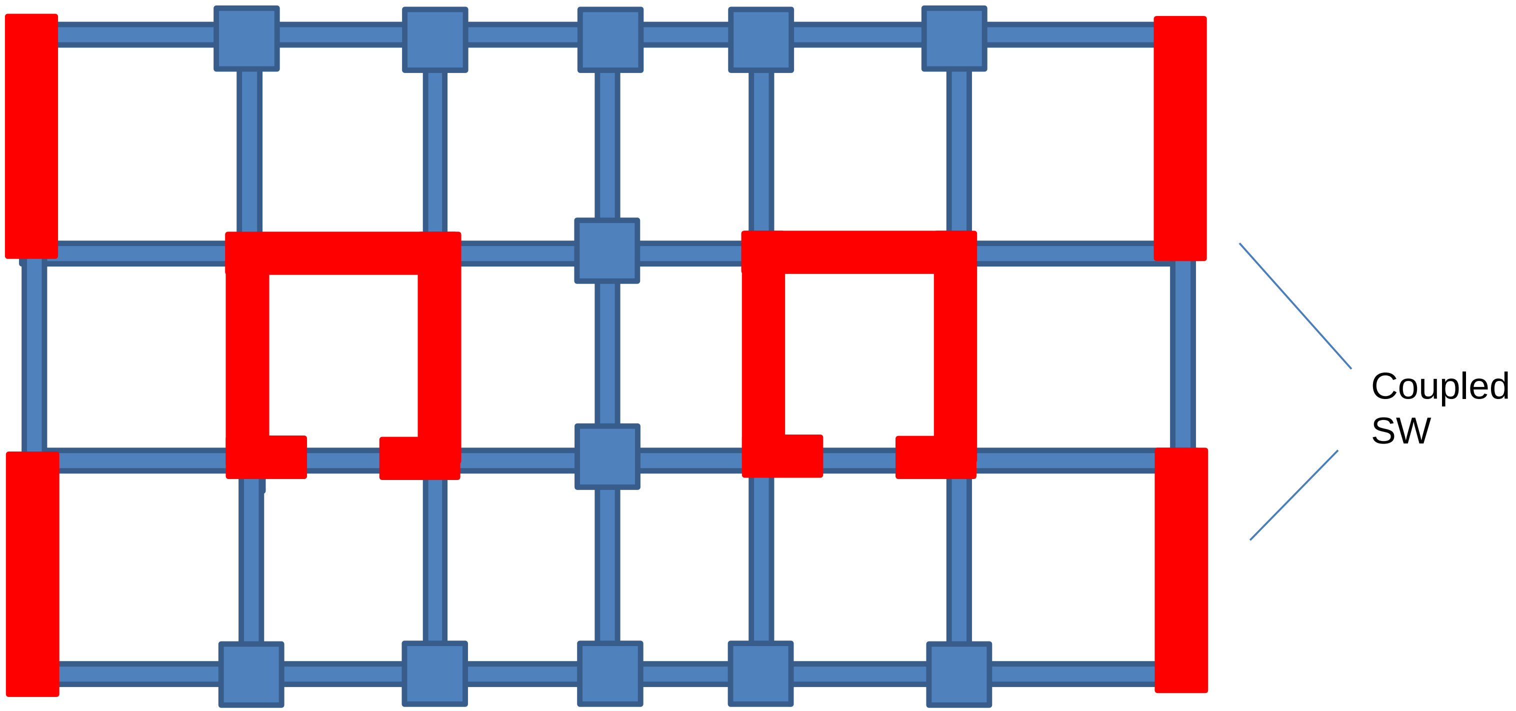
Coupled SW + SW + Frame systems

Behavior; similar to frame+SW systems



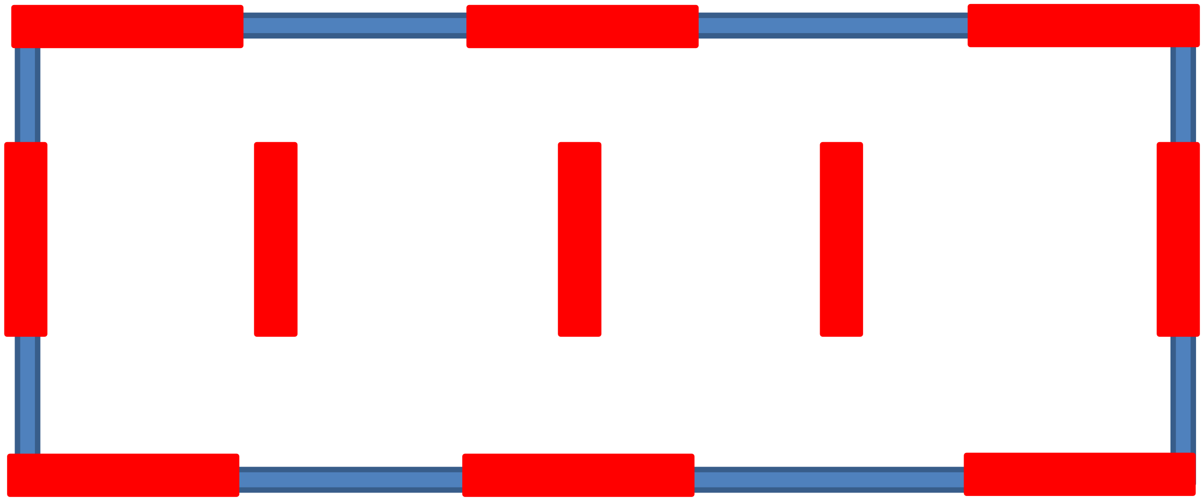


Coupled SW + Frame+ Core systems

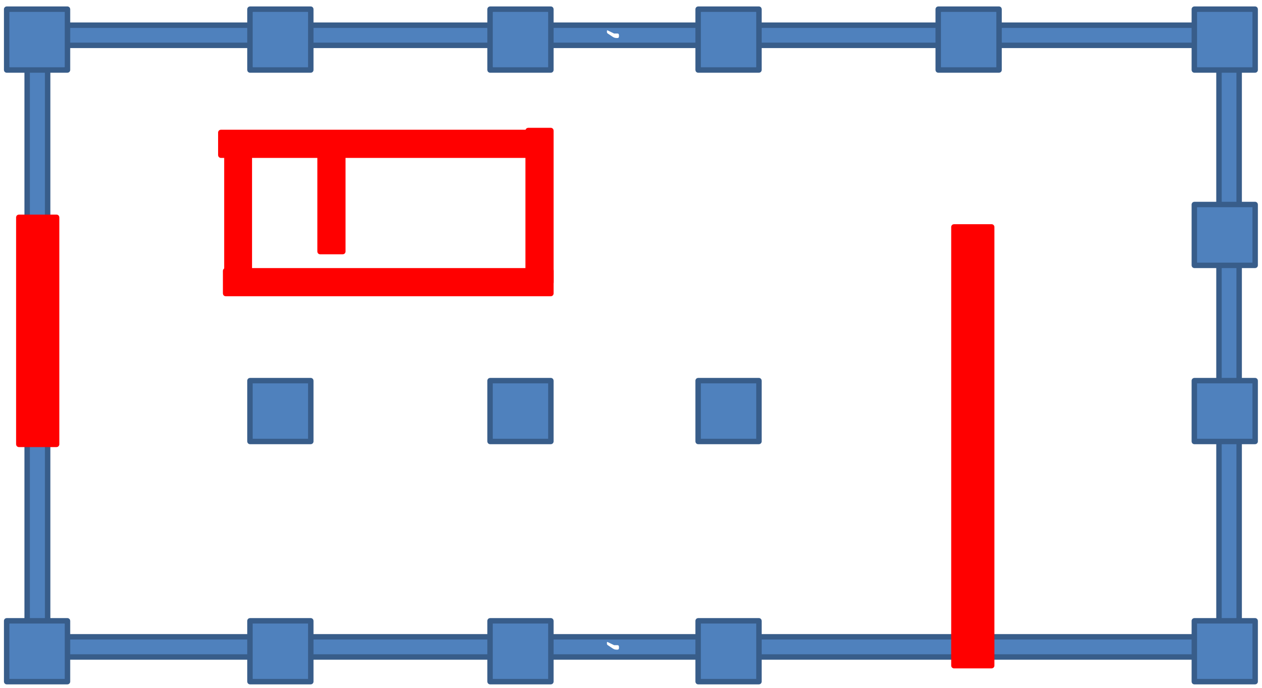


SW only systems

- Shear force is directly transferred from SW to slab
- Therefore, thickness of slab between SWs increases
- Special design is required



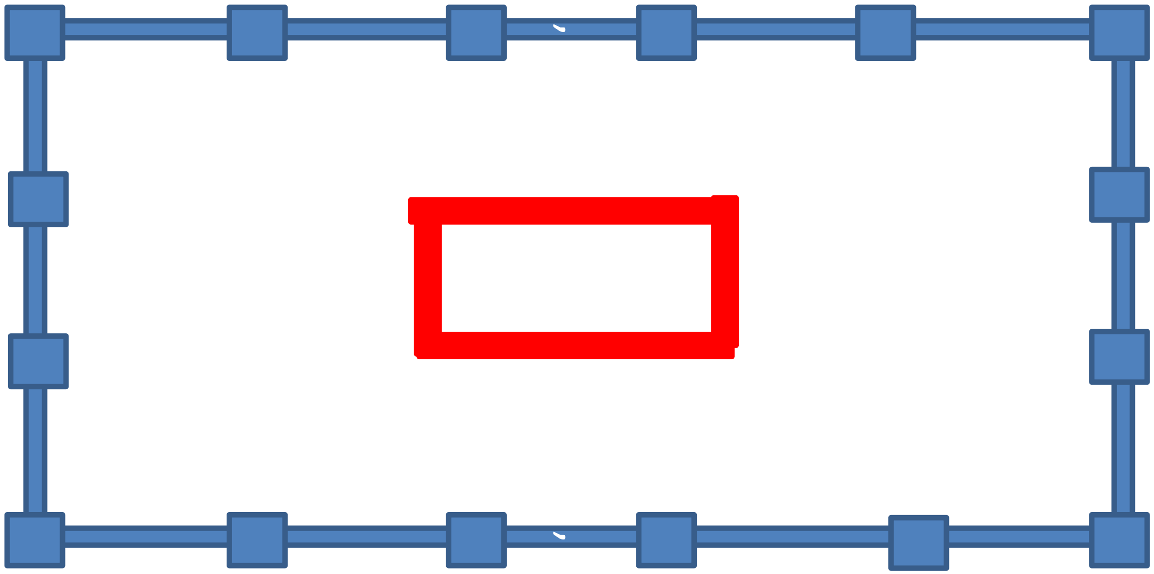
SW + column+core systems



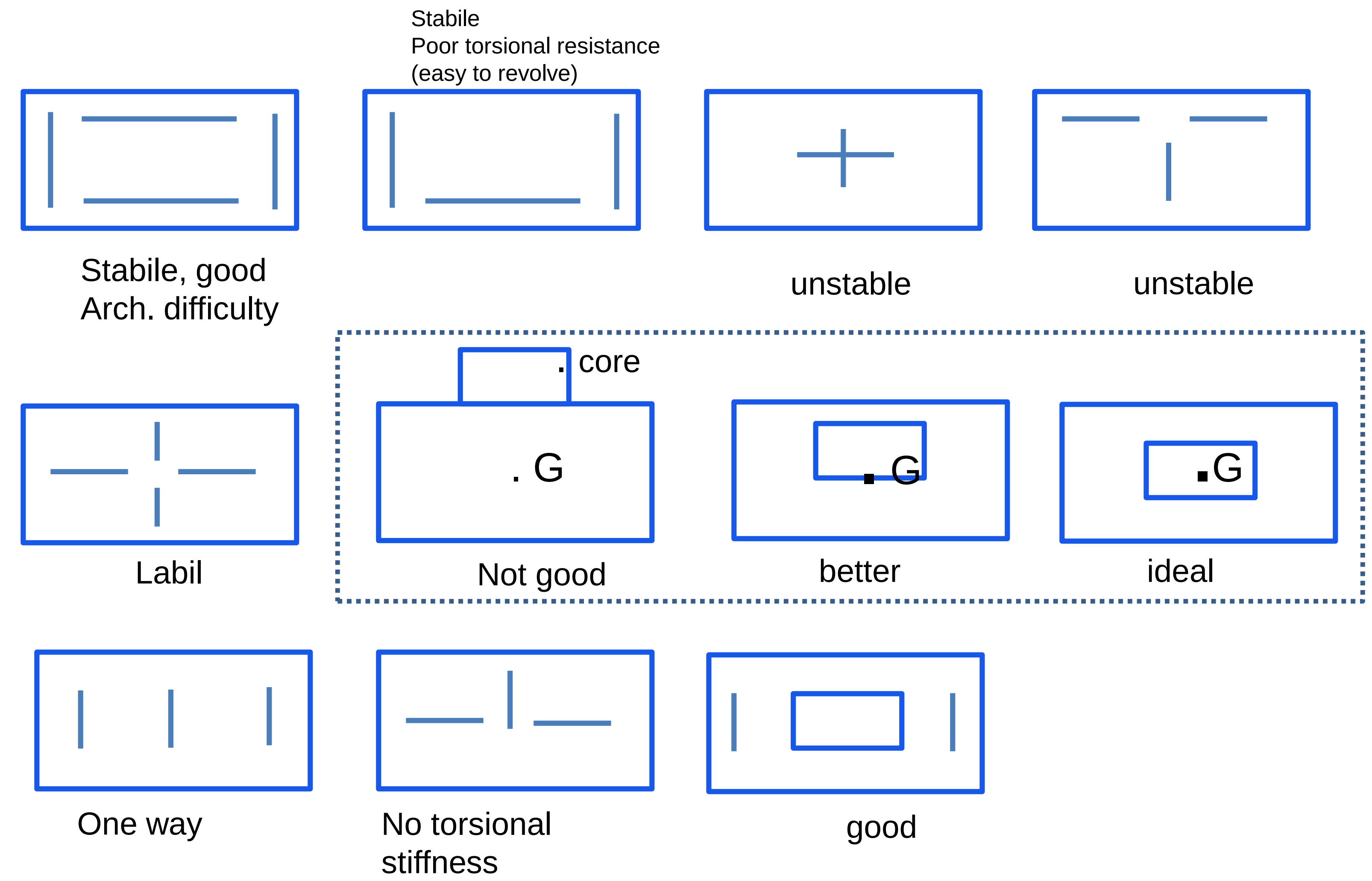
Tube Systems

- (surrounding) tube systems can be used for significantly high rise bldgs

- If the heigth of the bldg increases more;
  usage of tube + core system
- For the tallest bldgs, surrounding tubes are arranged as truss system
- In tube systems; all of lateral forces and a part of vertical loads are resisted by tube.

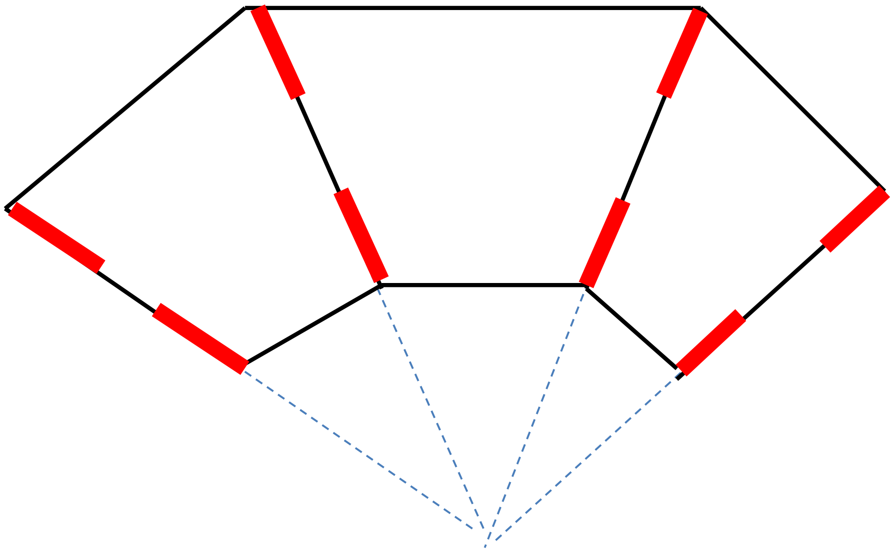


Design Remarks



Design Remarks

- If axes of SWs intersect at a point;
  it cause torsion problem



Design Remarks

- Axis of vertical LBS members should overlap/be continous as possible
- Loads should be transferred to soil in the shortest way
- Lateral load bearing/resisting members should be arranged at outer edges of building, as possible (except core)

Design Remarks

- The core should be close to Center of Gravity of bldg, where it is main LB member

- As a measure againist torsion; where a core is the main LB member;

  at least 2 parallel SW or frame at the sides/edges

OUTRIGGER AND BELT WALL SYSTEM

The structural arrangement for this system consists of a main concrete core connected to exterior columns by relatively stiff horizontal members such as a one or two-story deep walls commonly referred to as outriggers. The core may be centrally located with outriggers extending on both sides (Figure 3.44), or it may be located on one side of the building with outriggers extending to the building columns on one side (Figure 3.45).

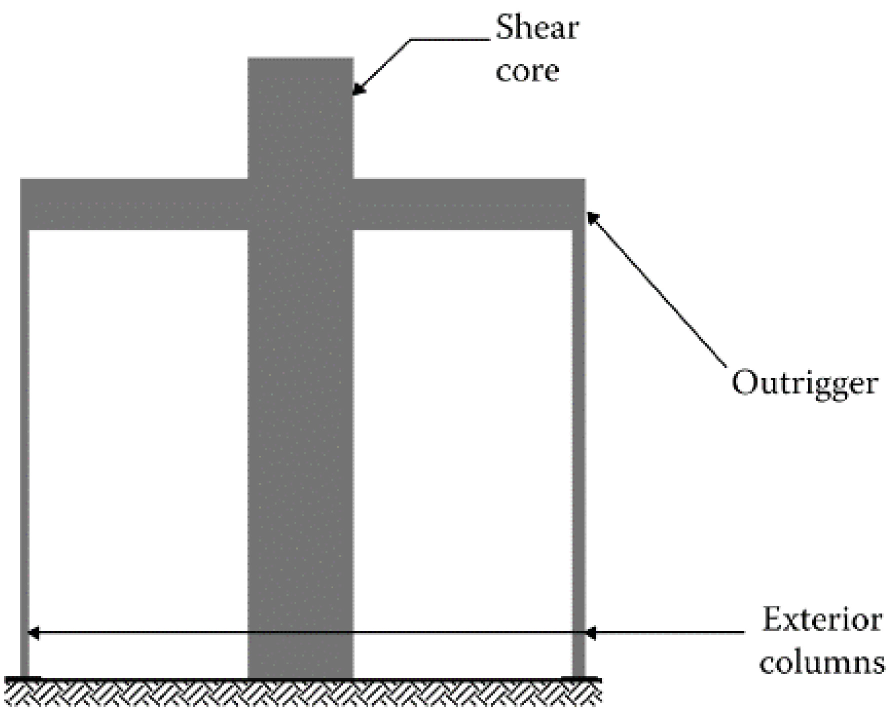


FIGURE 3.44 Outrigger and belt wall system with centrally located core.

Lateral load resisting members

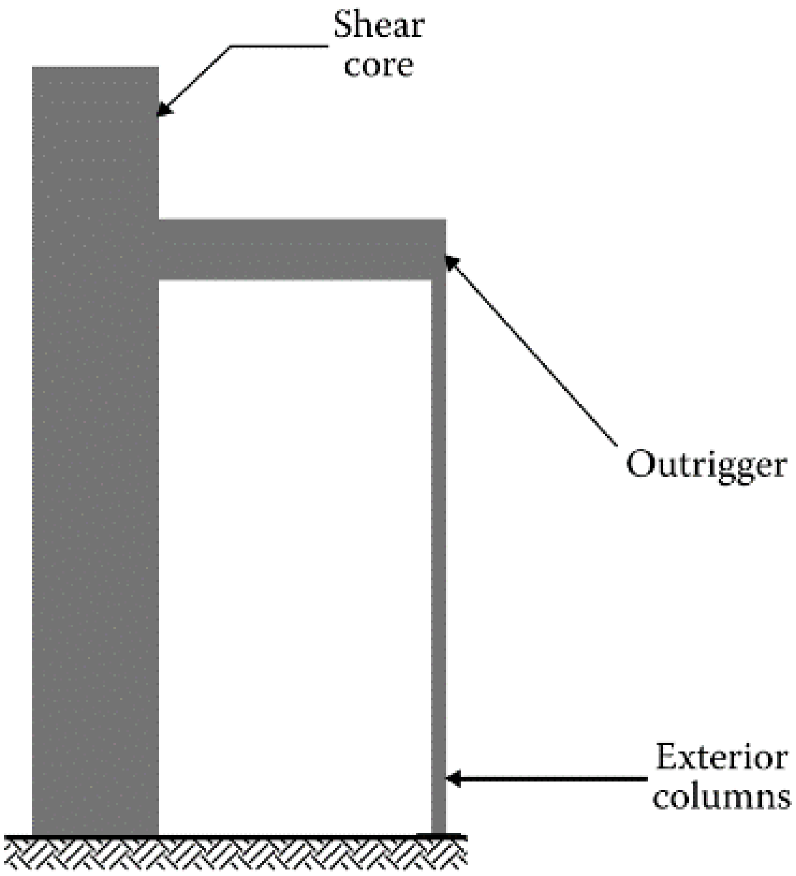


FIGURE 3.45 Outrigger and belt wall system with an offset core.

Lateral load resisting members

To understand the behavior of an outrigger system, consider a building stiffened by a story-high outrigger wall at top, as shown in Figure 3.48. Because the outrigger is at the top, the system is often referred to as a cap or hat wall system. The tie-down action of the cap wall generates a restoring couple at the building top, resulting in the occurrence of a point of contraflexure some distance from the top. The resulting reversal in curvature reduces the bending moment in the core and hence the building drift.

Although belt walls function as a horizontal fascia stiffener mobilizing other exterior columns, for simplicity in explaining the structural behavior, we will assume that the cumulative effect of the exterior columns may be represented by two equivalent columns, one at each end

Lateral load resisting members

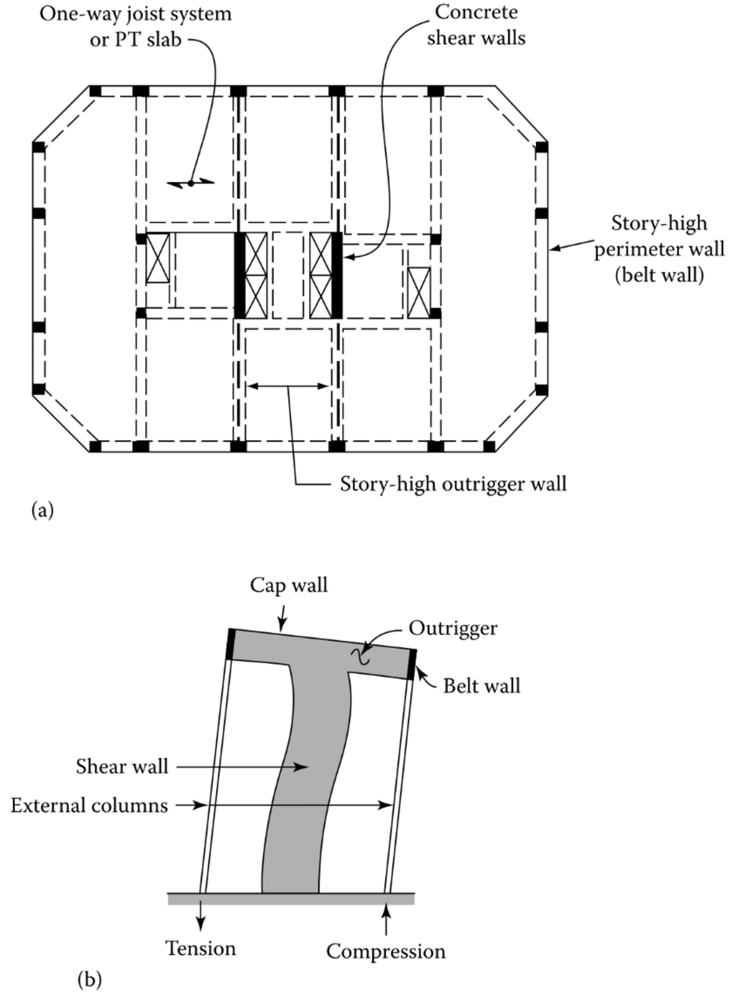


FIGURE 3.48 Cap wall system: (a) Plan and (b) Schematic section.

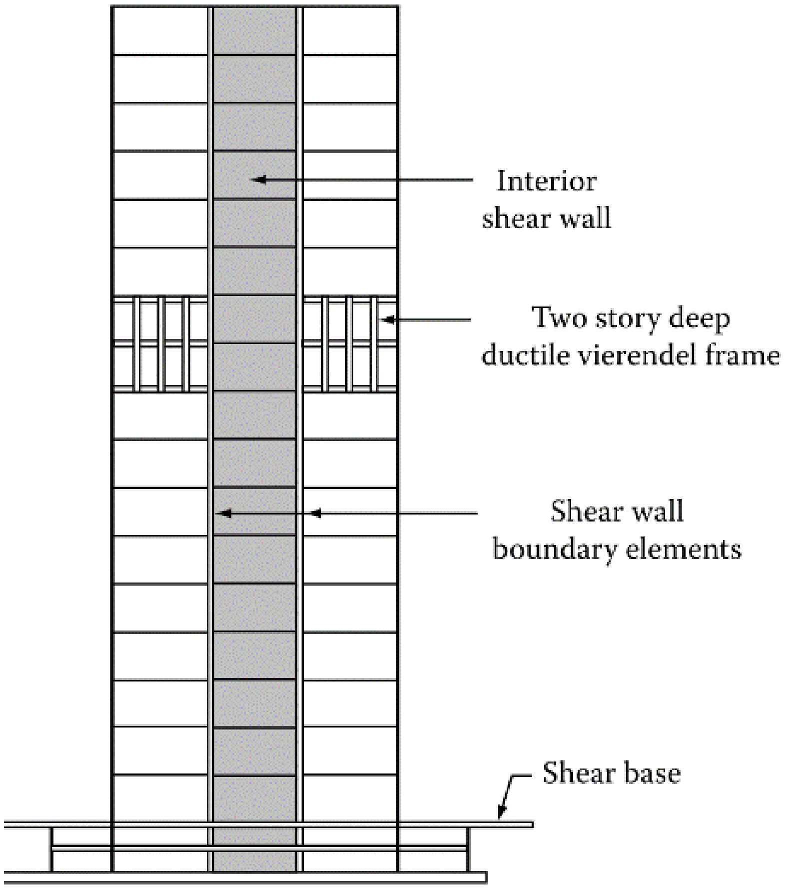


FIGURE 3.46 Vierendeel frames acting as outrigger and belt wall system.

Lateral load resisting members

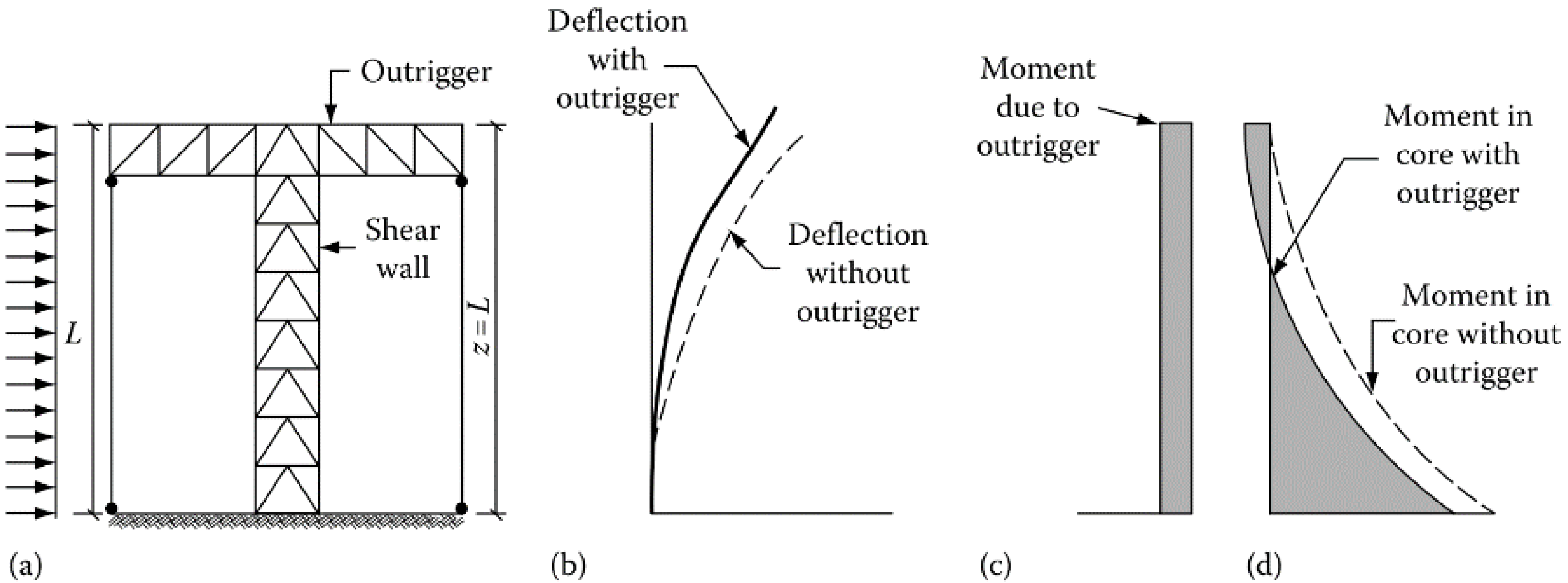


FIGURE 3.49 Outrigger located at top, $z = L$.

Petronas Kuleleri

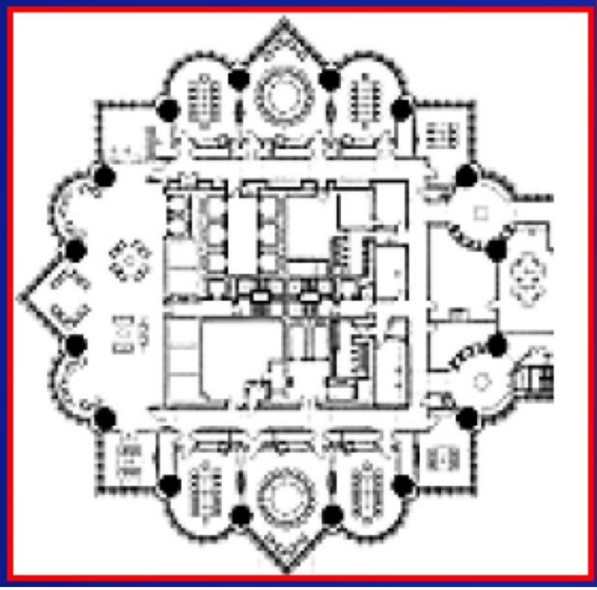
Yer: Malezya

Mimar: César Pelli

Tarih: 1995-1998

Yükseklik: 452 m

Kat: 88m



Jin Mao Binası

Yer: Sanghai

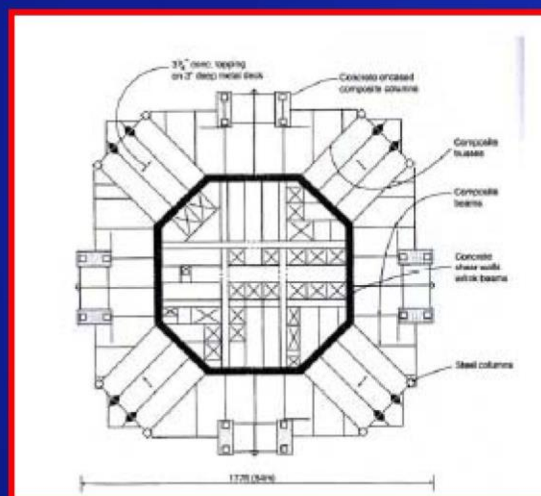
Mimar: Skidmore, Owings & Merrill

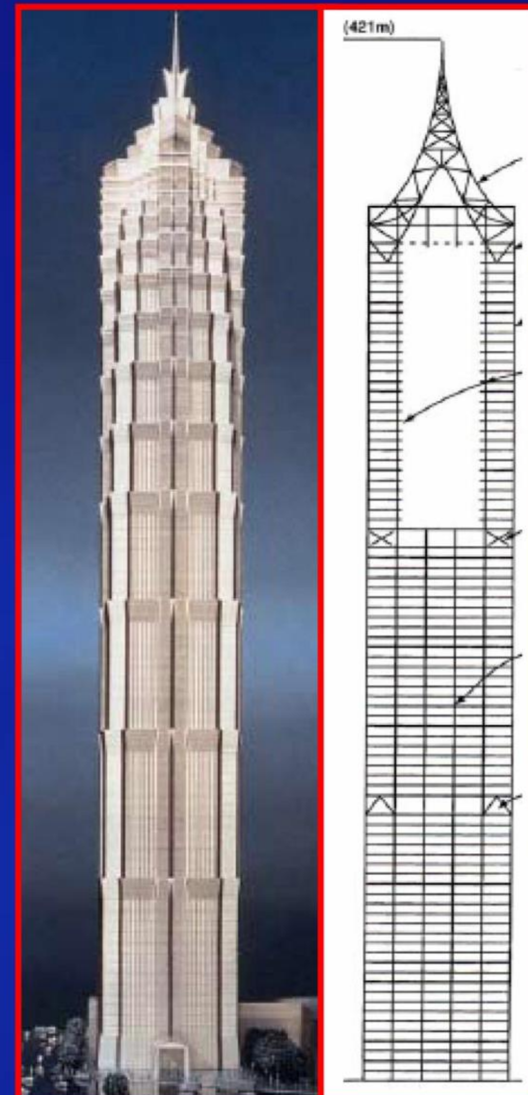
Yükseklik: 421 m

Kat : 88

Periyod: 5.7 sn

Betonarme

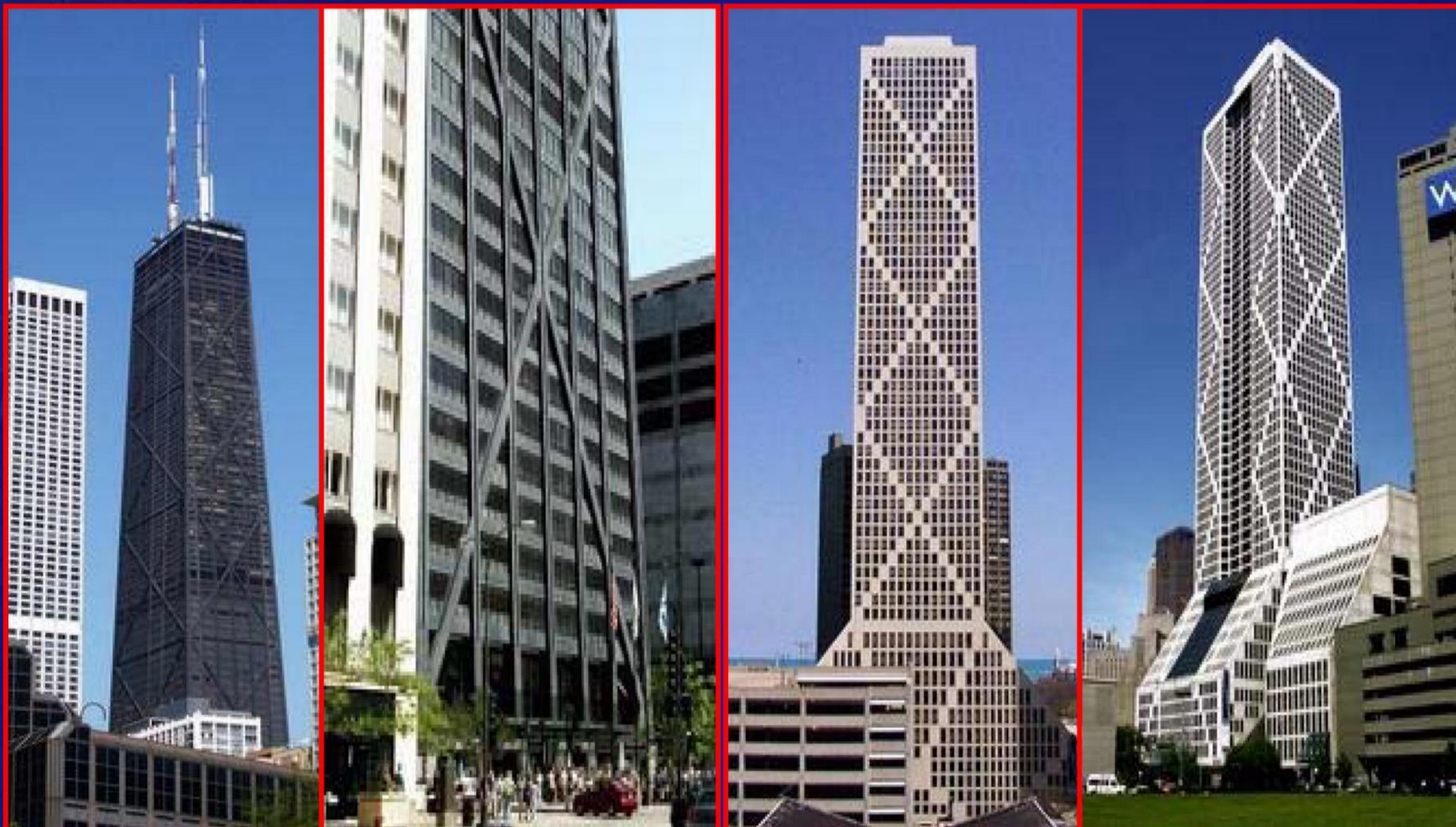




Hancock ve Onterie Binaları

Çelik, 344 m, 100 katlı, Chicago

Betonarme,174 m, 58 katlı, New York



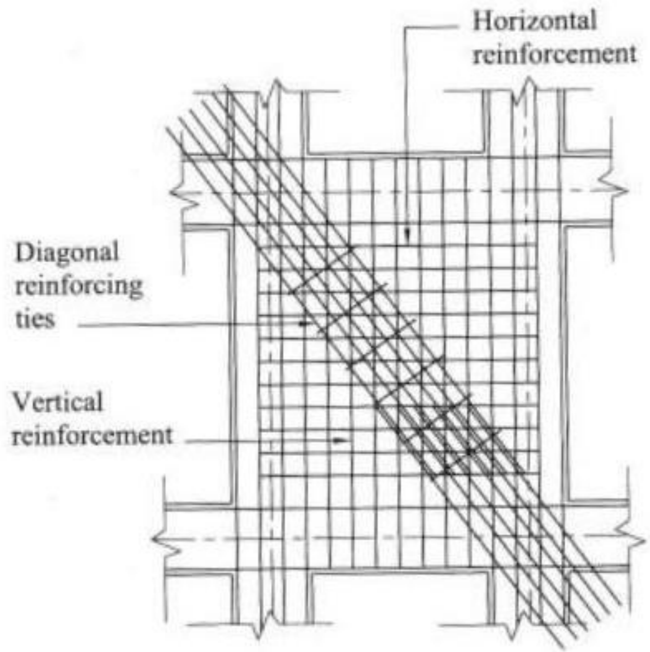
Onterie

Quick Facts

Location: Chicago, 441 East Erie St
Architect: SOM
Engineer: SOM
Start of Construction: 1979
Completion: 1985
Height: 571ft
Number of Floors: 58
Material: Concrete

Onterie

Figure 2. *Onterie Center street view*



igure 3. *Typical reinforcement detail for infill panesl between spandrels and columns*

Marina City

Quick Facts

Location: Chicago 300 North State St
Engineer: Severud Associates
Architect: Bertrand Goldberg
Start of Construction: 1959
Completion: 1964
Height: 562 ft (171 m)
Number of Floors: 61
Material: Concrete

Figure 1. *Marina City Towers*

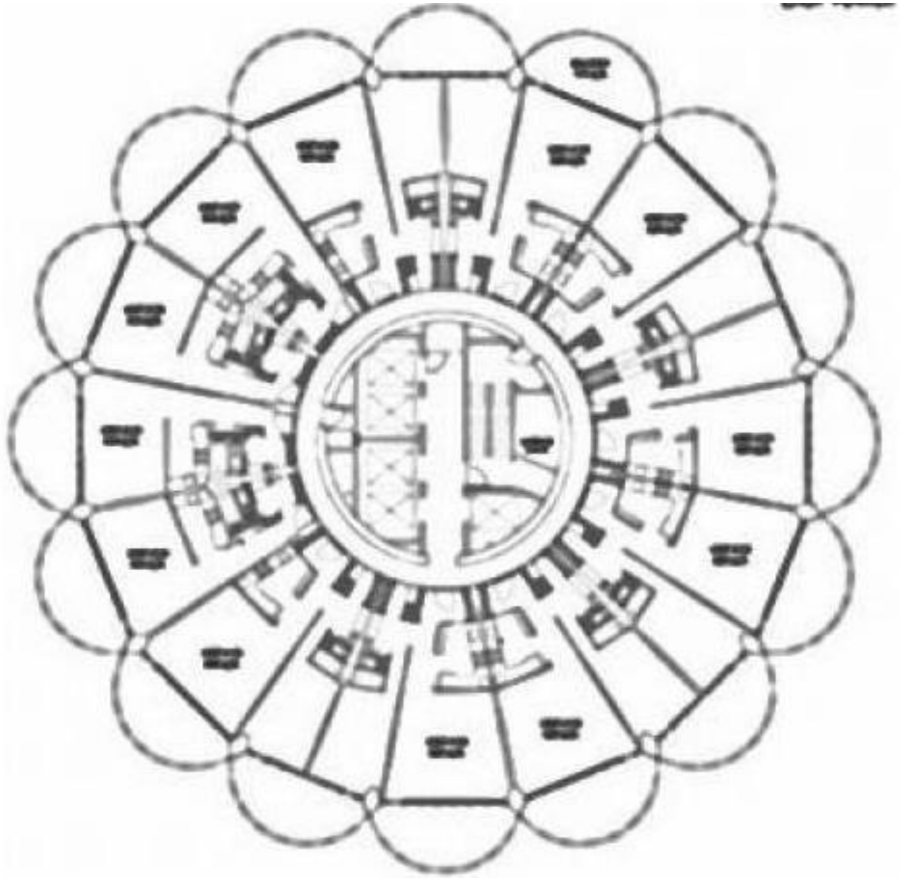
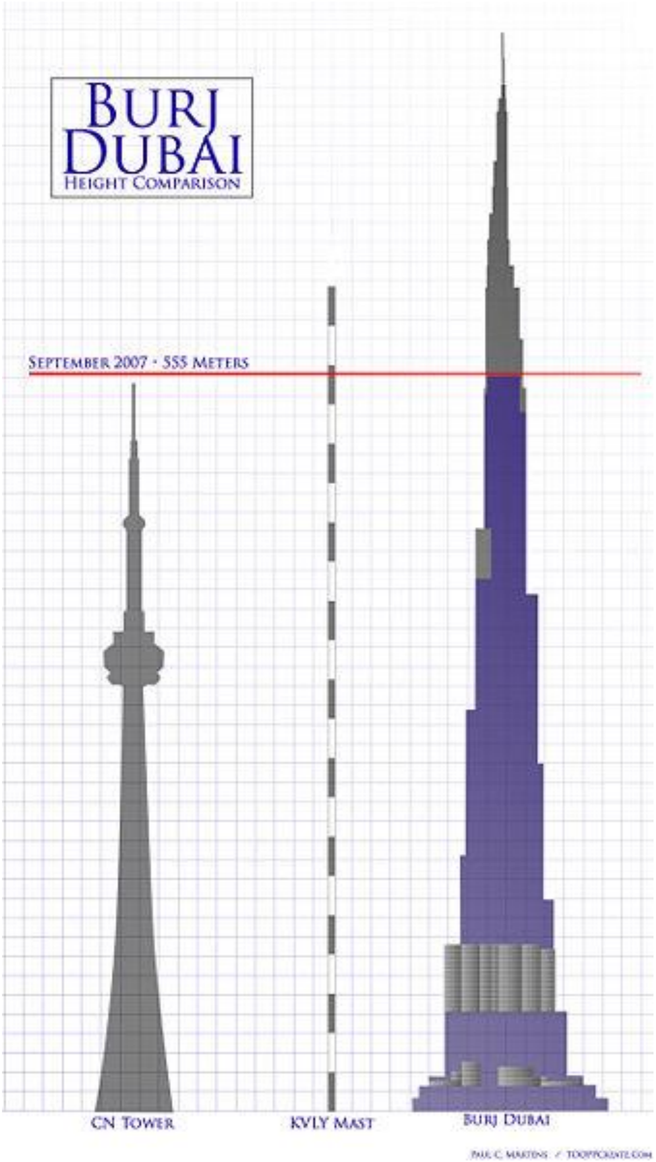


Figure 3. *Schematic Floor Plan of East Tower*


BURJ DUBAI


AFP


BURJ DUBAI
HEIGHT COMPARISON
SEPTEMBER 2007 · 555 METERS
CN TOWER
KVLY MAST
BURJ DUBAI